WOODLAKE DAM BREACH DESIGN

Woodlake Dam Rehabilitation
Woodlake CC Corp.
Vass, North Carolina

Schnabel Reference No: 17C21008.00
May 1, 2017

Schnabel ENGINEERING
SCHNABEL ENGINEERING SOUTH, P.C.

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Schnabel Engineering South, P.C.
License Number C-2599

May 1, 2017

Mr. Brian Shane Cook, PE, LSIT
State Dam Safety Engineer
NC DEQ - Land Quality Section
512 N. Salisbury Street, Room 519
1612 Mail Service
Raleigh, NC 27604

Subject: **Project 17C21008.00, Woodlake Dam Breach Design Submittal, Vass, NC**

Dear Mr. Cook:

SCHNABEL ENGINEERING SOUTH, P.C. (Schnabel) is pleased to submit our breach design for the Woodlake Dam project on the behalf of Woodlake CC Corp. (WCCC). This report includes tables, and appendices with relevant data collected for this design. The attached design drawings include the material specifications and installation procedures for the breach design.

We appreciate the opportunity to be of service for this project. Please call us if you have any questions regarding this report.

Sincerely,

SCHNABEL ENGINEERING SOUTH, P.C.

R. Indri

Robert Indri, PE
Associate

RTI:LS:MEL

Distribution:
Client (1 Copy),
Attn: Chris Meng and David Harris

NCDEQ: Dam Safety (2 Copies)
Attn: Shane Cook, PE; State Dam Safety Engineer

WOODLAKE DAM BREACH DESIGN
WOODLAKE DAM REHABILITATION
WOODLAKE CC CORP.
VASS, NORTH CAROLINA

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1.0 DESCRIPTION OF SITE AND PROPOSED CONSTRUCTION

1.1 Site Description

Woodlake Dam is located in Moore County, North Carolina, approximately 2,450 feet northwest of the intersection of Lobelia Road (SR 690) and McGill Road (SR 2017). The dam is owned by Woodlake CC Corp (WCCC). The primary purpose of the impoundment is recreation. Water from the impoundment is also used for irrigation at the adjacent Woodlake golf course. The dam impounds Lake Surf and has a maximum impoundment capacity of approximately 10,000 acre-feet at the top of the dam elevation of EL 230.5 feet. Our recent topographic survey at the project indicates a crest of embnkement elevation of EL 229.0 feet (NAVD 1988). Woodlake Dam is considered a large sized, high hazard dam by NCDEQ Dam Safety. A Site Vicinity Map is included in the Figures section.

Woodlake Dam consists of: an approximately 23 foot-high earth embankment; a reinforced concrete chute principal spillway with approximately 3.5-foot-high metal slide gates across the control section of the chute; and, two low-level outlets as independent structures.

1.2 Site Topography and Terminology

Our subcontractor, Allied Associates, PA (Allied) of Winston-Salem, NC, established survey control and performed a topographic survey of the site in April 2017. This survey was used as the basis for developing the design drawings. Elevations in the survey and in this report are in feet and reference the North American Vertical Datum of 1988 (NAVD88). Horizontal coordinates reference NC State Plane South, NAD 83.

Descriptive nomenclature for dams is based upon one looking downstream in the direction of flow. “Right” and “left” are referenced in this manner. The reservoir side is known as the upstream side with the opposite slope referred to as the downstream slope.

The abbreviation “EL” is used in this report to indicate elevations in feet.

1.3 Project History

In early October (starting on October 9, 2016), high water flows through the principal spillway from Hurricane Matthew caused portions of the concrete spillway to undermine, collapse, and displace. Emergency measures were taken, including opening of the two low-level outlets gates, and installation of large pumps to decrease the water levels in the reservoir. The principal spillway gates were closed in an attempt to reduce flows through the principal spillway and reduce the potential for continued displacement of the slabs and erosion of the subgrade. The Emergency Action Plan (EAP) for the project was implemented and downstream residences in the breach inundation zone were notified and evacuated.

During an on-site inspection on October 12, 2016, NCDEQ Dam Safety noted the following deficiencies at the dam:

- The middle section of the concrete spillway on the downstream side had collapsed;
- Erosion under the collapsed spillway section had occurred;
- The seepage drainage system had been damaged;

- The downstream spillway walls had been overtopped and soil erosion had occurred from behind the walls; and,
- Most of the gates were not completely functional and were damaged.

Under a March 15, 2017 court order, the owner has been ordered to:

- Maintain the water level in the impoundment at an elevation of EL 211 or below; and,
- Finish design and construction of a temporary full breach of the dam within 105 days of issuance of the court order.

A follow up letter from NC Dam Safety on April 19, 2017 requires that the final breach plans be submitted to NC Dam Safety by May 1, 2017.

1.4 Site Visit

Schnabel personnel visited the site on April 18, 2017 to observe the current condition of the dam. Photos taken during the site visit are included in Appendix A.

The left access road, right access road left embankment, both low level outlets, and spillway were observed. The embankment section to the right of the right low level outlet was not observed.

At the time of the visit, baseflow was flowing through the right low level outlet. The water level was approximately 6-inches above the invert of the inlet. The outlet empties into a plunge pool that appears to be rock-lined. The WCCC personnel onsite had not seen the plunge pool dewatered and did not know if it was fully rock-lined. The left low level outlet was not flowing at the time of the site visit. The left outlet empties onto a concrete apron. Both low level outlets had a significant amount of debris covering the inlets. We understand that both low level outlets gates are operable.

The top of the left embankment had bare areas, especially near the left abutment. Some woody vegetation is present along the shoreline. The shoreline also has riprap wave protection in place. No signs of seepage were observed along the downstream toe. The right embankment was not observed.

The spillway gates were in the closed position and not closely observed. According to WCCC, the gates were difficult to operate during Hurricane Matthew. The failed section of the downstream chute slab is in the center of the spillway. The material eroded from the under the failed section is deposited just downstream of the spillway end sill.

On the right side of the spillway exit, the distance from the top of the end sill to the natural ground below is about 6 feet. On the left side, the distance from the top of the end sill to natural ground is about 4 feet. Approximately 6 inches of the top of the sheetpile cutoff was exposed. Some sections of the sheetpile were in poor condition and the aggregate behind the sheetpile has begun eroding out from below the spillway.

1.5 Status of Breach Construction and Long-Term Plans

To meet project deadlines, the client has elected to pursue a design-build contract for completion of the breach. Crowder Construction (Crowder) has been selected as the general contractor and WCCC is

currently negotiating a contract with Crowder. Crowder has worked with Schnabel during the design phase by providing constructability reviews and cost estimating.

After the breach construction has been completed, WCCC has stated they intend to pursue a rehabilitation of the dam and restore the lake water surface to pre-breach levels.

1.6 Proposed Breach Design

The proposed breach will include removal of the existing principal spillway in its entirety. A single staged armored channel will be constructed centered on the existing principal spillway. The development and details of the channel are outlined in the next section of this report. Construction access will be from McGill Road to the left abutment of the dam. A spoils disposal area has been identified by WCCC and is shown in the design drawings.

Erosion and sediment control features will include sediment fence along the limits of construction and the onsite storage area. A temporary construction entrance will be installed where the left access road connects to McGill Road. The access road will be stabilized where necessary. The disturbed areas will be seeded and mulched.

2.0 HYDROLOGIC ANALYSIS

The hydrologic analysis of the watershed was modeled using HEC-HMS version 4.2. Below are descriptions of the procedures used by Schnabel. The data and calculations are included in Appendix B.

2.1 Breach Design Flood

The March 15, 2017 court order and NC Dam Safety require the breach design to be sized to pass the ¾ PMP, including full armoring within the breach section of the embankment up to the water surface elevation of the ¾ PMP.

2.2 Watershed

The watershed upstream of Woodlake is approximately 95 square miles and is comprised of agricultural areas, residential areas, golf courses, and commercial areas in Harnett, Lee, and Moore Counties. The watershed above Woodlake was delineated using NCFMP LiDAR topography. The watershed was subdivided into five subbasins in order to account for the confluences of Durhams Creek, Herds Creek, Little Crane Creek, and Beaver Creek with Crane Creek.

Three sections of Crane Creek upstream of dam were included in the watershed model using the Muskingum-Cunge routing method in HEC-HMS. The stream slopes and lengths were measured using the LiDAR topography. Typical cross sections and Manning's n values for these streams were taken from the preliminary FEMA HEC-RAS model.

2.3 Runoff Curve Number

An NRCS TR-55 runoff curve number (RCN) was calculated for each of the five subbasins. Both the existing land use and future land use was evaluated. The existing land use was developed from a

combination of aerial photography and the National Land Cover Dataset. The 2040 future land use was obtained from Harnett County and the zoning information was obtained from Lee and Moore Counties. The future land use and zoning categories were matched with the appropriate NRCS TR-55 RCN descriptions. The soils information was obtained from the NRCS Soil Data Mart for Harnett, Lee, and Moore Counties. The land use and soils data were used to calculate an existing conditions and future conditions curve number for each subbasin. A summary of the curve numbers for each subbasin is included in Table 1.

2.4 Lag Time

Lag time (T_L) is the period of time between the center of mass of excessive rainfall and the peak runoff at the outlet. The lag time for each subbasin was calculated using the Snyder's Method from *Hydrology and Hydraulic Systems*. Ram S. Gupta. Second Edition, Chapter 7, Section 7.11.1 and *Hydrology and Floodplain Analysis.* Bedient and Huber. Second Edition, Chapter 2, Section 2.4.

$$T_L = C_t (LL_{ca})^{0.5}$$

Where:

- C_t is the watershed storage coefficient based on regional data. C_t has been found to vary from 0.4 in mountain areas to 8.0 along the Gulf of Mexico.
- L is the length of main channel from the outlet to the upstream watershed boundary, miles
- L_{ca} is the length of main channel from the outlet to the watershed centroid, miles

Schnabel estimated C_t using the Taylor and Schwarz equation shown below.

$$C_t = 0.6/(S)^{0.5}$$

Where S = basin slope

A peaking coefficient, C_p, is also required when using Snyder's method to calculate runoff. Typical values of C_p range from 0.4 to 0.8. Based on other studies performed in the region, a C_p of 0.4 was selected.

For each subbasin, the below data was used to determine the watershed parameters.

Table 1: Watershed Parameters

Subbasin	Drainage Area (square miles)	Hydrologic Length (miles)	Average Slope (ft/ft)	Lag Time (hours)	Existing RCN	Future RCN
Durhams Creek	19.5	8.93	0.0681	6.8	67	72
Herds Creek	13.4	9.68	0.0646	7.4	66	70
Little Crane Creek	27.4	11.59	0.0605	8.5	68	71
Beaver Creek	19.8	10.46	0.0644	7.9	65	71
Woodlake	15.1	5.35	0.0598	4.7	73	79

2.5 Rainfall

2.5.1 Probable Maximum Precipitation (PMP)

The PMP rainfall depth values for the Woodlake Dam watershed was calculated using Hydrometeorological Reports (HMR) No. 51 and 52. The rainfall depths and other inputs were obtained from HMR-51 and distributed using the HMR-52 option in HEC-HMS. The calculated 72-hour distribution was truncated to the peak 24-hours of rainfall.

2.5.2 Frequency Storms

To develop the 1-year, 100-year, and 500-year storms, the 24-hour duration storm rainfall depths were obtained from the NOAA-National Weather Service's Precipitation Frequency Data Server website. The website data is based on the "Precipitation-Frequency Atlas of the United States" NOAA Atlas 14, Volume 2, Version 3. The rainfall depths for the storms were distributed using the frequency storm analysis in HEC-HMS.

Table 2: Summary of Rainfall Depths Analyzed

Storm Event	Rainfall Depth, 24-hour (in)	Existing Storm Inflow (cfs)	Future Storm Inflow (cfs)
1-year	3.09	1,416	1,956
100-year	8.19	10,536	12,002
500-year	10.3	15,291	16,982
¾ PMP	21.87	49,114	51,339

3.0 RESERVOIR STORAGE AND BREACH SIZING

The following sections discuss the methods and inputs used to model Woodlake Dam storage routing and breach sizing in the HEC-HMS model.

3.1 Reservoir Elevations and Storage

Prior to the breach, the reservoir level was controlled by 10 slide gates. The center gate has a top elevation of EL 222.77 and the remaining 9 gates have a top elevation of EL 223.83 when closed. Based on discussions with WCCC, under normal conditions all gates were kept closed. The reservoir level was typically even with the top of the center gate. The top of dam elevation varies between approximately elevation EL 228 and EL 229.

The reservoir storage was calculated using NCFMP topography for EL 220 and above and supplemented by historical data below EL 220. The reservoir storage at normal pool is approximately 10,400 acre-feet and the storage at top of dam is approximately 17,100 acre-feet.

3.2 Tailwater

The tailwater was evaluated to determine its effects on the hydraulic performance of the dam and breach opening. The tailwater flows and elevations were evaluated using the preliminary FEMA HEC-RAS model of Crane Creek from about 70 feet downstream of the dam to Crane Creek's confluence with the Little River. The tailwater was evaluated for a range of flows. The tailwater flows and elevations were taken

from FEMA station 26546.3 of the HEC-RAS model. The tailwater elevations and flow rates were added to the HEC-HMS model. The tailwater model was analyzed as a steady state flow analysis. A summary of the tailwater conditions for different flow rates is shown below:

Table 3: Breach Outflow Tailwater Elevations

Flow rate (cfs)	Tailwater (EL)
0	199.22
100	202.26
300	204.21
500	205.47
1000	207.28
3,000	209.90
6,000	211.64
10,000	212.49
10,500	212.65
20,000	215.24
25,000	216.39
36,000	218.03
40,000	218.63
60,000	220.93

3.3 Reservoir and Breach Routing

The proposed temporary breach will be a single stage channel with an inlet invert at EL 209. The bottom of the channel will be 175 feet wide with 3H:1V side slopes. The breach section will have a channel slope of 2%. The breach was modeled in the HEC-HMS model using a non-level top of dam option in the shape of the breach with a weir coefficient of 2.4. To be conservative, flow through the existing low level outlets was not included.

The results of the HEC-HMS model from the 100-year, 500-year, and ¾ PMP future conditions model are included below.

Table 4: Headwater/Tailwater Future Watershed Conditions

Storm Event	Rainfall Depth (inches)	Storm Outflow (cfs)	Headwater (ft)	Tailwater (ft)
100-year	8.19	11,102	215.2	212.8
500-year	10.3	15,682	216.4	214.1
¾ PMP	21.87	48,885	221.9	219.7

3.4 Control of Water

The 2.89-inch, 24-hour storm was used to size the control of water plan due to the expected short duration of the construction. The contractor may elect to provide a higher level of protection. We assumed the two low level outlets will be opened during construction. The upstream coffer dam elevation was set at

El 213. This is above the peak elevation of EL 212.8 during this storm, assuming only the right low level outlet can pass flow. The downstream coffer dam was set at El 206 which is higher than the tailwater elevation during this storm event of EL 203.

4.0 BREACH DESIGN

The 100-year storm and the ¾ PMP were used to design the breach section of the spillway. Due to the high tailwater at the site, the section of the breach below the 100-year elevation will be lined using articulating concrete blocks (ACBs). The section of the breach between the 100-year elevation and the ¾ PMP elevation will be grass-lined with turf reinforcement mats (TRM). The small headwater and tailwater differential at this site makes it more likely for the smaller storm events to have higher velocities than the larger storm events. For example, the tailwater during the ¾ PMP is more than 10-ft above the breach control section.

4.1 Model of Breach Section

The two-dimensional (2D) hydrodynamic modeling capabilities of the U.S. Army Corps of Engineers HEC-RAS Version 5.0.3 (HEC-RAS) computer model was used to estimate the velocities along the breach section during the 100-year storm. The velocity is one of the key parameters required to select the appropriate armoring material for the breach section.

The 2D component of HEC-RAS uses a high resolution sub-grid model where the computation cells do not have flat bottoms but rather are represented by geometric and hydraulic property tables based upon the underlying terrain. This feature allows for utilization of larger computational grid cell sizes while retaining the resolution of the topographic terrain.

The terrain surface for the breach area and surrounding area was created by combining the proposed breach topography and existing topography from the 2017 site survey referenced above, and LiDAR data for the area. The combined terrain was imported into the HEC-RAS 2D RAS Mapper. A Manning's n value of 0.018 was assigned to the breach section lined with ACBs, a Manning's n value of 0.025 was assigned to the breach section lined with TRMs, and a Manning's n value of 0.04 was assigned to the surrounding area. The limits of the 2D model area was defined using a grid computational spacing of 5-ft to 5-ft squares.

The 100-year storm hydrograph developed in HEC-HMS was used as the upstream boundary condition. The tailwater curve for the cross section immediately downstream of the dam developed in the Tailwater HEC-RAS model was used as the downstream boundary condition. The flow was modeled using the unsteady flow option. The HEC-RAS 2D model for the 100-year storm through the breach section shows velocities ranging from approximately 10 ft/s to 16 ft/s. The velocity results of the modeling are included in Appendix D.

4.2 Breach Lining Calculations

The ACB's were sized using an estimated velocity of 20 ft/s. This resulted in a recommended block size based on the Shoretec SD-475-OCT or equivalent product. This product is 4.75-inch thick block, open-celled, and tapered top in line with the flow direction. This product resulted in a factor of safety of 3. The calculations to size the ACBs are included in Appendix D

Because the TRMs will only be located along the side slopes of the breach section, a velocity of 10 ft/s was assumed. This is the velocity present along the side slopes of the breach section in the 2D model. The recommended product for this scenario is PYRAMAT® 75 high performance turf reinforcement mat (HPTRM).When vegetated, this product is capable of handling velocities up to 25 ft/s. The product data sheet is in Appendix D.

5.0 LIMITATIONS

We based the analyses and recommendations submitted in this report on the information revealed by our exploration. We attempted to provide for normal contingencies, but the possibility remains that unexpected conditions may be encountered during construction.

We have endeavored to complete the services identified herein in a manner consistent with that level of care and skill ordinarily exercised by members of the profession currently practicing in the same locality and under similar conditions as this project. No other representation, express or implied, is included or intended, and no warranty or guarantee is included or intended in this report, or other instrument of service.

6.0 REFERENCES

Bedient and Huber, *Hydrology and Floodplain Analysis*. Second Edition, Chapter 2, Section 2.4.

FEMA preliminary model of Crane Creek, obtained from NCFMP, April 2017

Gupta, Ram S. *Hydrology and Hydraulic Systems*. Second Edition, Chapter 7, Section 7.11.1

Harnett County Future Land Use, (http://gis.harnett.org/data-downloads/)

Lee County Zoning Data,
(http://www.leecountync.gov/Departments/GISStrategicServices/DownloadGISLayers.aspx)

Moore County Zoning Data, (https://www.moorecountync.gov/gis/fees-data-download)

NOAA-National Weather Service, Hydrometeorological Report No. 51 and 52, 1983

NOAA-National Weather Service's Precipitation Frequency Data Server website based on "Precipitation-Frequency Atlas of the United States" NOAA Atlas 14, Volume 2, Version 3

NRCS, *TR-55 Urban Hydrology for Small Watersheds* 1986

NRCS Soil Data Mart Harnett, Lee, and Moore Counties, (http://soildatamart.nrcs.usda.gov)

Topography from 2017 Allied Survey and Light Detection and Ranging (LiDAR) data for Cumberland and Harnett Counties from the North Carolina Floodplain Mapping Program (NCFMP)

Drawings:

Construction Plans and Specifications, Phase I Dam Remediation, Spillway Structure Slabs & Walls; Marks Enterprises of NC, PLLC; January, 2011.

Construction Plans and Specifications, Phase I Dam Remediation, Spillway Structure Slabs & Walls; Marks Enterprises of NC, PLLC; August, 2014.

Remedial Dam Repair Plans, Woodlake Dam, Moore County, North Carolina; S&ME; July, 1988.

Reports:

Dam Remediation Design Submittal, Woodlake Dam Phase I Spillway Remediation; Marks Enterprises of NC, PLLC; January 17, 2011.

NC DEQ – DEMLR letter, *Dam Safety Breach Plan Submittal, Woodlake Dam*, April 19, 2017

Review Comments Responses Documents, Dam Remediation Design Submittal, Woodlake Dam Phase I Spillway Remediation; Marks Enterprises of NC, PLLC; September 1, 2014.

State of North Carolina, NC DEQ – DEMLR v. Woodlake CC Corporation Consent Judgment, March 15, 2017

FIGURES

Source: Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community
Projection: NAD 1983 StatePlane North Carolina FIPS 3200 Feet

1,000 500 0 1,000 Feet

Scale: 1:12,000

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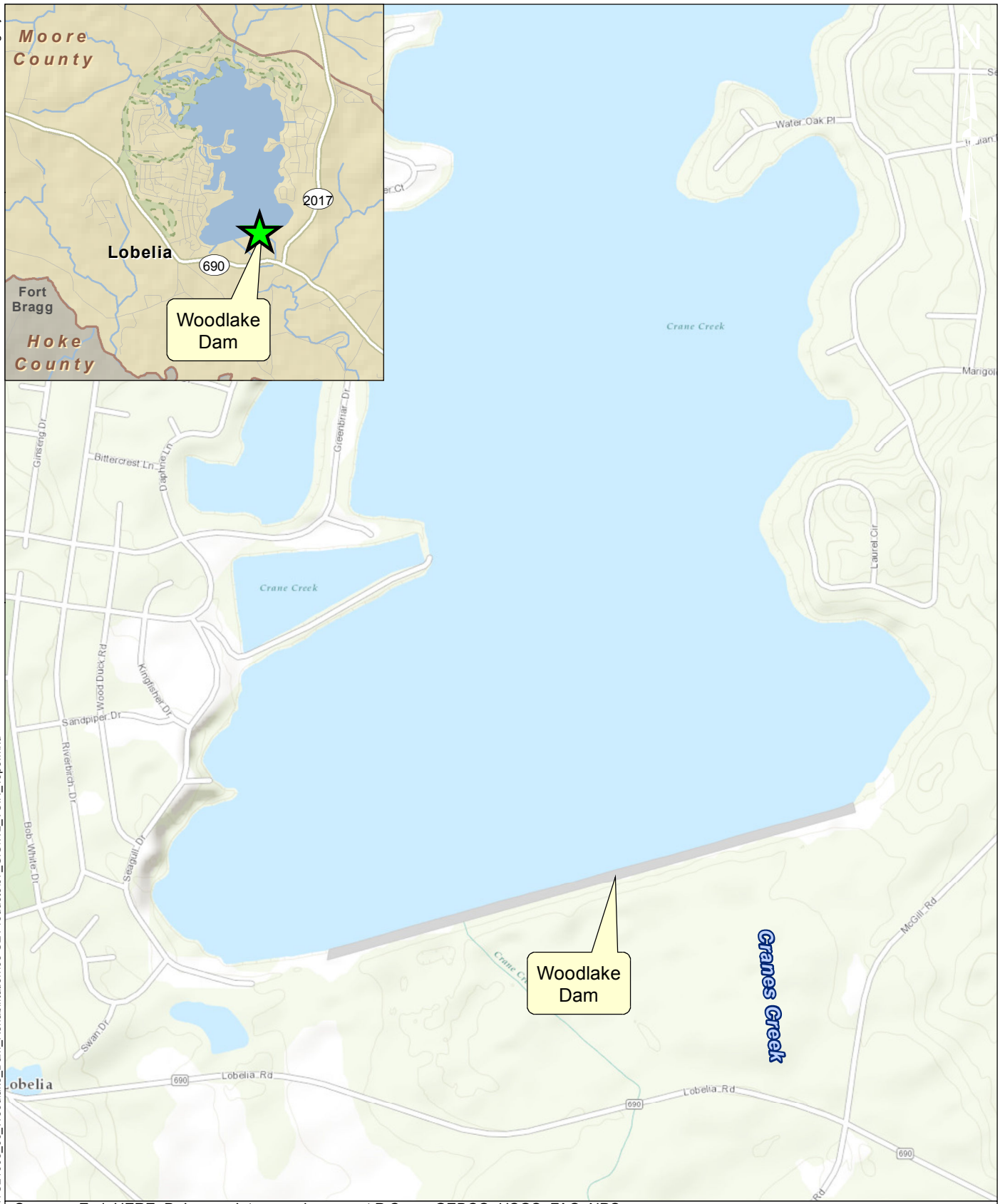
WOODLAKE DAM BREACH
WOODLAKE CC CORP
VASS, NORTH CAROLINA
PROJECT NO. 17C21008.00

SITE
VICINITY MAP

gnuyda

4/7/2017 G:\2017\Greensboro\17C21008_00_Woodlake_Dam_Rehabilitation\03-SE Products\07_GIS\WL_VCIN.mxd



Sources: Esri, HERE, DeLorme, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, MapmyIndia, © OpenStreetMap contributors, and the GIS User Community Projection: NAD 1983 StatePlane North Carolina FIPS 3200 Feet

1,000 500 0 1,000 Feet

Scale: 1:12,000

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WOODLAKE DAM BREACH
WOODLAKE CC CORP
VASS, NORTH CAROLINA
PROJECT NO. 17C21008.00

SITE
VICINITY MAP

4/25/2017 G:\2017\Greensboro\17C21008_00_Woodlake_Dam_Rehabilitation\03-SE Products\07_GIS\WL_VCIN_Topo.mxd gnuyda

APPENDIX A

SITE VISIT PHOTOS

PHOTOGRAPH: 1

Photo Taken: 04-18-17

LOCATION:

Left Embankment

COMMENTS:

Photo taken from the left abutment looking towards the spillway.

