

Biological and Sediment Disturbance: Wet and Dry Construction

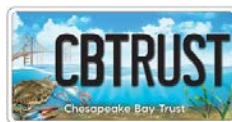
Howard County, MD

Comparison of Sediment Discharge and Biological Impacts During Wet and Dry Stream Construction

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List of Acronyms

Acronym	Definition
PPT	Precipitation
BBMS	Bonnie Branch main stem
BBT	Bonnie Branch tributary
CM	Centimeter
CMS	Cubic Meter per Second
FEMA	Federal Emergency Management Agency
FIS	Flood Insurance Study
HCC	Howard Community College
HC SCD	Howard County Soil Conservation District
IBI	Index of Biotic Integrity
kg	Kilogram
LOD	Limit of Disturbance
L/s	Liters per Second
MDE	Maryland Department of Environment
mg/L	Milligrams per Liter
NOAA	National Oceanographic and Atmospheric Administration
NTU	Nephelometric Turbidity Unit
NWS	National Weather Service
PRISM	Parameter-elevation Regressions on Independent Slopes Model
Q	Discharge
RFC	River Forecast Center
SSC	Suspended Sediment Concentration
TSS	Total Suspended Solids
USACOE	United States Army Corps of Engineers
USGS	United States Geological Survey
WQ	Water Quality

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Abstract

Sediment pollution is one of the leading causes of the poor health of the Chesapeake Bay. In addition to runoff, erosion of stream beds and stream banks are major sources of sediment to the Bay. Stream restoration projects that seek to stabilize banks and provide more frequent access to the floodplain can reduce these sources of sediment. In Maryland, stream restoration projects are required to divert water around the construction site and dewater the work area to allow work to be conducted “in the dry”. Construction “in the wet” where the contractor performs the restoration construction while the stream is actively moving through the work area is typically not allowed in Maryland even though there is little evidence to suggest any benefit in terms of construction duration or difference in sediment discharged during construction between the two techniques. We divided three small (~400 linear feet), first-order stream restoration projects in the Piedmont of Maryland into wet and dry construction areas and measured turbidity (NTU) as a surrogate for TSS and water level to estimate flow during construction. These estimates were combined with the duration of construction to calculate the total amount (kg) of sediment released during each type of construction. Results of the ANOVA on the amounts of sediment contributed per unit time (5 minutes) at each of the sites indicated that when the filtration device used in the dewatering of the work area is located adjacent to the stream channel, there is no significant difference in the amount of total sediment or sediment released per unit time between wet and dry construction techniques. If the filtration device is located further away from the channel, the amount of sediment released during the two construction techniques is significant. We also found that the total amount of sediment released during construction in the wet is less than 1% of the estimated total annual sediment load of the stream prior to restoration and that the amount of sediment released during construction in the wet is similar to that discharged during high flows or storm events with a recurrence interval <1yr. In addition, we found no difference between the duration of wet vs dry construction, no discernable pattern in the effect on the benthic invertebrate community, and no difference in impact to the riparian community between the two construction techniques.

1. Introduction

According to the Chesapeake Bay Trust (2018), sediment pollution is one of the leading causes of the Chesapeake Bay's poor health. While loose particles of sand, silt, and clay are natural parts of the environment, too much sediment can cloud the water and harm underwater grasses, fish, and shellfish. In addition to runoff from agricultural (CBT 2018) and urban land uses (Wright et al. 2006) as sources for sediment in the Bay, bank and bed erosion from streams is also recognized as a major contributor (Mukundan et al. 2010, Donovan et al. 2015). Donovan et al. (2015) found that after accounting for estimated redeposition, extrapolated net streambank sediment yields (72 Mg/km²/yr) constituted 70% of estimated average Piedmont watershed yields (104 Mg/km²/yr) and that 1st and 2nd order streams accounted for 62% of total streambank erosion. To address the sediments coming from stream bed and banks, restoration projects have and continue to be designed and constructed throughout the Chesapeake Bay Watershed. To support these and continued efforts, Schueler and Stack (2014) concluded after an extensive literature review of stream restoration projects that, when properly implemented, stream restoration does have sediment and nutrient reduction benefits.

While the intent of most stream restoration projects is to improve water quality, the act of construction itself can become a temporary source of suspended sediment. For example, Eason (2011) observed that stream construction conducted in the wet on a stream in Georgia created temporary Suspended Sediment Concentrations (SSC) of 100 to 1000 mg/L, 10 to 100 times higher than pre-construction conditions. However, Eason also noted that SSC concentrations quickly returned to background levels once in-stream construction was completed for the day. To avoid increased suspended sediment concentrations during construction, stream diversions can be constructed that allow construction to be conducted in the dry. Stream diversions are intended to (and assumed to) reduce sediments and associated nutrients from being transported downstream during construction, but little quantitative research has been performed to verify this assumption. Current policy in Maryland builds on this assumption and requires that stream baseflow be pumped or diverted around an active construction area despite the concern that failure of the stream diversion could result in "severe erosion of the disturbed section under construction" resulting in more sediment transport than construction in the wet is assumed to create (MDE 2000, MDE 2011). In addition, water within the active work zone must be pumped to an approved filtration device before being allowed to flow back into the stream. Filtration devices, however, do not remove all of the sediment suspended in the water (Kang and McLaughlin 2016).

1.1. Stream Construction Methods

The two main methods of constructing a stream restoration project are referred to as "working in the wet" and "working in the dry." Working in the wet is simply the act of implementing the stream restoration construction while the stream continues to flow through the active construction zone. To perform stream restoration construction in the wet, the contractor waits for periods of low flow (if possible) and performs channel grading and improvements while the stream or river is actively flowing. While this construction method may complicate the construction of deep-footed structures compared to construction in the dry, the perception is

that it might be overall faster, allow for better placement of finished elevations relative to the water surface, and cost less to implement.

Working in the dry can take two forms: construction of a new channel separate from the existing stream then diverting stream flow to the newly constructed channel upstream of construction, or pumping/diverting stream flow around the construction area, usually in a pipe or hose. Under either form, the active work zone must also be dewatered/pumped to an approved filtration device. However, since space is limited in most stream corridors within urban areas of Maryland, creating a separate channel and then diverting flow from the old one is less common than the use of pumps or temporary piped diversions to keep stream flow out of the active construction zone. To pump water around the work zone, sandbag dikes or cofferdams are installed at the upstream and downstream ends of a selected work area, and stream flow is pumped around the construction area. Water from within the construction area typically has high TSS concentrations and is therefore pumped into sediment filter bags or stilling basins (Clinton et al. 2004). Dry construction is performed in stages, often working from upstream to downstream in sections with the diversion typically removed at the end of each work day and replaced at the beginning of the next.

The interest in performing construction in the wet over in the dry is, in part, related to cost. Creation and maintenance of stream diversions used for work in the dry is a considerable construction expense that may account for 6% of the total project construction cost (estimated with data adjusted for inflation from MSHA 2014 and Templeton et al. 2008). Time spent establishing the diversion and waiting for the work area to dewater may also increase construction duration, further increasing costs. Quantifying both the cost and sediment load impacts of each technique will allow regulators to make more informed decisions to minimize environmental impacts, while encouraging cost-effective stream restoration.

1.2. Sediment Load, TSS, and Turbidity

Stream channels transport sediment as bed load or suspended solids. Bed load is the portion of the total sediment load that moves on or near the streambed by saltation (bouncing), sliding, or rolling along the bed layer. Suspended solids are the portion of the total sediment load that is transported in suspension via turbulence in the body of the stream flow. Suspended solids are comprised of significantly finer particle sizes than bedload and typically make up 75-95% of the total load in large, deep streams (Schueler and Stack 2014).

Total suspended solids (TSS) comprise the majority of sediments contributed to the Chesapeake Bay and are the focus of this study. To accurately assess the amount of TSS in the water column, grab or automated samples need to be obtained during different flow regimes and at different locations throughout the water column (APHA 2017). Obtaining samples in this manner is labor-intensive and expensive. Therefore, it is desirable to find surrogates that are easier and more cost effective to obtain but that still offer usable data for interpretation.

Strong correlations between TSS and turbidity have been demonstrated in other studies (Lewis 2002, Gippel 2006, Fraley et al. 2009, Eason 2011, Al-Yaseri et al. 2013, Steffy 2016). Turbidity is easier and less costly to continuously measure than TSS and can be used in combination with

measured flow data and select TSS measurements to develop a reliable model to predict TSS from turbidity data.

1.3. Biological Impact

This study also investigated the effect of each construction technique on the benthic macroinvertebrate community. Although present for a much shorter duration and over a shorter stream length, it has been hypothesized that construction may be analogous to stream drying during prolonged droughts, which can affect the densities, population age-structure, and community composition of macroinvertebrates (Boulton 2003, Lake 2003). In addition, Bernhardt and Palmer (2011) found that the impact on macroinvertebrate communities from restoration construction may persist from 1 to 16 years.

1.4. Riparian Disturbance

The extent of riparian disturbance depends on whether the contractor works from within the stream channel or from the floodplain. Since working in the dry requires additional construction outside of the stream for diversions or piping systems, working in the dry is assumed to have a greater impact on riparian vegetation than working in the wet.

1.5. Key Questions

In 2015, Straughan Environmental, Inc., proposed a study to the Chesapeake Bay Trust to determine the difference in turbidity, sediment load, and the effect on the benthic macroinvertebrates and riparian community between stream restoration construction conducted in the wet and in the dry. Permits for construction in the wet were obtained from the United States Army Corps of Engineers (USACOE), the Maryland Department of Environment (MDE), and the Howard County Soil Conservation District (HC SCD) demonstrating agency support of the study.

The key questions this study investigates are:

- 1) Is there a difference in sediment load generated between wet and dry construction techniques expressed as:
 - a) Total sediment load released during construction, and
 - b) Mean sediment load released per unit time.
- 2) What, if any, affect does working in the wet vs working in the dry have on the benthic macroinvertebrate community?
- 3) Is there a difference in the area of riparian vegetation disturbed between wet and dry construction techniques?

2. Methods and Materials

Straughan coordinated with the Chesapeake Bay Trust, USACOE, MDE, and HC SCD to identify three pending stream restoration projects that were similar in size and used similar stream bank stabilization/restoration techniques. The final three stream restoration projects chosen were located on Bonnie Branch Main Stem (BBMS) and Bonnie Branch Tributary (BBT) located along Bonnie Branch Road, near Ellicott City, and a small stream on the campus of Howard County Community College (HCC) (Figure 1).

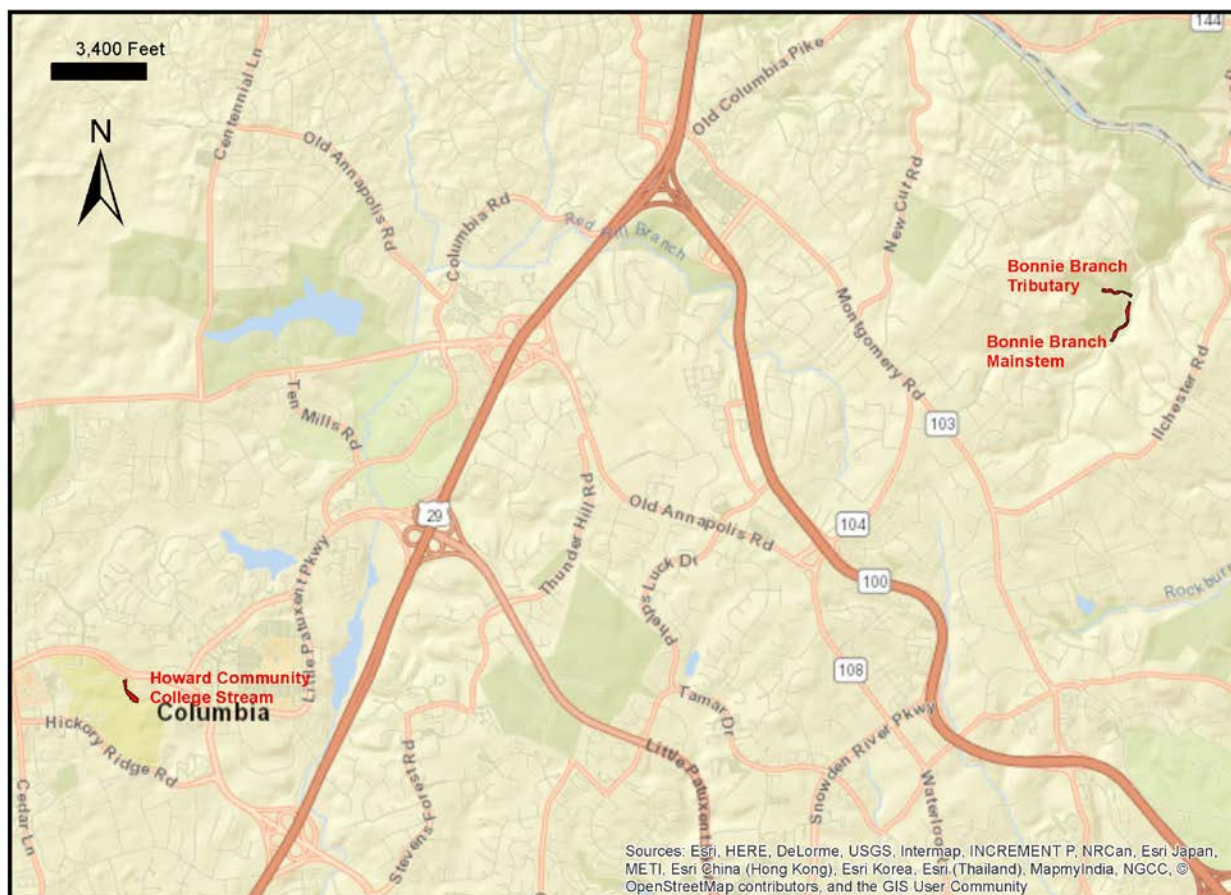


Figure 1. Study Site Locations within Howard County, Maryland

The study sites were all first order Maryland Piedmont streams. The drainage area for BBMS was 3.11 square kilometers, 16% forested, and 26.6% impervious. The drainage area for BBT was 0.34 square kilometers, 45.8% forested, and 18.8% impervious. The drainage area for HCC was 0.48 square kilometers, 9.0% forested, and 58.7% impervious.

Each of the study streams was divided into dry construction and wet construction reaches (see Appendix A). Conceptual sample point locations to collect water quality, flow, and benthic macroinvertebrate data along each stream are illustrated in Figure 2. Prior to construction, water depth, velocity, turbidity, TSS, and benthic data were collected upstream of the proposed

restoration reach. Once construction was initiated, additional water quality stations were added downstream of the active work zone.