PHOTOGRAPH: 2

Photo Taken: 04-18-17

LOCATION:

Right Embankment

COMMENTS:

Photo taken from the spillway looking towards the right abutment

PHOTOGRAPH: 3

Photo Taken: 04-18-17

LOCATION:

Left Low Level Outlet

COMMENTS:

Photo taken from the lake bed looking downstream.

PHOTOGRAPH: 4

Photo Taken: 04-18-17

LOCATION:

Left Low Level Outlet

COMMENTS:

Photo taken from the pipe outlet looking downstream

PHOTOGRAPH: 5

Photo Taken: 04-18-17

LOCATION:

Right Low Level Outlet

COMMENTS:

Photo taken from the lake shoreline looking towards the right and downstream.

PHOTOGRAPH: 6

Photo Taken: 04-18-17

LOCATION:

Right Low Level Outlet

COMMENTS:

Photo taken from the pipe outlet looking downstream

PHOTOGRAPH: 7

Photo Taken: 04-18-17

LOCATION:

Right Low Level Outlet

COMMENTS:

Photo taken from the lake shoreline looking towards the right and downstream.

PHOTOGRAPH: 8

Photo Taken: 04-18-17

LOCATION:

Right Low Level Outlet

COMMENTS:

Photo taken from the pipe outlet looking downstream

PHOTOGRAPH: 9

Photo Taken: 04-18-17

LOCATION:

Downstream Endsill

COMMENTS:

Photo taken from the right side of the endsill looking towards the left.

PHOTOGRAPH: 10

Photo Taken: 04-18-17

LOCATION:

Close up view of the damaged sheetpile

COMMENTS:

Photo taken near the center of the spillway endsill

PHOTOGRAPH: 11

Photo Taken: 04-18-17

LOCATION:

Spillway

COMMENTS:

Photo taken from the lake bed looking downstream.

PHOTOGRAPH: 12

Photo Taken: 04-18-17

LOCATION:

Close up view of the damaged spillway chute

COMMENTS:

Photo taken from the left side of the damaged area looking right and downstream

APPENDIX B

HYDROLOGIC DATA AND CALCULATIONS

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CALCULATION COVER SHEET

Project	Project Number
Woodlake Dam	17C21008

Title

Hydrologic Calculations

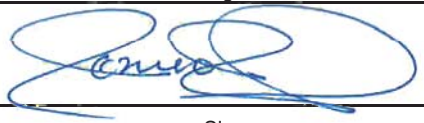
Computer Programs Used	Version/Release No.
HEC-HMS	4.2
Excel	2010

Purpose and Objective

The purposed was to delineate the watershed and subbasins, calculate the Curve Number for both existing and future land use, calculate the lag time using Snyder's method, and extract the rainfall values for the 1-year, 100-year, 500-year and 3/4 PMP.

Summary of Conclusions

The watershed is 95 square miles. The average existing conditions curve number is 68 while the future conditions curve number is 72. The lag time for each subbasin ranged from 4.7 hours to 8.6 hours.

Originator			
Laura Shearin-Feimster			Apr 30, 2017
Print	Sign		Date
Checked			
Maridee Romero-Graves			May 1, 2017
Print	Sign		Date

NOAA Atlas 14, Volume 2, Version 3
Location name: Cameron, North Carolina, USA*
Latitude: 35.3152°, Longitude: -79.2516°
Elevation: 362.41 ft**
* source: ESRI Maps
** source: USGS

POINT PRECIPITATION FREQUENCY ESTIMATES

G.M. Bonnin, D. Martin, B. Lin, T. Parzybok, M.Yekta, and D. Riley

NOAA, National Weather Service, Silver Spring, Maryland

PF_tabular | PF_graphical | Maps_&_aerials

PF tabular

PDS-based point precipitation frequency estimates with 90% confidence intervals (in inches)[1]

Duration	Average recurrence interval (years)									
	1	2	5	10	25	50	100	200	500	1000
5-min	**0.439** (0.399-0.487)	**0.519** (0.472-0.575)	**0.603** (0.547-0.668)	**0.664** (0.601-0.734)	**0.734** (0.661-0.810)	**0.783** (0.703-0.864)	**0.828** (0.740-0.913)	**0.868** (0.772-0.958)	**0.915** (0.806-1.01)	**0.951** (0.831-1.05)
10-min	**0.702** (0.637-0.777)	**0.830** (0.755-0.920)	**0.966** (0.876-1.07)	**1.06** (0.962-1.17)	**1.17** (1.05-1.29)	**1.25** (1.12-1.38)	**1.32** (1.18-1.45)	**1.38** (1.22-1.52)	**1.45** (1.27-1.60)	**1.50** (1.31-1.65)
15-min	**0.877** (0.797-0.972)	**1.04** (0.949-1.16)	**1.22** (1.11-1.35)	**1.34** (1.22-1.49)	**1.48** (1.33-1.64)	**1.58** (1.42-1.74)	**1.66** (1.49-1.83)	**1.74** (1.54-1.92)	**1.82** (1.60-2.01)	**1.88** (1.64-2.07)
30-min	**1.20** (1.09-1.33)	**1.44** (1.31-1.60)	**1.74** (1.57-1.92)	**1.95** (1.76-2.15)	**2.20** (1.98-2.42)	**2.38** (2.14-2.62)	**2.55** (2.28-2.81)	**2.70** (2.40-2.98)	**2.90** (2.56-3.20)	**3.04** (2.66-3.36)
60-min	**1.50** (1.36-1.66)	**1.81** (1.64-2.00)	**2.23** (2.02-2.46)	**2.53** (2.29-2.80)	**2.92** (2.63-3.23)	**3.22** (2.90-3.56)	**3.51** (3.13-3.87)	**3.79** (3.37-4.18)	**4.16** (3.67-4.59)	**4.44** (3.88-4.90)
2-hr	**1.77** (1.59-1.98)	**2.14** (1.93-2.39)	**2.67** (2.40-2.98)	**3.06** (2.75-3.42)	**3.58** (3.20-4.00)	**3.99** (3.55-4.45)	**4.38** (3.88-4.89)	**4.79** (4.20-5.33)	**5.32** (4.63-5.92)	**5.73** (4.94-6.39)
3-hr	**1.88** (1.70-2.10)	**2.27** (2.06-2.54)	**2.84** (2.57-3.18)	**3.29** (2.97-3.67)	**3.90** (3.49-4.34)	**4.38** (3.89-4.87)	**4.86** (4.30-5.41)	**5.37** (4.70-5.97)	**6.07** (5.26-6.75)	**6.63** (5.68-7.37)
6-hr	**2.24** (2.03-2.48)	**2.71** (2.46-3.00)	**3.39** (3.08-3.75)	**3.93** (3.56-4.35)	**4.67** (4.20-5.15)	**5.27** (4.70-5.80)	**5.88** (5.20-6.47)	**6.52** (5.71-7.16)	**7.40** (6.40-8.13)	**8.11** (6.93-8.92)
12-hr	**2.64** (2.40-2.93)	**3.19** (2.90-3.54)	**4.03** (3.65-4.46)	**4.69** (4.23-5.19)	**5.62** (5.03-6.19)	**6.38** (5.67-7.01)	**7.16** (6.31-7.86)	**8.00** (6.97-8.78)	**9.18** (7.87-10.1)	**10.1** (8.57-11.1)
24-hr	**3.09** (2.86-3.34)	**3.73** (3.46-4.04)	**4.70** (4.35-5.09)	**5.46** (5.04-5.91)	**6.50** (5.99-7.04)	**7.34** (6.74-7.94)	**8.19** (7.50-8.87)	**9.08** (8.29-9.82)	**10.3** (9.36-11.1)	**11.3** (10.2-12.2)
2-day	**3.60** (3.35-3.88)	**4.34** (4.04-4.68)	**5.43** (5.04-5.86)	**6.29** (5.83-6.78)	**7.47** (6.89-8.05)	**8.40** (7.73-9.05)	**9.36** (8.59-10.1)	**10.3** (9.46-11.2)	**11.7** (10.6-12.6)	**12.8** (11.6-13.8)
3-day	**3.83** (3.57-4.11)	**4.60** (4.29-4.94)	**5.73** (5.33-6.14)	**6.61** (6.14-7.09)	**7.83** (7.25-8.39)	**8.79** (8.11-9.43)	**9.79** (9.00-10.5)	**10.8** (9.91-11.6)	**12.2** (11.2-13.1)	**13.3** (12.1-14.4)
4-day	**4.05** (3.78-4.33)	**4.86** (4.55-5.20)	**6.02** (5.62-6.43)	**6.93** (6.46-7.39)	**8.19** (7.60-8.74)	**9.19** (8.50-9.81)	**10.2** (9.42-10.9)	**11.3** (10.4-12.1)	**12.7** (11.7-13.6)	**13.9** (12.7-14.9)
7-day	**4.66** (4.36-4.99)	**5.57** (5.21-5.96)	**6.80** (6.35-7.28)	**7.78** (7.26-8.32)	**9.13** (8.49-9.77)	**10.2** (9.46-10.9)	**11.3** (10.5-12.1)	**12.4** (11.5-13.3)	**14.0** (12.9-15.0)	**15.2** (13.9-16.4)
10-day	**5.31** (5.01-5.66)	**6.33** (5.96-6.73)	**7.63** (7.17-8.11)	**8.65** (8.12-9.18)	**10.0** (9.37-10.6)	**11.1** (10.4-11.8)	**12.2** (11.3-12.9)	**13.3** (12.3-14.1)	**14.8** (13.7-15.8)	**16.0** (14.7-17.0)
20-day	**7.16** (6.75-7.61)	**8.46** (7.98-8.99)	**10.0** (9.43-10.6)	**11.2** (10.6-11.9)	**12.9** (12.1-13.7)	**14.2** (13.3-15.1)	**15.5** (14.4-16.5)	**16.8** (15.6-17.9)	**18.6** (17.2-19.8)	**20.0** (18.4-21.3)
30-day	**8.91** (8.42-9.45)	**10.5** (9.91-11.1)	**12.2** (11.5-13.0)	**13.6** (12.8-14.4)	**15.3** (14.4-16.3)	**16.7** (15.7-17.7)	**18.1** (16.9-19.2)	**19.4** (18.1-20.6)	**21.2** (19.8-22.6)	**22.6** (21.0-24.1)
45-day	**11.3** (10.7-11.9)	**13.2** (12.5-14.0)	**15.2** (14.3-16.0)	**16.6** (15.7-17.6)	**18.6** (17.5-19.6)	**20.0** (18.9-21.1)	**21.5** (20.2-22.6)	**22.9** (21.4-24.1)	**24.7** (23.1-26.1)	**26.1** (24.3-27.6)
60-day	**13.5** (12.9-14.3)	**15.8** (15.0-16.7)	**17.9** (17.0-18.9)	**19.6** (18.5-20.6)	**21.7** (20.5-22.8)	**23.2** (22.0-24.5)	**24.8** (23.4-26.1)	**26.3** (24.7-27.7)	**28.2** (26.5-29.8)	**29.6** (27.8-31.4)

[1] Precipitation frequency (PF) estimates in this table are based on frequency analysis of partial duration series (PDS).

Numbers in parenthesis are PF estimates at lower and upper bounds of the 90% confidence interval. The probability that precipitation frequency estimates (for a given duration and average recurrence interval) will be greater than the upper bound (or less than the lower bound) is 5%. Estimates at upper bounds are not checked against probable maximum precipitation (PMP) estimates and may be higher than currently valid PMP values.

Please refer to NOAA Atlas 14 document for more information.

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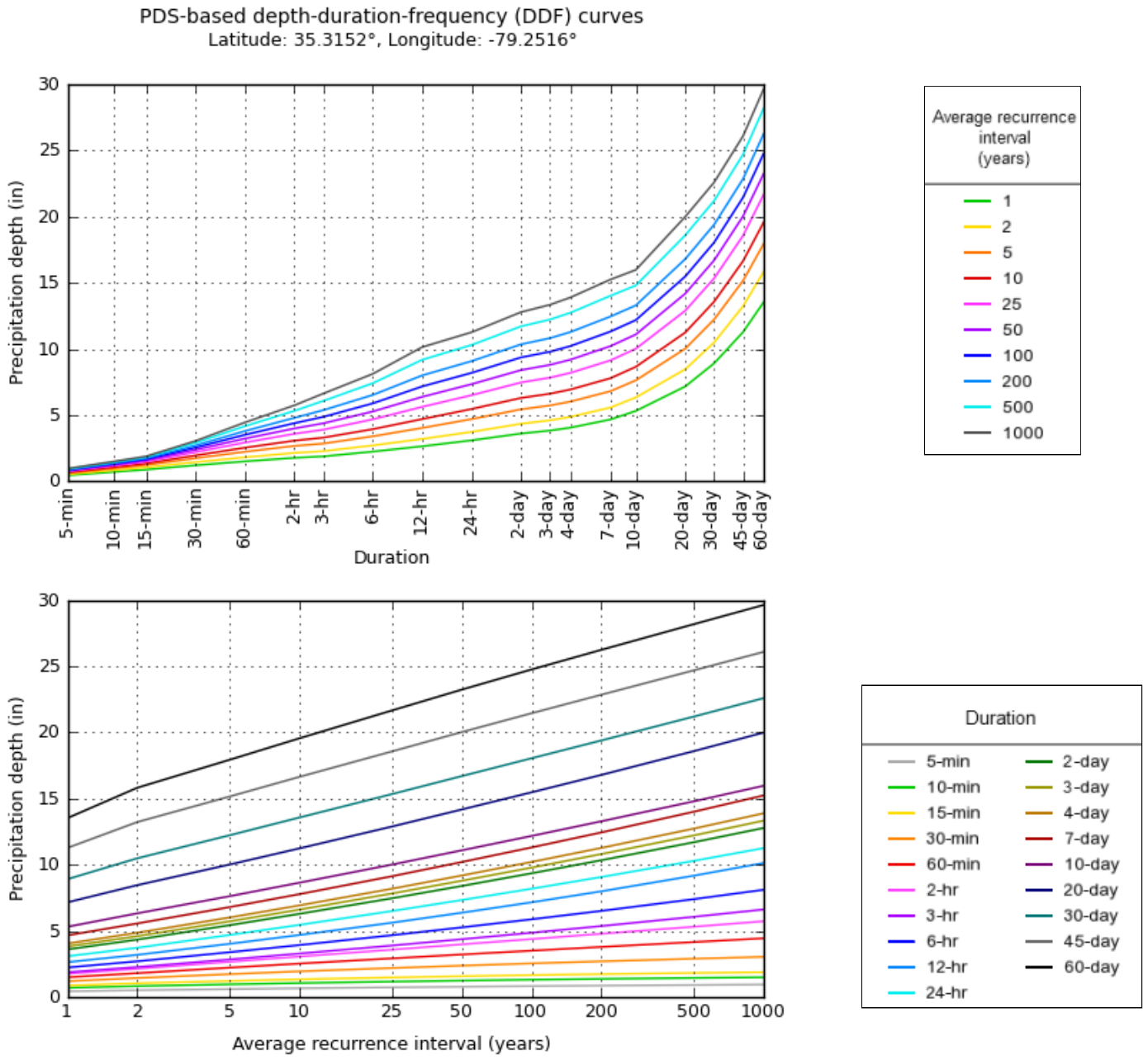
PF graphical



NOAA Atlas 14, Volume 2, Version 3

Created (GMT): Mon Mar 27 14:51:30 2017

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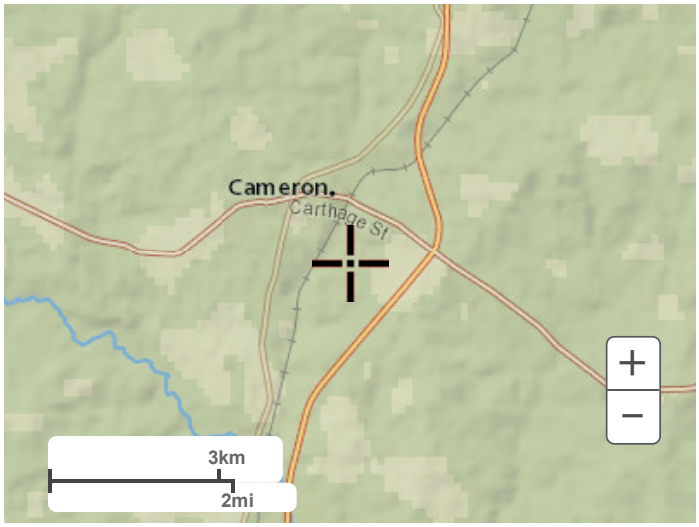
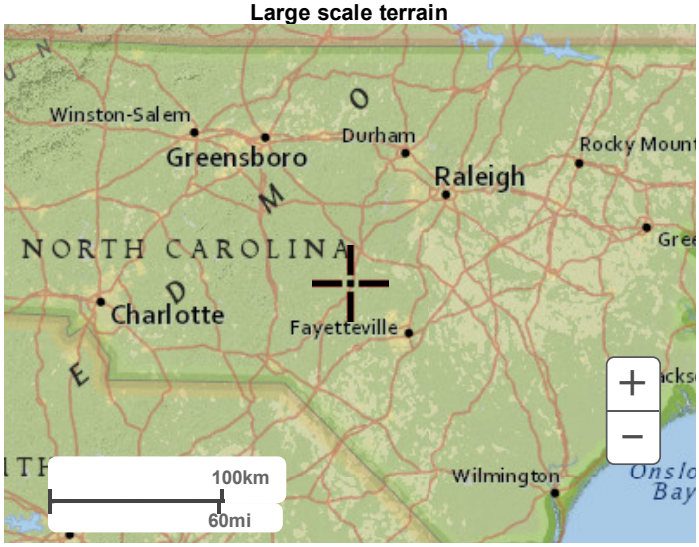
Maps & aerials

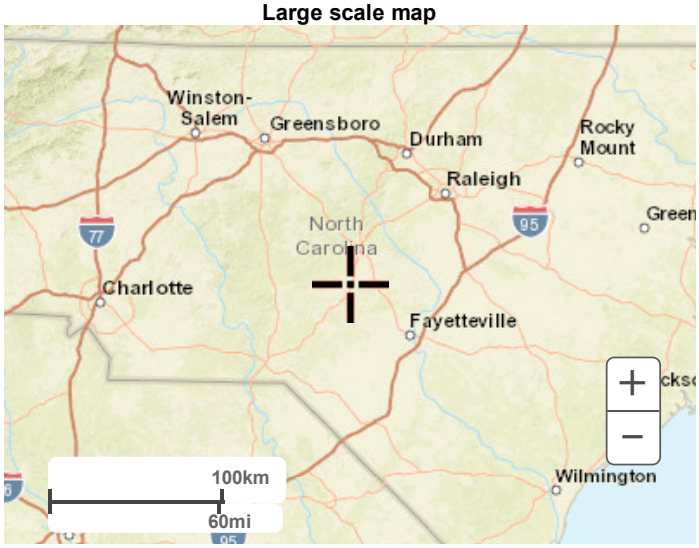
Small scale terrain



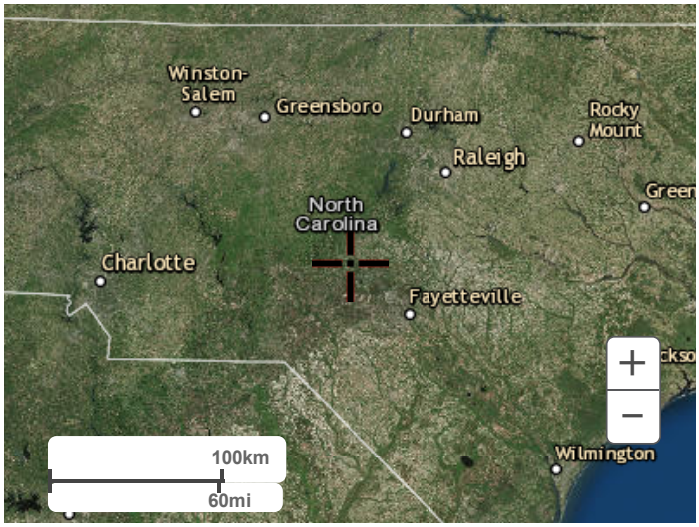
Large scale terrain



Large scale map



Large scale aerial



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US Department of Commerce
National Oceanic and Atmospheric Administration
National Weather Service
National Water Center
1325 East West Highway
Silver Spring, MD 20910
Questions?: HDSC.Questions@noaa.gov

Disclaimer

Project:	Woodlake Dam		**HMR51 PMP Values**	
Client:	WCC Corp			
Location:	Moore County NC			