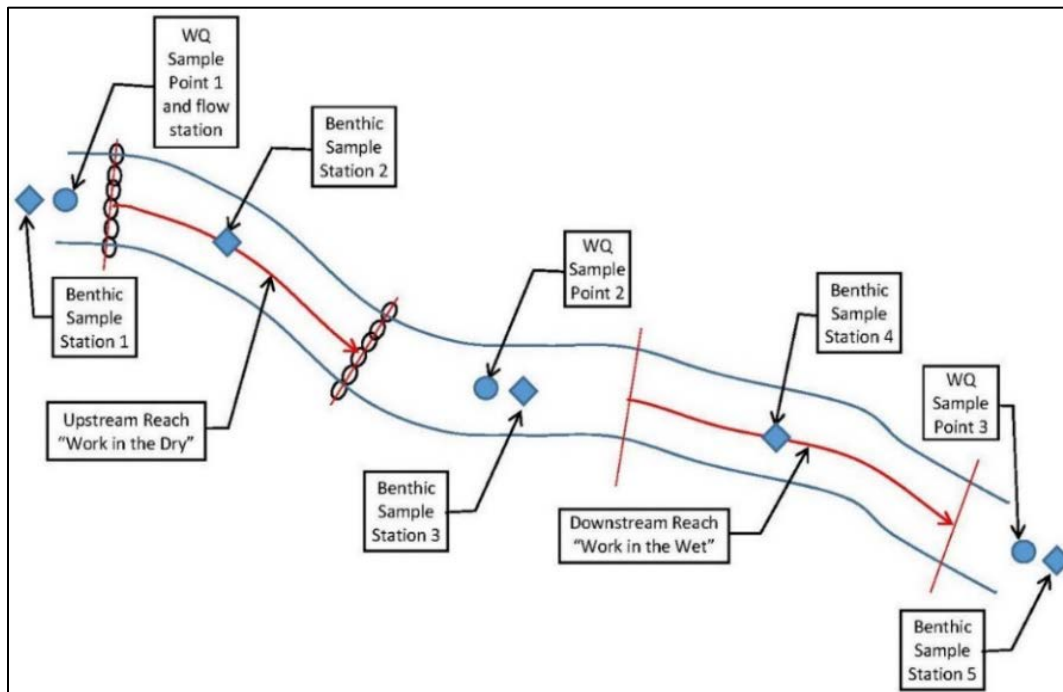


Figure 2. Sample Station Schematic

2.1. Pre-Construction Data Collection and Analysis

For a period of three months prior to construction, Straughan monitored water level and turbidity upstream of each project site. Straughan measured water level (cm), discharge (L/s), turbidity (NTU), and Total Suspended Solids (TSS mg/L) on each stream at a location immediately upstream of proposed construction (Figure 2 WQ Sample Point 1). Regression equations were explored using pre-construction data to develop water level to discharge, NTU to TSS, and discharge to TSS relationships for each stream. Equations with the highest R^2 , best fit the data, and that produced positive (i.e., avoided estimates of negative values) and conservative (i.e., produced estimates closer to the values used to generate the models) were used to estimate discharge (Q L/s) from water level (cm) and TSS mg/L from NTU measurements obtained during construction. Discharge and TSS estimates were then combined to estimate the total sediment load released over the duration of each construction technique and per unit time. Bed substrate and bank soil samples were also obtained from the upstream and downstream reaches and submitted for texture analysis.

2.1.1. Water Level and Discharge

Pre-construction water levels were monitored using automated pressure sensors installed within two wells at each project site. Wells were constructed of 4-inch perforated PVC and attached to metal fence posts driven into the soil or stream bed. A Van Essen Baro-Diver Barometric Pressure Logger was fitted into one well located out of the stream channel to measure and record atmospheric pressure. A Van Essen Water Level Logger with a pressure transducer was placed in the second well to monitor and record water depth within the stream.

Barometric pressure and water depth were set to record at the same time every 5 minutes. Data from the Barometric Pressure Logger were used to adjust water level by compensating for atmospheric pressure.

Straughan measured stream cross-sectional area and velocity at varying water levels during a minimum of four sampling events following the procedures described in Buchanan and Somers (1969) to develop discharge estimates. A Pygmy current meter was used to measure stream velocity using the 0.6-depth method at a cross section immediately downstream of the water quality sample point. The accuracy of the velocity meter was tested by obtaining velocity measurements at United States Geological Survey (USGS) gauge 01593450 and comparing discharge rates calculated using velocity data collected with the Pygmy to the discharges recorded at the gauge. Discharge values calculated using the velocity data from the Pygmy current meter were within 5% of the gauge data.

Regression equations using water level, velocity, and cross-section area were explored to develop a stage-discharge relationship for each monitoring station. The resulting discharge estimates were compared to discharge rates obtained from the USGS StreamStats web application and the stream restoration design reports (Biohabitats 2015, KCI 2016) to determine if observed and modelled discharges could be related to specific event recurrence intervals.

While comparison of total sediment contributed as a result of different construction techniques is the goal of the project, it is not a measure that is readily understood by the public. One method for comparing the amount of sediment released during dry vs wet construction that was explored was to compare it to the amount of sediment released during a particular flood event. To do this, sediment rating curves were developed using estimated sediment loads and calculated peak discharge rates from the pre-construction storm data. The rating curves were then used to estimate discharge rates and recurrence intervals using the amount of sediment (kg) released during construction.

2.1.2. Turbidity and TSS

To obtain turbidity and TSS samples, monitoring and automated sampling equipment were also fitted into the monitoring wells located in the main flow path of the stream channel. Turbidity was measured using a YSI 600 OMS V2 fitted with a YSI 6136 sonde that uses scattered white light to measure the density of suspended solids in Nephelometric Turbidity Units (NTU). The sonde was fitted with a wiper mechanism to prevent the optical path from becoming fouled and recording spurious turbidity measurements. The sonde was set to record at 15-minute intervals starting at the top of the hour. An ISCO 6712 portable sampler was set to collect one water sample every 30 minutes for TSS analysis when the water level rose above baseflow and to collect a total of 24 water samples for each storm event. The ISCO recorded the date and time for each bottle filled. The suspended sediment samples were filtered, dried, and weighed using Standard Methods 2540 D-11 (Guy, 1969). Due to the differences in start time and sampling interval, the timing of TSS samples did not coincide with the exact time turbidity measurements were obtained with the YSI sonde. To prepare data for analysis, turbidity values were interpolated between the two closest datapoints before and after the TSS measurement

was taken. A linear relationship between the two turbidity data points was assumed. Suspended sediment data and the corresponding estimated turbidity values were used to develop regression equations to allow turbidity measurements obtained during construction to serve as a surrogate for suspended sediment measurements.

2.1.3. Bed and Bank Composition

Stream bank and bed samples were taken from the stream reaches designated for wet and dry construction at each study site. Sediment samples were taken using a hand shovel from three locations within each reach. The samples from location were mixed to form a composite sample for each reach. Samples were placed in one-gallon-sized bags and sent to a geotechnical lab for particle size analysis using ASTM D422. Bed samples were collected within the same stream reaches as bank samples. The method used followed the procedure designed by Klingeman and Emmitt (1982) and described in Fraley et al. (2009). A bottomless basin of known volume was placed in the stream bed approximately 5 cm below the bed material. The volume of water in the basin was known based on the water depth. Large rocks and material were removed from inside the basin. The bed was then thoroughly agitated and mixed to suspend the bed material inside the basin. A sample was collected and then analyzed for total suspended solids using Standard Methods 2540 D. The results were used to characterize streambed fine sediments likely to be disturbed and released to the stream channel during construction.

2.2. Data Collection During Construction

Turbidity and water levels were monitored throughout the duration of construction at each of the study sites. Upstream turbidity and water level monitors were left in place and a second turbidity sensor was placed downstream of each active construction area. The upstream turbidity monitor provided baseline turbidity for water entering the construction area. The downstream monitor measured the turbidity created by construction. Upstream and downstream turbidity values were subtracted to determine the net effect of construction on turbidity.

Sediment disturbance from in-stream construction was expected to be highly variable and to fluctuate with construction equipment activity. To compensate for this, Straughan reduced the optical turbidity sensor monitoring interval to 5-minute intervals.

Straughan personnel were not on-site during the duration of construction activities at each study location, study funds were not available to cover this activity. Straughan relied on daily logs of instream activity provided by a contractor-supplied on-site construction inspector who recorded the beginning and completion of instream work activities each day. The duration of in-stream construction, in conjunction with the measured differences in turbidity and water depth, and the modelled TSS and discharge volumes allowed for the total sediment load released by each construction technique to be calculated. Single factor ANOVAs were used to test for differences in mean load released per unit time (5 minutes) during dry and wet construction techniques for each stream site. Total sediment load released during dry and wet construction periods were also compared for each stream site.

2.3. Benthic Macroinvertebrates

Benthic macroinvertebrate samples were collected using standard Maryland Biological Stream Survey (DNR 2007) methods. A D-frame net was used to take 20 jabs upstream of the stream construction area, within the area for dry construction, within the area for wet construction, and downstream of the project site. Upstream and downstream samples were used as controls for comparison of IBI scores obtained from the dry and wet construction areas. Each stream reach was sampled prior to construction and again one year after construction was completed. Pre-construction samples were taken at the BBMS (80 jabs) and BBT (60 jabs) sites on September 8, 2015 within cobble/riffle, vegetated bank, snag, sand, leaf pack and root wad habitat features. Post-construction samples were taken on September 9 and 10, 2017 at BBMS (80 jabs) and BBT (60 jabs), respectively. Samples were taken primarily in cobble/riffle habitats with some root wads and leaf packs also sampled. Due to the short length of the constructed area on BBT, the downstream mainstem sample point was used as a control for both streams. Prior to construction at the HCC site, 72 jabs were taken on April 15, 2016 in primarily cobble, leaf pack and root wad habitats. Due to low flow and several down trees, there was insufficient stream length available to obtain 80 jabs. One-year post-construction samples were obtained at the HCC site on April 6, 2018. A total of 80 jabs were obtained in primarily cobble habitats with some leaf packs and root wads sampled. Samples were preserved in ethanol and shipped to Aquatic Resources Center, Inc. for processing.

Biological measures were calculated for each sample based on tolerance values and combined to develop an overall Index of Biotic Integrity (IBI) value and score for each stream reach using methods MBSS biological measures (DNR 2005). DNR tolerance values were not available for Nematoda, Lumbricidae, Orthocladiinae, Tanyptodinae, Sperchonopsis, Neoporus, or Ephrydidae. Tolerance values from NYSDEC 2009 were used for these taxa. Tolerance values were used to calculate six MBSS biological measures (DNR 2005): Total Number of Taxa, Total Number of EPT Taxa, Total Number of Ephemeroptera Taxa, Percent Chironomidae, Percent Intolerant Individuals, and Percent Clingers.

3. Results

Prior to construction, automated water level and turbidity data were collected at BBMS and BBT from August 10, 2015 to December 28, 2015 and at HCC from September 7, 2016 to January 24, 2017. The dates velocity measurements were obtained, dates of storm events when water samples were obtained for TSS analysis, and the dates and duration of dry and wet construction at each site are listed in Table 2.

Table 1. Dates of Pre-Construction and Construction Data Collection.

Site	Pre-Construction Velocity Measurements	Pre-Construction NTU/TSS Sampling	Dry Construction	Wet Construction
BBMS	9/30/2015	9/29/2015	7/12/2016	7/19/2016
	10/01/2015	10/01/2015	7/14/2016	7/20/2016
	10/28/2015	10/03/2015	7/15/2016	7/21/2016
	11/10/2015	10/19/2019	7/18/2016	7/22/2016
		10/28/2015	(4 days)	(4 days)
		12/1/2015		
BBT				8/4/2016
	9/30/2015	9/29/2015	7/28/2016	8/5/2016
	10/01/2015	10/1/2015	8/2/2016	8/8/2016
	10/28/2015	10/28/2015	8/3/2016	8/9/2016
			(3 days)	8/10/2016
				(5 days)
HHC	11/30/2016	11/11/2016	2/6/2017	2/8/2017
	1/23/2017	01/23/2017	2/7/2017	2/9/2017
			(2 days)	(2 days)

Construction occurred at the BBMS and BBT sites in the summer of 2016 and at HCC during the winter of 2017. One of the project assumptions was that construction in the dry would take longer than construction in the wet. The duration of construction at BBMS and HCC was the same for each construction technique. The duration of wet construction at the BBT site was actually longer than the dry construction due to the excessive turbidity created during construction, crews could not see below the surface of the water to properly place footers. The crews eventually had to dewater the work area to complete construction.

Typical restoration techniques installed included stone/boulder toe, log rolls, embedded logs, and riffle grade controls at each study area. At BBMS, only the left bank (facing downstream) was stabilized. Stabilization activities at BBT and HCC included both right and left banks. Channel geometries were not extensively changed through construction of new alignments, construction was undertaken to stabilize banks and allow for improved access to a floodplain. Stream construction lengths were similar across each reach. BBMS dry and wet construction study lengths were each 180 linear feet. BBT dry construction length was 170 and wet was 175 linear feet. HCC dry construction length was 170 linear feet and wet was 200 linear feet.

3.1. Particle Size Distribution

Table 2 summarizes the results of the particle size distribution of bed and bank material within each study area. Stream banks are composed of fine sand or smaller material, which would be readily suspended in the water column. Bed materials were coarser at the BBMS and HCC sites (some gravel) but predominately fine at BBT. Given the similarity in predominant particle sizes, construction activities along the stream banks can be assumed to be capable of creating similar amounts of turbidity and TSS at each of the project locations.

Table 2. Bed and Bank Particle Size Distribution

Stream	Sample Location	Texture	% Silt & Clay	D50 (mm)	Bed Load TSS (g/m ²)*
Bonnie Branch Main Stem	US Bank	Predominantly fine sand and silt	12%	0.096	
	DS Bank	Predominantly silt and clay	46%	0.067	
	US Stream	Predominantly fine gravel to medium sand	28%	1.730	80.264
	DS Stream	Predominantly fine sand and silt	16%	0.094	69.088
Bonnie Branch Tributary	US Bank	Fine to medium sand	38%	0.311	
	DS Bank	Predominantly fine sand and silt	44%	0.090	
	US Stream	Predominantly fine sand and silt	9%	0.144	56.896
	DS Stream	Fine sand and clay with some gravel	17%	0.133	41.656
Howard County Community College	US Bank	Predominantly fine sand	28%	0.241	
	DS Bank	Medium to fine sand	14%	0.400	
	US Stream	Gravel and sand	2%	2.330	82.296
	DS Stream	Gravel and sand	7%	3.709	142.24

*In-situ bed agitation TSS sample.

3.2. Stage-Discharge Relationship

The velocity and depth measurements obtained prior to construction were used to develop equations to predict discharge in liters per second (L/s) from water level data obtained during pre-construction storm events and during construction.

3.2.1. BBMS

Depth and velocity measurements were obtained during four sampling events at BBMS prior to construction. Table 3 lists the dates and start times of the water velocity measurements, associated water levels observed, and calculated discharges.

Table 3. BBMS Pre-Construction Depth and Discharge Measurements

Date	Start Time	Diver depth (cm)	Discharge (L/s)
9/30/2015	10:00	34.91	46.95
10/1/2015	16:00	51.54	641.65
10/1/2015	17:30	45.94	417.26
10/28/15	11:19	34.43	19.09
10/28/15	15:42	39.13	145.74
10/28/15	15:52	38.32	133.45
11/10/2015	12:00	36.76	64.53
11/10/2015	12:10	36.34	61.58

The stage-discharge relationship for BBMS using these data is shown in Figure 3. The power equation ($y = 4E-11x^{7.7743}$) had a $R^2 = 0.9036$ and was used to estimate discharge from water levels measured during construction.

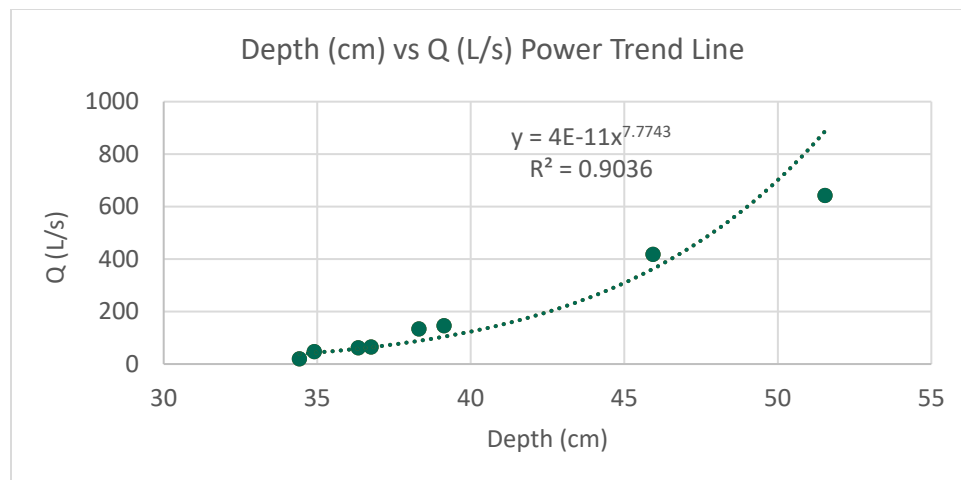


Figure 3. Stage-Discharge Relationship for BBMS

Water levels and discharge rates coinciding with flow measurements obtained during the fall 2015 sample events and calculated during construction are presented in Table 4. During review of the initial results, concern was raised that the water levels and discharges observed during pre-construction data collection were outside of the range of water levels observed during construction. Water depths at the BBMS during construction were on average 30% lower than depths during pre-construction. It was understood that, in order to collect a range of depth and discharge data points to develop a model, that pre-construction data would be collected over a range of flow regimes typically higher than baseflow conditions. To determine if lower water level observations were valid (i.e., due to seasonal variability and not movement of the water level monitor or alteration of the stream channel), Straughan reviewed precipitation data for the pre-construction and construction data collection periods.

Table 4. Water Levels and Discharge at BBMS

Variable		Pre-Construction	Dry Construction	Wet Construction
Water Level (cm)	Minimum	34.43	21.79	21.70
	Maximum	52.91	24.38	25.96
	Median	42.99	22.81	22.63
Discharge (L/s)	Minimum	19.09	1.01	0.00
	Maximum	641.65	2.42	3.95
	Median	98.99	1.45	1.36

Monthly precipitation departures were obtained for Howard County from the National Weather Service (NWS) Middle Atlantic River Forecast Center (RFC) (NOAA NWS 2018). Precipitation departures provide the observed monthly rainfall and compare it to “normal” precipitation totals for that month. Table 5 provides the monthly precipitation departures from September 2015 to August 2016, collected from NWS Middle Atlantic RFC.

Table 5. RFC Precipitation Departures for the BBMS Study Period.

Date	Mean PPT Total (cm)	Departure from Average (cm)	% Departure from Average
Sep-15	10.16	-0.25	-10% to +10%

Oct-15	9.65	0.25	-10% to +10%
Nov-15	6.86	-2.29	26% to 50% below
Dec-15	12.19	3.30	26% to 50% above
Jan-16	11.43	3.30	26% to 50% above
Feb-16	12.45	4.57	51% to 75% above
Mar-16	5.33	-4.83	26% to 50% below
Apr-16	5.33	-3.81	26% to 50% below
May-16	15.49	4.06	26% to 50% above
Jun-16	11.68	1.78	11% to 25% above
Jul-16	17.27	7.11	51% to 75% above
Aug-16	8.89	0.51	-10% to +10%

The pre-construction data collected in the fall of 2015 were collected during a period when precipitation levels were average. The December 1st pre-construction data were collected after November when levels were below average. Construction occurred in July 2016, which appeared to be 51% to 75% above average precipitation that month and had the highest monthly precipitation totals for the year. To validate the RFC data, Straughan obtained additional data from the Parameter-elevation Regressions on Independent Slopes Model (PRISM) Climate Group at Oregon State University, which includes daily precipitation as well as monthly totals.

Patterns in the PRISM monthly data were similar to the RFC values. However, a rain gage within the PRISM data indicated that as much as 15.00 cm of rain fell during the July 29-30, 2016 Ellicott City 1,000-year storm event, 2 miles northwest of Bonnie Branch (Grumm et al. 2016). Construction at BBMS occurred from July 12 to July 22, 2016, ending a week before the major storm event. If the events after construction are removed from the monthly totals, the total rainfall for the month could have been as low as 2.27 cm. The average rainfall total for the pre-construction data (September 2015-December 2015) was 9.72 cm. Thus, construction at the BBMS site occurred when precipitation levels were 77% lower than the monthly average observed during pre-construction data collection. We concluded that the lack of rainfall prior to construction explains the reduction in stream depth recorded at the monitoring station for BBMS and that the data are valid.

3.2.2. BBT

Depth and velocity measurements were obtained during three sampling events at BBT prior to construction. Dates, start times, depths, and calculated discharge rates for the sample events are listed in Table 6.

Table 6. BBT Pre-Construction Depth and Discharge Measurements

Date	Start Time	Diver depth (cm)	Discharge (L/s)
9/30/2015	10:45	11.58	8.48
10/1/2015	15:30	15.67	40.67
10/1/2015	16:45	14.03	24.62
10/1/2015	17:00	14.79	29.25

10/28/15	10:38	9.13	2.90
10/28/15	10:53	8.96	2.16
10/28/15	15:12	11.04	12.14
10/28/15	15:19	10.90	12.04
10/28/15	15:25	10.90	7.55

The stage-discharge relationship for BBT is shown in Figure 4. The power equation ($y = 8E-05x^{4.8192}$) had a $R^2 = 0.9322$

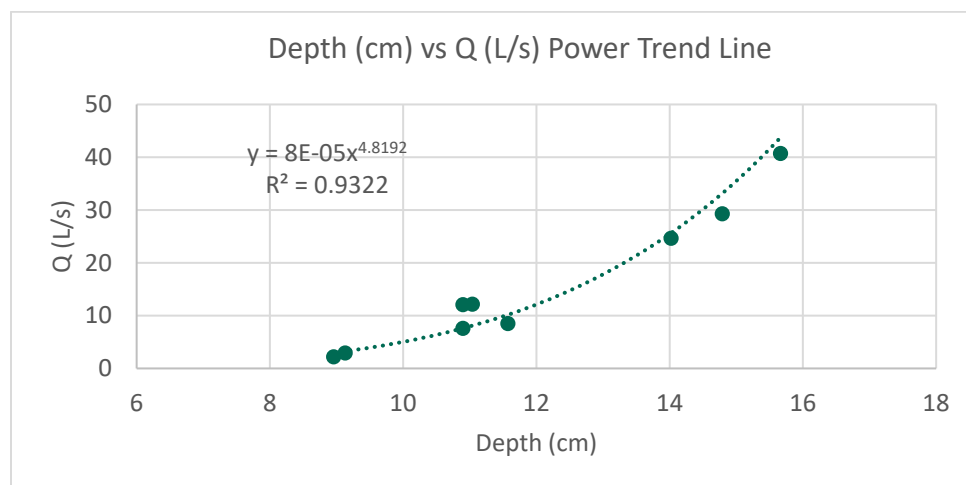


Figure 4. Stage-Discharge Relationship for BBT

On July 29, 2016, the surrounding area received a 1,000-year storm event. High flows within the BBT dislodged monitoring equipment. The equipment was retrieved, checked to ensure function, and reinstalled. When the monitor was reinstalled, it was installed at a slightly lower elevation within the channel than before, artificially elevating the water depth recorded in the data. Since water levels in the stream were visually similar prior to the flood and after the monitor was reinstalled, 14.4 cm was subtracted from the data collected after reinstallation so that mean and median water levels and estimated discharge rates were similar to pre-storm values. Water levels and discharge rates coinciding with velocity measurements obtained during the fall of 2015 and during construction are presented in Table 7.

Table 7. Water Levels and Discharge at BBT

Variable		Pre-Construction	Dry Construction	Wet Construction
Water Level (cm)	Minimum	11.11	0.26	0.36
	Maximum	16.08	2.34	2.38
	Median	14.79	1.34	1.07
Discharge (L/s)	Minimum	8.48	0.00	0.00
	Maximum	40.67	4.83	5.25
	Median	29.25	0.32	0.11

3.2.3. HCC

Depth and velocity measurements were obtained twice during two sampling events at HCC prior to construction. Dates, start times, depths, and calculated discharge rates for the sample events are listed in Table 8.

Table 8. HCC Pre-Construction Depth and Discharge Measurements

Date	Start Time	Diver depth (cm)	Discharge (L/s)
11/30/2016	10:40:24	61.88	45.84
11/30/2016	11:10:24	58.92	44.20
1/23/2017	11:40:24	48.87	15.81
1/23/2017	12:55:24	52.85	30.97

The stage-discharge relationship for HCC is shown in Figure 5. The power equation ($y = 7E-07x^{4.4016}$) and a $R^2 = 0.9011$.

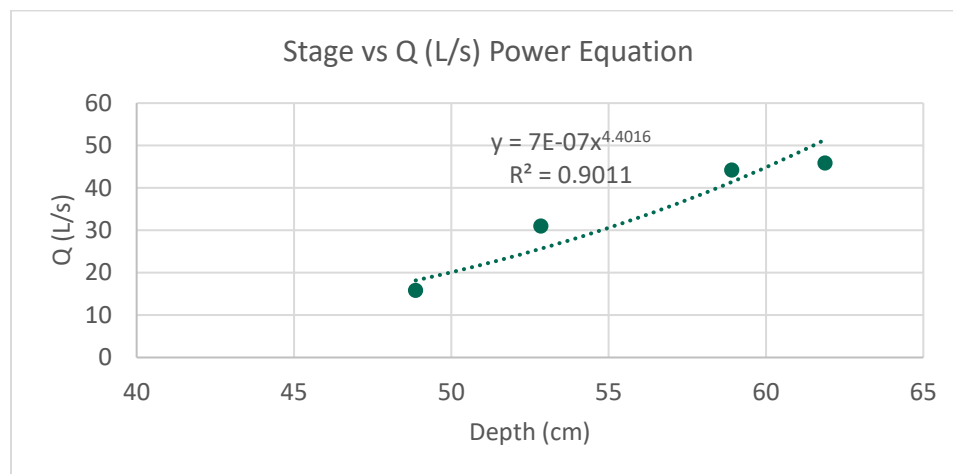


Figure 5. Stage-Discharge Relationship for HCC

Water levels coinciding with flow measurements and estimated during construction are presented in Table 9.

Table 9. Water Levels and Discharge at HCC

Variable		Pre-Construction	Dry Construction 2/6/2017 -2/7/2017	Wet Construction 2/8/2017 – 2/9/2017
Water Level (cm)	Minimum	43.35	37.47	19.37
	Maximum	61.88	46.04	46.05
	Median	51.84	39.27	44.38
Discharge (L/s)	Minimum	15.81	5.91	0.32
	Maximum	45.84	14.64	14.58
	Median	30.97	7.27	12.42

3.2.4. Peak Flows and Storm Return Intervals

The estimated peak discharge rates for the 1.25-, 2-, 5-, 10-, 25-, 50-, and 100-year flood intervals for each site obtained from StreamStats and the design reports are presented in Table 10.

Table 10. Estimated Peak Discharge Rates (L/s) at Different Return Intervals for BBMS, BBT, and HCC

	BBMS		BBT		HCC	
	StreamStats	Design Report	StreamStats	Design Report	StreamStats	Design Report
1.25-year	2,860	2,832	270	38	804	866
2-year	5,012	4,984	558	272	1,308	1,271
5-year	9,684	9,713	1,311	-	2,353	-
10-year	14,243	14,300	2,158	2,425	3,341	2,665
25-year	22,314	22,455	3,851	-	5,012	-
50-year	30,582	30,582	5,748	-	6,711	-
100-year	40,776	41,059	8,353	6,016	8,778	5,785

Of the pre-construction storm events when water level, turbidity, and TSS measurements were taken at BBMS, only one had a calculated discharge in the range of a peak flow. The power stage-discharge equation predicted a peak flow of 5,284 L/s for an event on September 29, 2015. This discharge approximated a 2-year event. Maximum discharges calculated using the power equation for the other storms were well below the estimated peak discharge of the 1.25-year storm. The maximum discharges calculated for the BBT (47.5 L/s on December 1, 2015) and HCC sites (96 L/s on November 30, 2016) were also well below the 1.25- year estimated peak flows.

The larger drainage area for the BBMS site created greater discharges than the other sites. BBMS also continued to carry baseflow through almost the entirety of the study while BBT and HCC exhibited negligible flows during summer months and periods of low rainfall.

3.3. NTU-TSS Relationship

Turbidity (NTUs) and TSS were sampled during storm events prior to construction to develop models to estimate TSS from NTU data collected during construction.

3.3.1. BBMS

Pre-construction turbidity measurements and water samples for TSS (mg/L) analysis were obtained during storms that occurred on September 30, October 1, 3, 19, 28, and December 1, 2015. Over the course of the six storms, a total of 140 water samples were obtained at 30-

minute intervals. Of these, nine outliers were removed from the dataset where either NTU or TSS exhibited a dramatic increase or decrease for one or two consecutive datapoints that did not 1) follow the pattern of the data or 2) was not paired with a similar rise or fall in the corresponding measurement. The linear regression equation developed from pre-construction NTU and TSS data ($y = 1.5996x$) had a $R^2 = 0.8134$

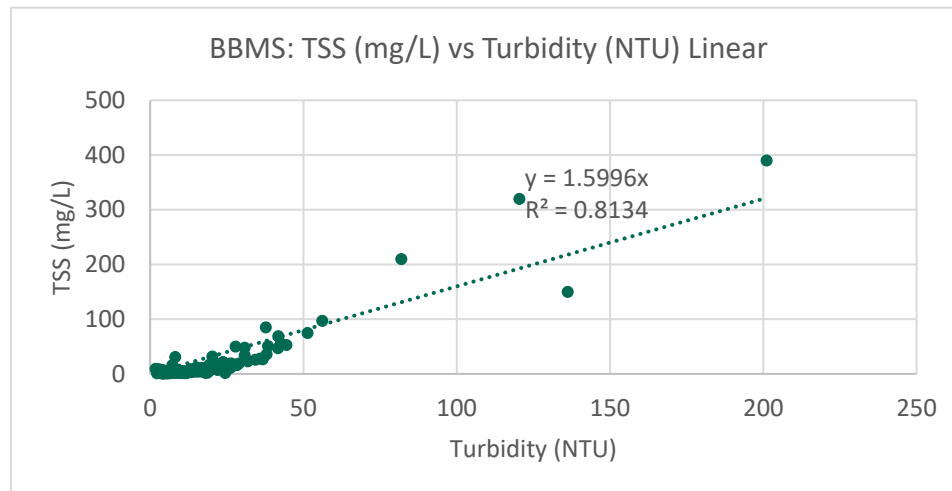


Figure 6. Linear Regression to Estimate TSS from NTU at BBMS

During construction, when upstream NTU values were subtracted from NTU data collected downstream of construction, it was noticed that many of the differences were minor (less than 5 NTU, the visual limit). Many of the minor differences were also negative (e.g., -1.0 NTU), meaning that turbidity was lower downstream of construction compared to upstream. To remove minor differences in the data, a threshold limit was established and any difference between upstream and downstream NTU closer to zero than the limit (either positive or negative) was assumed to be 0.0, i.e., no difference in NTU upstream and downstream of the construction reach. The threshold was set to the visible limit of 5.0 NTU. Therefore, differences between upstream and downstream turbidity between -2.50 and 2.50 were adjusted to zero to remove "noise" of very small changes between upstream and downstream turbidity. This was done on the data at the other sites as well.