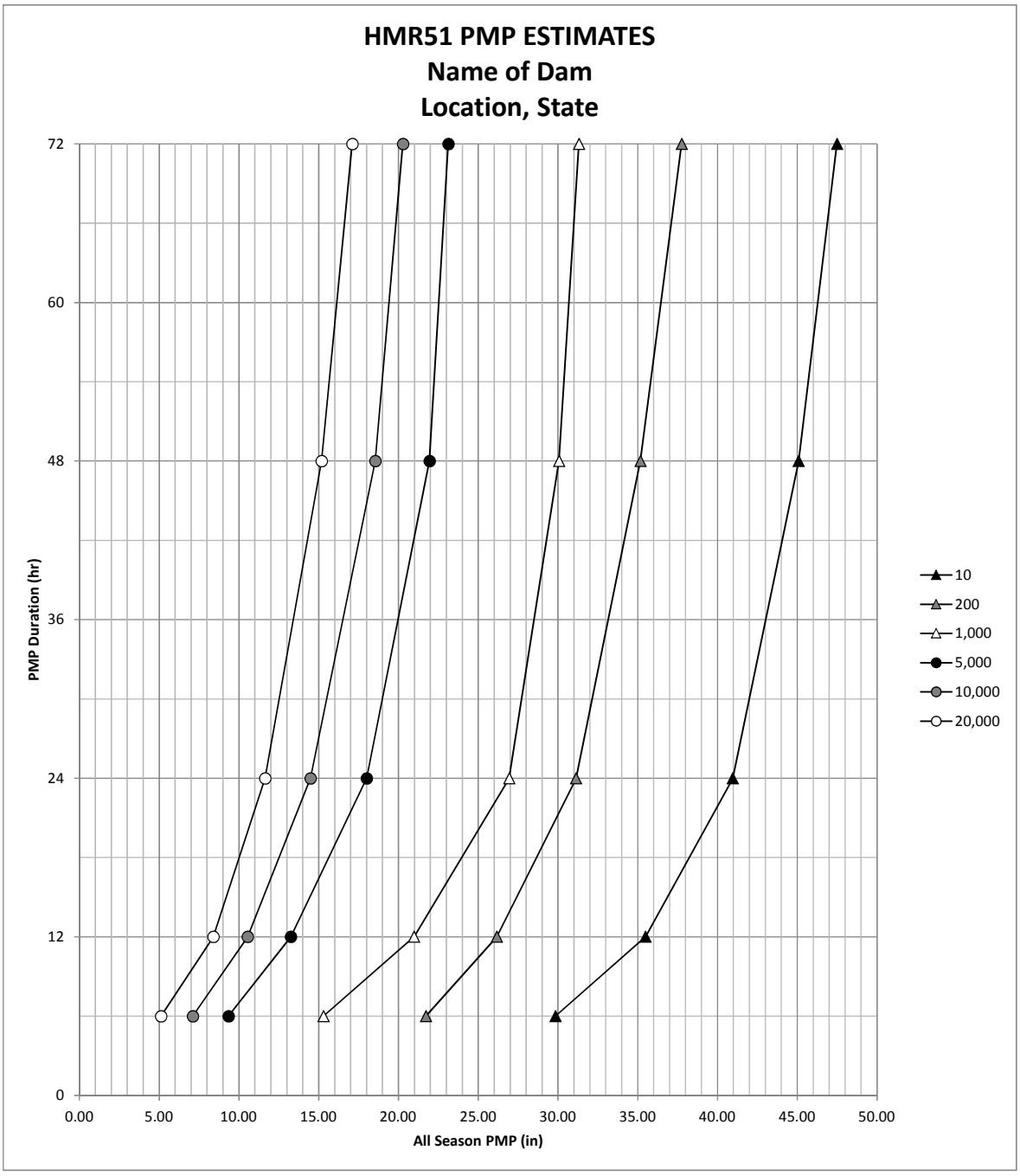
Schnabel ENGINEERING

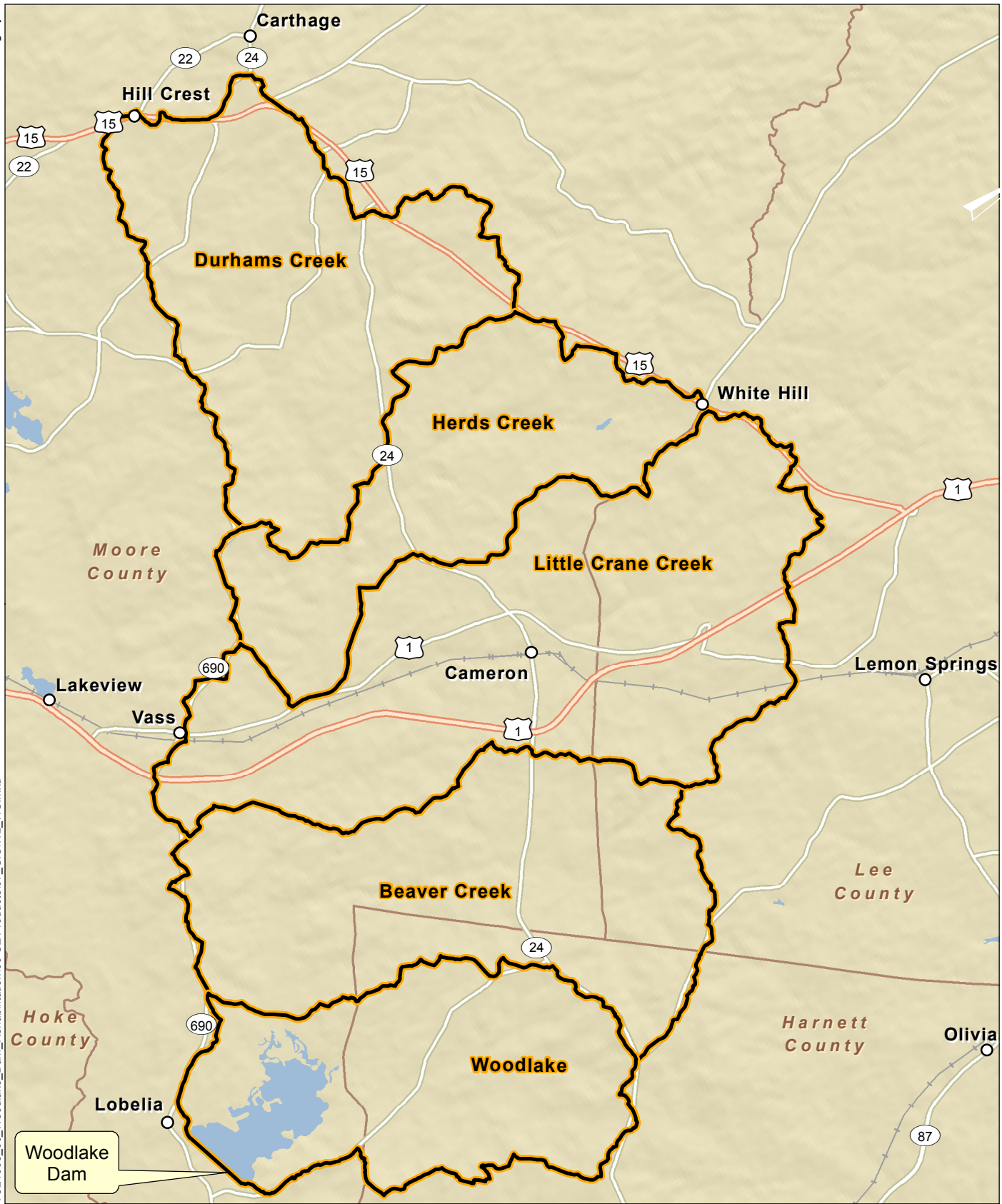
By	Date:		Sheet
LES	3/22/2017		1
Checked	Chk Date:		Job No
BMC	3/28/2017		17C21008

	6	12	24	48	72
10	29.84	35.47	40.95	45.08	47.48
200	21.72	26.16	31.13	35.17	37.75
1,000	15.30	20.97	26.94	30.07	31.31
5,000	9.34	13.25	18.01	21.94	23.12
10,000	7.10	10.54	14.49	18.54	20.27
20,000	5.11	8.39	11.63	15.17	17.10

X Coordinate: 1924807.37
Y Coordinate: 569996.297

Preferred Orientation: 200
1 to 6 Ratio: 0.281





Source: ESRI MediaKit(2010), Terrain/Watershed Boundary derived from NCFMP LiDAR,

Projection: NAD 1983 StatePlane North Carolina FIPS 3200 Feet

10,000 5,000 0 10,000 Feet

Scale: 1:120,000

Schnabel ENGINEERING

WOODLAKE DAM BREACH
WOODLAKE CC CORP
VASS, NORTH CAROLINA
PROJECT NO. 17C21008.00

WATERSHED MAP

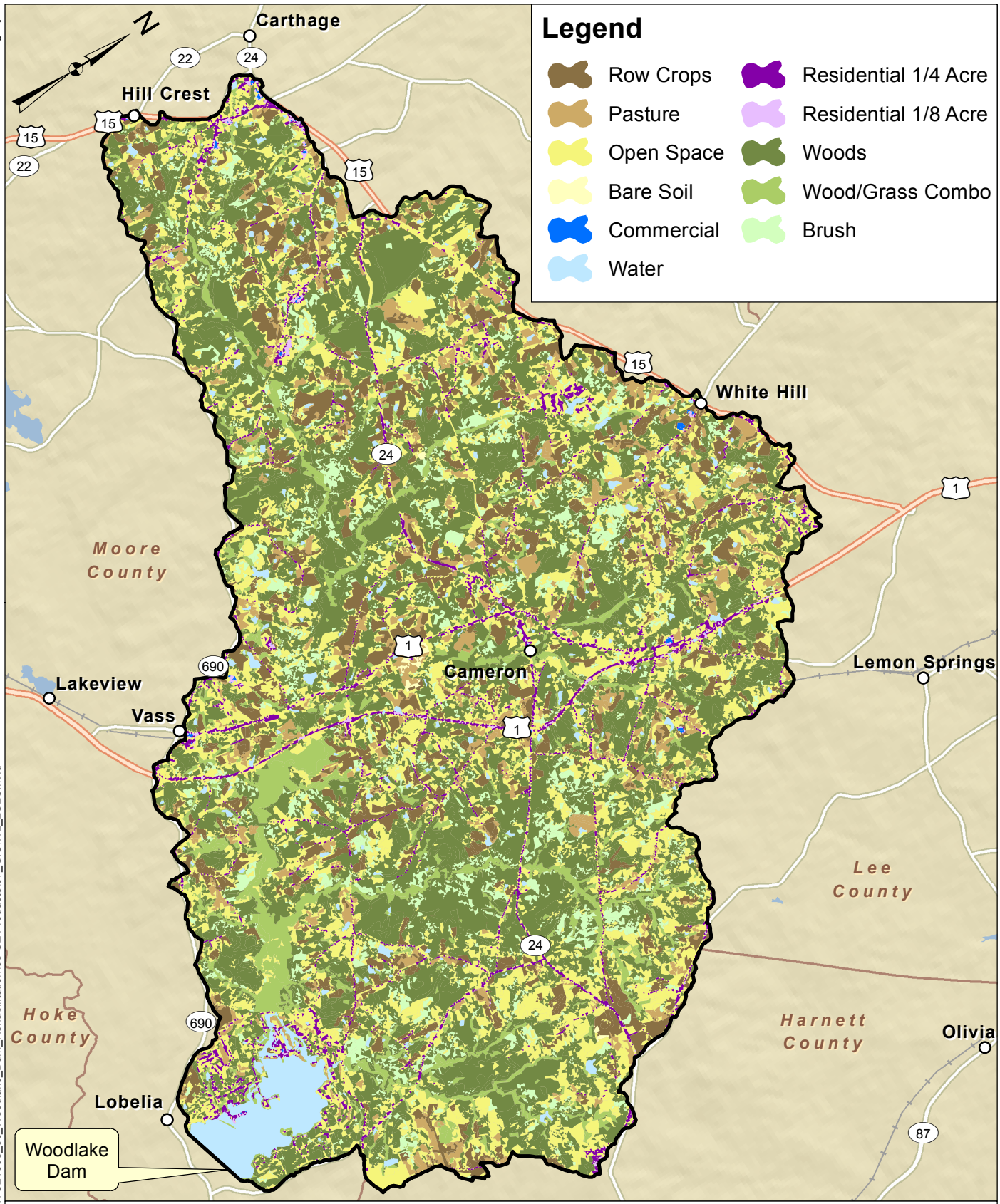
4/20/2017 G:\2017\Greensboro\17C21008_00_Woodlake_Dam_Rehabilitation\03-SE Products\07_GIS\WL_WS.mxd gnuyda

Project:	Woodlake Dam - 17C21008				
Subject:	Lag Time for Woodlake Dam Subbasins				
Date:	20-Apr-17	By:	LES	Checked:	MRG
Filename:	C:\Users\lshearin\Desktop\02-HH\Hydrology\[Lag Time-Snyder.xlsx]Snyder				
Data Source:	Centroid Locations and Stream Lengths Measured in GIS				
Notes:	Typical Values for Ct and Cp Ct = 0.6/(S)^0.5, Cp = 0.4 to 0.8, where S = basin slope				
	From "Introduction to Hydrology 4th Ed." Table 12.3 and "Hydrology and Hydraulic Systems 2nd Ed". Page 356				

Subbasin	Durhams Creek		Subbasin	Herds Creek	
Stream Length, L	8.93	miles	Stream Length, L	9.68	miles
Length From Centroid, Lc	4.09	miles	Length From Centroid, Lc	4.64	miles
Basin Slope	0.0681	ft/ft	Basin Slope	0.0646	ft/ft
Ct	2.30		Ct	2.36	
Cp			Cp		
Lag Time, T_l	6.766	hr	Lag Time, T_l	7.392	hr

Subbasin	Little Crane Creek		Subbasin	Beaver Creek	
Stream Length, L	11.59	miles	Stream Length, L	10.46	miles
Length From Centroid, Lc	5.72	miles	Length From Centroid, Lc	5.23	miles
Basin Slope	0.0605	ft/ft	Basin Slope	0.0644	ft/ft
Ct	2.44		Ct	2.36	
Cp			Cp		
Lag Time, T_l	8.585	hr	Lag Time, T_l	7.854	hr

Subbasin	Woodlake	
Stream Length, L	5.35	miles
Length From Centroid, Lc	1.65	miles
Basin Slope	0.0598	ft/ft
Ct	2.45	
Cp		
Lag Time, T_l	4.716	hr



Source: National Land Cover Dataset 2011 Zone 14, Multi-Resolution Land Characteristics (MRLC) Consortium, ESRI MediaKit(2010), Terrain/Watershed Boundary derived from NCFMP LiDAR
Projection: NAD 1983 StatePlane North Carolina FIPS 3200 Feet

10,000 5,000 0 10,000 Feet

Scale: 1:120,000

Schnabel ENGINEERING

WOODLAKE DAM BREACH
WOODLAKE CC CORP
VASS, NORTH CAROLINA
PROJECT NO. 17C21008.00

LAND USE/
LAND COVER MAP

4/20/2017 G:\2017\Greensboro\17C21008_00_Woodlake_Dam_Rehabilitation\03-SE Products\07_GIS\WL_LULC.mxd gnuyda

SCHNABEL ENGINEERING

BY	Guy Nuyda	**DATE**	04/17/17	
CHKD. BY	LES	**DATE**	04/18/17	**JOB NO.** 17P21017.00
SUBJECT	Woodlake Dam SubWatershed - Herds, Existing Conditions			

The purpose of this analysis is to develop runoff curve numbers for the land cover information classifications
that are mapped in the drainage area of the Woodlake Dam SubWatershed - Herds in Harnet, Moore, and Lee Counties, North Carolina.

Hydrologic Soil Group	Cover Description (Cover type, treatment, and hydrologic description; % impervious; connected or unconnected, etc)	CN	Area (Acres)	Product (CN*Area)
A	Bare Soil	77	0.39	29.7
A	Brush	30	34.69	1,040.8
A	Commercial	89	0.14	12.7
A	Open Space	68	362.90	24,676.9
A	Pasture	39	126.53	4,934.7
A	Residential 1/4 Acre	61	61.57	3,755.9
A	Residential 1/8 Acre	77	3.41	262.5
A	Row Crops	65	229.82	14,938.1
A	Wood/Grass Combo	32	10.91	349.2
A	Woods	30	210.29	6,308.6
B	Bare Soil	86	5.44	467.5
B	Brush	48	513.70	24,657.7
B	Commercial	92	1.55	142.9
B	Open Space	79	1,246.21	98,450.2
B	Pasture	61	368.59	22,483.9
B	Residential 1/4 Acre	75	135.60	10,170.2
B	Residential 1/8 Acre	85	1.66	141.4
B	Row Crops	75	825.66	61,924.3
B	Wood/Grass Combo	58	138.83	8,052.4
B	Woods	55	2,107.96	115,937.7
C	Brush	65	203.97	13,257.9
C	Commercial	94	5.95	559.4
C	Open Space	86	393.14	33,809.8
C	Pasture	74	62.86	4,651.4
C	Residential 1/4 Acre	83	10.71	889.1
C	Residential 1/8 Acre	90	2.43	218.7
C	Row Crops	82	131.47	10,780.9
C	Wood/Grass Combo	72	207.53	14,942.2
C	Woods	70	933.61	65,352.9
D	Brush	73	10.12	738.8
D	Open Space	89	10.20	907.5
D	Wood/Grass Combo	79	24.37	1,925.0
D	Woods	77	34.31	2,642.1
W	Water	100	145.69	14,569.3
		Totals	**8562**	**563982**

Total (square miles): 13.4

Composite CN: 66

References:

Land Cover for Harnett, Lee, and Moore Counties obtained from National Land Cover Dataset 2011 Zone 14, Multi-Resolution Land Characteristics (MRLC) Consortium (http://www.epa.gov/mrlc/nlcd.html)
Soils obtained from NRCS Soil Data Mart for Harnett, Lee, and Moore Counties, North Carolina
NRCS TR-55, Second Edition, June 1986
NRCS Part 630 HNEH, Chapter 9, Hydrologic Soil-Cover Complexes, 2004

SCHNABEL ENGINEERING

BY	Guy Nuyda	**DATE**	04/17/17	
CHKD. BY	LES	**DATE**	04/18/17	**JOB NO.** 17P21017.00
SUBJECT	Woodlake Dam SubWatershed - Durham, Existing Conditions			

The purpose of this analysis is to develop runoff curve numbers for the land cover information classifications
that are mapped in the drainage area of the Woodlake Dam SubWatershed - Durham in Harnet, Moore, and Lee Counties, North Carolina.

Hydrologic Soil Group	Cover Description (Cover type, treatment, and hydrologic description; % impervious; connected or unconnected, etc)	CN	Area (Acres)	Product (CN*Area)
A	Brush	30	9.03	270.8
A	Commercial	89	2.46	219.3
A	Open Space	68	226.88	15,428.2
A	Pasture	39	56.51	2,203.8
A	Residential 1/4 Acre	61	55.84	3,406.4
A	Residential 1/8 Acre	77	13.58	1,045.7
A	Row Crops	65	97.85	6,360.4
A	Wood/Grass Combo	32	5.32	170.4
A	Woods	30	247.65	7,429.4
B	Brush	48	442.26	21,228.3
B	Commercial	92	7.11	654.5
B	Open Space	79	1,862.98	147,175.8
B	Pasture	61	509.27	31,065.7
B	Residential 1/4 Acre	75	175.95	13,196.1
B	Residential 1/8 Acre	85	25.96	2,206.3
B	Row Crops	75	1,176.50	88,237.5
B	Wood/Grass Combo	58	157.58	9,139.8
B	Woods	55	3,276.17	180,189.3
C	Brush	65	308.70	20,065.8
C	Commercial	94	5.02	471.7
C	Open Space	86	762.27	65,554.9
C	Pasture	74	95.38	7,058.4
C	Residential 1/4 Acre	83	91.41	7,587.0
C	Residential 1/8 Acre	90	14.24	1,281.2
C	Row Crops	82	192.39	15,776.0
C	Wood/Grass Combo	72	309.61	22,291.6
C	Woods	70	1,909.12	133,638.7
D	Brush	73	22.28	1,626.3
D	Commercial	95	0.96	91.0
D	Open Space	89	34.78	3,095.1
D	Pasture	80	1.10	88.3
D	Residential 1/4 Acre	87	1.26	109.7
D	Residential 1/8 Acre	92	3.44	316.6
D	Row Crops	86	3.71	319.5
D	Wood/Grass Combo	79	103.64	8,187.5
D	Woods	77	128.15	9,867.4
W	Water	100	164.49	16,449.5
		Totals	**12501**	**843504**

Total (square miles): 19.5

Composite CN: 67

References:

Land Cover for Harnett, Lee, and Moore Counties obtained from National Land Cover Dataset 2011
Soils obtained from NRCS Soil Data Mart for Harnett, Lee, and Moore Counties, North Carolina
NRCS TR-55, Second Edition, June 1986
NRCS Part 630 HNEH, Chapter 9, Hydrologic Soil-Cover Complexes, 2004

SCHNABEL ENGINEERING

BY	Guy Nuyda	**DATE**	04/17/17	
CHKD. BY	LES	**DATE**	04/18/17	**JOB NO.** 17P21017.00
SUBJECT	Woodlake Dam SubWatershed - Crane, Existing Conditions			

The purpose of this analysis is to develop runoff curve numbers for the land cover information classifications
that are mapped in the drainage area of the Woodlake Dam SubWatershed - Crane in Harnet, Moore, and Lee Counties, North Carolina.

Hydrologic Soil Group	Cover Description (Cover type, treatment, and hydrologic description; % impervious; connected or unconnected, etc)	CN	Area (Acres)	Product (CN*Area)
A	Brush	30	61.66	1,849.8
A	Commercial	89	1.82	162.3
A	Open Space	68	771.74	52,478.5
A	Pasture	39	215.37	8,399.3
A	Residential 1/4 Acre	61	91.25	5,566.0
A	Residential 1/8 Acre	77	5.63	433.1
A	Row Crops	65	438.17	28,481.3
A	Wood/Grass Combo	32	23.67	757.5
A	Woods	30	593.84	17,815.1
B	Bare Soil	86	46.40	3,990.5
B	Brush	48	497.99	23,903.7
B	Commercial	92	8.11	745.8
B	Open Space	79	2,853.35	225,414.8
B	Pasture	61	760.33	46,379.9
B	Residential 1/4 Acre	75	496.57	37,243.0
B	Residential 1/8 Acre	85	45.93	3,904.4
B	Row Crops	75	1,718.81	128,910.6
B	Wood/Grass Combo	58	345.19	20,021.0
B	Woods	55	3,357.74	184,675.7
C	Bare Soil	91	2.21	201.3
C	Brush	65	220.49	14,331.6
C	Commercial	94	0.21	19.6
C	Open Space	86	871.10	74,914.9
C	Pasture	74	148.53	10,991.0
C	Residential 1/4 Acre	83	83.20	6,905.6
C	Residential 1/8 Acre	90	7.67	690.0
C	Row Crops	82	235.86	19,340.8
C	Wood/Grass Combo	72	255.54	18,398.6
C	Woods	70	1,410.70	98,748.9
D	Bare Soil	94	0.57	53.6
D	Brush	73	120.40	8,789.2
D	Commercial	95	1.08	103.0
D	Open Space	89	306.02	27,236.2
D	Pasture	80	34.72	2,777.3
D	Residential 1/4 Acre	87	19.53	1,699.0
D	Residential 1/8 Acre	92	5.61	515.9
D	Row Crops	86	40.09	3,447.9
D	Wood/Grass Combo	79	408.73	32,289.3
D	Woods	77	763.46	58,786.8
W	Water	100	251.20	25,120.0
		Totals	**17520**	**1196493**

Total (square miles): **27.4**

Composite CN: **68**

References:

Land Cover for Harnett, Lee, and Moore Counties obtained from National Land Cover Dataset 2011 Zone 14, Multi-Resolution Land Characteristics (MRLC) Consortium (http://www.epa.gov/mrlc/nlcd.html)
Soils obtained from NRCS Soil Data Mart for Harnett, Lee, and Moore Counties, North Carolina
NRCS TR-55, Second Edition, June 1986
NRCS Part 630 HNEH, Chapter 9, Hydrologic Soil-Cover Complexes, 2004

SCHNABEL ENGINEERING

BY	Guy Nuyda	**DATE**	04/17/17	
CHKD. BY	LES	**DATE**	04/18/17	**JOB NO.** 17P21017.00
SUBJECT	Woodlake Dam SubWatershed - Beaver, Existing Conditions			

The purpose of this analysis is to develop runoff curve numbers for the land cover information classifications
that are mapped in the drainage area of the Woodlake Dam SubWatershed - Beaver in Harnet, Moore, and Lee Counties, North Carolina.