Table 11 contains the mean, minimum, maximum, and median values of turbidity data collected during the six storms prior to construction and increase in NTUs from upstream to downstream observed during dry and wet construction. Mean, maximum, and median NTU values during both dry ($n=498$) and wet ($n=451$) construction periods were outside the values observed during the pre-construction storms.

Table 11. BBMS NTU Summary Statistics

	Pre-construction	Dry Construction Increase in NTU	Wet Construction Increase in NTU
Mean	18.48	548.00	313.85
Max	201.04	1,298.34	1,206.91
Min	1.71	2.62	4.15
Median	11.61	668.43	99.98

Mean, minimum, maximum, and median TSS values estimated from NTU increases measured during dry and wet construction at BBMS are included in Table 12. NTU data used as inputs to the model and predicted TSS values for both construction techniques were outside the range of preconstruction data used to develop the equations, so results are extrapolated.

Table 12. BBMS TSS (mg/L) Summary Statistics

	Pre-construction TSS mg/L	Dry Construction TSS mg/L	Wet Construction TSS mg/L
Mean	19.21	415.59	495.36
Max	390.00	2,076.82	1,930.57
Min	1.00	0.00	0.00
Median	4.40	0.00	156.89

3.3.2. BBT

Pre-construction turbidity measurements and water samples for TSS (mg/L) analysis were obtained during storm events on October 1, 28 and December 1, 2015. During the October 28, 2015 storm, two very large spikes occurred within the turbidity data accompanying small spikes in TSS. Turbidity readings during these spikes are >1,000 NTU, more than 20 times the other turbidity levels observed during the other two storm events at BBT. There are no associated increases in water level or discharge that occur with these spikes, which span more than four hours of a 5-6 hour storm event. We believe these spikes in turbidity represent erroneous data. Our experience with using automated data loggers within PVC housings is that sediment can become trapped within the housing, essentially burying the turbidity monitor. Macroinvertebrates, leaves, and other detritus can also become lodged within the monitor, temporarily interrupting the flow of light and providing a false turbidity reading. These data points were omitted when developing the regression equations used to estimate TSS during construction at the BBT site. NTU to TSS regression equations are based on data collected during the October 1 and December 1, 2015 storm events.

Over the course of the two storms, a total of 48 water samples (24 sample points per storm) were obtained at 30-minute intervals for TSS analysis. Of the 48 data points, 14 outliers were removed from the dataset where either NTU or TSS exhibited a dramatic increase or decrease for one or two consecutive datapoints that did not 1) follow the pattern of the data or 2) was not paired with a similar rise or fall in the corresponding measurement.

The linear regression equation ($y = 1.0702x$) had an $R^2 = 0.4876$ (Figure 8). As with BBMS, the equation was modified to force the line through the origin.

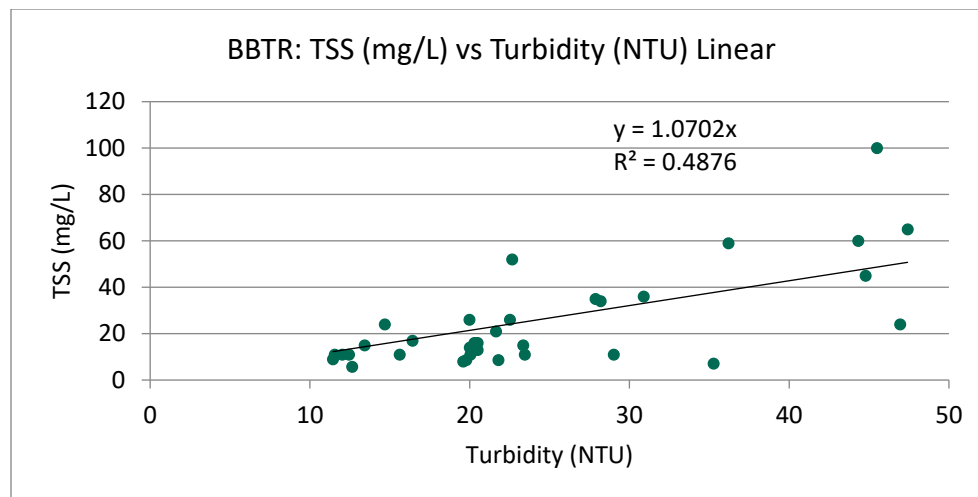


Figure 7. Linear Regression to Estimate TSS from NTU at BBT

Table 13 contains the mean, minimum, maximum, and median values of turbidity data for the two storms and for data collected during dry and wet construction. During both dry (n=323) and wet (n=460) construction periods, mean and maximum values for the difference between upstream-downstream NTUs were outside of the range of values observed during the pre-construction storms.

Table 13. BBT NTU Summary Statistic

	Pre-construction	Dry Construction Increase in NTU	Wet Construction Increase in NTU
Mean	25.42	81.10	123.61
Max	47.41	1,116.39	1,236.45
Min	11.44	3.05	2.50
Median	21.72	45.93	20.32

Mean, minimum, maximum, and median TSS values estimated from NTU increases are included in Table 14. NTU measurements and predicted TSS values for both construction techniques were outside the range of preconstruction data used to develop the equations, so results are extrapolated.

Table 14. BBT TSS (mg/L) Summary Statistics

	Pre-construction TSS mg/L	Dry Construction TSS mg/L	Wet Construction TSS mg/L
Mean	23.63	19.89	114.17
Max	100.00	1,194.76	1,323.25
Min	5.70	0.00	0.00
Median	15.00	0.00	17.41

3.3.3. HCC

Pre-construction turbidity measurements and water samples for TSS (mg/L) analysis were obtained during storm events on September 27, 28, November 29, 30, 2016 and January 11 and

23, 2017. Over the course of the storms, a total of 129 water samples were obtained at 30-minute intervals for TSS analysis. Of the 129 data points, 51 outliers were removed from the dataset where either NTU or TSS exhibited a dramatic increase or decrease for one or two consecutive datapoints that did not 1) follow the pattern of the data or 2) was not paired with a similar rise or fall in the corresponding measurement.

One factor that complicated the use and analysis of data from the HCC site was that, unlike the BBMS and BBT sites where the study reaches encompassed the entire length of all proposed construction, the dry and wet study reaches at HCC were located in the middle of a longer stream restoration project (see site plans in Appendix A). During dry construction at the HCC site, highly turbid water from upstream construction pooled at the upstream sensor. In addition, the discharge point of the diversion was also incorrectly located downstream of the downstream turbidity sensor. Therefore, the difference between upstream and downstream NTU values could not be determined. We observed that the turbidity of water entering the site during wet construction at HCC had a median value of 3.40 NTUs, below the visual detection limit. The data from the turbidity meter downstream of the dry construction only was used to calculate TSS. The linear regression equation developed from preconstruction NTU and TSS data ($y = 0.977x$) had an $R^2 = 0.6451$.

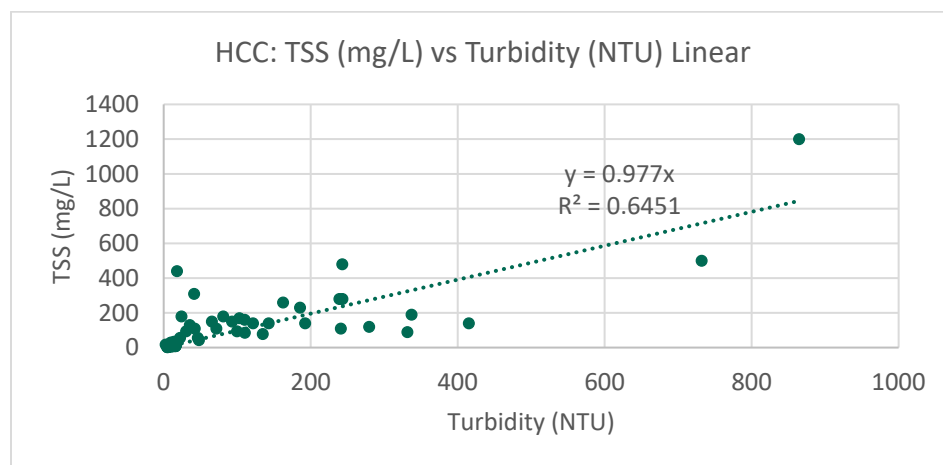


Figure 8. Linear Regression to Estimate TSS from NTU at HCC

Table 15 contains the mean, minimum, maximum, and median values of turbidity data for the six storms and for data collected during dry and wet construction. Unlike BBMS and BBT, mean, maximum, minimum, and median NTU during dry (n=253) and the increase in NTU during wet (n=165) construction periods were similar to the values observed prior to construction.

Table 15. HCC NTU Summary Statistics

	Pre-construction	Dry Construction NTU	Wet Construction Increase in NTU
Mean	61.59	93.47	44.56
Max	864.43	1,038.20	633.10
Min	2.49	24.30	3.10
Median	16.30	73.30	24.20

Mean, minimum, maximum, and median TSS values estimated from NTU during dry and wet construction at HCC are included in Table 16. Unlike at the BBMS and BBT sites, NTU data used as inputs to the model and predicted TSS values for both construction techniques were within the range of preconstruction data used to develop the equations.

Table 16. HCC TSS (mg/L) Summary Statistics

	Pre-construction TSS mg/L	Dry Construction TSS mg/L	Wet Construction TSS mg/L
Mean	93.55	91.32	40.64
Max	1,200.00	1,014.32	618.54
Min	3.10	23.74	0.00
Median	25.00	71.61	23.25

3.4. Sediment Load Comparison

Estimated TSS mg/L values were multiplied by estimates for Q (L/s) to develop estimates of sediment load per unit time (sampled once per 5 minutes) for the duration of dry and wet construction at each site. Estimates per unit time were summed to estimate the total amount of sediment (kg) discharged during the entirety of each type of construction. The total amount of sediment was then placed in the context of estimated total annual sediment load and the load contributed by the pre-construction storms.

$$\text{Total Load During Construction (kg)} = \text{TSS} \left(\frac{\text{mg}}{\text{L}} \right) * Q \left(\frac{\text{L}}{\text{s}} \right) * \left(\frac{\text{kg}}{\text{mg}} \right)$$

3.4.1. BBMS

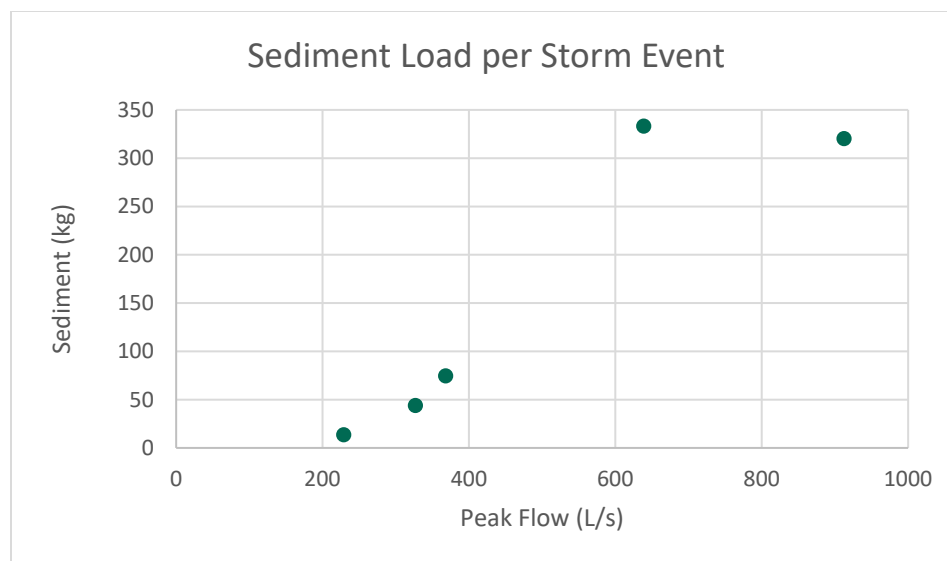
The total estimated sediment load created by the four days of dry construction at BBMS (TSS * Q = Load kg) was 104.70 kg. The total estimated sediment load created by the four days of wet construction was 99.97 kg. The results of the ANOVA (alpha = 0.050, F = 0.426, p=0.514) indicate that there was no difference in the mean load contributed per unit time between dry and wet construction techniques at the BBMS site.

To place these results in context; prior to restoration the annual amount of sediment produced by the stream banks at the BBMS site was calculated to be 19,087 kg/yr (Biohabitats 2015). The total sediment load produced during the four days of dry construction is approximately 0.55% of the pre-construction annual total. The total amount of sediment produced during the four days of wet construction is approximately 0.52% of the pre-construction annual total.

Estimates of the peak flow and total amount of sediment transported during each of the pre-construction storm events is presented in Table 17. The first storm was larger than the other five and had a much higher sediment load, which would have masked the effect of the other storms and was omitted from the analysis. Figure 9 represents the five storms with total estimated sediment in the range of that contributed by wet and/or dry construction (approximately 100 kg). A sediment load of 100 kg is equal to an approximate peak flow of 450 L/s. Since the 1.25-yr event has an estimated peak flow of 2,800 L/s, an event with a peak flow of 450 L/s and that transported 100 kg of sediment would be a frequent event that happens several times a year.

Table 17. Estimated Sediment Discharge During Pre-Construction Storms

Dates of Storms	Peak Flow (L/s)	Cumulative Sediment Load (kg)
September 30, 2015	5,284	7,366
October 1, 2015	913	320
October 3, 2015	368	74
October 19, 2015	327	44
October 28, 2015	229	13
December 1, 2015	639	333

*Figure 9. Sediment Load per Pre-construction Storm Event at BBMS*

3.4.2. BBT

The total estimated sediment load created during the three days of dry construction ($TSS * Q = \text{Load kg}$) at BBT was 0.46 kg. The total estimated sediment load created during the five days of wet construction was 4.30 kg. The results of the ANOVA ($\alpha = 0.050$, $F = 27.44$, $p < 0.001$) indicate that there was a significant difference in the mean load contributed per unit time between dry and wet construction techniques at the BBT site. Wet construction contributed more sediment to the stream than dry.

That said, water levels and discharge rates were so low during the construction of BBT due to the below average precipitation conditions, that actual discharge of water or sediment during either construction technique was negligible. Prior to restoration, the total amount of sediment produced by the stream banks at the BBT site was estimated to be 3,882.75 kg/yr (KCI 2016). The total amount of sediment produced during the three days of dry construction was 0.01% of the pre-construction annual total. The total amount of sediment produced during the five days of wet construction was 0.11% of the pre-construction annual total.

Estimated peak flows and the cumulative sediment load for the two pre-construction storm events at BBT are presented in Table 18. The two storms were very similar, too similar in fact to develop a useful equation relating sediment load to peak flow. The estimated peak flow for the 1.25-yr event at BBT was estimated to be 270 L/s using StreamStats and 38 L/s according to the design report. Regardless of which number is used, an event with a sediment discharge similar to the 4.30 kg of sediment created by wet construction is likely to occur several times a year.

Table 18. Estimated Sediment Discharge During Pre-Construction Storms

Date of Storms	Peak Flow (L/s)	Cumulative Sediment Load (kg)
October 1, 2015	46.7	19.9
December 4, 2015	47.5	18.9

3.4.3. HCC

The total estimated sediment load created during the two days of dry construction at the HCC site ($TSS * Q = \text{Load kg}$) was 51.25 kg. The total estimated sediment load created during the two days of wet construction was 61.04 kg. The results of the ANOVA ($\alpha = 0.050$, $F = 3.809$, $p=0.052$) indicate that there was no significant difference in the mean load contributed per unit time between dry and wet construction techniques at the HCC site. However, since the upstream turbidity meter was not collecting usable data during dry construction, only the data from the downstream turbidity monitor was used in the analysis. Thus, the NTUs and subsequent TSS and sediment load are likely overestimated for dry construction.

Prior to restoration, the total amount of sediment produced by the stream banks at the HCC site was calculated to be 20,683.82 kg/yr (KCI 2016). The total sediment load produced during the two days of dry construction is approximately 0.25% of the pre-construction annual total. The total amount of sediment produced during the two days of wet construction is approximately 0.30% of the pre-construction annual total.

Estimates of the total amount of sediment transported during each of the pre-construction storm events at HCC is presented in Table 19. The last storm was longer than the other five (it covered the entire 12-hour sample period and was likely longer) and had several periods of high flow and high TSS unlike the other storms. Although its peak flow was only 42 L/s, its cumulative sediment load was an order of magnitude higher than other observed events. This outlier was omitted from the data in Figure 10. A sediment load of 61 kg (amount discharged during wet construction) is approximately equal to a peak flow of 105 L/s. Since the 1.25-yr event has an estimated peak flow of 800 L/s, an event with a peak flow of 105 L/s that transports 61 kg of sediment would be a frequent event occurring several times a year.

Table 19. Estimated Sediment Discharge During Pre-Construction Storms

Date of Storm	Peak Flow (L/s)	Cumulative Sediment Load (kg)
September 27, 2016	28	15
September 28, 2016	47	72
November 29, 2016	30	13
November 30, 2016	96	37

January 11, 2017	21	12
January 23, 2017	42	328

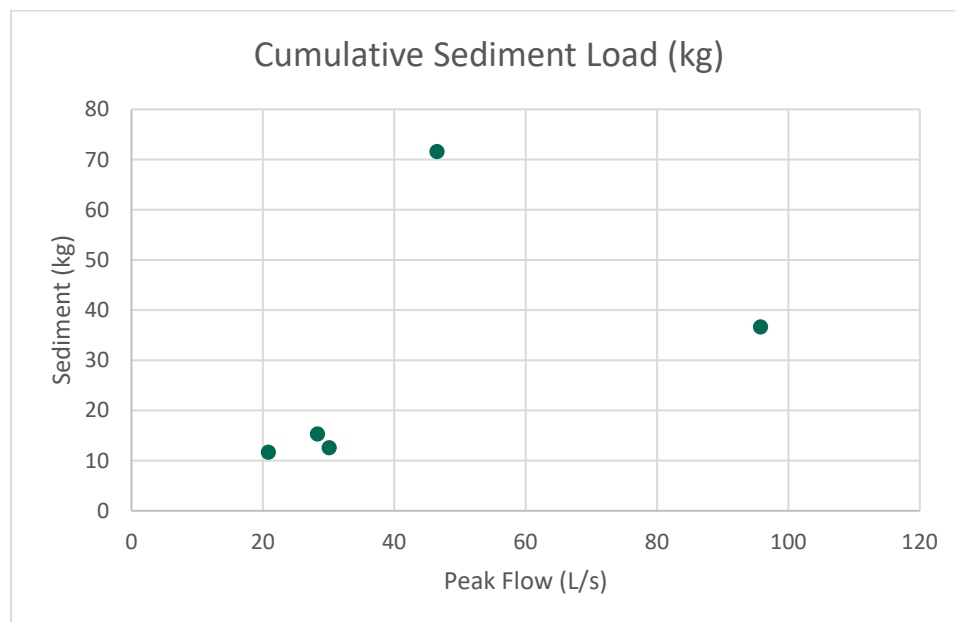


Figure 10. Sediment Load per Pre-construction Storm Event at HCC

3.5. Macroinvertebrates

All proposed study sites are located within the Piedmont Physiographic Province on forested Howard County property, all sites are proximate to potential sources of macroinvertebrate colonists (Sundermann et al., 2011). BBMS would also receive a steady supply of colonists from upstream. The difference between the pre- and post-construction IBI scores for the upstream, dry construction, wet construction, and downstream reaches for each metric and site and the associated ANOVA p value to test for differences in score across treatments are presented in Table 17. Negative values (in red) indicate that the IBI score for that metric at that site was lower one year after construction compared to the IBI score for that site before construction.

Table 20. Results of Single Factor Anova on IBI Scores per Metric

IBI Metric	Site	Difference between Pre- and Post-Construction IBI Score				p value
		Upstream	"Dry"	"Wet"	Downstream	
Total Taxa	BBMS	(2.0)	(4.0)	(2.0)	(2.0)	0.317
	BBTR	(2.0)	(2.0)	(2.0)		
	HCC	(1.0)	(2.0)	(1.0)	(4.0)	
EPT taxa	BBMS	0.0	0.0	0.0	0.0	0.676
	BBTR	2.0	0.0	2.0		
	HCC	0.0	0.0	0.0	0.0	
Ephemeroptera taxa	BBMS	2.0	0.0	0.0	2.0	0.471
	BBTR	0.0	0.0	0.0		
	HCC	0.0	0.0	0.0	0.0	
% Chironomidae	BBMS	0.0	0.0	0.0	(2.0)	0.260
	BBTR	0.0	2.0	0.0		
	HCC	0.0	0.0	0.0	0.0	
% Intolerant Individuals	BBMS	0.0	0.0	0.0	0.0	0.885
	BBTR	2.0	0.0	0.0		
	HCC	(2.0)	(2.0)	(2.0)	(2.0)	
% Clingers	BBMS	2.0	2.0	2.0	0.0	0.615
	BBTR	0.0	2.0	0.0		
	HCC	0.0	0.0	0.0	0.0	
MBSS IBI	BBMS	0.3	(0.3)	0.0	(0.3)	0.465
	BBTR	0.4	0.4	0.0		
	HCC	(0.5)	(0.7)	(0.5)	(1.0)	

A qualitative comparison of pre- and post-construction macroinvertebrate IBI Score indicates a general reduction in Total Number of Taxa within each sample reach at each stream. No changes in IBI scores were observed for Total Number of EPT Taxa or Total Number of Ephemeroptera Taxa. Results were mixed for Percent Chironomidea, Percent Intolerant Individuals (notable decrease across the HCC site), and overall IBI Score. Percent Clingers was the only measure where IBI score seemed to increase or remain unchanged. Results of single factor ANOVA indicated that there were no statistical differences in Pre- vs Post-Construction IBI Scores at upstream, dry, wet, or downstream sample reaches for any metric at these three streams¹.

3.6. Riparian Area

Visual comparison of the LODs for the sections of stream channel to be constructed in the dry or in the wet indicated no difference in impacts to riparian vegetation. At all three study sites, the LOD was created to allow construction access to the stream and proposed grading to occur.

¹ These results should only be applied to the difference in pre- vs post-construction IBI score for dry vs wet construction at these three locations, compared to the upstream and downstream control reaches. These results should not be extrapolated to infer that there are no differences in pre- vs post-construction IBI scores across stream restoration projects as a whole.

At all three sites, LODs were similarly minimized to avoid impacts to large trees and other regulated resources regardless of proposed construction technique.

4. Discussion and Conclusions

4.1. Sediment Loads

A comparison of sediment loads between wet vs dry construction varied by sampling site. At the BBMS site, there was no statistical difference in sediment load per unit time between dry vs wet construction. At the BBT sites, the difference in sediment released between dry and wet construction techniques was significantly different (dry being lower). At the HCC site, there was no statistical difference between wet vs dry construction regarding sediment load (although insufficient data may have resulted in an overestimate of sediment load during dry construction, as noted in Section 3.4.3).

As was stated earlier, the construction techniques were similar at all three locations. However, the location of the filtration device used to filter the water pumped out of the work area was not. At the BBMS site, the sediment bag was located immediately adjacent to the stream channel (Photographs 1 and 2). Photograph 1 shows the location of the sediment bag relative to the stream diversion discharge on the morning the pump around was set up (left side). The turbidity monitoring station (black and white tube) was originally placed too far upstream to capture discharge from the sediment bag and diversion and was relocated to the proper downstream position at the beginning of the second day of construction (Photograph 2).



Photograph 1. Location of the Sediment Bag and Diversion Discharge



Photograph 2. Adjusted Location of Monitoring Equipment

At the BBT site, conditions were so dry during construction, that while the downstream dike was set up, the work area did not need to be dewatered (lower right Photograph 3). The negligible amount of flow at the BBT site meant that little to no sediment was discharged from the site regardless of construction technique employed.

At the HCC site, the sediment bag was located away from the stream channel and there was sufficient flow within the channel to calculate a sediment load per unit time for comparison of the two construction techniques. However, the lack of upstream turbidity data during the dry construction likely led to an overestimate of sediment contributed during that construction technique resulting in no significant difference between wet and dry construction.

Dewatering costs for the two Bonnie Branch sites were a total of \$9,102 for both sites (costs were lumped for the two sites and not available separately). Total construction cost for the two Bonnie Branch sites was \$490,006. Dewatering for the dry construction stream areas was approximately 1.86% of the overall construction cost but includes only half of what would normally have to have been dewatered. Dewatering for the entire construction of BBMS and BBT would have been approximately 3.65% of the overall cost, which is still lower than it could have been due to the dry weather during the summer of 2016. At the HHC site, the cost of dewatering was \$11,273 out of a total construction cost of \$702,533 (1.60%), however, these amounts include additional stream restoration activities upstream and downstream of the study area.



Photograph 3. BBT Dry Construction Looking Upstream.

Our interpretation of these results is that the observed differences in dry vs wet sediment loads is likely due to the location of the filtering device used to dewater the work area. Sediment bags are not designed to filter the fine sediments that create high turbidity and only reduce sediments by approximately 70% (Kang and McLaughlin 2016). Therefore, it was not surprising that when the bag was located immediately adjacent the stream channel, fine materials that were not filtered out would increase the turbidity in the stream compared to locating the bag further away from the channel.

The differences between upstream and downstream turbidity levels at BBMS for dry and wet construction are shown on Figure 11. During construction in the wet, turbidity spiked when construction began and generally decreased over time throughout the day. On the last day of working in the wet, crews were able to work from the bank and no equipment entered the channel and turbidity levels were very low throughout the entire day. When working in the dry, large spikes in turbidity are seen throughout the entire day, possibly even when no work is being conducted from within the channel since the pump would have continued to run and keep the area dewatered even when crews were not actively working in the stream.

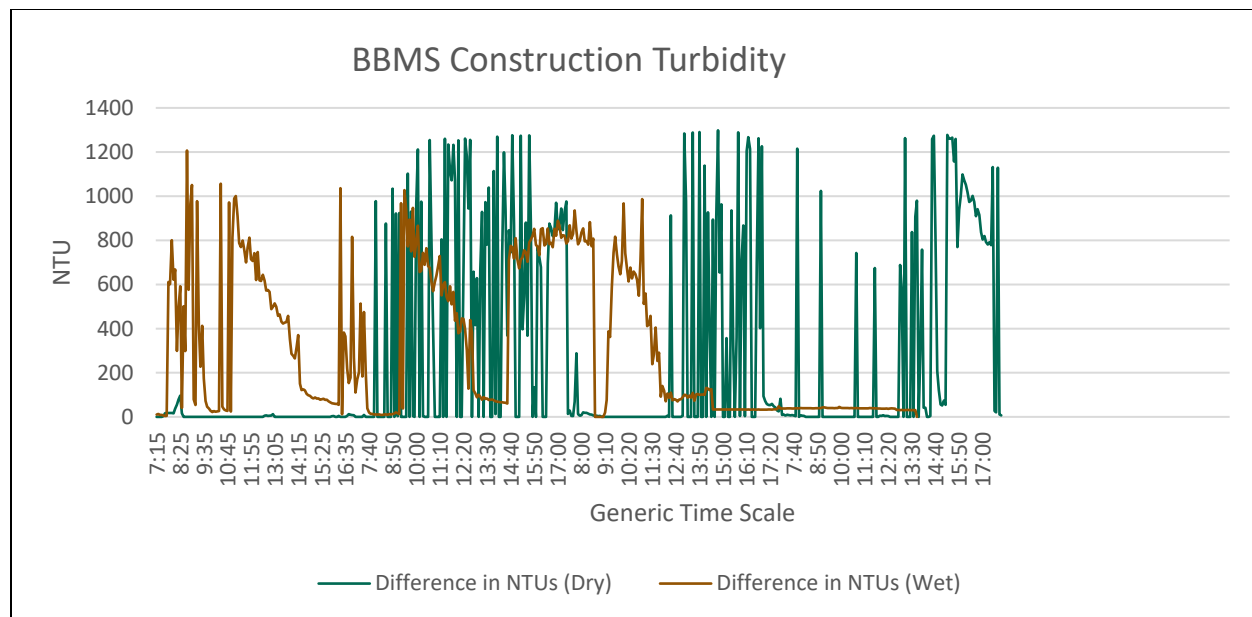


Figure 11. BBMS Turbidity Levels During Dry and Wet Construction

Identifying the location of the filtering device relative to the stream as a cause of high turbidity and sediment loads is one result of this study that practitioners can implement immediately to decrease sediment loads during construction (given adequate LOD by reviewers to place the filtration device further from the channel).

The amount of sediment contributed during wet construction for each of the (albeit short duration) stream restoration projects was less than 1.0% of the estimated annual total of the stream prior to construction and about as much as a typical storm event contribute several times a year.

4.2. Biological Impact

There were no significant differences or discernable patterns in pre- vs post-construction IBI scores observed in wet vs dry construction areas. The lack of a difference is possibly due to the short length (linear feet) and duration of stream construction relative to the abundance of colonists available from upstream.