Hydrologic Soil Group	Cover Description (Cover type, treatment, and hydrologic description; % impervious; connected or unconnected, etc)	CN	Area (Acres)	Product (CN*Area)
A	Brush	30	94.49	2,834.7
A	Open Space	68	751.54	51,104.4
A	Pasture	39	118.02	4,602.8
A	Residential 1/4 Acre	61	122.95	7,500.1
A	Residential 1/8 Acre	77	3.67	282.4
A	Row Crops	65	498.19	32,382.1
A	Wood/Grass Combo	32	18.63	596.2
A	Woods	30	749.76	22,492.9
B	Brush	48	615.93	29,564.5
B	Open Space	79	1,298.00	102,542.2
B	Pasture	61	178.64	10,896.9
B	Residential 1/4 Acre	75	106.10	7,957.2
B	Residential 1/8 Acre	85	0.92	77.8
B	Row Crops	75	467.75	35,081.0
B	Wood/Grass Combo	58	264.31	15,330.0
B	Woods	55	3,074.97	169,123.5
C	Brush	65	197.84	12,859.3
C	Commercial	94	0.22	20.9
C	Open Space	86	564.04	48,507.7
C	Pasture	74	111.00	8,213.8
C	Residential 1/4 Acre	83	30.62	2,541.7
C	Residential 1/8 Acre	90	0.32	28.7
C	Row Crops	82	155.53	12,753.3
C	Wood/Grass Combo	72	538.84	38,796.3
C	Woods	70	1,128.27	78,978.9
D	Brush	73	130.82	9,549.9
D	Open Space	89	171.74	15,285.3
D	Pasture	80	5.72	457.3
D	Residential 1/4 Acre	87	4.87	424.0
D	Row Crops	86	13.18	1,133.6
D	Wood/Grass Combo	79	606.30	47,897.7
D	Woods	77	571.69	44,019.9
W	Water	100	98.03	9,802.6
		Totals	**12693**	**823640**

Total (square miles): 19.8

Composite CN: 65

References:

Land Cover for Harnett, Lee, and Moore Counties obtained from National Land Cover Dataset 2011 Zone 14, Multi-Resolution Land Characteristics (MRLC) Consortium (http://www.epa.gov/mrlc/nlcd.html)
Soils obtained from NRCS Soil Data Mart for Harnett, Lee, and Moore Counties, North Carolina
NRCS TR-55, Second Edition, June 1986
NRCS Part 630 HNEH, Chapter 9, Hydrologic Soil-Cover Complexes, 2004

SCHNABEL ENGINEERING

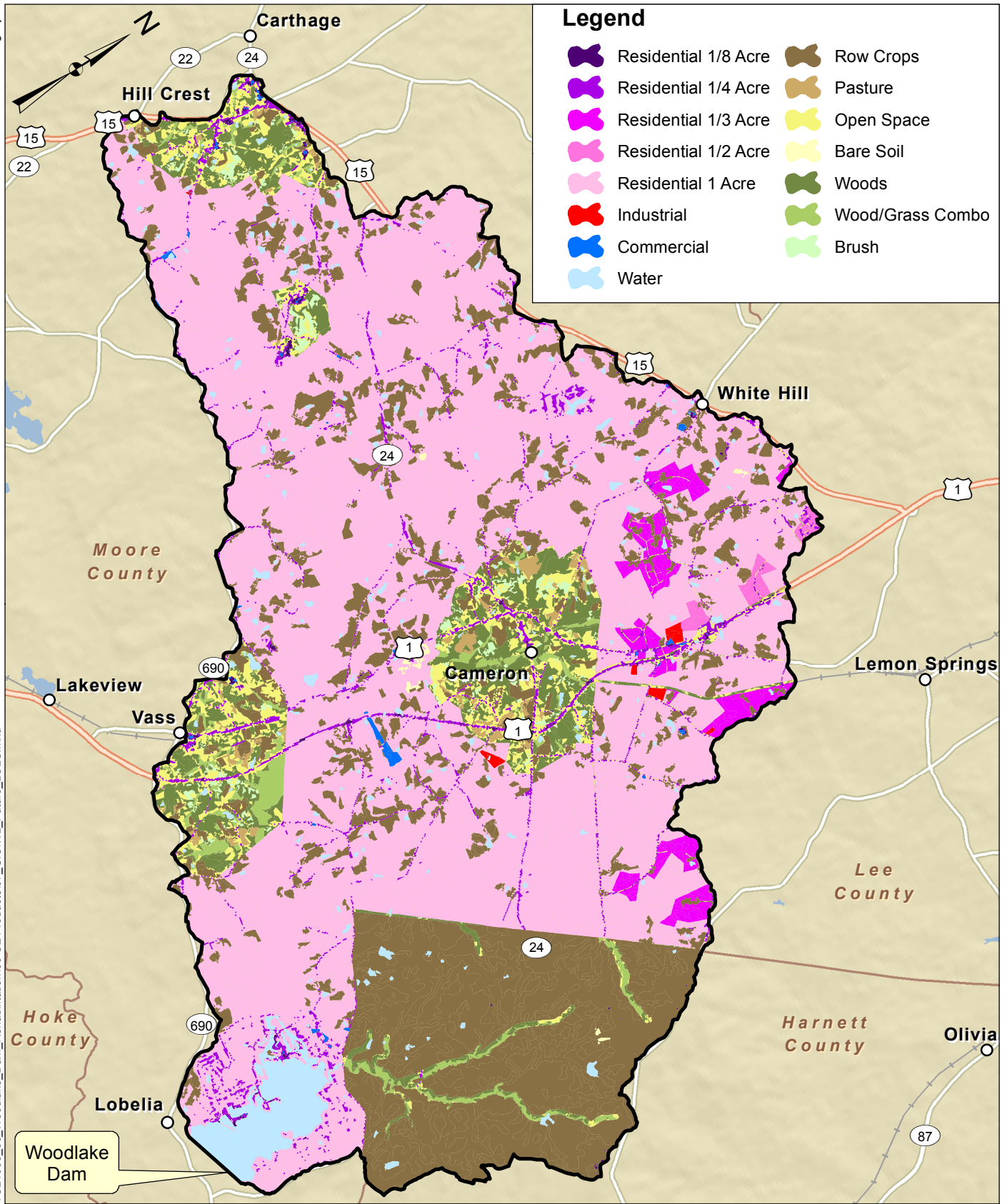
BY	Guy Nuyda	**DATE**	04/17/17	
CHKD. BY	LES	**DATE**	04/18/17	**JOB NO.** 17P21017.00
SUBJECT	Woodlake Dam SubWatershed - Beaver, Existing Conditions			

The purpose of this analysis is to develop runoff curve numbers for the land cover information classifications
that are mapped in the drainage area of the Woodlake Dam SubWatershed - Beaver in Harnet, Moore, and Lee Counties, North Carolina.

Hydrologic Soil Group	Cover Description (Cover type, treatment, and hydrologic description; % impervious; connected or unconnected, etc)	CN	Area (Acres)	Product (CN*Area)
A	Bare Soil	77	7.05	543.2
A	Brush	30	15.43	462.8
A	Open Space	68	574.85	39,090.1
A	Pasture	39	102.26	3,988.3
A	Residential 1/4 Acre	61	88.50	5,398.5
A	Residential 1/8 Acre	77	2.29	176.2
A	Row Crops	65	203.22	13,209.1
A	Wood/Grass Combo	32	10.17	325.3
A	Woods	30	253.77	7,613.2
B	Brush	48	173.40	8,323.1
B	Open Space	79	843.94	66,670.9
B	Pasture	61	133.24	8,127.8
B	Residential 1/4 Acre	75	84.18	6,313.6
B	Residential 1/8 Acre	85	2.36	201.0
B	Row Crops	75	291.31	21,848.6
B	Wood/Grass Combo	58	136.99	7,945.2
B	Woods	55	1,243.79	68,408.5
C	Bare Soil	91	0.76	69.2
C	Brush	65	202.06	13,133.9
C	Commercial	94	1.43	134.7
C	Open Space	86	978.39	84,141.3
C	Pasture	74	109.35	8,091.7
C	Residential 1/4 Acre	83	160.22	13,298.3
C	Residential 1/8 Acre	90	15.85	1,426.7
C	Row Crops	82	130.06	10,665.0
C	Wood/Grass Combo	72	270.03	19,442.0
C	Woods	70	1,357.18	95,002.6
D	Bare Soil	94	0.16	15.2
D	Brush	73	82.70	6,037.3
D	Open Space	89	199.67	17,770.9
D	Pasture	80	10.98	878.7
D	Residential 1/4 Acre	87	27.89	2,426.1
D	Residential 1/8 Acre	92	0.54	49.9
D	Row Crops	86	5.39	463.8
D	Wood/Grass Combo	79	268.30	21,195.8
D	Woods	77	489.35	37,680.0
W	Water	100	1,171.15	117,114.9
		Totals	**9648**	**707683**
		Total (square miles):	**15.1**	
			Composite CN:	**73**

References:

Land Cover for Harnett, Lee, and Moore Counties obtained from National Land Cover Dataset 2011 Zone 14, Multi-Resolution Land Characteristics (MRLC) Consortium (http://www.epa.gov/mrlc/nlcd.html)
Soils obtained from NRCS Soil Data Mart for Harnett, Lee, and Moore Counties, North Carolina
NRCS TR-55, Second Edition, June 1986
NRCS Part 630 HNEH, Chapter 9, Hydrologic Soil-Cover Complexes, 2004



Source: Moore, Lee, and Harnett County GIS Departments, National Land Cover Dataset 2011 Zone 14, Multi-Resolution Land Characteristics (MRLC) Consortium, ESRI MediaKit(2010), Terrain/Watershed Boundary derived from NCFMP LiDAR
Projection: NAD 1983 StatePlane North Carolina FIPS 3200 Feet

10,000 5,000 0 10,000 Feet

Scale: 1:120,000

Schnabel ENGINEERING

WOODLAKE DAM BREACH
WOODLAKE CC CORP
VASS, NORTH CAROLINA
PROJECT NO. 17C21008.00

FUTURE LAND USE/
LAND COVER MAP

gnuyda

4/20/2017 G:\2017\Greensboro\17C21008_00_Woodlake_Dam_Rehabilitation\03-SE Products\07_GIS\WL_Future_LULC.mxd

SCHNABEL ENGINEERING

BY	Guy Nuyda	**DATE**	04/18/17	
CHKD. BY	LES	**DATE**	04/19/17	**JOB NO.** 17P21017.00
SUBJECT	Woodlake Dam SubWatershed - Herds, Future Conditions			

The purpose of this analysis is to develop runoff curve numbers for the land cover information classifications
that are mapped in the drainage area of the Woodlake Dam SubWatershed - Herds in Harnet, Moore, and Lee Counties, North Carolina.

Hydrologic Soil Group	Cover Description (Cover type, treatment, and hydrologic description; % impervious; connected or unconnected, etc)	CN	Area (Acres)	Product (CN*Area)
A	Bare Soil	77	0.39	29.7
A	Commercial	89	1.64	145.8
A	Open Space	68	1.78	121.4
A	Pasture	39	0.02	0.9
A	Residential 1 Acre	51	742.61	37,873.2
A	Residential 1/4 Acre	61	61.53	3,753.4
A	Residential 1/8 Acre	77	3.39	261.0
A	Row Crops	65	229.28	14,903.5
B	Bare Soil	86	5.44	467.5
B	Commercial	92	4.05	372.9
B	Industrial	88	1.00	88.1
B	Open Space	79	0.87	69.1
B	Pasture	61	0.08	4.9
B	Residential 1 Acre	68	4,372.51	297,330.7
B	Residential 1/4 Acre	75	134.08	10,056.3
B	Residential 1/8 Acre	85	1.49	126.7
B	Row Crops	75	825.65	61,923.7
B	Woods	55	0.02	1.2
C	Commercial	94	5.98	562.3
C	Open Space	86	1.14	97.9
C	Pasture	74	0.16	12.0
C	Residential 1 Acre	79	1,799.54	142,163.3
C	Residential 1/3 Acre	81	0.03	2.6
C	Residential 1/4 Acre	83	10.69	887.1
C	Residential 1/8 Acre	90	2.42	218.0
C	Row Crops	82	131.47	10,780.9
C	Woods	70	0.24	16.5
D	Residential 1 Acre	84	79.00	6,635.8
W	Water	100	145.69	14,569.3
		Totals	**8562**	**603476**
		Total (square miles):	**13.4**	
			Composite CN:	**70**

References:

Land Cover for Harnett, Lee, and Moore Counties obtained from National Land Cover Dataset 2011 Zone 14, Multi-Resolution Land Characteristics (MRLC) Consortium (http://www.epa.gov/mrlc/nlcd.html) in addition to zoning and future zoning data from Harnett, Lee and Moore County GIS Departments
Soils obtained from NRCS Soil Data Mart for Harnett, Lee, and Moore Counties, North Carolina
NRCS TR-55, Second Edition, June 1986
NRCS Part 630 HNEH, Chapter 9, Hydrologic Soil-Cover Complexes, 2004

SCHNABEL ENGINEERING

BY	Guy Nuyda	**DATE**	04/18/17	
CHKD. BY	LES	**DATE**	04/19/17	**JOB NO.** 17P21017.00
SUBJECT	Woodlake Dam SubWatershed - Durhams, Future Conditions			

The purpose of this analysis is to develop runoff curve numbers for the land cover information classifications
that are mapped in the drainage area of the Woodlake Dam SubWatershed - Durham in Harnet, Moore, and Lee Counties, North Carolina.

Hydrologic Soil Group	Cover Description (Cover type, treatment, and hydrologic description; % impervious; connected or unconnected, etc)	CN	Area (Acres)	Product (CN*Area)
A	Brush	30	1.47	44.1
A	Commercial	89	7.50	667.1
A	Open Space	68	46.81	3,183.3
A	Pasture	39	5.25	204.6
A	Residential 1 Acre	51	457.08	23,311.2
A	Residential 1/4 Acre	61	54.77	3,340.8
A	Residential 1/8 Acre	77	13.58	1,045.6
A	Row Crops	65	97.85	6,360.4
A	Wood/Grass Combo	32	0.28	8.9
A	Woods	30	30.54	916.3
B	Brush	48	82.70	3,969.4
B	Commercial	92	15.87	1,459.8
B	Industrial	88	1.62	142.2
B	Open Space	79	259.58	20,507.0
B	Pasture	61	17.31	1,055.8
B	Residential 1 Acre	68	5,606.62	381,250.2
B	Residential 1/4 Acre	75	174.10	13,057.5
B	Residential 1/8 Acre	85	25.50	2,167.8
B	Row Crops	75	1,176.48	88,235.8
B	Wood/Grass Combo	58	20.09	1,165.0
B	Woods	55	253.93	13,966.0
C	Brush	65	62.81	4,083.0
C	Commercial	94	5.02	471.7
C	Open Space	86	325.63	28,004.1
C	Pasture	74	18.81	1,392.2
C	Residential 1 Acre	79	2,546.24	201,153.2
C	Residential 1/4 Acre	83	91.41	7,587.0
C	Residential 1/8 Acre	90	14.24	1,281.2
C	Row Crops	82	192.39	15,776.0
C	Wood/Grass Combo	72	62.54	4,503.1
C	Woods	70	369.04	25,832.8
D	Brush	73	7.69	561.5
D	Commercial	95	2.00	190.4
D	Open Space	89	12.71	1,130.9
D	Residential 1 Acre	84	237.91	19,984.5
D	Residential 1/4 Acre	87	0.98	85.3
D	Residential 1/8 Acre	92	3.44	316.6
D	Row Crops	86	3.71	319.5
D	Wood/Grass Combo	79	11.97	945.5
D	Woods	77	18.90	1,455.4
W	Water	100	164.49	16,449.5
		Totals	**12501**	**897582**
		Total (square miles):	**19.5**	
			Composite CN:	**72**

References:

Land Cover for Harnett, Lee, and Moore Counties obtained from National Land Cover Dataset 2011 Zone 14, Multi-Resolution Land Characteristics (MRLC) Consortium (http://www.epa.gov/mrlc/nlcd.html) in addition to zoning and future zoning data from Harnett, Lee and Moore County GIS Departments

Soils obtained from NRCS Soil Data Mart for Harnett, Lee, and Moore Counties, North Carolina

NRCS TR-55, Second Edition, June 1986

NRCS Part 630 HNEH, Chapter 9, Hydrologic Soil-Cover Complexes, 2004

SCHNABEL ENGINEERING

BY	Guy Nuyda	**DATE**	04/18/17	
CHKD. BY	LES	**DATE**	04/29/17	**JOB NO.** 17P21017.00
SUBJECT	Woodlake Dam SubWatershed - Crane, Future Conditions			

The purpose of this analysis is to develop runoff curve numbers for the land cover information classifications
that are mapped in the drainage area of the Woodlake Dam SubWatershed - Crane in Harnet, Moore, and Lee Counties, North Carolina.

Hydrologic Soil Group	Cover Description (Cover type, treatment, and hydrologic description; % impervious; connected or unconnected, etc)	CN	Area (Acres)	Product (CN*Area)
A	Brush	30	9.50	285.1
A	Commercial	89	13.65	1,214.4
A	Industrial	81	1.38	111.6
A	Open Space	68	181.07	12,312.6
A	Pasture	39	35.52	1,385.4
A	Residential 1 Acre	51	1,036.15	52,843.4
A	Residential 1/2 Acre	54	67.88	3,665.3
A	Residential 1/3 Acre	57	229.98	13,109.0
A	Residential 1/4 Acre	61	90.92	5,546.4
A	Residential 1/8 Acre	77	5.61	432.2
A	Row Crops	65	432.60	28,119.2
A	Wood/Grass Combo	32	7.92	253.3
A	Woods	30	90.97	2,729.0
B	Bare Soil	86	46.40	3,990.5
B	Brush	48	183.77	8,821.2
B	Commercial	92	36.50	3,358.1
B	Industrial	88	51.91	4,567.9
B	Open Space	79	1,147.70	90,668.4
B	Pasture	61	248.58	15,163.3
B	Residential 1 Acre	68	4,450.52	302,635.3
B	Residential 1/2 Acre	70	43.23	3,026.3
B	Residential 1/3 Acre	72	240.92	17,346.5
B	Residential 1/4 Acre	75	488.94	36,670.6
B	Residential 1/8 Acre	85	42.15	3,583.0
B	Row Crops	75	1,700.78	127,558.5
B	Wood/Grass Combo	58	160.07	9,283.8
B	Woods	55	1,288.95	70,892.1
C	Bare Soil	91	2.21	201.3
C	Brush	65	38.67	2,513.7
C	Commercial	94	19.16	1,800.8
C	Industrial	91	11.21	1,020.4
C	Open Space	86	285.23	24,529.4
C	Pasture	74	31.20	2,308.5
C	Residential 1 Acre	79	1,871.53	147,851.2
C	Residential 1/2 Acre	80	59.84	4,787.5
C	Residential 1/3 Acre	81	188.55	15,272.4
C	Residential 1/4 Acre	83	83.15	6,901.5
C	Residential 1/8 Acre	90	7.65	688.8
C	Row Crops	82	235.34	19,298.3
C	Wood/Grass Combo	72	69.35	4,993.5
C	Woods	70	332.40	23,267.8
D	Bare Soil	94	0.57	53.6
D	Brush	73	9.90	722.9
D	Commercial	95	1.08	103.0
D	Open Space	89	71.95	6,403.9
D	Pasture	80	6.52	521.2
D	Residential 1 Acre	84	1,032.84	86,758.3
D	Residential 1/2 Acre	85	47.67	4,051.5
D	Residential 1/3 Acre	86	103.92	8,936.9
D	Residential 1/4 Acre	87	19.53	1,699.0
D	Residential 1/8 Acre	92	5.61	515.9
D	Row Crops	86	40.09	3,447.9
D	Wood/Grass Combo	79	220.76	17,440.4
D	Woods	77	139.77	10,762.6
W	Water	100	251.20	25,120.0
		Totals	**17520**	**1241545**
	Total (square miles):		**27.4**	
		Composite CN:		**71**

References:

Land Cover for Harnett, Lee, and Moore Counties obtained from National Land Cover Dataset 2011 Zone 14, Multi-Resolution Land Characteristics (MRLC) Consortium (http://www.epa.gov/mrlc/nlcd.html) in addition to zoning and future zoning data from Harnett, Lee and Moore County GIS Departments

Soils obtained from NRCS Soil Data Mart for Harnett, Lee, and Moore Counties, North Carolina

NRCS TR-55, Second Edition, June 1986

NRCS Part 630 HNEH, Chapter 9, Hydrologic Soil-Cover Complexes, 2004

SCHNABEL ENGINEERING

BY	Guy Nuyda	**DATE**	04/18/17	
CHKD. BY	LES	**DATE**	04/19/17	**JOB NO.** 17C21008.00
SUBJECT	Woodlake Dam SubWatershed - Beaver, Future Conditions			

The purpose of this analysis is to develop runoff curve numbers for the land cover information classifications
that are mapped in the drainage area of the Woodlake Dam SubWatershed - Beaver in Harnet, Moore, and Lee Counties, North Carolina.

Hydrologic Soil Group	Cover Description (Cover type, treatment, and hydrologic description; % impervious; connected or unconnected, etc)	CN	Area (Acres)	Product (CN*Area)
A	Brush	30	2.53	75.8
A	Commercial	89	0.76	67.4
A	Industrial	81	8.00	647.8
A	Open Space	68	34.63	2,354.9
A	Pasture	39	1.33	51.7
A	Residential 1 Acre	51	1,125.56	57,403.4
A	Residential 1/3 Acre	57	71.73	4,088.9
A	Residential 1/4 Acre	61	56.56	3,450.3
A	Residential 1/8 Acre	77	3.67	282.4
A	Row Crops	65	1,030.71	66,995.9
A	Wood/Grass Combo	32	0.09	2.8
A	Woods	30	21.70	651.0
B	Brush	48	12.20	585.7
B	Industrial	88	15.58	1,371.1
B	Open Space	79	82.40	6,509.8
B	Pasture	61	22.33	1,362.1
B	Residential 1 Acre	68	4,315.83	293,476.4
B	Residential 1/3 Acre	72	64.38	4,635.2
B	Residential 1/4 Acre	75	88.08	6,605.7
B	Residential 1/8 Acre	85	0.92	77.8
B	Row Crops	75	1,245.07	93,380.5
B	Wood/Grass Combo	58	28.42	1,648.3
B	Woods	55	131.81	7,249.4
C	Brush	65	6.52	423.7
C	Commercial	94	0.22	20.9
C	Open Space	86	59.76	5,139.3
C	Pasture	74	17.99	1,331.0
C	Residential 1 Acre	79	1,764.20	139,371.5
C	Residential 1/3 Acre	81	132.38	10,722.8
C	Residential 1/4 Acre	83	24.96	2,071.8
C	Residential 1/8 Acre	90	0.32	28.7
C	Row Crops	82	566.28	46,435.1
C	Wood/Grass Combo	72	48.43	3,486.9
C	Woods	70	106.33	7,443.1
D	Brush	73	1.10	80.2
D	Open Space	89	16.26	1,447.5
D	Pasture	80	1.03	82.4
D	Residential 1 Acre	84	1,073.58	90,181.0
D	Residential 1/3 Acre	86	57.87	4,976.4
D	Residential 1/4 Acre	87	3.75	325.9
D	Row Crops	86	213.39	18,351.2
D	Wood/Grass Combo	79	96.15	7,596.0
D	Woods	77	41.22	3,173.6
W	Water	100	98.03	9,802.6
		Totals	**12694**	**905466**
	Total (square miles):		**19.8**	
			Composite CN:	**71**

References:

Land Cover for Harnett, Lee, and Moore Counties obtained from National Land Cover Dataset 2011 Zone 14, Multi-Resolution Land Characteristics (MRLC) Consortium (http://www.epa.gov/mrlc/nlcd.html) in addition to zoning and future zoning data from Harnett, Lee and Moore County GIS Departments

Soils obtained from NRCS Soil Data Mart for Harnett, Lee, and Moore Counties, North Carolina

NRCS TR-55, Second Edition, June 1986

NRCS Part 630 HNEH, Chapter 9, Hydrologic Soil-Cover Complexes, 2004

SCHNABEL ENGINEERING

BY	Guy Nuyda	**DATE**	04/18/17	
CHKD. BY	LES	**DATE**	04/19/17	**JOB NO.** 17P21017.00
SUBJECT	Woodlake Dam SubWatershed - Woodlake, Future Conditions			

The purpose of this analysis is to develop runoff curve numbers for the land cover information classifications
that are mapped in the drainage area of the Woodlake Dam SubWatershed - Beaver in Harnet, Moore, and Lee Counties, North Carolina.