4.3. Riparian Disturbance

When the comparison of riparian impacts between dry and wet construction was first proposed, it was thought that working in the wet would allow the contractors to work directly in the stream channel and that they would not need to create additional LOD outside of the channel to move equipment and access portions of the channel for construction. In order to test for potential differences in riparian impacts from wet vs dry construction, the stream design would have to account for the construction access. It would also require that streams be large enough that equipment could access the work area entirely from within the channel. This was not the case with BBT and HCC, which were very small streams (less than 15 feet wide at bankfull).

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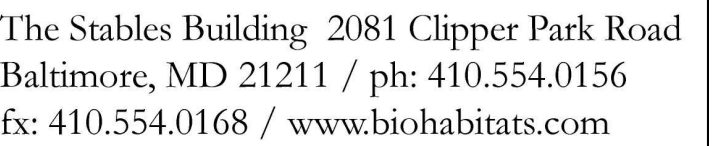
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Appendices

Appendix A. Bonnie Branch and Howard County Community College Stream Restoration Site Plans

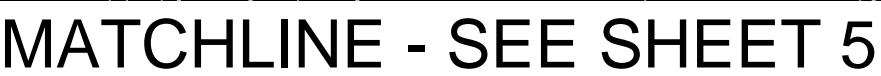
HOWARD COUNTY
STORMWATER MANAGEMENT DIVISION
6751 COLUMBIA GATEWAY DRIVE
SUITE 514
COLUMBIA, MD 21046

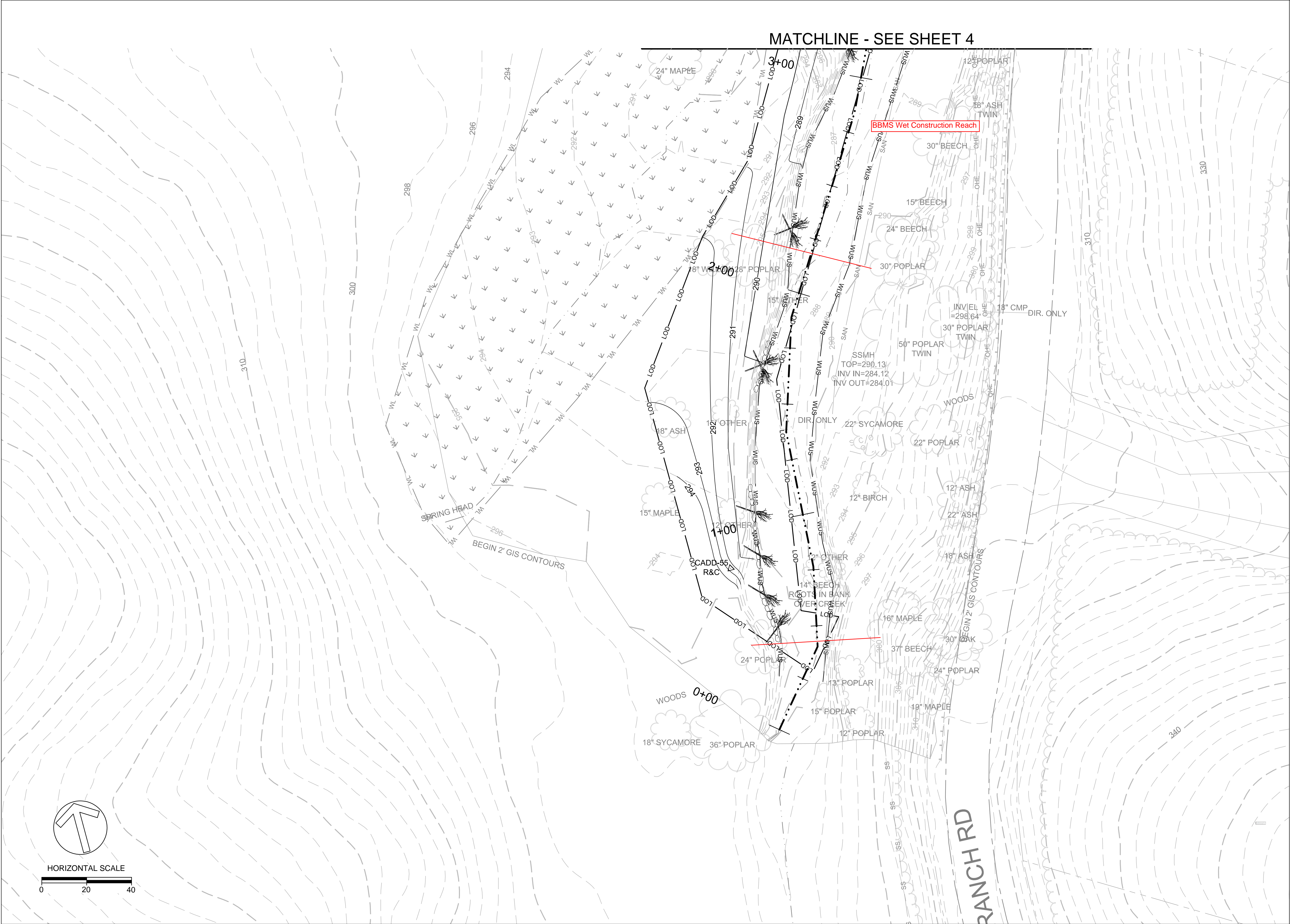
No.	Name	Sex	Age	Date	Time	Place	Remarks
1	John Doe	Male	25	10/10/2023	10:00	City Center	First sighting
2	Jane Smith	Female	30	10/10/2023	11:30	City Center	Second sighting
3	Robert Johnson	Male	45	10/10/2023	14:00	City Center	Third sighting
4	Emily White	Female	22	10/10/2023	16:45	City Center	Fourth sighting
5	Michael Brown	Male	35	10/10/2023	18:20	City Center	Fifth sighting
6	Sarah Davis	Female	28	10/10/2023	19:15	City Center	Sixth sighting
7	David Wilson	Male	40	10/10/2023	20:30	City Center	Seventh sighting
8	Olivia Taylor	Female	20	10/10/2023	21:00	City Center	Eighth sighting
9	James Miller	Male	38	10/10/2023	22:15	City Center	Ninth sighting
10	Ava Garcia	Female	24	10/10/2023	23:00	City Center	Tenth sighting
11	Noah Hernandez	Male	32	10/10/2023	00:45	City Center	Eleventh sighting
12	Isabella Lopez	Female	26	10/10/2023	01:30	City Center	Twelfth sighting
13	Liam Martinez	Male	33	10/10/2023	02:15	City Center	Thirteenth sighting
14	Mia Anderson	Female	21	10/10/2023	03:00	City Center	Fourteenth sighting
15	Ethan Thomas	Male	37	10/10/2023	03:45	City Center	Fifteenth sighting
16	Avery Clark	Female	23	10/10/2023	04:30	City Center	Sixteenth sighting
17	Lucas Lewis	Male	31	10/10/2023	05:15	City Center	Seventeenth sighting
18	Sophia King	Female	27	10/10/2023	06:00	City Center	Eighteenth sighting
19	Benjamin Hall	Male	34	10/10/2023	06:45	City Center	Nineteenth sighting
20	Charlotte Young	Female	25	10/10/2023	07:30	City Center	Twentieth sighting
21	Henry Adams	Male	36	10/10/2023	08:15	City Center	Twenty-first sighting
22	Amelia Baker	Female	24	10/10/2023	09:00	City Center	Twenty-second sighting
23	Sebastian Nelson	Male	30	10/10/2023	09:45	City Center	Twenty-third sighting
24	Harper Hill	Female	22	10/10/2023	10:30	City Center	Twenty-fourth sighting
25	Julian Scott	Male	39	10/10/2023	11:15	City Center	Twenty-fifth sighting
26	Evelyn Green	Female	26	10/10/2023	12:00	City Center	Twenty-sixth sighting
27	Isaac Wright	Male	32	10/10/2023	12:45	City Center	Twenty-seventh sighting
28	Abigail King	Female	23	10/10/2023	13:30	City Center	Twenty-eighth sighting
29	Wyatt Hall	Male	35	10/10/2023	14:15	City Center	Twenty-ninth sighting
30	Madeline Young	Female	21	10/10/2023	15:00	City Center	Thirtieth sighting
31	Grayson Adams	Male	33	10/10/2023	15:45	City Center	Thirty-first sighting
32	Skylar Baker	Female	25	10/10/2023	16:30	City Center	Thirty-second sighting
33	Robert Nelson	Male	37	10/10/2023	17:15	City Center	Thirty-third sighting
34	Madison Hill	Female	24	10/10/2023	18:00	City Center	Thirty-fourth sighting
35	Christopher Scott	Male	31	10/10/2023	18:45	City Center	Thirty-fifth sighting
36	Chloe Green	Female	22	10/10/2023	19:30	City Center	Thirty-sixth sighting
37	Isaac Wright	Male	34	10/10/2023	20:15	City Center	Thirty-seventh sighting
38	Abigail King	Female	23	10/10/2023	21:00	City Center	Thirty-eighth sighting
39	Wyatt Hall	Male	35	10/10/2023	21:45	City Center	Thirty-ninth sighting
40	Madeline Young	Female	21	10/10/2023	22:30	City Center	Fortieth sighting
41	Grayson Adams	Male	33	10/10/2023	23:15	City Center	Forty-first sighting
42	Skylar Baker	Female	25	10/10/2023	00:00	City Center	Forty-second sighting
43	Robert Nelson	Male	37	10/10/2023	00:45	City Center	Forty-third sighting
44	Madison Hill	Female	24	10/10/2023	01:30	City Center	Forty-fourth sighting
45	Christopher Scott	Male	31	10/10/2023	02:15	City Center	Forty-fifth sighting
46	Chloe Green	Female	22	10/10/2023	03:00	City Center	Forty-sixth sighting
47	Isaac Wright	Male	34	10/10/2023	03:45	City Center	Forty-seventh sighting
48	Abigail King	Female	23	10/10/2023	04:30	City Center	Forty-eighth sighting
49	Wyatt Hall	Male	35	10/10/2023	05:15	City Center	Forty-ninth sighting
50	Madeline Young	Female	21	10/10/2023	06:00	City Center	Fiftieth sighting



BONNIE BRANCH BANK STABILIZATION PROJECT

TITLE: PROPOSED CONDITIONS

4 OF 13



CLIENT

HOWARD COUNTY
STORMWATER MANAGEMENT DIVISION
6751 COLUMBIA GATEWAY DRIVE
SUITE 514
COLUMBIA, MD 21046

DATE:

ISSUES / REVISIONS

3/XX/2015

60% SUBMITTAL



The Stables Building 2081 Clipper Park Road
Baltimore, MD 21211 / ph: 410.554.0156
fx: 410.554.0168 / www.biohabitats.com
Restore the Earth & Inspire Ecological Stewardship

BONNIE BRANCH
BANK STABILIZATION
PROJECT

TITLE:

PROPOSED
CONDITIONS

PROJECT NO.:

13005.19

SCALE: VALUE

SEAL:

BY: AL,TB

CHECK: MT

DWG. NO.:

5 OF 13

PLOTTED: 10:41 AM on Wednesday, November 16, 2016
 FILE: c:\Users\jwies\christopher.dell\cma4400\DES-P001-Howard-CC.dgn

SEQUENCE OF CONSTRUCTION:

- THE CONTRACTOR SHALL NOTIFY "MISS UTILITY" AT 1-800-257-7777, HOWARD COUNTY DEPARTMENT OF PUBLIC WORKS/BUREAU OF ENGINEERING/ CONSTRUCTION INSPECTION DIVISION (410) 313-1880 AT LEAST SEVEN (7) DAYS PRIOR TO BEGINNING WORK. THE CONTRACTOR SHALL NOTIFY THE MARYLAND DEPARTMENT OF THE ENVIRONMENT (MDE) NON-TIDAL WETLANDS AND WATERWAYS INSPECTIONS, WATER MANAGEMENT ADMINISTRATION (410) 537-3510 AT LEAST FIVE (5) DAYS PRIOR TO BEGINNING OF ANY WORK. IN-STREAM WORK IS PROHIBITED FROM MARCH 1 TO MAY 31, INCLUSIVE, STREAM CLASSIFICATION: USE IV.
- OBTAIN GRADING PERMIT AND OTHER NECESSARY PERMITS FOR CONSTRUCTION FROM THE COUNTY AT THE PRE-CONSTRUCTION MEETING. MDE PERMIT TRACKING NO. 16-NI-3234/201661425.
- ALL NECESSARY EASEMENTS OR RIGHTS-OF-ENTRY SHALL BE SECURED PRIOR TO THE START OF THE PROJECT.
- THE CONTRACTOR SHALL COORDINATE AN ON-SITE PRE-CONSTRUCTION MEETING PER THE HOWARD SOIL CONSERVATION DISTRICT (HSCD) STANDARD SEDIMENT CONTROL NOTES. THE LOD SHALL BE STAKED OUT PRIOR TO THIS MEETING. ALL TREE SAVES SHALL BE IDENTIFIED DURING THE MEETING.
- THE CONTRACTOR AND ITS DRIVERS SHALL TAKE EXTRA PRECAUTION WHEN DRIVING AND HAULING MATERIALS ON THE ACCESS ROAD, SITE AREAS AND CHANNEL TO MINIMIZE IMPACT TO EXISTING FEATURES, SUCH AS TREES, WETLANDS, U.S. WATERS, THE STREAM BED AND CHANNEL SLOPES AND NEWLY CONSTRUCTED FEATURES.
- INSTALL ORANGE CONSTRUCTION FENCE (OCF) AS SHOWN ON THE PLANS. HOWARD COUNTY DPW SHALL APPROVE THE LOCATION PRIOR TO ANY REMOVAL OR ANY CLEARING ACTIVITIES. PHASE II OCF CAN BE INSTALLED PRIOR TO THAT PHASE OF THE WORK, RATHER THAN AT THE BEGINNING OF THE PROJECT DUE TO ITS HIGH VISIBILITY ON THE CAMPUS. (5 DAYS)
- CONSTRUCTION SHALL BE PERFORMED FOR THE FOLLOWING PHASES:
 - PHASE I LPR-1 STA. 20+70 TO STA. 25+30, 460 LF DRY CONSTRUCTION (20 DAYS)
 - PHASE II UNNAMED TRIB STA. 1+00 TO STA. 4+30, 330 LF DRY CONSTRUCTION (17 DAYS)
 - PHASE III UNNAMED TRIB STA. 7+25 TO STA. 10+00, 275 LF DRY CONSTRUCTION (14 DAYS)
 - PHASE IV UNNAMED TRIB STA. 10+00 TO STA. 12+18, 218 LF DRY CONSTRUCTION (11 DAYS)
 - PHASE V, STAGE 1 UNNAMED TRIB STA. 12+18 TO STA. 13+60, 142 LF DRY CONSTRUCTION (7 DAYS)
 - PHASE V, STAGE 2 UNNAMED TRIB STA. 13+60 TO STA. 15+12, 152 LF WET CONSTRUCTION (6 DAYS) (SEE NOTE 6 BELOW AND SHEET ES-03 REGARDING "IN THE WET CONSTRUCTION")
 - PHASE VI, STAGE 2 UNNAMED TRIB STA. 15+12 TO STA. 17+50, 238 LF DRY CONSTRUCTION (12 DAYS)
- AT EACH PHASE, THE CONTRACTOR SHALL:
 - CONSTRUCT AND/OR MAINTAIN THE STABILIZED ENTRANCE. (1 DAY)
 - CLEAR AND GRUB ONLY AS NECESSARY FOR INSTALLATION OF EROSION AND SEDIMENT CONTROL DEVICES AND INSTALL SILT FENCE, PERIMETER CONTROLS. (5 DAYS)
 - INSTALL SAND BAG DIVERSIONS IN THE STREAM CHANNEL AND PUMPAROUND SYSTEMS, DEWATER BEHIND THE SANDBAGS. (1 DAY)
 - UPON RECEIVING PERMISSION TO PROCEED FROM THE INSPECTOR, EXCAVATE AND INSTALL STREAM RESTORATION IMPROVEMENTS. (SEE ABOVE DURATIONS).
 - UPON ESC INSPECTOR APPROVAL, REMOVE THE SANDBAG DIVERSIONS AND CONTINUE WITH THE NEXT PHASE. (1 DAY)