Hydrologic Soil Group	Cover Description (Cover type, treatment, and hydrologic description; % impervious; connected or unconnected, etc)	CN	Area (Acres)	Product (CN*Area)
A	Bare Soil	77	7.05	543.1
A	Brush	30	0.002	0.1
A	Open Space	68	1.76	119.9
A	Residential 1 Acre	51	159.53	8,136.1
A	Residential 1/4 Acre	61	31.65	1,930.6
A	Residential 1/8 Acre	77	2.29	176.1
A	Row Crops	65	1,049.04	68,187.3
A	Wood/Grass Combo	32	2.56	81.8
A	Woods	30	3.36	100.7
B	Brush	48	0.01	0.5
B	Commercial	92	1.41	129.4
B	Open Space	79	11.26	889.8
B	Residential 1 Acre	68	443.45	30,154.6
B	Residential 1/4 Acre	75	42.83	3,212.0
B	Residential 1/8 Acre	85	2.00	170.4
B	Row Crops	75	2,333.13	174,984.6
B	Wood/Grass Combo	58	19.75	1,145.7
B	Woods	55	54.63	3,004.6
C	Bare Soil	91	0.76	69.2
C	Commercial	94	10.25	963.1
C	Open Space	86	12.92	1,111.4
C	Pasture	74	0.00	0.1
C	Residential 1 Acre	79	762.12	60,207.5
C	Residential 1/4 Acre	83	136.02	11,289.7
C	Residential 1/8 Acre	90	15.70	1,412.8
C	Row Crops	82	2,182.82	178,991.3
C	Wood/Grass Combo	72	62.71	4,515.4
C	Woods	70	41.25	2,887.5
D	Bare Soil	94	0.16	15.2
D	Commercial	95	0.16	14.8
D	Open Space	89	19.46	1,731.7
D	Residential 1 Acre	84	312.81	26,276.0
D	Residential 1/4 Acre	87	27.64	2,405.1
D	Residential 1/8 Acre	92	0.54	49.9
D	Row Crops	86	469.68	40,392.4
D	Wood/Grass Combo	79	140.07	11,065.2
D	Woods	77	114.20	8,793.6
W	Water	100	1,170.85	117,085.1
		Totals	**9646**	**762244**
		Total (square miles):	**15.1**	
			Composite CN:	**79**

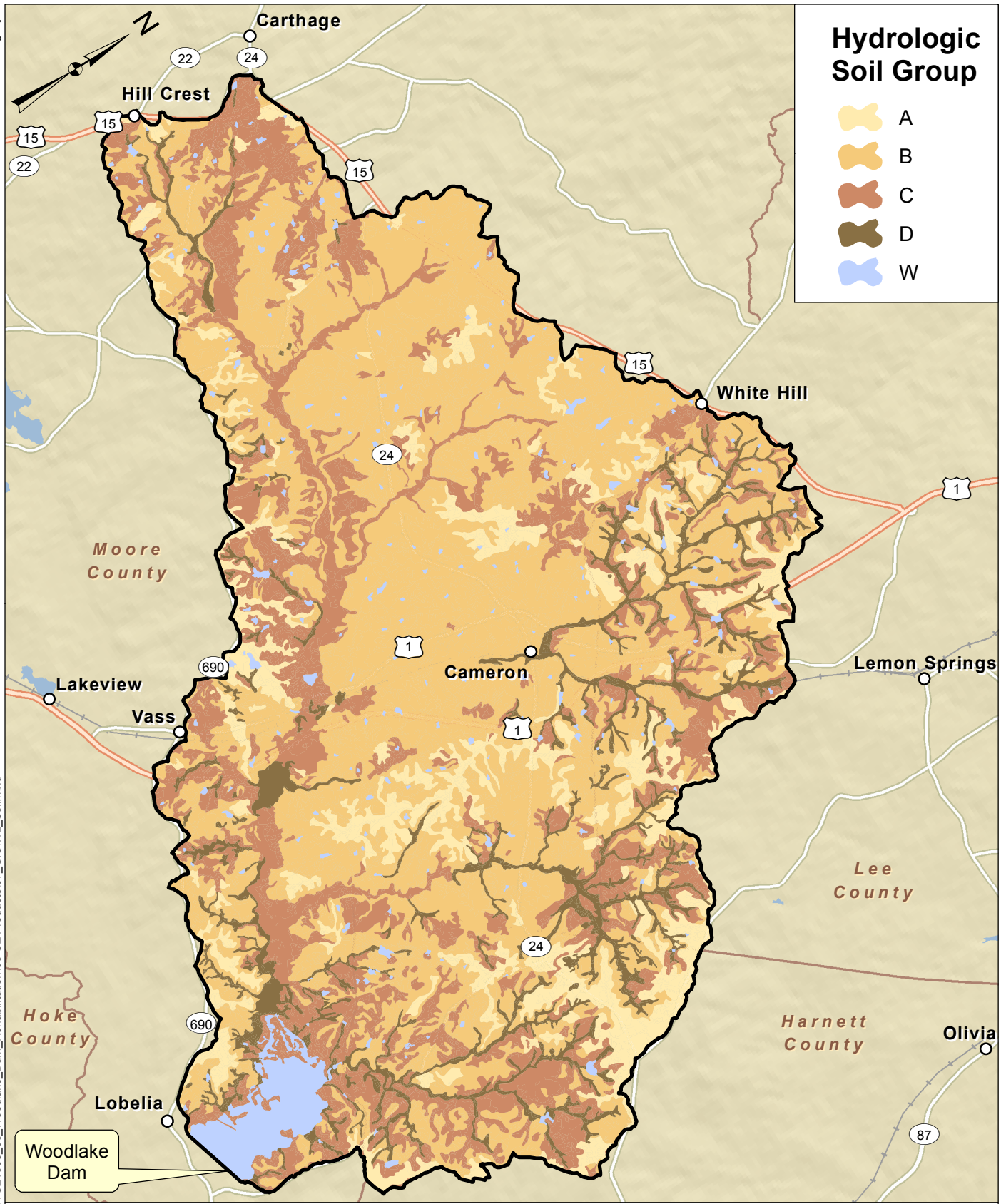
References:

Land Cover for Harnett, Lee, and Moore Counties obtained from National Land Cover Dataset 2011 Zone 14, Multi-Resolution Land Characteristics (MRLC) Consortium (http://www.epa.gov/mrlc/nlcd.html) in addition to zoning and future zoning data from Harnett, Lee and Moore County GIS Departments

Soils obtained from NRCS Soil Data Mart for Harnett, Lee, and Moore Counties, North Carolina

NRCS TR-55, Second Edition, June 1986

NRCS Part 630 HNEH, Chapter 9, Hydrologic Soil-Cover Complexes, 2004



Source: USGS/Soils DataMart, ESRI MediaKit(2010), Terrain/Watershed Boundary derived from NCFMP LiDAR

Projection: NAD 1983 StatePlane North Carolina FIPS 3200 Feet

10,000 5,000 0 10,000 Feet

Scale: 1:120,000

Schnabel ENGINEERING

WOODLAKE DAM BREACH
WOODLAKE CC CORP
VASS, NORTH CAROLINA
PROJECT NO. 17C21008.00

HYDROLOGIC SOIL GROUP MAP

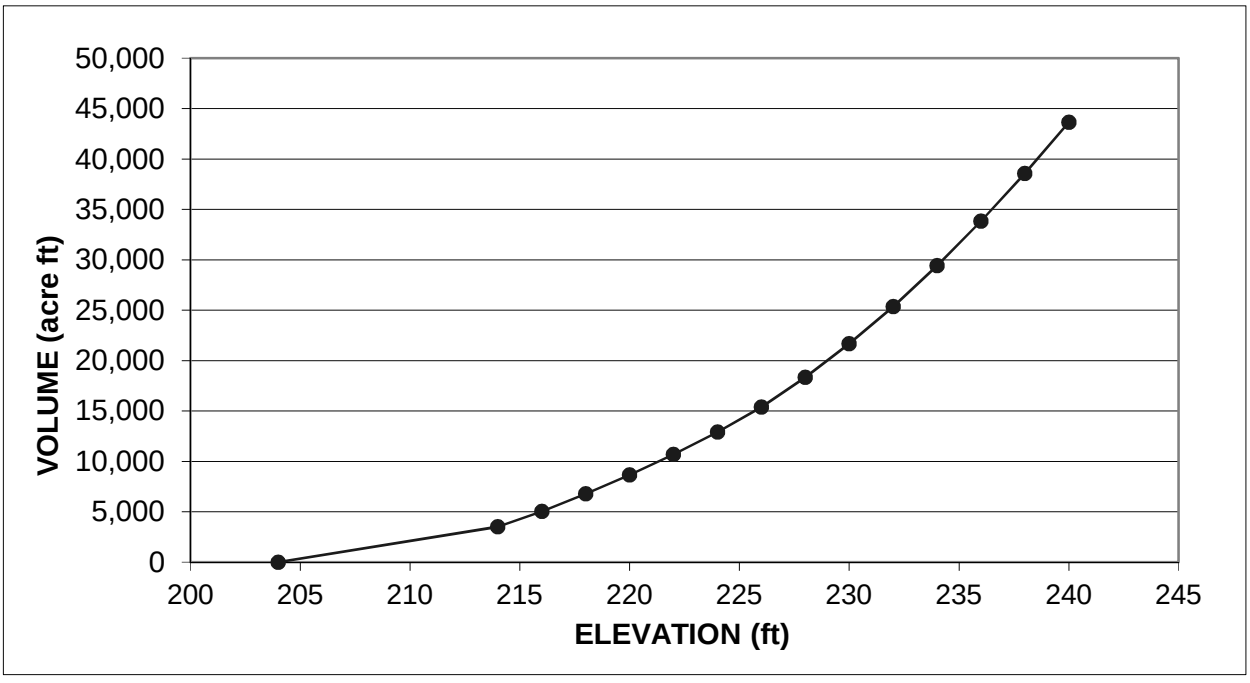
4/25/2017 G:\2017\Greensboro\17C21008_00_Woodlake_Dam_Rehabilitation\03-SE Products\07_GIS\WL_Soil.mxd gnuyda

Project: Woodlake Dam - 17C21008
Subject: Stage Storage
Date 4/10/2017
Filename: G:\2017\Greensboro\17C21008_00_Woodlake_Dam_Rehabilitation\03-SE

By DS/BMC Checked LES

Data Source: Elevation 220 and above are from NCFMP LiDAR Topography
Elevations below 220 are from historic As-Built data
Elevation 214 is estimated based on the data trend

Elevation	Surface Area		Volume	
	Sq. Ft.	Acres	Acre Ft.	Million Gallons
204	-	0	0	0
214	-	700	3,500	1,140
216	-	830	5,030	1,639
218	-	922	6,782	2,210
220	-	952	8,656	2,820
222	-	1077	10,686	3,482
224	-	1143	12,905	4,205
226	-	1351	15,398	5,017
228	-	1577	18,326	5,971
230	-	1754	21,657	7,057
232	-	1939	25,351	8,260
234	-	2124	29,414	9,584
236	-	2280	33,818	11,019
238	-	2464	38,561	12,564
240	-	2618	43,643	14,220



APPENDIX C

HEC-HMS AND TAILWATER CALCULATIONS

Schnabel ENGINEERING

CALCULATION COVER SHEET

Project	Project Number
Woodlake Dam	17C21008

Title

HEC-HMS and HEC-RAS model input and output

Computer Programs Used	Version/Release No.
HEC-HMS	4.2
HEC-RAS	4.1

Purpose and Objective

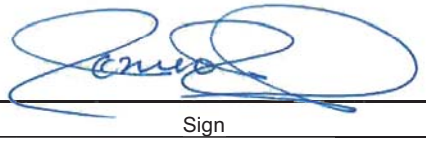
The upstream watershed and reservoir were analyzed to calculate the storage, elevation, and outflow of the reservoir with the proposed breach section in place during the 100-year, 500-year, and 3/4PMP storm events. The breach section is 175-ft wide with 3H:1V side slopes.

The downstream section of Crane Creek was analyzed in order to consider the impacts of tailwater on the site.

Summary of Conclusions

The maximum water surface elevation during the 3/4 PMP assuming future watershed conditions and the proposed breach is installed is elevation 221.9 ft. During this event, the downstream tailwater elevation is 219.7 ft. The 3/4PMP has a rainfall of 21.87 inches in 24 hours.

Originator	Print	Sign	Date
Laura Shearin-Feimster			Apr 30, 2017

Checked	Print	Sign	Date
Maridee Romero-Graves			May 1, 2017

HEC-HMS: Watershed Inputs
Basin Model "Multibasin - Existing"
Description:

Subbasin	Area (mi^2)	Curve Number	Lag Time Method	Standard Lag (hr)	Peaking Coefficie
Durhams Creek	19.53	67	Snyder	6.766	0.4
Herds Creek	13.38	66	Snyder	7.392	0.4
Little Crane Creek	27.38	68	Snyder	8.531	0.4
Beaver Creek	19.83	65	Snyder	7.854	0.4
Woodlake	15.07	73	Snyder	4.716	0.4

Reach	Method	Length (ft)	Slope (ft/ft)	Shape	Manning's n	Width (ft)	Side Slope	Inve
Upper Crane Creek	Muskingum Cunge	14712	0.002		0.055		3	
Middle Crane Creek	Muskingum Cunge	11292	0.001		0.055		3	
Lower Crane Creek	Muskingum Cunge	19417	0.001		0.055		3	

Current as of 19 April 2017 at 19:33:30

HEC-HMS: Reservoir Model Inputs
Basin Model "Multibasin - Existing"
Description:

Reservoir: Woodlake Dam
Description:
Initial Elevation (ft): 209
Tailwater Condition: Outflow - Tailwater

Top of Dam Type	Overflow Coefficient
Non-Level Dam	2.4

Current as of 19 April 2017 at 19:33:30

HEC-HMS: Watershed Inputs
Basin Model "Multibasin - Future"
Description:

Subbasin	Area (mi^2)	Curve Number	Lag Time Method	Standard Lag (hr)	Peaking Coefficient
Durhams Creek	19.53	72	Snyder	6.766	0.4
Herds Creek	13.38	70	Snyder	7.392	0.4
Little Crane Creek	27.38	71	Snyder	8.531	0.4
Beaver Creek	19.83	71	Snyder	7.854	0.4
Woodlake	15.07	79	Snyder	4.716	0.4

Reach	Method	Length (ft)	Slope (ft/ft)	Shape	Manning's n	Width (ft)	Side Slope	Invert E
Upper Crane Creek	Muskingum Cunge	14712	0.002		0.055		3	
Middle Crane Creek	Muskingum Cunge	11292	0.001		0.055		3	
Lower Crane Creek	Muskingum Cunge	19417	0.001		0.055		3	

Current as of 19 April 2017 at 20:41:12

HEC-HMS: Reservoir Model Inputs
Basin Model "Multibasin - Future"
Description:

Reservoir: Woodlake Dam
Description:
Initial Elevation (ft): 209
Tailwater Condition: Outflow - Tailwater

Top of Dam Type	Overflow Coefficient
Non-Level Dam	2.4

Current as of 19 April 2017 at 20:41:12

HEC-HMS: Reservoir Model Inputs
Basin Model "Upstream Cofferdam"

Reservoir: Woodlake Dam
Initial Elevation (ft): 206.3
Tailwater Condition: Outflow - Tailwater

Top of Dam Type	Overflow Coefficient	Top Elevation (ft)	Crest Length (ft)
Level Dam	2.6	229	2000

Outlet Parameters:

Outlet Type	No. of Barrels	Culvert Shape	Culvert Length	Diameter (ft
Culvert	1	Circular	165	6

Outlet Parameters Continued:

Inlet Elevation (ft)	Entrance Loss Coefficient	Outlet Elevation (ft)	Exit Loss Coefficient	Manni
206.3	1	204.6	1	0.018

Current as of 27 April 2017 at 12:32:10

Project: Woodlake Dam Simulation Run: 0.75 PMP - Existing

Reservoir: Woodlake Dam

Start of Run:	01Jan2017, 00:00	Basin Model:	Multibasin - Existing
End of Run:	07Jan2017, 00:00	Meteorologic Model:	Woodlake PMP-24hr
Compute Time:	27Apr2017, 20:31:21	Control Specifications:	6 days, 5 min incr

Volume Units: IN

Computed Results

Peak Inflow:	49114.0 (CFS)	Date/Time of Peak Inflow:	01Jan2017, 23:30
Peak Discharge:	46650.7 (CFS)	Date/Time of Peak Discharge:	02Jan2017, 01:35
Inflow Volume:	17.01 (IN)	Peak Storage:	9119.9 (AC-FT)
Discharge Volume:	17.01 (IN)	Peak Elevation:	221.61 (FT)

Project: Woodlake Dam Simulation Run: 0.75 PMP - Future

Reservoir: Woodlake Dam

Start of Run:	01Jan2017, 00:00	Basin Model:	Multibasin - Future
End of Run:	07Jan2017, 00:00	Meteorologic Model:	Woodlake PMP-24hr
Compute Time:	27Apr2017, 20:31:28	Control Specifications:	6 days, 5 min incr

Volume Units: IN

Computed Results

Peak Inflow:	51339.1 (CFS)	Date/Time of Peak Inflow:	01Jan2017, 23:25
Peak Discharge:	48884.9 (CFS)	Date/Time of Peak Discharge:	02Jan2017, 01:25
Inflow Volume:	17.85 (IN)	Peak Storage:	9408.1 (AC-FT)
Discharge Volume:	17.85 (IN)	Peak Elevation:	221.89 (FT)

Project: Woodlake Dam Simulation Run: 500-year - Existing

Reservoir: Woodlake Dam

Start of Run:	01Jan2017, 00:00	Basin Model:	Multibasin - Existing
End of Run:	07Jan2017, 00:00	Meteorologic Model:	500-year-24hr
Compute Time:	27Apr2017, 20:27:09	Control Specifications:	6 days, 5 min incr

Volume Units: IN

Computed Results

Peak Inflow:	15291.3 (CFS)	Date/Time of Peak Inflow:	01Jan2017, 21:35
Peak Discharge:	14175.2 (CFS)	Date/Time of Peak Discharge:	02Jan2017, 00:40
Inflow Volume:	5.56 (IN)	Peak Storage:	3852.4 (AC-FT)
Discharge Volume:	5.56 (IN)	Peak Elevation:	215.99 (FT)

Project: Woodlake Dam Simulation Run: 500-year- Future

Reservoir: Woodlake Dam

Start of Run:	01Jan2017, 00:00	Basin Model:	Multibasin - Future
End of Run:	07Jan2017, 00:00	Meteorologic Model:	500-year-24hr
Compute Time:	27Apr2017, 20:30:33	Control Specifications:	6 days, 5 min incr

Volume Units: IN

Computed Results

Peak Inflow:	16982.0 (CFS)	Date/Time of Peak Inflow:	01Jan2017, 21:20
Peak Discharge:	15682.2 (CFS)	Date/Time of Peak Discharge:	02Jan2017, 00:30
Inflow Volume:	6.16 (IN)	Peak Storage:	4174.9 (AC-FT)
Discharge Volume:	6.15 (IN)	Peak Elevation:	216.36 (FT)

Project: Woodlake Dam Simulation Run: 100-year - Existing

Reservoir: Woodlake Dam

Start of Run:	01Jan2017, 00:00	Basin Model:	Multibasin - Existing
End of Run:	07Jan2017, 00:00	Meteorologic Model:	100-year-24hr
Compute Time:	27Apr2017, 20:18:55	Control Specifications:	6 days, 5 min incr

Volume Units: IN

Computed Results

Peak Inflow:	10535.9 (CFS)	Date/Time of Peak Inflow:	01Jan2017, 21:50
Peak Discharge:	9794.3 (CFS)	Date/Time of Peak Discharge:	02Jan2017, 01:05
Inflow Volume:	3.89 (IN)	Peak Storage:	2921.2 (AC-FT)
Discharge Volume:	3.89 (IN)	Peak Elevation:	214.77 (FT)

Project: Woodlake Dam Simulation Run: 100-year - Future

Reservoir: Woodlake Dam

Start of Run:	01Jan2017, 00:00	Basin Model:	Multibasin - Future
End of Run:	07Jan2017, 00:00	Meteorologic Model:	100-year-24hr
Compute Time:	27Apr2017, 20:19:02	Control Specifications:	6 days, 5 min incr

Volume Units: IN

Computed Results

Peak Inflow:	12002.1 (CFS)	Date/Time of Peak Inflow:	01Jan2017, 21:35
Peak Discharge:	11101.8 (CFS)	Date/Time of Peak Discharge:	02Jan2017, 00:50
Inflow Volume:	4.41 (IN)	Peak Storage:	3219.5 (AC-FT)
Discharge Volume:	4.40 (IN)	Peak Elevation:	215.16 (FT)

Project: Woodlake Dam Simulation Run: 1-year - Existing

Reservoir: Woodlake Dam

Start of Run:	01Jan2017, 00:00	Basin Model:	Multibasin - Existing
End of Run:	07Jan2017, 00:00	Meteorologic Model:	1-year - 24 hr
Compute Time:	27Apr2017, 09:15:03	Control Specifications:	6 days, 5 min incr

Volume Units: IN

Computed Results

Peak Inflow:	1415.7 (CFS)	Date/Time of Peak Inflow:	02Jan2017, 00:30
Peak Discharge:	1316.8 (CFS)	Date/Time of Peak Discharge:	02Jan2017, 04:00
Inflow Volume:	0.56 (IN)	Peak Storage:	1604.0 (AC-FT)
Discharge Volume:	0.56 (IN)	Peak Elevation:	210.87 (FT)

Project: Woodlake Dam Simulation Run: 1-year - Future

Reservoir: Woodlake Dam

Start of Run:	01Jan2017, 00:00	Basin Model:	Multibasin - Future
End of Run:	07Jan2017, 00:00	Meteorologic Model:	1-year - 24 hr
Compute Time:	27Apr2017, 20:18:48	Control Specifications:	6 days, 5 min incr

Volume Units: IN

Computed Results

Peak Inflow:	1956.4 (CFS)	Date/Time of Peak Inflow:	01Jan2017, 23:30
Peak Discharge:	1845.5 (CFS)	Date/Time of Peak Discharge:	02Jan2017, 02:45
Inflow Volume:	0.76 (IN)	Peak Storage:	1700.3 (AC-FT)
Discharge Volume:	0.76 (IN)	Peak Elevation:	211.29 (FT)

Project: Woodlake Dam Simulation Run: UpstCoffe

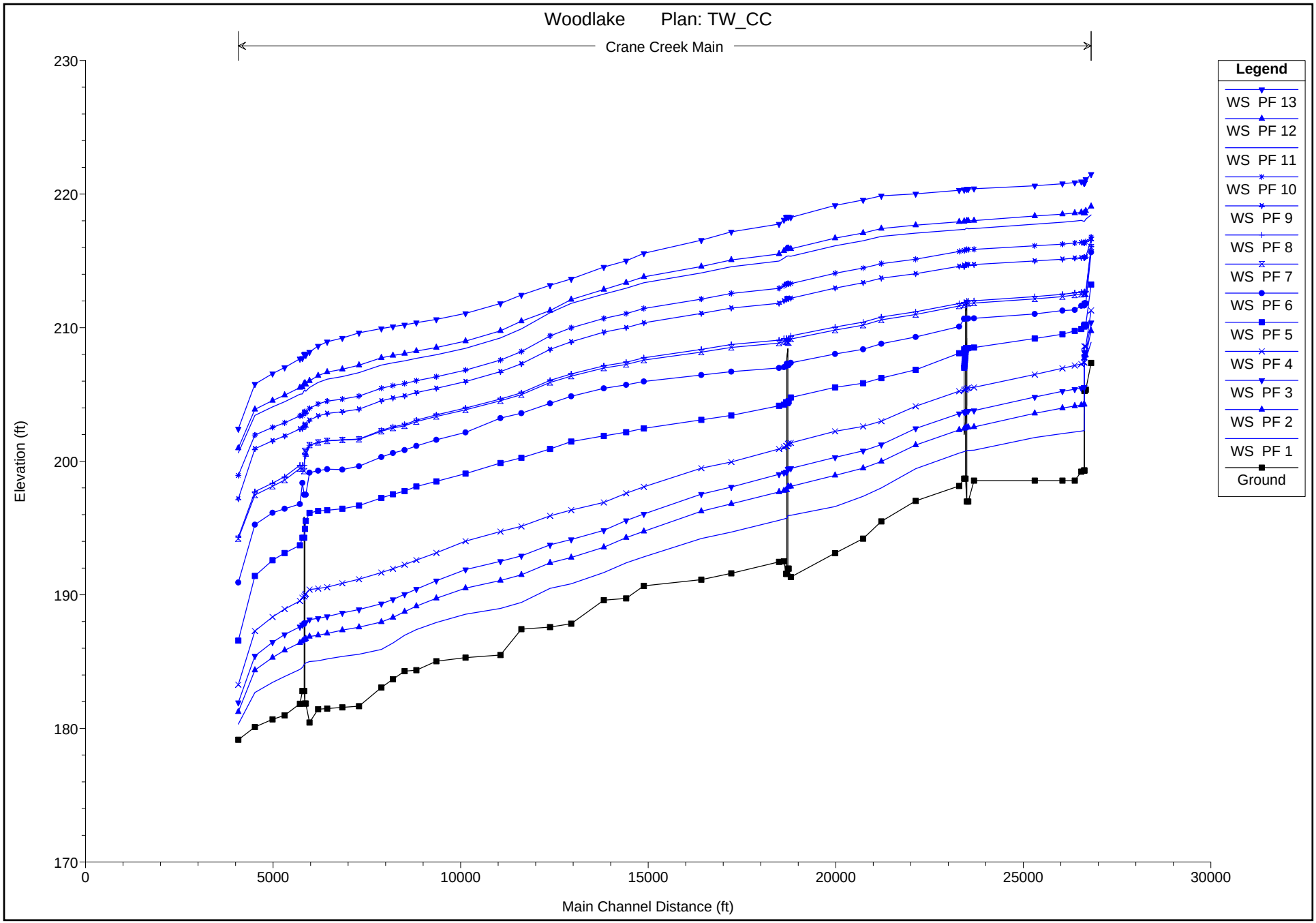
Reservoir: Woodlake Dam

Start of Run:	01Jan2017, 00:00	Basin Model:	Upstream Cofferdam
End of Run:	07Jan2017, 00:00	Meteorologic Model:	Cofferdam
Compute Time:	27Apr2017, 20:15:46	Control Specifications:	6 days, 5 min incr

Volume Units: IN

Computed Results

Peak Inflow:	1141.9 (CFS)	Date/Time of Peak Inflow:	02Jan2017, 01:10
Peak Discharge:	168.0 (CFS)	Date/Time of Peak Discharge:	03Jan2017, 07:50
Inflow Volume:	0.45 (IN)	Peak Storage:	2043.7 (AC-FT)
Discharge Volume:	0.22 (IN)	Peak Elevation:	212.76 (FT)


Woodlake Plan: TW_CC
Crane Creek Main
Legend
WS PF 13
WS PF 12
WS PF 11
WS PF 10
WS PF 9
WS PF 8
WS PF 7
WS PF 6
WS PF 5
WS PF 4
WS PF 3
WS PF 2
WS PF 1
Ground
Elevation (ft)
230
220
210
200
190
180
170
0
5000
10000
15000
20000
25000
30000
Main Channel Distance (ft)

HEC-RAS Plan: TW_CC River: Crane Creek Reach: Main

Reach	River Sta	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
		(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
Main	26808.1	100.00	207.36	208.90	208.90	209.28	0.019499	4.96	20.15	26.11	1.00
Main	26808.1	300.00	207.36	209.75	209.75	210.40	0.016521	6.45	46.53	35.86	1.00
Main	26808.1	500.00	207.36	210.37	210.37	211.09	0.016150	6.78	73.69	51.81	1.00
Main	26808.1	1000.00	207.36	211.29	211.29	212.18	0.015120	7.55	132.42	75.55	1.01
Main	26808.1	3000.00	207.36	213.23	213.23	214.54	0.013148	9.18	326.75	125.35	1.00
Main	26808.1	6000.00	207.36	215.65	215.65	216.04	0.019594	5.02	1194.37	1535.73	1.00
Main	26808.1	10000.00	207.36	216.03	216.03	216.45	0.019158	5.20	1923.24	2309.65	1.00
Main	26808.1	10500.00	207.36	216.06	216.06	216.49	0.018964	5.22	2012.98	2387.66	1.00
Main	26808.1	20000.00	207.36	216.58	216.58	217.08	0.017651	5.71	3499.89	3431.05	1.00
Main	26808.1	25000.00	207.36	216.77	216.77	217.32	0.017282	5.94	4207.37	3828.94	1.00
Main	26808.1	36000.00	207.36	218.44	217.09	218.61	0.001574	3.26	11043.52	4105.09	0.35
Main	26808.1	40000.00	207.36	219.08	217.18	219.21	0.000960	2.93	13650.96	4109.57	0.28
Main	26808.1	60000.00	207.36	221.49	217.63	221.59	0.000351	2.55	23577.55	4126.59	0.19
Main	26664.6	100.00	205.35	207.65	205.51	207.65	0.000003	0.16	628.63	273.37	0.02
Main	26664.6	300.00	205.35	207.93	205.69	207.94	0.000021	0.43	705.88	273.39	0.05
Main	26664.6	500.00	205.35	208.16	205.82	208.16	0.000045	0.65	766.96	274.33	0.07
Main	26664.6	1000.00	205.35	208.60	206.09	208.62	0.000110	1.12	890.69	277.01	0.11
Main	26664.6	3000.00	205.35	210.22	206.91	210.30	0.000260	2.25	1344.19	282.90	0.18
Main	26664.6	6000.00	205.35	211.82	207.82	212.00	0.000404	3.38	1798.40	282.90	0.23
Main	26664.6	10000.00	205.35	212.53	208.82	212.90	0.000762	4.98	3037.53	2459.44	0.33
Main	26664.6	10500.00	205.35	212.68	208.93	213.07	0.000763	5.05	3433.46	2603.54	0.33
Main	26664.6	20000.00	205.35	215.31	210.84	215.64	0.000575	5.38	11494.31	3380.03	0.30
Main	26664.6	25000.00	205.35	216.44	211.73	216.73	0.000502	5.40	15511.49	3485.75	0.29
Main	26664.6	36000.00	205.35	218.12	214.36	218.44	0.000502	5.93	21498.26	3634.38	0.29
Main	26664.6	40000.00	205.35	218.74	214.71	219.06	0.000488	6.04	23761.74	3689.95	0.29
Main	26664.6	60000.00	205.35	221.10	215.99	221.45	0.000489	6.73	32641.64	3844.74	0.30
Main	26634.2	100.00	205.27	207.65	205.43	207.65	0.000001	0.15	654.12	274.90	0.02
Main	26634.2	300.00	205.27	207.93	205.60	207.94	0.000008	0.41	731.73	274.90	0.04
Main	26634.2	500.00	205.27	208.16	205.74	208.16	0.000018	0.63	792.98	274.90	0.07
Main	26634.2	1000.00	205.27	208.60	206.01	208.62	0.000045	1.09	916.14	274.90	0.11
Main	26634.2	3000.00	205.27	210.21	206.82	210.29	0.000110	2.21	1359.11	274.90	0.17
Main	26634.2	6000.00	205.27	211.82	207.73	211.99	0.000175	3.33	1799.95	274.90	0.23
Main	26634.2	10000.00	205.27	212.52	208.72	212.88	0.000331	4.91	3453.06	3182.79	0.32
Main	26634.2	10500.00	205.27	212.68	208.83	213.05	0.000332	4.98	3957.26	3203.47	0.32
Main	26634.2	20000.00	205.27	215.24	210.75	215.61	0.000279	5.57	12467.57	3356.96	0.31
Main	26634.2	25000.00	205.27	216.34	211.64	216.70	0.000260	5.77	16171.28	3410.77	0.31
Main	26634.2	36000.00	205.27	217.98	214.21	218.40	0.000278	6.54	21925.64	3638.36	0.32
Main	26634.2	40000.00	205.27	218.58	214.55	219.01	0.000275	6.70	24174.00	3747.40	0.32
Main	26634.2	60000.00	205.27	220.86	215.96	221.39	0.000299	7.77	32897.93	3916.78	0.35
Main	26632.6	100.00	205.27	207.65	205.43	207.65	0.000001	0.15	656.11	277.10	0.02
Main	26632.6	300.00	205.27	207.93	205.59	207.94	0.000008	0.41	734.35	277.10	0.04
Main	26632.6	500.00	205.27	208.16	205.74	208.16	0.000018	0.63	796.09	277.10	0.07
Main	26632.6	1000.00	205.27	208.60	206.01	208.62	0.000044	1.09	920.22	277.10	0.11
Main	26632.6	3000.00	205.27	210.21	206.82	210.29	0.000108	2.20	1366.75	277.10	0.17
Main	26632.6	6000.00	205.27	211.82	207.72	211.99	0.000170	3.33	1811.15	277.10	0.23
Main	26632.6	10000.00	205.27	212.52	208.72	212.88	0.000322	4.90	3471.46	3195.20	0.32
Main	26632.6	10500.00	205.27	212.68	208.83	213.05	0.000323	4.97	3977.09	3211.17	0.32
Main	26632.6	20000.00	205.27	215.24	210.74	215.61	0.000273	5.58	12484.15	3355.40	0.31
Main	26632.6	25000.00	205.27	216.34	211.61	216.70	0.000255	5.78	16179.00	3402.79	0.31
Main	26632.6	36000.00	205.27	217.97	214.19	218.40	0.000274	6.56	21919.66	3628.10	0.32
Main	26632.6	40000.00	205.27	218.57	214.53	219.01	0.000272	6.74	24147.07	3746.93	0.33
Main	26632.6	60000.00	205.27	220.85	215.96	221.39	0.000296	7.82	32851.21	3916.20	0.35
Main	26630.1	Inl Struct									
Main	26626.7	100.00	199.31	202.29	199.47	202.29	0.000003	0.12	826.12	277.34	0.01
Main	26626.7	300.00	199.31	204.26	199.64	204.26	0.000004	0.22	1372.79	278.60	0.02
Main	26626.7	500.00	199.31	205.54	199.77	205.54	0.000006	0.29	1730.00	278.60	0.02
Main	26626.7	1000.00	199.31	207.39	200.05	207.39	0.000009	0.45	2246.01	278.60	0.03
Main	26626.7	3000.00	199.31	210.10	200.85	210.11	0.000033	1.00	3000.15	278.60	0.05
Main	26626.7	6000.00	199.31	211.67	201.75	211.72	0.000084	1.75	3439.01	278.60	0.09
Main	26626.7	10000.00	199.31	212.51	202.74	212.62	0.000181	2.68	5138.54	3201.98	0.13
Main	26626.7	10500.00	199.31	212.67	202.86	212.78	0.000188	2.76	5646.69	3244.44	0.13
Main	26626.7	20000.00	199.31	215.24	204.76	215.39	0.000243	3.53	14167.36	3359.13	0.16
Main	26626.7	25000.00	199.31	216.33	205.63	216.49	0.000251	3.75	17864.32	3410.76	0.16
Main	26626.7	36000.00	199.31	217.96	207.36	218.15	0.000297	4.33	23573.57	3614.44	0.18
Main	26626.7	40000.00	199.31	218.56	207.96	218.75	0.000302	4.46	25781.05	3731.30	0.18
Main	26626.7	60000.00	199.31	220.84	210.64	221.07	0.000355	5.21	34491.43	3926.21	0.20
Main	26617.2	100.00	199.30	202.29	199.46	202.29	0.000002	0.12	833.67	278.94	0.01
Main	26617.2	300.00	199.30	204.26	199.63	204.26	0.000004	0.22	1382.69	279.00	0.02
Main	26617.2	500.00	199.30	205.54	199.76	205.54	0.000006	0.29	1740.41	279.00	0.02
Main	26617.2	1000.00	199.30	207.39	200.03	207.39	0.000009	0.44	2257.15	279.00	0.03
Main	26617.2	3000.00	199.30	210.10	200.83	210.11	0.000033	1.00	3012.33	279.00	0.05
Main	26617.2	6000.00	199.30	211.67	201.73	211.72	0.000086	1.74	3451.74	279.00	0.09

HEC-RAS Plan: TW_CC River: Crane Creek Reach: Main (Continued)

Reach	River Sta	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
		(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
Main	26617.2	10000.00	199.30	212.51	202.72	212.62	0.000185	2.67	5184.75	3259.52	0.13
Main	26617.2	10500.00	199.30	212.67	202.83	212.78	0.000193	2.74	5701.53	3298.32	0.13
Main	26617.2	20000.00	199.30	215.24	204.71	215.38	0.000247	3.49	14239.04	3362.87	0.15
Main	26617.2	25000.00	199.30	216.33	205.59	216.48	0.000254	3.70	17939.70	3394.27	0.16
Main	26617.2	36000.00	199.30	217.96	207.32	218.14	0.000299	4.27	23619.23	3585.29	0.17
Main	26617.2	40000.00	199.30	218.56	207.91	218.75	0.000307	4.41	25812.65	3700.14	0.18
Main	26617.2	60000.00	199.30	220.84	210.59	221.06	0.000360	5.15	34522.45	3953.24	0.20
Main	26546.3	100.00	199.22	202.26	200.65	202.29	0.000665	1.27	78.70	42.65	0.16
Main	26546.3	300.00	199.22	204.21	201.44	204.25	0.000554	1.70	178.01	59.05	0.17
Main	26546.3	500.00	199.22	205.47	202.00	205.53	0.000511	2.03	269.21	102.62	0.17
Main	26546.3	1000.00	199.22	207.28	203.06	207.38	0.000565	2.67	570.41	316.81	0.19
Main	26546.3	3000.00	199.22	209.90	205.69	210.09	0.000893	4.22	1798.25	2363.02	0.25
Main	26546.3	6000.00	199.22	211.64	208.40	211.71	0.000486	3.50	6437.14	3144.83	0.19
Main	26546.3	10000.00	199.22	212.49	210.34	212.59	0.000746	4.57	8092.58	3210.60	0.24
Main	26546.3	10500.00	199.22	212.65	210.47	212.75	0.000742	4.60	8410.88	3234.28	0.24
Main	26546.3	20000.00	199.22	215.24	211.50	215.34	0.000700	5.10	13667.25	3347.86	0.24
Main	26546.3	25000.00	199.22	216.39	211.51	216.43	0.000332	3.70	24879.56	3440.90	0.17
Main	26546.3	36000.00	199.22	218.03	212.36	218.08	0.000369	4.17	30666.77	3646.93	0.18
Main	26546.3	40000.00	199.22	218.63	212.55	218.68	0.000382	4.34	32888.99	3717.30	0.18
Main	26546.3	60000.00	199.22	220.93	212.99	220.99	0.000419	4.93	41600.70	3887.39	0.19
Main	26371.1	100.00	198.55	202.19	200.03	202.20	0.000333	0.94	106.60	45.55	0.11
Main	26371.1	300.00	198.55	204.13	200.81	204.17	0.000421	1.48	203.36	54.63	0.13
Main	26371.1	500.00	198.55	205.39	201.32	205.45	0.000458	1.86	280.26	70.60	0.14
Main	26371.1	1000.00	198.55	207.17	202.33	207.28	0.000632	2.66	503.95	343.07	0.18
Main	26371.1	3000.00	198.55	209.76	204.98	209.93	0.000970	4.06	1895.43	2317.90	0.23
Main	26371.1	6000.00	198.55	211.33	208.77	211.57	0.001385	5.37	2998.46	2873.58	0.28
Main	26371.1	10000.00	198.55	212.44	210.06	212.49	0.000467	3.32	11594.51	2892.00	0.17
Main	26371.1	10500.00	198.55	212.61	210.32	212.65	0.000458	3.32	12065.60	2894.34	0.17
Main	26371.1	20000.00	198.55	215.21	211.90	215.24	0.000382	3.44	19757.10	3203.60	0.16
Main	26371.1	25000.00	198.55	216.33	211.90	216.37	0.000399	3.70	23672.64	3563.52	0.16
Main	26371.1	36000.00	198.55	217.97	211.91	218.02	0.000424	4.06	29627.54	3692.01	0.17
Main	26371.1	40000.00	198.55	218.57	211.91	218.62	0.000421	4.14	31879.49	3738.51	0.17
Main	26371.1	60000.00	198.55	220.86	212.60	220.92	0.000456	4.66	40592.95	3868.86	0.18
Main	26042.9	100.00	198.55	202.07	199.94	202.09	0.000381	0.99	100.95	44.45	0.12
Main	26042.9	300.00	198.55	203.98	200.72	204.02	0.000468	1.53	197.70	56.84	0.14
Main	26042.9	500.00	198.55	205.24	201.27	205.29	0.000491	1.90	275.22	69.29	0.15
Main	26042.9	1000.00	198.55	206.96	202.33	207.07	0.000668	2.70	513.47	425.97	0.18
Main	26042.9	3000.00	198.55	209.50	204.94	209.67	0.000958	4.00	2038.64	1802.27	0.23
Main	26042.9	6000.00	198.55	211.28	208.68	211.33	0.000478	3.17	8002.12	2963.19	0.17
Main	26042.9	10000.00	198.55	212.33	209.94	212.38	0.000544	3.60	11111.44	2987.08	0.18
Main	26042.9	10500.00	198.55	212.49	210.04	212.54	0.000528	3.58	11610.75	2988.07	0.18
Main	26042.9	20000.00	198.55	215.13	211.01	215.17	0.000405	3.57	19670.36	3323.09	0.16
Main	26042.9	25000.00	198.55	216.25	211.28	216.29	0.000390	3.68	23696.14	3673.93	0.16
Main	26042.9	36000.00	198.55	217.89	211.86	217.93	0.000413	4.03	29794.05	3784.98	0.17
Main	26042.9	40000.00	198.55	218.49	212.02	218.54	0.000408	4.10	32099.57	3826.29	0.17
Main	26042.9	60000.00	198.55	220.78	212.76	220.83	0.000441	4.61	41002.84	3973.24	0.18
Main	25304.3	100.00	198.55	201.77	199.83	201.79	0.000423	1.04	96.61	42.68	0.12
Main	25304.3	300.00	198.55	203.59	200.56	203.63	0.000593	1.67	179.44	48.60	0.15
Main	25304.3	500.00	198.55	204.81	201.08	204.87	0.000654	2.08	241.94	59.30	0.17
Main	25304.3	1000.00	198.55	206.49	202.10	206.58	0.000695	2.62	779.15	648.18	0.18
Main	25304.3	3000.00	198.55	209.19	205.75	209.24	0.000474	2.73	3531.07	2560.48	0.16
Main	25304.3	6000.00	198.55	211.02	207.65	211.08	0.000500	3.17	5744.71	3273.11	0.17
Main	25304.3	10000.00	198.55	212.15	208.70	212.17	0.000317	2.69	13450.46	3288.63	0.14
Main	25304.3	10500.00	198.55	212.32	208.77	212.34	0.000312	2.70	13957.18	3299.53	0.14
Main	25304.3	20000.00	198.55	214.99	209.87	215.02	0.000255	2.78	23667.90	3408.76	0.13
Main	25304.3	25000.00	198.55	216.13	210.33	216.15	0.000248	2.88	27561.93	3455.27	0.13
Main	25304.3	36000.00	198.55	217.75	211.21	217.78	0.000285	3.29	33188.98	3487.90	0.14
Main	25304.3	40000.00	198.55	218.35	211.21	218.38	0.000288	3.39	35302.85	3509.13	0.14
Main	25304.3	60000.00	198.55	220.62	211.58	220.66	0.000343	3.99	43585.57	3810.79	0.16
Main	23685.1	100.00	198.55	200.83	199.60	200.85	0.000839	1.15	86.95	55.79	0.16
Main	23685.1	300.00	198.55	202.57	200.17	202.61	0.000672	1.56	192.65	65.54	0.16
Main	23685.1	500.00	198.55	203.79	200.61	203.84	0.000625	1.78	302.28	124.53	0.16
Main	23685.1	1000.00	198.55	205.53	201.44	205.60	0.000605	2.25	696.03	679.56	0.17
Main	23685.1	3000.00	198.55	208.51	203.84	208.60	0.000599	2.98	2086.77	2407.31	0.18
Main	23685.1	6000.00	198.55	210.70	206.44	210.72	0.000251	2.25	8866.54	3790.18	0.12
Main	23685.1	10000.00	198.55	211.84	207.61	211.87	0.000336	2.78	11428.81	3898.75	0.14
Main	23685.1	10500.00	198.55	212.01	207.72	212.05	0.000335	2.81	11822.07	3905.06	0.14
Main	23685.1	20000.00	198.55	214.72	209.60	214.76	0.000342	3.24	17902.82	3972.33	0.15
Main	23685.1	25000.00	198.55	215.86	210.50	215.90	0.000351	3.45	20448.24	4029.23	0.15
Main	23685.1	36000.00	198.55	217.42	210.51	217.48	0.000440	4.12	23961.92	4188.92	0.17
Main	23685.1	40000.00	198.55	218.02	210.53	218.09	0.000456	4.29	25299.07	4311.97	0.18
Main	23685.1	60000.00	198.55	220.40	211.40	220.44	0.000225	3.27	51663.94	4408.68	0.13

HEC-RAS Plan: TW_CC River: Crane Creek Reach: Main (Continued)