NOTES:

- THE CONTRACTOR SHALL NOT UNLOAD OR DUMP MATERIALS SUCH AS RIPRAP OR BOULDERS ON TOP OF ANY EXISTING UTILITY LINES.
- THE CONTRACTOR IS TO REMOVE STONE, CONCRETE, AND GRAVEL AND STABILIZE THE ACCESS ROAD AND TEMPORARY STAGING AREAS AFTER CONSTRUCTION.
- THE CONTRACTOR IS TO REMOVE ALL SEDIMENT CONTROL MEASURES ALONG THE TEMPORARY STAGING / STOCKPILE AREAS, ACCESS ROADS, STREAM CROSSINGS AND STREAM BANKS.
- THE EROSION SEDIMENT CONTROL (ESC) PLANS ARE PRESENTED IN FIVE (5) CONSTRUCTION PHASES (I-V) SHOWN ON FIVE (5) PLANS. (ES-01 TO ES-05)
- ESC NOTES AND DETAILS ARE PROVIDED ON TWO SHEETS FOLLOWING THE PLANS. (ES-06, ES-07)
- THE WET VERSUS DRY CONSTRUCTION REACHES ON THIS TASK ARE BEING PERFORMED AND STREAM MONITORING BEING CONDUCTED UNDER THE FOLLOWING GRANT:

RESTORATION RESEARCH GRANT SPONSORED BY THE CHESAPEAKE BAY TRUST (CBT), THE MARYLAND DEPARTMENT OF NATURAL RESOURCE (DNR), AND THE U.S. ENVIRONMENTAL PROTECTION AGENCY (EPA).

"UNDER A PARTNERSHIP AMONG CBT, DNR, AND EPA TO SUPPORT RESEARCH TO BETTER UNDERSTAND STREAM RESTORATION PERFORMANCE AND FUNCTION, STRAUGHAN ENVIRONMENTAL PROPOSES A PROJECT TO ASSESS THE DIFFERENCE IN WATER QUALITY (TURBIDITY, RIPARIAN HABITAT, OTHER BIOLOGICAL EFFECTS) BETWEEN STREAM RESTORATION WORK "IN THE WET" AND "IN THE DRY" (I.E., CONSTRUCTION WORK WITH AND WITHOUT DIVERTING STREAM FLOW). STRAUGHAN, AS A CBT RESEARCH GRANT RECIPIENT AND IN PARTNERSHIP WITH HOWARD COUNTY AND THE CENTER FOR WATERSHED PROTECTION, PROPOSES TO QUANTIFY AND COMPARE IN DETAIL THE BENEFITS AND DRAWBACKS OF BOTH WET AND DRY CONSTRUCTION TECHNIQUES, WITH THE UNDERSTANDING THAT THE STANDARD PRACTICE OF EMPLOYING STREAM DIVERSION (FOR WORKING IN THE DRY) IS INTENDED TO REDUCE SEDIMENT AND NUTRIENTS FROM BEING TRANSPORTED DOWNSTREAM DURING CONSTRUCTION, THOUGH LITTLE QUANTITATIVE RESEARCH HAS BEEN PERFORMED TO JUSTIFY THIS ASSUMPTION."

- SOIL STABILIZATION MATTING IS TO BE PLACED THROUGHOUT THE MAJORITY OF THE SITE DUE TO THE ABUNDANCE OF STEEP SLOPES AND HIGHLY ERODIBLE SOILS FOUND ON SITE. NATURAL FIBER MATTING SHALL BE PLACED THROUGHOUT THE PROJECT SITE WHERE ANY GRADING IS PERFORMED WITH THE EXCEPTION OF AREAS USING REINFORCED NATURAL FIBER MATTING AS SHOWN IN THE DETAILS. AREAS WHERE CLEARING AND GRADING ARE NOT PERFORMED (E.G., LOCATIONS OF HOSE FOR PUMP AROUND, CONSTRUCTION ACCESS, OR AREAS NOT GRADED) DO NOT REQUIRE THE APPLICATION OF SOIL STABILIZATION MATTING.

- WORK AREAS SHALL BE PERMANENTLY STABILIZED DAILY BEFORE LEAVING THE WORKSITE.

- PROVIDE TEMPORARY WOOD MATS FOR CONSTRUCTION TRAFFIC THROUGH WETLAND AREAS. WOOD MATS SHALL BE REVIEWED AND APPROVED BY THE INSPECTOR AS APPLIED DURING CONSTRUCTION. ALL MATERIAL SHALL BE REMOVED UPON CONSTRUCTION COMPLETION.

FINAL

- INSTALL LANDSCAPING AS SPECIFIED ON THE PLAN. (2 WEEKS)

- WHEN ALL AREAS ARE STABILIZED AND PERMANENT VEGETATION IS ESTABLISHED, AND WITH PERMISSION OF THE HOWARD COUNTY EROSION SEDIMENT CONTROL INSPECTOR, REMOVE ALL REMAINING EROSION AND SEDIMENT CONTROL MEASURES AND PERMANENTLY STABILIZE ANY AREAS DISTURBED BY THE REMOVAL PROCESS. (2 DAYS)

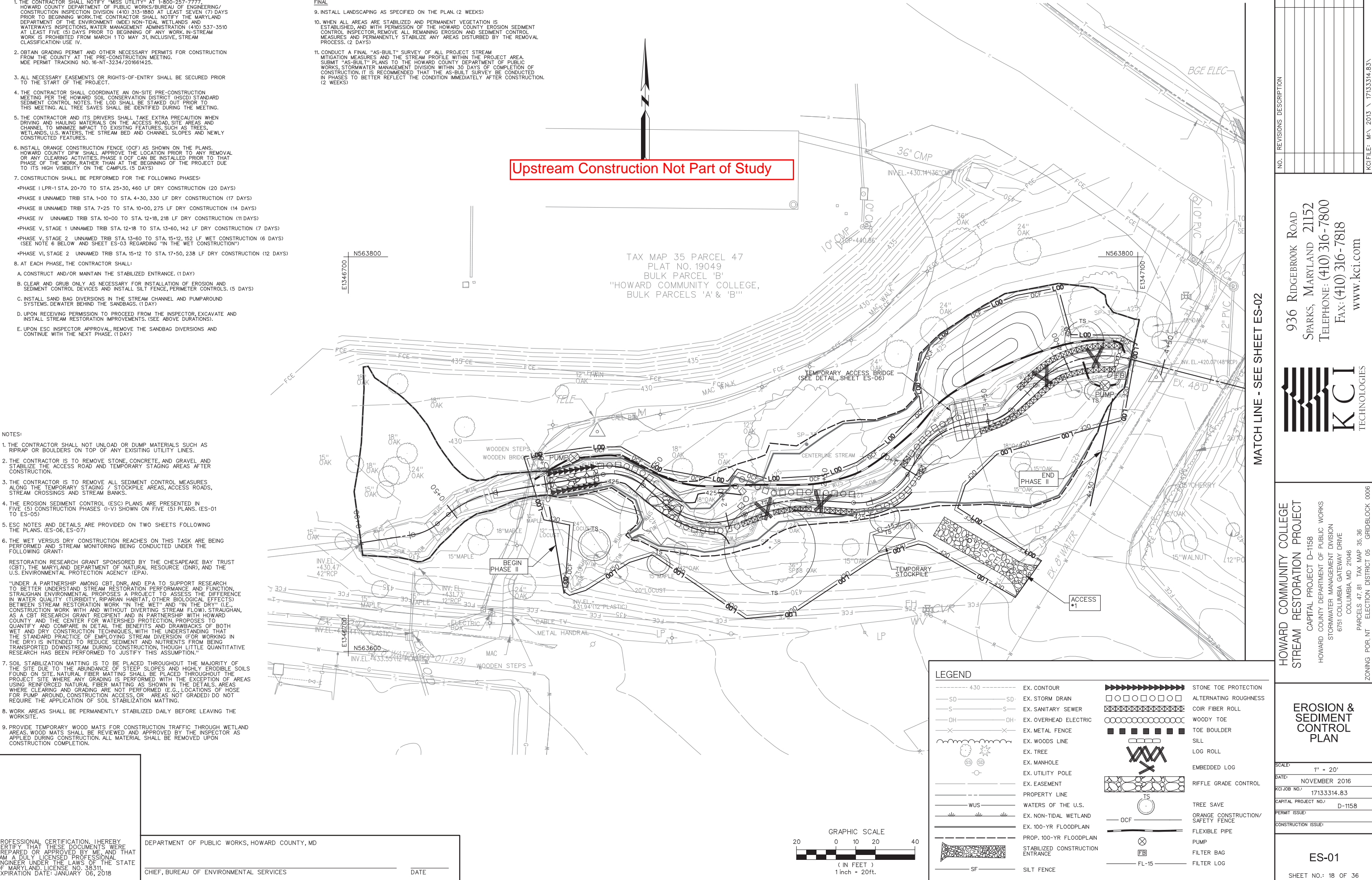
- CONDUCT A FINAL "AS-BUILT" SURVEY OF ALL PROJECT STREAM MITIGATION MEASURES AND THE STREAM PROFILE WITHIN THE PROJECT AREA. SUBMIT "AS-BUILT" PLANS TO THE HOWARD COUNTY DEPARTMENT OF PUBLIC WORKS, STORMWATER MANAGEMENT DIVISION WITHIN 30 DAYS OF COMPLETION OF CONSTRUCTION. IT IS RECOMMENDED THAT THE AS-BUILT SURVEY BE CONDUCTED IN PHASES TO BETTER REFLECT THE CONDITION IMMEDIATELY AFTER CONSTRUCTION. (2 WEEKS)

PROFESSIONAL CERTIFICATION. I HEREBY CERTIFY THAT THESE DOCUMENTS WERE PREPARED OR APPROVED BY ME, AND THAT I AM A DULY LICENSED PROFESSIONAL ENGINEER UNDER THE LAWS OF THE STATE OF MARYLAND, LICENSE NO. 38311, EXPIRATION DATE: JANUARY 06, 2018

DEPARTMENT OF PUBLIC WORKS, HOWARD COUNTY, MD

CHIEF, BUREAU OF ENVIRONMENTAL SERVICES

DATE



HOWARD COMMUNITY COLLEGE
STREAM RESTORATION PROJECT

CAPITAL PROJECT D-1158
HOWARD COUNTY DEPARTMENT OF PUBLIC WORKS
STORMWATER MANAGEMENT DIVISION
6751 COLUMBIA GATEWAY DRIVE
COLUMBIA MD 21046

PARCELS 47, 81 TAX MAP 35, 36
ZONING: POR-NT ELECTION DISTRICT 05 GRIDBLOCK 0006

EROSION & SEDIMENT CONTROL PLAN

SCALE: 1" = 20'

DATE: NOVEMBER 2016

KCIJOB NO.: 17133314.83

CAPITAL PROJECT NO.: D-1158

PERMIT ISSUE:

CONSTRUCTION ISSUE:

ES-01

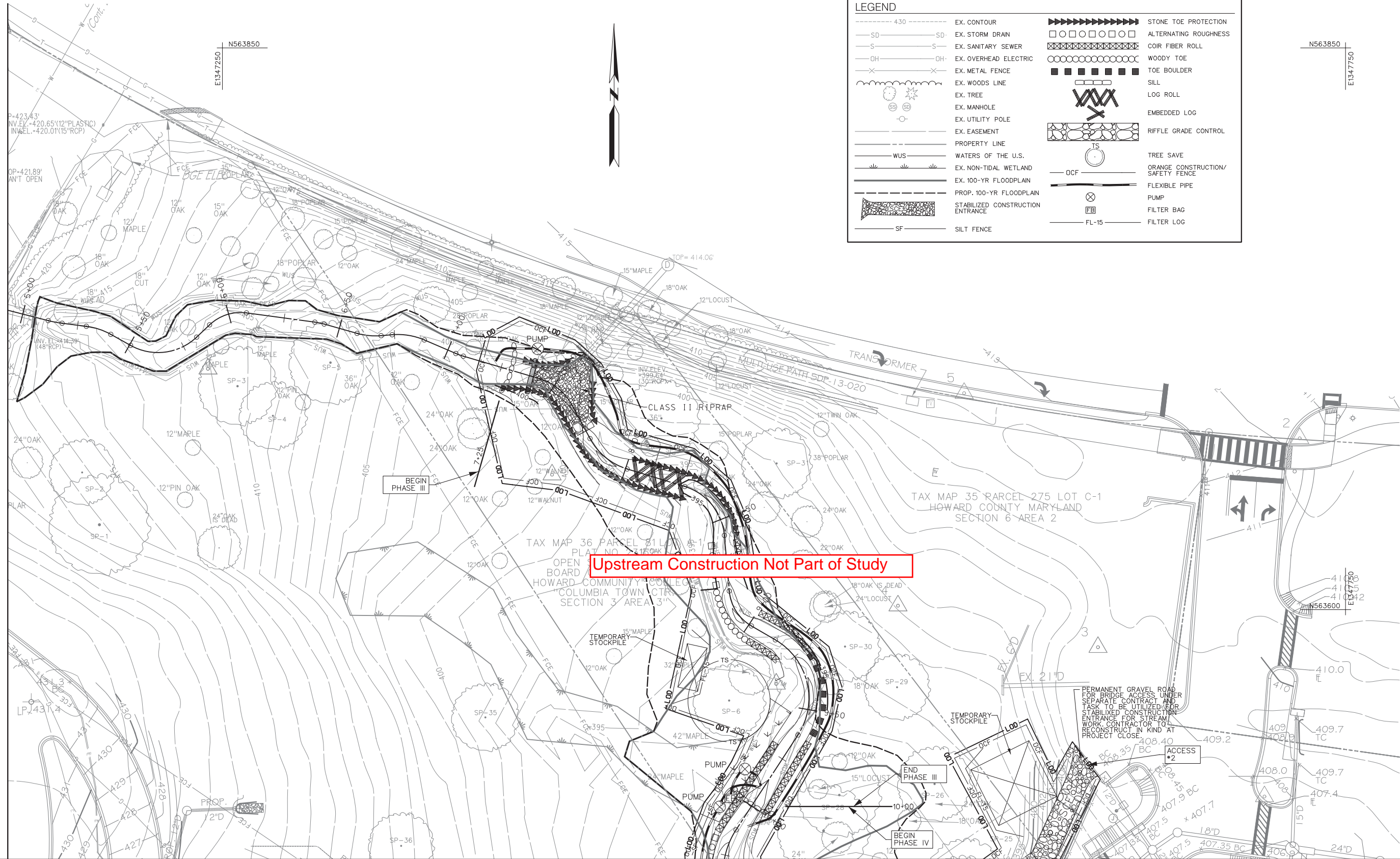
SHEET NO.: 18 OF 36

NO.	REVISIONS DESCRIPTION	DATE

936 RIDGEBROOK ROAD
SPARKS, MARYLAND 21152
TELEPHONE: (410) 316-7800
Fax: (410) 316-7818
www.kci.com



MATCH LINE - SEE SHEET ES-01



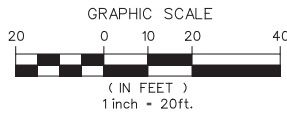
MATCH LINE - SEE SHEET ES-03

LEGEND			
SD	SD	EX. CONTOUR	STONE TOE PROTECTION
S	S	EX. STORM DRAIN	ALTERNATING ROUGHNESS
OH	OH	EX. SANITARY SEWER	COIR FIBER ROLL
X	X	EX. OVERHEAD ELECTRIC	WOODY TOE
		EX. METAL FENCE	TOE BOULDER
		EX. WOODS LINE	SILL
		EX. TREE	LOG ROLL
		EX. MANHOLE	EMBEDDED LOG
		EX. UTILITY POLE	RIFFLE GRADE CONTROL
		EX. EASEMENT	TREE SAVE
		PROPERTY LINE	ORANGE CONSTRUCTION/ SAFETY FENCE
WUS	WUS	WATERS OF THE U.S.	FLEXIBLE PIPE
		EX. NON-TIDAL WETLAND	PUMP
		EX. 100-YR FLOODPLAIN	FILTER BAG
		PROP. 100-YR FLOODPLAIN	FILTER LOG
		STABILIZED CONSTRUCTION ENTRANCE	
SF	SF	SILT FENCE	

Upstream Construction Not Part of Study

NOTES:

- SOIL STABILIZATION MATTING IS TO BE PLACED THROUGHOUT THE MAJORITY OF THE SITE DUE TO THE ABUNDANCE OF STEEP SLOPES AND HIGHLY ERODIBLE SOILS FOUND ON SITE. NATURAL FIBER MATTING SHALL BE PLACED THROUGHOUT THE PROJECT SITE WHERE ANY GRADING IS PERFORMED WITH THE EXCEPTION OF AREAS USING REINFORCED NATURAL FIBER MATTING AS SHOWN IN THE DETAILS, AREAS WHERE CLEARING AND GRADING ARE NOT PERFORMED (E.G., LOCATIONS OF HOSE FOR PUMP AROUND, CONSTRUCTION ACCESS, OR AREAS NOT GRADED) DO NOT REQUIRE THE APPLICATION OF SOIL STABILIZATION MATTING.
- WORK AREAS SHALL BE PERMANENTLY STABILIZED DAILY BEFORE LEAVING THE WORKSITE.
- PROVIDE TEMPORARY WOOD MATS FOR CONSTRUCTION TRAFFIC THROUGH WETLAND AREAS. WOOD MATS SHALL BE REVIEWED AND APPROVED BY THE INSPECTOR AS APPLIED DURING CONSTRUCTION. ALL MATERIAL SHALL BE REMOVED UPON CONSTRUCTION COMPLETION.



PROFESSIONAL CERTIFICATION. I HEREBY CERTIFY THAT THESE DOCUMENTS WERE PREPARED OR APPROVED BY ME AND THAT I AM A DULY LICENSED PROFESSIONAL ENGINEER UNDER THE LAWS OF THE STATE OF MARYLAND, LICENSE NO. 38311, EXPIRATION DATE: JANUARY 06, 2018

DEPARTMENT OF PUBLIC WORKS, HOWARD COUNTY, MD

CHIEF, BUREAU OF ENVIRONMENTAL SERVICES

DATE

NO.	REVISIONS DESCRIPTION	DATE

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HOWARD COMMUNITY COLLEGE
STREAM RESTORATION PROJECT
CAPITAL PROJECT D-1158
HOWARD COUNTY DEPARTMENT OF PUBLIC WORKS
STORMWATER MANAGEMENT DIVISION
6751 COLUMBIA GATEWAY DRIVE
COLUMBIA MD 21046
PARCELS 47.81 TAX MAP 35.35
ZONING POR NT ELECTION DISTRICT 05 GRIDBLOCK 0006

EROSION & SEDIMENT CONTROL PLAN

SCALE:	1" = 20'
DATE:	NOVEMBER 2016
KCI JOB NO.:	17133314.83
CAPITAL PROJECT NO.:	D-1158
PERMIT ISSUE:	
CONSTRUCTION ISSUE:	

ES-02

SHEET NO.: 19 OF 36

PROPOSED PARKING GARAGE AND BRIDGE UNDER SEPARATE CONTRACT AND TASK

TAX MAP 36, PARCEL 81, LOT A-2
PLAT NO. 23152
OPEN SPACE-NON-CREDITED
BOARD OF TRUSTEES OF
HOWARD COMMUNITY
COLLEGE
"COLUMBIA TOWN CTR.
SECTION 3 AREA 3"

TAX MAP 36, PARCEL 81, LOT A-3
PLAT NO. 23152
OPEN SPACE-NON-CREDITED
BOARD OF TRUSTEES OF
HOWARD COMMUNITY COLLEGE
"COLUMBIA TOWN CTR.
SECTION 3 AREA 3"

TAX MAP 35, PARCEL 271, LOT 2A
BANKERS TRUST CO
T.C., 6/1
SECTION 6 AREA 1

HCC Dry Construction

HCC Wet Construction

LEGEND

EX. CONTOUR	STONE TOE PROTECTION
EX. STORM DRAIN	ALTERNATING ROUGHNESS
EX. SANITARY SEWER	COIR FIBER ROLL
EX. OVERHEAD ELECTRIC	WOODY TOE
EX. METAL FENCE	TOE BOULDER
EX. WOODS LINE	SILL
EX. TREE	LOG ROLL
EX. MANHOLE	EMBEDDED LOG
EX. UTILITY POLE	RIFFLE GRADE CONTROL
EX. EASEMENT	TREE SAVE
PROPERTY LINE	ORANGE CONSTRUCTION/SAFETY FENCE
WATERS OF THE U.S.	FLEXIBLE PIPE
EX. NON-TIDAL WETLAND	PUMP
EX. 100-YR FLOODPLAIN	FILTER BAG
PROP. 100-YR FLOODPLAIN	FL-15
STABILIZED CONSTRUCTION ENTRANCE	FILTER LOG
SF	SILT FENCE

GRAPHIC SCALE

20 0 10 20 40

(IN FEET)
1 inch = 20ft.

DEPARTMENT OF PUBLIC WORKS, HOWARD COUNTY, MD

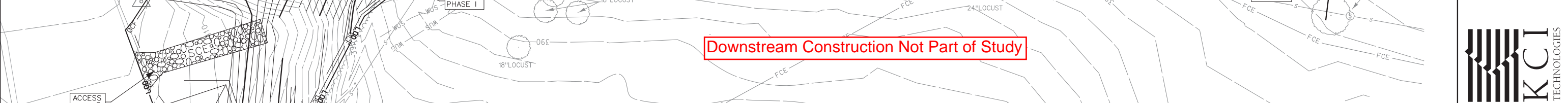
CHIEF, BUREAU OF ENVIRONMENTAL SERVICES

[illegible]The logo for KCI Technologies, featuring the letters 'KCI' in a large, bold, serif font, with 'TECHNOLOGIES' in a smaller, sans-serif font below it. To the left of the text is a stylized graphic consisting of several vertical bars of varying heights, some with diagonal lines, creating a sense of depth and structure.

HOWARD COMMUNITY COLLEGE
STREAM RESTORATION PROJECT
CAPITAL PROJECT D-1158
HOWARD COUNTY DEPARTMENT OF PUBLIC WORKS
STORMWATER MANAGEMENT DIVISION
6751 COLUMBIA GATEWAY DRIVE
COLUMBIA, MD 21046
PARCELS 47.81 TAX MAP 35.36
ZONING FOR, NT ELECTION DISTRICT 05 GLOBLOCK C

SCALE:	1" = 20'
DATE:	NOVEMBER 2016
KCI JOB NO.:	17133314.83
CAPITAL PROJECT NO.:	D-1158
PERMIT ISSUE:	
CONSTRUCTION ISSUE:	

SHEET NO.: 20 OF 36

[illegible][illegible]

TEMPORARY STOCKPILE

TEMPORARY CONSTRUCTION ACCESS FROM HICKORY ROAD

LEGEND

TAX MAP 35 PARCEL 47 PLAT NO. 19050
BOARD OF TRUSTEES OF HOWARD COUNTY COMMUNITY COLLEGE
LOT PAR A

N562800
E1347800


HOWARD COMMUNITY COLLEGE
STREAM RESTORATION PROJECT
CAPITAL PROJECT D-1158
HOWARD COUNTY DEPARTMENT OF PUBLIC WORKS
STORMWATER MANAGEMENT DIVISION
6751 COLUMBIA GATEWAY DRIVE
COLUMBIA, MD 21046
PARCELS 47.81 TAX MAP 35.36
ZONING POR.NT ELECTION DISTRICT 05 GRIDBLOCK 0006





CONTINUATION, SHEET ES-05)

Legend:

- 4.30
- SD EX. STORM DRAIN
- S EX. SANITARY SEWER
- OH EX. OVERHEAD ELECTRIC
- X EX. METAL FENCE
- EX. WOODS LINE
- STONE TOE PROTECTION
- ALTERNATING ROUGHNESS
- COIR FIBER ROLL
- WOODY TOE
- TOE BOULDER
- SOIL

EROSION & SEDIMENT CONTROL PLAN

<p>MATCH LINE - SEE SHEET ES-05</p> <p>NOTES:</p> <p>1. SOIL STABILIZATION MATTING IS TO BE PLACED THROUGHOUT THE MAJORITY OF THE SITE DUE TO THE ABUNDANCE OF STEEP SLOPES AND HIGHLY ERODIBLE SOILS FOUND ON SITE. NATURAL FIBER MATTING SHALL BE PLACED THROUGHOUT THE PROJECT SITE WHERE ANY GRADING IS PERFORMED WITH THE EXCEPTION OF AREAS USING REINFORCED NATURAL FIBER MATTING AS SHOWN IN THE DETAILS. AREAS WHERE CLEARING AND GRADING ARE NOT PERFORMED (E.G., LOCATIONS OF ROSE FOR PUMP AROUND, CONSTRUCTION ACCESS, OR AREAS NOT GRADED) DO NOT REQUIRE THE APPLICATION OF SOIL STABILIZATION MATTING.</p>		<p>EX. WOODS LINE</p> <p>LOG ROLL</p> <p>EX. TREE</p> <p>EX. MANHOLE</p> <p>EX. UTILITY POLE</p> <p>EX. EASEMENT</p> <p>PROPERTY LINE</p> <p>WATERS OF THE U.S.</p> <p>EX. NON-TIDAL WETLAND</p> <p>EX. 100-YR FLOODPLAIN</p> <p>ORANGE CONSTRUCTION/SAFETY FENCE</p>

PROFESSIONAL CERTIFICATION. I HEREBY CERTIFY THAT THESE DOCUMENTS WERE PREPARED OR APPROVED BY ME, AND THAT I AM A DULY LICENSED PROFESSIONAL ENGINEER UNDER THE LAWS OF THE STATE OF MARYLAND.	DEPARTMENT OF PUBLIC WORKS, HOWARD COUNTY, MD 2. WORK AREAS SHALL BE PERMANENTLY STABILIZED DAILY BEFORE LEAVING THE WORKSITE. 3. PROVIDE TEMPORARY WOOD MATS FOR CONSTRUCTION TRAFFIC THROUGH WETLAND AREAS. WOOD MATS SHALL BE REVIEWED AND APPROVED BY THE INSPECTOR AS APPLIED DURING CONSTRUCTION. ALL MATERIAL SHALL BE REMOVED UPON COMPLETION OF CONSTRUCTION.	GRAPHIC SCALE 	EX. 100-YR FLOODPLAIN PROP. 100-YR FLOODPLAIN  STABILIZED CONSTRUCTION ENTRANCE FLEXIBLE PIPE  PUMP FILTER BAG  FILTER BAG
---	--	--	---

OF MARYLAND, LICENSE NO. 38311
 EXPIRATION DATE: JANUARY 06, 2018

DEPARTMENT OF PUBLIC WORKS, HOWARD COUNTY, MD

CHIEF, BUREAU OF ENVIRONMENTAL SERVICES

DATE

MATCH LINE - SEE SHEET ES-05

NOTES: _____ EX. UTILITY POLE _____ EX. EASEMENT _____ RIFFLE GRADE CONTROL

- | | | |
|---|---|---|
| <p>PROFESSIONAL CERTIFICATION. I HEREBY CERTIFY THAT THESE DOCUMENTS WERE PREPARED OR APPROVED BY ME, AND THAT I AM DULY LICENSED TO PRACTICE AS A CIVIL ENGINEER UNDER THE LAWS OF THE STATE OF MARYLAND, LICENSE NO. 38311, EXPIRATION DATE 01/01/2018.</p> | <p>DEPARTMENT OF PUBLIC WORKS, HOWARD COUNTY, MD</p> <p>CHIEF, BUREAU OF ENVIRONMENTAL SERVICES</p> <p>DATE _____</p> | <p>1713314.83</p> <p>CAPITAL PROJECT NO.: D-1158</p> <p>PERMIT ISSUE:</p> <p>CONSTRUCTION ISSUE:</p> <p style="text-align: right; font-size: 1.2em;">ES-04</p> <p style="text-align: right;">SHEET NO. 01 OF 30</p> |
|---|---|---|

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PROPERTY LINE

WUS

OCF

EX. NON-TIDAL WETLANDS

EX. 100-YR FLOODPLAIN

PROP. 100-YR FLOODPLAIN

STABILIZED CONSTRUCTION ENTRANCE

SF

SILT FENCE

GRAPHIC SCALE

(IN FEET)

1 inch = 20 ft.

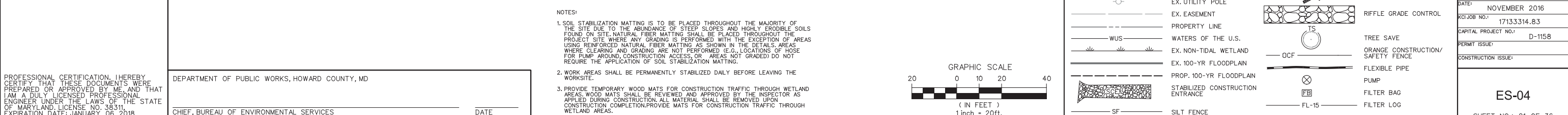
ORANGE CONSTRUCTION/SAFETY FENCE

FLEXIBLE PIPE

PUMP

FILTER BAG

FILTER LOG

[illegible]