Reach	River Sta	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
		(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
Main	23533.1	100.00	196.98	200.81	197.89	200.82	0.000061	0.53	190.21	64.20	0.05
Main	23533.1	300.00	196.98	202.54	198.50	202.56	0.000129	0.98	306.53	70.14	0.08
Main	23533.1	500.00	196.98	203.76	198.95	203.78	0.000165	1.27	402.35	141.94	0.10
Main	23533.1	1000.00	196.98	205.48	199.78	205.53	0.000240	1.84	659.84	868.12	0.12
Main	23533.1	3000.00	196.98	208.47	201.97	208.52	0.000246	2.36	3732.05	2936.75	0.13
Main	23533.1	6000.00	196.98	210.68	204.65	210.69	0.000085	1.58	14758.88	3803.54	0.08
Main	23533.1	10000.00	196.98	211.82	207.45	211.83	0.000114	1.94	19118.86	3933.43	0.09
Main	23533.1	10500.00	196.98	212.00	207.64	212.01	0.000113	1.95	19801.35	3957.27	0.09
Main	23533.1	20000.00	196.98	214.71	209.22	214.72	0.000112	2.19	30578.10	4104.35	0.10
Main	23533.1	25000.00	196.98	215.84	209.50	215.85	0.000115	2.32	35510.34	4170.95	0.10
Main	23533.1	36000.00	196.98	217.40	210.00	217.42	0.000147	2.78	42289.82	4477.89	0.11
Main	23533.1	40000.00	196.98	218.00	209.69	218.02	0.000150	2.87	44968.05	4503.68	0.11
Main	23533.1	60000.00	196.98	220.37	210.37	220.40	0.000174	3.33	55746.08	4603.06	0.13
Main	23474.5	Mult Open									
Main	23424.1	100.00	198.70	200.72	199.54	200.75	0.001065	1.43	70.17	45.48	0.20
Main	23424.1	300.00	198.70	202.45	200.22	202.50	0.000769	1.67	187.13	101.09	0.19
Main	23424.1	500.00	198.70	203.67	200.74	203.72	0.000584	1.84	288.19	296.84	0.17
Main	23424.1	1000.00	198.70	205.36	201.77	205.45	0.000626	2.45	470.77	758.36	0.19
Main	23424.1	3000.00	198.70	208.38	203.75	208.46	0.000481	2.91	2820.78	2377.85	0.18
Main	23424.1	6000.00	198.70	210.66	206.09	210.67	0.000123	1.73	12068.71	2989.07	0.09
Main	23424.1	10000.00	198.70	211.69	208.05	211.70	0.000175	2.19	15157.86	3030.85	0.11
Main	23424.1	10500.00	198.70	211.87	208.23	211.89	0.000172	2.20	15733.20	3034.95	0.11
Main	23424.1	20000.00	198.70	214.66	209.50	214.68	0.000164	2.47	24555.93	3388.20	0.11
Main	23424.1	25000.00	198.70	215.77	209.50	215.80	0.000168	2.63	28443.86	3624.51	0.12
Main	23424.1	36000.00	198.70	217.36	209.51	217.39	0.000225	3.24	34551.40	4027.53	0.14
Main	23424.1	40000.00	198.70	217.96	209.51	217.99	0.000230	3.35	36996.36	4134.63	0.14
Main	23424.1	60000.00	198.70	220.32	210.56	220.36	0.000249	3.79	46780.97	4152.79	0.15
Main	23289.2	100.00	198.15	200.61	199.12	200.63	0.000779	1.20	83.36	47.25	0.16
Main	23289.2	300.00	198.15	202.35	199.82	202.39	0.000793	1.69	177.01	122.92	0.17
Main	23289.2	500.00	198.15	203.57	200.32	203.63	0.000767	1.96	257.91	283.34	0.18
Main	23289.2	1000.00	198.15	205.25	201.30	205.35	0.000829	2.59	457.05	642.22	0.20
Main	23289.2	3000.00	198.15	208.09	203.84	208.32	0.001275	4.26	1162.27	1763.38	0.26
Main	23289.2	6000.00	198.15	210.08	206.05	210.51	0.001951	6.09	1737.36	2900.83	0.34
Main	23289.2	10000.00	198.15	211.62	208.31	211.66	0.000400	3.03	10115.31	3012.48	0.16
Main	23289.2	10500.00	198.15	211.81	208.48	211.85	0.000395	3.04	10502.03	3016.98	0.15
Main	23289.2	20000.00	198.15	214.60	210.16	214.64	0.000391	3.48	16591.41	3391.98	0.16
Main	23289.2	25000.00	198.15	215.70	210.16	215.75	0.000406	3.72	19309.32	3587.31	0.16
Main	23289.2	36000.00	198.15	217.33	210.24	217.36	0.000251	3.12	33338.07	3976.04	0.13
Main	23289.2	40000.00	198.15	217.93	210.48	217.96	0.000264	3.27	35795.02	4162.61	0.14
Main	23289.2	60000.00	198.15	220.29	211.43	220.33	0.000277	3.64	45634.91	4179.41	0.14
Main	22130.7	100.00	197.03	199.44	198.21	199.48	0.001321	1.51	66.44	39.75	0.21
Main	22130.7	300.00	197.03	201.21	198.95	201.28	0.001172	2.10	143.04	46.81	0.21
Main	22130.7	500.00	197.03	202.46	199.48	202.55	0.001142	2.45	204.23	51.77	0.22
Main	22130.7	1000.00	197.03	204.12	200.51	204.24	0.001120	3.02	561.66	341.51	0.23
Main	22130.7	3000.00	197.03	206.84	203.91	206.98	0.001086	3.89	1884.23	1022.37	0.24
Main	22130.7	6000.00	197.03	209.30	205.72	209.45	0.001055	4.56	3489.90	2308.68	0.25
Main	22130.7	10000.00	197.03	210.98	206.80	211.08	0.000798	4.37	7541.59	3316.03	0.22
Main	22130.7	10500.00	197.03	211.19	206.93	211.28	0.000773	4.35	7922.48	3360.79	0.22
Main	22130.7	20000.00	197.03	214.04	208.99	214.12	0.000660	4.61	13268.40	3810.78	0.21
Main	22130.7	25000.00	197.03	215.13	209.73	215.22	0.000670	4.86	15380.92	3992.71	0.21
Main	22130.7	36000.00	197.03	217.08	210.78	217.11	0.000243	3.15	34518.20	4379.73	0.13
Main	22130.7	40000.00	197.03	217.67	211.03	217.70	0.000241	3.21	37160.21	4580.27	0.13
Main	22130.7	60000.00	197.03	220.02	212.05	220.05	0.000255	3.57	48147.68	4693.78	0.14
Main	21215.1	100.00	195.50	198.01	196.81	198.06	0.001862	1.83	54.65	31.34	0.24
Main	21215.1	300.00	195.50	199.98	197.65	200.07	0.001505	2.43	123.52	38.69	0.24
Main	21215.1	500.00	195.50	201.24	198.27	201.36	0.001474	2.82	190.31	75.05	0.25
Main	21215.1	1000.00	195.50	203.00	199.47	203.16	0.001336	3.41	555.38	362.58	0.25
Main	21215.1	3000.00	195.50	206.22	203.29	206.29	0.000640	3.16	2789.71	1236.51	0.18
Main	21215.1	6000.00	195.50	208.80	204.79	208.86	0.000529	3.39	5123.95	2224.71	0.18
Main	21215.1	10000.00	195.50	210.58	205.67	210.63	0.000445	3.42	9715.98	3210.15	0.16
Main	21215.1	10500.00	195.50	210.80	205.77	210.84	0.000435	3.42	10173.34	3374.84	0.16
Main	21215.1	20000.00	195.50	213.70	207.29	213.75	0.000396	3.71	17002.22	3927.10	0.16
Main	21215.1	25000.00	195.50	214.79	207.85	214.84	0.000403	3.90	19615.43	3941.34	0.16
Main	21215.1	36000.00	195.50	216.83	208.81	216.89	0.000428	4.33	24708.65	4067.47	0.17
Main	21215.1	40000.00	195.50	217.42	209.16	217.48	0.000440	4.48	26188.38	4074.01	0.18
Main	21215.1	60000.00	195.50	219.87	210.47	219.90	0.000218	3.40	49193.77	4120.67	0.13
Main	20730.1	100.00	194.21	197.37	195.68	197.40	0.001007	1.40	71.21	38.52	0.18
Main	20730.1	300.00	194.21	199.49	196.58	199.53	0.000810	1.73	173.54	58.18	0.18
Main	20730.1	500.00	194.21	200.78	197.23	200.84	0.000778	1.91	278.87	128.21	0.18
Main	20730.1	1000.00	194.21	202.61	198.36	202.68	0.000630	2.26	671.52	314.95	0.17
Main	20730.1	3000.00	194.21	205.84	201.14	205.94	0.000626	3.08	2075.23	675.83	0.19
Main	20730.1	6000.00	194.21	208.38	203.26	208.51	0.000696	3.87	3847.47	1822.78	0.20

HEC-RAS Plan: TW_CC River: Crane Creek Reach: Main (Continued)

Reach	River Sta	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
		(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
Main	20730.1	10000.00	194.21	210.19	204.96	210.31	0.000699	4.28	6989.83	2896.28	0.21
Main	20730.1	10500.00	194.21	210.42	204.99	210.54	0.000680	4.27	7409.12	3046.44	0.21
Main	20730.1	20000.00	194.21	213.36	207.36	213.48	0.000621	4.67	13358.02	3745.68	0.20
Main	20730.1	25000.00	194.21	214.46	207.40	214.57	0.000606	4.82	15786.44	3760.87	0.20
Main	20730.1	36000.00	194.21	216.50	209.60	216.61	0.000595	5.15	20307.42	3782.26	0.21
Main	20730.1	40000.00	194.21	217.08	209.90	217.20	0.000609	5.31	21597.89	3788.88	0.21
Main	20730.1	60000.00	194.21	219.56	211.86	219.71	0.000686	6.10	27151.66	3874.27	0.23
Main	19983.1	100.00	193.12	196.60	194.75	196.64	0.001046	1.42	70.45	38.42	0.18
Main	19983.1	300.00	193.12	198.94	195.74	198.98	0.000677	1.53	196.48	69.47	0.16
Main	19983.1	500.00	193.12	200.29	196.48	200.33	0.000588	1.65	307.05	109.64	0.15
Main	19983.1	1000.00	193.12	202.24	197.65	202.29	0.000429	1.89	832.66	407.24	0.14
Main	19983.1	3000.00	193.12	205.53	200.13	205.59	0.000354	2.35	2810.63	799.59	0.14
Main	19983.1	6000.00	193.12	208.03	202.54	208.11	0.000409	2.99	4517.51	1691.41	0.16
Main	19983.1	10000.00	193.12	209.82	204.01	209.90	0.000458	3.48	7466.28	2540.77	0.17
Main	19983.1	10500.00	193.12	210.05	204.13	210.13	0.000460	3.53	7840.01	2769.85	0.17
Main	19983.1	20000.00	193.12	212.96	205.82	213.07	0.000570	4.49	13364.67	3888.20	0.20
Main	19983.1	25000.00	193.12	214.07	206.51	214.18	0.000567	4.68	16089.66	4172.68	0.20
Main	19983.1	36000.00	193.12	216.12	207.92	216.24	0.000551	4.97	21315.18	4216.52	0.20
Main	19983.1	40000.00	193.12	216.70	208.25	216.82	0.000558	5.10	22787.91	4220.03	0.20
Main	19983.1	60000.00	193.12	219.15	210.51	219.29	0.000599	5.71	29047.95	4237.57	0.21
Main	18803.2	100.00	191.33	195.95	193.20	195.97	0.000346	1.23	81.17	26.23	0.12
Main	18803.2	300.00	191.33	198.12	194.29	198.18	0.000662	2.00	149.97	37.80	0.18
Main	18803.2	500.00	191.33	199.47	195.03	199.56	0.000711	2.47	206.16	45.73	0.19
Main	18803.2	1000.00	191.33	201.37	196.51	201.56	0.000955	3.53	339.13	117.12	0.23
Main	18803.2	3000.00	191.33	204.77	200.05	204.97	0.000950	4.57	2003.15	839.41	0.25
Main	18803.2	6000.00	191.33	207.37	204.13	207.52	0.000765	4.75	3994.84	1526.74	0.23
Main	18803.2	10000.00	191.33	209.15	205.42	209.30	0.000789	5.25	6518.47	2005.54	0.24
Main	18803.2	10500.00	191.33	209.39	205.52	209.53	0.000776	5.26	6796.61	2211.73	0.24
Main	18803.2	20000.00	191.33	212.20	207.12	212.38	0.000904	6.36	10210.62	3129.43	0.26
Main	18803.2	25000.00	191.33	213.29	207.69	213.47	0.000953	6.79	12903.53	3280.13	0.27
Main	18803.2	36000.00	191.33	215.35	208.96	215.54	0.000988	7.41	16577.22	3456.18	0.28
Main	18803.2	40000.00	191.33	215.90	209.37	216.10	0.001021	7.66	17591.13	3460.61	0.29
Main	18803.2	60000.00	191.33	218.25	210.76	218.50	0.001181	8.83	21866.49	3476.52	0.32
Main	18744.7	100.00	191.96	195.94	193.23	195.95	0.000236	0.99	101.29	35.50	0.10
Main	18744.7	300.00	191.96	198.10	194.23	198.14	0.000392	1.63	184.53	43.56	0.14
Main	18744.7	500.00	191.96	199.45	194.82	199.51	0.000456	2.03	250.99	54.71	0.16
Main	18744.7	1000.00	191.96	201.35	195.98	201.49	0.000640	2.95	363.24	120.04	0.19
Main	18744.7	3000.00	191.96	204.48	199.22	204.86	0.001289	5.32	1293.67	758.17	0.29
Main	18744.7	6000.00	191.96	207.19	202.49	207.44	0.000964	5.38	3392.67	1541.22	0.26
Main	18744.7	10000.00	191.96	208.88	205.92	209.20	0.001206	6.52	4894.15	2241.83	0.30
Main	18744.7	10500.00	191.96	209.08	206.04	209.42	0.001286	6.79	5197.74	2399.38	0.31
Main	18744.7	20000.00	191.96	212.17	207.94	212.31	0.000718	5.75	14529.44	3363.95	0.24
Main	18744.7	25000.00	191.96	213.29	208.09	213.40	0.000609	5.51	18292.22	3393.43	0.22
Main	18744.7	36000.00	191.96	215.36	210.74	215.45	0.000492	5.31	25345.46	3409.39	0.20
Main	18744.7	40000.00	191.96	215.92	210.99	216.01	0.000487	5.38	27262.00	3413.51	0.20
Main	18744.7	60000.00	191.96	218.29	211.98	218.38	0.000491	5.79	35372.28	3431.15	0.21
Main	18708.3	Bridge									
Main	18677.2	100.00	191.57	195.72	192.93	195.74	0.000262	1.00	99.74	36.89	0.11
Main	18677.2	300.00	191.57	197.85	193.96	197.90	0.000377	1.62	185.10	42.06	0.14
Main	18677.2	500.00	191.57	199.20	194.65	199.26	0.000488	2.05	243.57	46.49	0.16
Main	18677.2	1000.00	191.57	201.14	195.87	201.28	0.000731	2.92	347.67	88.06	0.20
Main	18677.2	3000.00	191.57	204.42	198.96	204.62	0.000865	4.16	1877.92	910.89	0.23
Main	18677.2	6000.00	191.57	207.10	203.76	207.25	0.000696	4.38	4016.92	1638.83	0.22
Main	18677.2	10000.00	191.57	208.96	204.92	209.15	0.000862	5.35	5826.07	2638.34	0.25
Main	18677.2	10500.00	191.57	209.17	205.04	209.39	0.000942	5.65	6076.61	2771.46	0.26
Main	18677.2	20000.00	191.57	212.13	206.87	212.18	0.000374	4.02	19016.66	3288.97	0.17
Main	18677.2	25000.00	191.57	213.24	207.16	213.29	0.000348	4.05	22711.21	3328.13	0.17
Main	18677.2	36000.00	191.57	215.32	208.73	215.37	0.000316	4.14	29653.61	3342.55	0.16
Main	18677.2	40000.00	191.57	215.88	208.77	215.94	0.000322	4.25	31532.44	3346.53	0.16
Main	18677.2	60000.00	191.57	218.25	210.44	218.32	0.000355	4.79	39475.93	3361.25	0.17
Main	18619.6	100.00	192.51	195.68	194.14	195.71	0.000741	1.41	71.01	34.87	0.17
Main	18619.6	300.00	192.51	197.80	194.92	197.86	0.000688	1.98	151.87	41.37	0.18
Main	18619.6	500.00	192.51	199.13	195.49	199.22	0.000747	2.39	209.64	45.45	0.20
Main	18619.6	1000.00	192.51	201.04	196.61	201.22	0.000944	3.36	313.52	168.06	0.23
Main	18619.6	3000.00	192.51	204.24	199.66	204.53	0.001242	5.03	1621.72	1006.36	0.28
Main	18619.6	6000.00	192.51	207.04	204.23	207.21	0.000788	4.74	3854.82	1822.89	0.24
Main	18619.6	10000.00	192.51	208.97	205.32	209.06	0.000557	4.39	7582.87	2783.71	0.20
Main	18619.6	10500.00	192.51	209.19	205.43	209.29	0.000553	4.42	7862.90	2911.04	0.20
Main	18619.6	20000.00	192.51	212.01	207.07	212.13	0.000660	5.42	11400.76	3235.07	0.23
Main	18619.6	25000.00	192.51	213.14	207.50	213.25	0.000614	5.46	15644.36	3277.92	0.22
Main	18619.6	36000.00	192.51	215.20	208.21	215.32	0.000653	6.04	19399.21	3292.51	0.23
Main	18619.6	40000.00	192.51	215.75	208.51	215.89	0.000688	6.30	20404.06	3296.41	0.24

HEC-RAS Plan: TW_CC River: Crane Creek Reach: Main (Continued)

Reach	River Sta	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
		(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
Main	18619.6	60000.00	192.51	218.07	209.80	218.25	0.000853	7.52	24624.63	3310.20	0.27
Main	18487.3	100.00	192.47	195.58	194.09	195.61	0.000799	1.44	69.33	34.74	0.18
Main	18487.3	300.00	192.47	197.70	194.86	197.77	0.000727	2.02	148.22	40.22	0.19
Main	18487.3	500.00	192.47	199.02	195.43	199.11	0.000847	2.42	206.76	48.92	0.21
Main	18487.3	1000.00	192.47	200.92	196.57	201.09	0.000987	3.33	321.07	225.92	0.24
Main	18487.3	3000.00	192.47	204.15	199.70	204.36	0.000976	4.39	1961.25	1248.00	0.25
Main	18487.3	6000.00	192.47	206.99	203.78	207.10	0.000612	4.14	4509.90	1739.70	0.21
Main	18487.3	10000.00	192.47	208.84	204.82	208.98	0.000697	4.86	6256.00	2676.24	0.23
Main	18487.3	10500.00	192.47	209.06	204.92	209.20	0.000698	4.91	6467.04	2797.92	0.23
Main	18487.3	20000.00	192.47	211.83	206.50	212.03	0.000915	6.32	9095.45	3176.95	0.27
Main	18487.3	25000.00	192.47	212.95	207.13	213.14	0.000939	6.68	12180.01	3216.58	0.28
Main	18487.3	36000.00	192.47	214.98	208.29	215.21	0.001015	7.46	15092.84	3232.39	0.29
Main	18487.3	40000.00	192.47	215.52	208.68	215.76	0.001076	7.81	15858.95	3236.77	0.30
Main	18487.3	60000.00	192.47	217.76	210.21	218.10	0.001366	9.42	19059.12	3249.44	0.35
Main	17215.5	100.00	191.61	194.70	192.94	194.72	0.000617	1.25	79.76	37.24	0.15
Main	17215.5	300.00	191.61	196.81	193.73	196.86	0.000693	1.77	169.20	50.56	0.17
Main	17215.5	500.00	191.61	198.07	194.30	198.13	0.000694	2.10	251.82	98.01	0.18
Main	17215.5	1000.00	191.61	199.95	195.42	200.05	0.000678	2.64	579.32	346.73	0.19
Main	17215.5	3000.00	191.61	203.44	198.55	203.53	0.000535	3.16	2581.63	1435.84	0.18
Main	17215.5	6000.00	191.61	206.71	201.35	206.74	0.000203	2.37	8355.23	2202.89	0.12
Main	17215.5	10000.00	191.61	208.52	202.59	208.55	0.000251	2.87	11891.22	2637.61	0.13
Main	17215.5	10500.00	191.61	208.74	202.70	208.78	0.000247	2.88	12370.83	2644.49	0.13
Main	17215.5	20000.00	191.61	211.47	203.73	211.51	0.000286	3.46	18199.95	2717.37	0.15
Main	17215.5	25000.00	191.61	212.56	205.62	212.61	0.000311	3.76	20580.34	2761.65	0.15
Main	17215.5	36000.00	191.61	214.56	206.50	214.62	0.000352	4.28	25006.80	2824.91	0.17
Main	17215.5	40000.00	191.61	215.07	206.50	215.13	0.000378	4.51	26132.68	2861.29	0.17
Main	17215.5	60000.00	191.61	217.17	207.44	217.28	0.000505	5.54	30803.77	3012.90	0.20
Main	16416	100.00	191.14	194.21	192.35	194.24	0.000586	1.27	78.66	34.19	0.15
Main	16416	300.00	191.14	196.26	193.16	196.31	0.000688	1.77	177.69	75.09	0.17
Main	16416	500.00	191.14	197.54	193.76	197.60	0.000645	2.01	304.32	132.01	0.17
Main	16416	1000.00	191.14	199.48	195.02	199.55	0.000575	2.42	748.45	333.13	0.17
Main	16416	3000.00	191.14	203.10	197.99	203.17	0.000458	2.94	2449.71	536.64	0.16
Main	16416	6000.00	191.14	206.45	200.22	206.54	0.000434	3.47	4730.88	981.23	0.17
Main	16416	10000.00	191.14	208.17	201.88	208.30	0.000605	4.45	6824.03	1454.27	0.20
Main	16416	10500.00	191.14	208.37	202.00	208.51	0.000668	4.72	7116.37	1468.48	0.21
Main	16416	20000.00	191.14	211.07	203.85	211.22	0.000752	5.59	11457.19	1732.55	0.23
Main	16416	25000.00	191.14	212.13	204.70	212.30	0.000789	5.95	13373.53	1901.39	0.24
Main	16416	36000.00	191.14	214.10	205.53	214.28	0.000850	6.60	17220.27	1994.01	0.25
Main	16416	40000.00	191.14	214.58	208.47	214.77	0.000903	6.90	18179.22	2012.24	0.26
Main	16416	60000.00	191.14	216.55	209.92	216.81	0.001150	8.26	22216.10	2080.97	0.30
Main	14882.6	100.00	190.67	192.85	191.56	192.89	0.001447	1.74	57.47	30.78	0.22
Main	14882.6	300.00	190.67	194.76	192.38	194.85	0.001389	2.47	121.69	36.52	0.24
Main	14882.6	500.00	190.67	196.05	193.01	196.19	0.001429	2.91	171.62	40.43	0.25
Main	14882.6	1000.00	190.67	198.09	194.22	198.28	0.001413	3.63	380.49	192.09	0.26
Main	14882.6	3000.00	190.67	202.46	198.01	202.55	0.000566	3.31	2420.49	576.16	0.18
Main	14882.6	6000.00	190.67	205.97	200.65	206.05	0.000427	3.49	5259.73	1332.90	0.16
Main	14882.6	10000.00	190.67	207.58	201.74	207.66	0.000529	4.18	7860.63	1829.16	0.19
Main	14882.6	10500.00	190.67	207.75	201.86	207.84	0.000538	4.25	8178.11	1875.50	0.19
Main	14882.6	20000.00	190.67	210.37	203.63	210.47	0.000646	5.16	13458.37	2134.81	0.21
Main	14882.6	25000.00	190.67	211.44	204.17	211.54	0.000642	5.34	15760.41	2174.52	0.21
Main	14882.6	36000.00	190.67	213.36	206.75	213.47	0.000690	5.89	20172.05	2373.29	0.23
Main	14882.6	40000.00	190.67	213.80	207.03	213.92	0.000729	6.14	21216.92	2377.60	0.23
Main	14882.6	60000.00	190.67	215.57	208.89	215.73	0.000933	7.32	25437.84	2398.26	0.27
Main	14411.7	100.00	189.73	192.39	190.68	192.42	0.000727	1.32	75.58	36.91	0.16
Main	14411.7	300.00	189.73	194.28	191.50	194.34	0.000849	1.94	154.76	47.50	0.19
Main	14411.7	500.00	189.73	195.56	192.10	195.64	0.000896	2.26	221.49	56.23	0.20
Main	14411.7	1000.00	189.73	197.61	193.24	197.74	0.000907	2.89	360.61	95.39	0.21
Main	14411.7	3000.00	189.73	202.18	196.16	202.30	0.000555	3.36	1874.71	422.42	0.18
Main	14411.7	6000.00	189.73	205.72	199.81	205.85	0.000491	3.85	4029.79	1102.03	0.18
Main	14411.7	10000.00	189.73	207.24	201.42	207.42	0.000678	4.85	6073.81	1487.47	0.22
Main	14411.7	10500.00	189.73	207.41	201.58	207.59	0.000686	4.92	6326.33	1493.64	0.22
Main	14411.7	20000.00	189.73	209.99	203.90	210.19	0.000807	5.91	10376.38	1690.86	0.25
Main	14411.7	25000.00	189.73	211.05	204.95	211.26	0.000860	6.33	12207.00	1885.27	0.26
Main	14411.7	36000.00	189.73	212.95	207.54	213.18	0.000916	6.96	16261.61	2216.32	0.27
Main	14411.7	40000.00	189.73	213.37	207.93	213.61	0.000978	7.29	17180.84	2220.91	0.28
Main	14411.7	60000.00	189.73	215.00	209.33	215.33	0.001300	8.83	20820.74	2238.06	0.32
Main	13816.9	100.00	189.60	191.67	190.61	191.73	0.002129	1.93	51.89	32.28	0.27
Main	13816.9	300.00	189.60	193.56	191.43	193.66	0.001598	2.49	120.46	40.24	0.25
Main	13816.9	500.00	189.60	194.83	192.03	194.96	0.001521	2.86	174.72	45.29	0.26
Main	13816.9	1000.00	189.60	196.91	193.20	197.09	0.001291	3.49	403.05	214.40	0.25
Main	13816.9	3000.00	189.60	201.90	196.72	201.99	0.000504	3.28	2157.60	416.99	0.18
Main	13816.9	6000.00	189.60	205.46	199.37	205.57	0.000492	3.92	3729.86	1400.64	0.18

HEC-RAS Plan: TW_CC River: Crane Creek Reach: Main (Continued)

Reach	River Sta	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
		(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
Main	13816.9	10000.00	189.60	206.97	200.73	207.07	0.000509	4.26	7414.06	2015.88	0.19
Main	13816.9	10500.00	189.60	207.14	200.86	207.24	0.000517	4.32	7659.48	2045.57	0.19
Main	13816.9	20000.00	189.60	209.66	203.02	209.78	0.000628	5.25	11450.01	2246.87	0.21
Main	13816.9	25000.00	189.60	210.69	204.03	210.82	0.000677	5.65	13019.39	2279.87	0.22
Main	13816.9	36000.00	189.60	212.51	206.19	212.69	0.000854	6.73	16049.60	2799.84	0.26
Main	13816.9	40000.00	189.60	212.85	206.71	213.07	0.000995	7.34	16757.51	2813.18	0.28
Main	13816.9	60000.00	189.60	214.54	207.99	214.71	0.000887	7.29	26096.64	2836.84	0.26
Main	12947.1	100.00	187.84	190.83	188.93	190.85	0.000577	1.16	85.99	43.28	0.15
Main	12947.1	300.00	187.84	192.80	189.78	192.84	0.000599	1.59	188.58	60.77	0.16
Main	12947.1	500.00	187.84	194.15	190.37	194.20	0.000540	1.80	278.41	72.56	0.16
Main	12947.1	1000.00	187.84	196.35	191.46	196.43	0.000479	2.27	518.99	149.88	0.16
Main	12947.1	3000.00	187.84	201.47	194.01	201.61	0.000432	3.21	1418.51	208.39	0.17
Main	12947.1	6000.00	187.84	204.86	196.65	205.12	0.000618	4.57	2386.30	1308.48	0.21
Main	12947.1	10000.00	187.84	206.37	198.81	206.62	0.000692	5.16	5570.09	1823.17	0.23
Main	12947.1	10500.00	187.84	206.53	199.04	206.78	0.000704	5.24	5801.02	1845.59	0.23
Main	12947.1	20000.00	187.84	208.94	202.61	209.24	0.000915	6.54	9880.73	2632.70	0.27
Main	12947.1	25000.00	187.84	209.99	206.14	210.27	0.000908	6.75	12117.09	3099.26	0.27
Main	12947.1	36000.00	187.84	211.82	206.74	212.09	0.000908	7.16	17081.06	3736.84	0.27
Main	12947.1	40000.00	187.84	212.10	207.76	212.40	0.000996	7.56	17927.00	3749.95	0.28
Main	12947.1	60000.00	187.84	213.65	209.52	214.00	0.001239	8.83	22586.45	3838.85	0.32
Main	12383.6	100.00	187.59	190.49	188.70	190.51	0.000618	1.26	79.08	36.40	0.15
Main	12383.6	300.00	187.59	192.40	189.51	192.46	0.000759	1.93	155.26	43.23	0.18
Main	12383.6	500.00	187.59	193.74	190.09	193.82	0.000808	2.31	216.24	47.64	0.19
Main	12383.6	1000.00	187.59	195.91	191.22	196.06	0.000881	3.11	326.11	53.61	0.21
Main	12383.6	3000.00	187.59	200.92	194.20	201.24	0.000987	4.79	1009.14	268.37	0.25
Main	12383.6	6000.00	187.59	204.33	197.13	204.68	0.000986	5.68	2804.28	2076.72	0.26
Main	12383.6	10000.00	187.59	205.90	201.57	206.18	0.000953	5.96	5326.70	3004.16	0.26
Main	12383.6	10500.00	187.59	206.05	201.71	206.33	0.000969	6.05	5517.27	3011.97	0.26
Main	12383.6	20000.00	187.59	208.37	205.32	208.68	0.001191	7.31	8468.28	3162.67	0.29
Main	12383.6	25000.00	187.59	209.38	205.96	209.71	0.001249	7.75	9783.28	3255.19	0.30
Main	12383.6	36000.00	187.59	211.12	206.99	211.49	0.001414	8.71	12090.40	3648.09	0.33
Main	12383.6	40000.00	187.59	211.28	207.33	211.71	0.001656	9.47	12324.33	3700.48	0.36
Main	12383.6	60000.00	187.59	213.18	208.69	213.37	0.000951	7.59	23943.22	3832.90	0.27
Main	11618.5	100.00	187.43	189.43	188.67	189.52	0.004159	2.39	41.79	31.38	0.37
Main	11618.5	300.00	187.43	191.50	189.52	191.60	0.001796	2.50	119.96	44.14	0.27
Main	11618.5	500.00	187.43	192.92	190.13	193.03	0.001389	2.66	187.92	51.53	0.25
Main	11618.5	1000.00	187.43	195.13	191.27	195.29	0.001163	3.24	314.24	65.53	0.24
Main	11618.5	3000.00	187.43	200.26	194.04	200.51	0.000889	4.37	1139.57	260.10	0.23
Main	11618.5	6000.00	187.43	203.59	197.16	203.94	0.000998	5.54	2291.78	1194.25	0.26
Main	11618.5	10000.00	187.43	204.98	200.13	205.37	0.001250	6.60	4798.49	1788.27	0.30
Main	11618.5	10500.00	187.43	205.12	200.13	205.51	0.001269	6.69	4987.86	1877.24	0.30
Main	11618.5	20000.00	187.43	207.29	203.81	207.71	0.001513	7.97	7980.33	2260.32	0.33
Main	11618.5	25000.00	187.43	208.21	204.66	208.66	0.001666	8.64	9382.01	2604.46	0.35
Main	11618.5	36000.00	187.43	209.91	206.62	210.36	0.001723	9.32	12469.75	3010.15	0.36
Main	11618.5	40000.00	187.43	210.49	206.96	210.71	0.001068	7.47	19143.64	3241.17	0.29
Main	11618.5	60000.00	187.43	212.44	208.04	212.66	0.001067	7.93	26012.30	3574.80	0.29
Main	11060.9	100.00	185.50	188.98	186.76	189.00	0.000376	1.06	94.19	38.86	0.12
Main	11060.9	300.00	185.50	191.07	187.60	191.11	0.000488	1.60	187.15	50.16	0.15
Main	11060.9	500.00	185.50	192.51	188.19	192.56	0.000517	1.89	264.69	57.68	0.16
Main	11060.9	1000.00	185.50	194.74	189.33	194.84	0.000558	2.51	405.05	68.48	0.17
Main	11060.9	3000.00	185.50	199.86	192.26	200.09	0.000643	3.95	1043.89	222.90	0.20
Main	11060.9	6000.00	185.50	203.23	194.93	203.47	0.000645	4.67	3730.88	1785.05	0.21
Main	11060.9	10000.00	185.50	204.53	198.20	204.79	0.000806	5.52	5886.03	1935.89	0.24
Main	11060.9	10500.00	185.50	204.66	198.42	204.93	0.000824	5.61	6106.09	1943.36	0.24
Main	11060.9	20000.00	185.50	206.70	204.10	207.00	0.001047	6.83	9613.01	2073.74	0.28
Main	11060.9	25000.00	185.50	207.57	204.66	207.88	0.001131	7.32	11168.13	2186.99	0.29
Main	11060.9	36000.00	185.50	209.23	205.62	209.55	0.001216	8.01	14402.38	3043.77	0.31
Main	11060.9	40000.00	185.50	209.76	205.93	210.09	0.001231	8.20	15558.36	3264.90	0.31
Main	11060.9	60000.00	185.50	211.81	207.19	212.07	0.001135	8.36	25846.44	3690.38	0.30
Main	10131.1	100.00	185.30	188.55	186.66	188.57	0.000573	1.25	80.06	35.38	0.15
Main	10131.1	300.00	185.30	190.50	187.51	190.56	0.000726	1.94	154.97	41.20	0.18
Main	10131.1	500.00	185.30	191.89	188.10	191.98	0.000783	2.33	215.00	45.21	0.19
Main	10131.1	1000.00	185.30	194.02	189.24	194.17	0.000926	3.16	334.47	75.35	0.22
Main	10131.1	3000.00	185.30	199.07	192.33	199.36	0.000950	4.66	1024.83	230.61	0.24
Main	10131.1	6000.00	185.30	202.16	195.65	202.63	0.001299	6.36	1655.19	1683.55	0.29
Main	10131.1	10000.00	185.30	203.85	199.20	204.04	0.000776	5.29	7078.71	2785.62	0.23
Main	10131.1	10500.00	185.30	203.98	199.40	204.16	0.000782	5.33	7396.61	2800.99	0.23
Main	10131.1	20000.00	185.30	205.97	203.46	206.12	0.000795	5.80	12534.86	2970.56	0.24
Main	10131.1	25000.00	185.30	206.82	203.90	206.97	0.000793	5.97	14754.32	3073.50	0.24
Main	10131.1	36000.00	185.30	208.46	204.63	208.60	0.000794	6.30	19018.09	3584.03	0.24
Main	10131.1	40000.00	185.30	208.99	204.84	209.13	0.000792	6.40	20423.60	3605.71	0.24
Main	10131.1	60000.00	185.30	211.07	205.77	211.19	0.000737	6.56	31374.73	4144.76	0.24

HEC-RAS Plan: TW_CC River: Crane Creek Reach: Main (Continued)

Reach	River Sta	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
		(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
Main	9351.3	100.00	185.03	187.93	186.47	187.97	0.001108	1.56	64.22	33.53	0.20
Main	9351.3	300.00	185.03	189.74	187.36	189.83	0.001243	2.36	127.12	36.90	0.22
Main	9351.3	500.00	185.03	191.05	187.91	191.17	0.001429	2.70	185.20	48.89	0.24
Main	9351.3	1000.00	185.03	193.14	189.06	193.32	0.001295	3.41	321.82	98.16	0.25
Main	9351.3	3000.00	185.03	198.49	192.19	198.68	0.000742	3.99	1377.68	346.38	0.21
Main	9351.3	6000.00	185.03	201.61	195.32	201.80	0.000741	4.70	3562.16	1726.95	0.22
Main	9351.3	10000.00	185.03	203.35	198.16	203.49	0.000636	4.70	7799.81	3190.34	0.21
Main	9351.3	10500.00	185.03	203.47	198.35	203.61	0.000642	4.74	8156.36	3213.40	0.21
Main	9351.3	20000.00	185.03	205.46	202.39	205.57	0.000641	5.12	14200.63	3420.97	0.21
Main	9351.3	25000.00	185.03	206.33	202.86	206.43	0.000618	5.19	16858.03	3522.82	0.21
Main	9351.3	36000.00	185.03	207.97	203.96	208.07	0.000593	5.38	21906.36	3919.39	0.21
Main	9351.3	40000.00	185.03	208.51	204.16	208.61	0.000588	5.44	23557.71	4007.38	0.21
Main	9351.3	60000.00	185.03	210.62	204.98	210.71	0.000549	5.60	35119.90	4552.68	0.20
Main	8820.8	100.00	184.36	187.40	185.83	187.43	0.000934	1.42	70.31	37.50	0.18
Main	8820.8	300.00	184.36	189.15	186.70	189.22	0.001041	2.08	144.03	46.48	0.21
Main	8820.8	500.00	184.36	190.43	187.28	190.52	0.001025	2.41	207.42	52.81	0.21
Main	8820.8	1000.00	184.36	192.60	188.39	192.74	0.000908	3.02	371.49	91.14	0.22
Main	8820.8	3000.00	184.36	198.11	191.24	198.32	0.000674	4.01	1305.41	336.54	0.21
Main	8820.8	6000.00	184.36	201.15	194.05	201.42	0.000787	5.06	3039.15	1548.65	0.23
Main	8820.8	10000.00	184.36	202.97	197.44	203.17	0.000706	5.18	7745.81	3250.42	0.23
Main	8820.8	10500.00	184.36	203.07	197.71	203.28	0.000740	5.33	8066.91	3346.10	0.23
Main	8820.8	20000.00	184.36	205.14	202.15	205.27	0.000647	5.39	15027.36	3697.29	0.22
Main	8820.8	25000.00	184.36	206.03	202.59	206.15	0.000612	5.41	18055.64	3820.79	0.22
Main	8820.8	36000.00	184.36	207.70	203.90	207.81	0.000574	5.53	23738.98	4123.62	0.21
Main	8820.8	40000.00	184.36	208.25	204.11	208.35	0.000566	5.59	25586.96	4270.33	0.21
Main	8820.8	60000.00	184.36	210.37	204.94	210.47	0.000536	5.79	37378.65	4826.27	0.21
Main	8505.2	100.00	184.29	186.97	185.80	187.02	0.001882	1.80	55.50	35.22	0.25
Main	8505.2	300.00	184.29	188.74	186.68	188.82	0.001563	2.37	126.67	45.78	0.25
Main	8505.2	500.00	184.29	190.05	187.26	190.15	0.001346	2.61	191.36	52.98	0.24
Main	8505.2	1000.00	184.29	192.27	188.38	192.42	0.001099	3.17	321.40	62.47	0.24
Main	8505.2	3000.00	184.29	197.77	191.12	198.06	0.000899	4.51	958.85	343.77	0.24
Main	8505.2	6000.00	184.29	200.83	193.76	201.15	0.000918	5.36	2910.44	1140.33	0.25
Main	8505.2	10000.00	184.29	202.65	197.56	202.92	0.000910	5.79	6648.11	2896.69	0.25
Main	8505.2	10500.00	184.29	202.75	197.95	203.02	0.000935	5.89	6934.15	3037.05	0.26
Main	8505.2	20000.00	184.29	204.90	202.12	205.07	0.000769	5.81	13921.59	3653.50	0.24
Main	8505.2	25000.00	184.29	205.82	203.01	205.96	0.000708	5.76	16955.24	3799.39	0.23
Main	8505.2	36000.00	184.29	207.51	203.93	207.64	0.000647	5.82	22578.32	4066.04	0.22
Main	8505.2	40000.00	184.29	208.06	204.14	208.18	0.000642	5.90	24390.14	4204.97	0.22
Main	8505.2	60000.00	184.29	210.21	204.99	210.31	0.000578	5.97	36441.05	4826.61	0.22
Main	8195.5	100.00	183.68	186.40	185.20	186.45	0.001842	1.77	56.43	36.15	0.25
Main	8195.5	300.00	183.68	188.30	186.08	188.38	0.001273	2.28	131.58	42.62	0.23
Main	8195.5	500.00	183.68	189.65	186.66	189.76	0.001200	2.58	194.74	64.82	0.23
Main	8195.5	1000.00	183.68	191.95	187.72	192.10	0.000975	3.12	361.51	77.96	0.22
Main	8195.5	3000.00	183.68	197.53	190.72	197.79	0.000822	4.41	1053.78	360.73	0.23
Main	8195.5	6000.00	183.68	200.61	193.39	200.88	0.000819	5.14	3287.64	1405.88	0.24
Main	8195.5	10000.00	183.68	202.48	196.91	202.67	0.000694	5.13	7351.78	2923.96	0.22
Main	8195.5	10500.00	183.68	202.57	197.35	202.76	0.000719	5.24	7613.91	2975.71	0.23
Main	8195.5	20000.00	183.68	204.73	201.79	204.86	0.000631	5.32	14616.60	3826.94	0.22
Main	8195.5	25000.00	183.68	205.66	202.44	205.77	0.000593	5.32	17685.66	3943.65	0.21
Main	8195.5	36000.00	183.68	207.37	203.25	207.47	0.000555	5.44	23344.93	4074.67	0.21
Main	8195.5	40000.00	183.68	207.92	203.52	208.01	0.000548	5.50	25161.29	4152.65	0.21
Main	8195.5	60000.00	183.68	210.08	204.42	210.16	0.000500	5.59	37498.91	4737.86	0.20
Main	7885.6	100.00	183.06	185.91	184.57	185.95	0.001402	1.63	61.35	36.22	0.22
Main	7885.6	300.00	183.06	187.97	185.45	188.03	0.000987	2.08	144.23	44.24	0.20
Main	7885.6	500.00	183.06	189.33	186.03	189.42	0.000945	2.40	208.02	49.07	0.21
Main	7885.6	1000.00	183.06	191.67	187.13	191.81	0.000878	3.08	330.60	56.47	0.21
Main	7885.6	3000.00	183.06	197.26	190.00	197.54	0.000818	4.49	1124.18	391.63	0.23
Main	7885.6	6000.00	183.06	200.31	192.90	200.62	0.000876	5.40	2733.25	1365.18	0.24
Main	7885.6	10000.00	183.06	202.24	197.84	202.45	0.000752	5.42	6842.66	2649.61	0.23
Main	7885.6	10500.00	183.06	202.31	198.28	202.54	0.000786	5.56	7049.58	2740.20	0.24
Main	7885.6	20000.00	183.06	204.53	201.60	204.67	0.000677	5.59	13899.20	3752.19	0.22
Main	7885.6	25000.00	183.06	205.47	202.39	205.60	0.000638	5.60	16919.88	3825.60	0.22
Main	7885.6	36000.00	183.06	207.19	203.24	207.31	0.000589	5.69	22483.65	3962.23	0.21
Main	7885.6	40000.00	183.06	207.74	203.50	207.85	0.000581	5.74	24260.99	4075.95	0.21
Main	7885.6	60000.00	183.06	209.93	204.38	210.02	0.000509	5.71	36468.88	4530.63	0.20
Main	7289.6	100.00	181.67	185.56	183.28	185.57	0.000349	1.04	95.71	37.83	0.12
Main	7289.6	300.00	181.67	187.58	184.17	187.62	0.000492	1.71	175.11	40.67	0.15
Main	7289.6	500.00	181.67	188.90	184.76	188.97	0.000605	2.17	230.08	42.49	0.16
Main	7289.6	1000.00	181.67	191.17	185.82	191.31	0.000802	3.03	330.62	45.97	0.20
Main	7289.6	3000.00	181.67	196.68	188.85	197.01	0.000954	4.79	970.47	293.94	0.24
Main	7289.6	6000.00	181.67	199.63	192.05	200.03	0.001131	5.98	2335.60	1711.33	0.26
Main	7289.6	10000.00	181.67	201.64	197.08	201.93	0.000997	6.08	5563.94	2970.67	0.25
Main	7289.6	10500.00	181.67	201.66	197.08	201.98	0.001084	6.35	5615.72	2981.82	0.26

HEC-RAS Plan: TW_CC River: Crane Creek Reach: Main (Continued)

Reach	River Sta	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
		(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
Main	7289.6	20000.00	181.67	203.90	201.23	204.15	0.001091	6.89	11017.26	3458.48	0.27
Main	7289.6	25000.00	181.67	204.88	202.00	205.10	0.001030	6.91	13492.62	3495.07	0.27
Main	7289.6	36000.00	181.67	206.63	203.06	206.83	0.000999	7.18	18021.65	3572.33	0.26
Main	7289.6	40000.00	181.67	207.19	203.33	207.39	0.000987	7.25	19470.37	3578.77	0.26
Main	7289.6	60000.00	181.67	209.62	204.36	209.70	0.000512	5.58	36113.38	3615.70	0.19
Main	6845.4	100.00	181.58	185.39	183.22	185.41	0.000414	1.07	93.07	40.85	0.13
Main	6845.4	300.00	181.58	187.36	184.12	187.40	0.000528	1.65	182.02	49.61	0.15
Main	6845.4	500.00	181.58	188.64	184.71	188.71	0.000584	2.01	249.11	53.84	0.16
Main	6845.4	1000.00	181.58	190.87	185.79	190.98	0.000659	2.67	377.63	62.30	0.18
Main	6845.4	3000.00	181.58	196.44	188.60	196.64	0.000594	3.82	1419.73	975.91	0.19
Main	6845.4	6000.00	181.58	199.38	191.38	199.60	0.000658	4.64	2940.36	1313.81	0.21
Main	6845.4	10000.00	181.58	201.59	195.05	201.65	0.000286	3.35	9112.58	1761.22	0.14
Main	6845.4	10500.00	181.58	201.60	195.58	201.67	0.000312	3.51	9145.77	1761.49	0.15
Main	6845.4	20000.00	181.58	203.71	199.32	203.81	0.000454	4.56	12888.69	1797.46	0.18
Main	6845.4	25000.00	181.58	204.65	200.48	204.76	0.000502	4.95	14589.80	1820.96	0.19
Main	6845.4	36000.00	181.58	206.34	200.49	206.48	0.000596	5.69	17698.06	1848.65	0.21
Main	6845.4	40000.00	181.58	206.88	200.49	207.03	0.000627	5.93	18701.68	1860.63	0.22
Main	6845.4	60000.00	181.58	209.22	201.87	209.42	0.000755	6.96	23150.85	1917.30	0.25
Main	6441.7	100.00	181.49	185.20	183.16	185.22	0.000508	1.16	86.44	39.57	0.14
Main	6441.7	300.00	181.49	187.11	184.09	187.16	0.000643	1.77	169.15	47.93	0.17
Main	6441.7	500.00	181.49	188.37	184.68	188.45	0.000715	2.15	232.98	53.39	0.18
Main	6441.7	1000.00	181.49	190.58	185.76	190.70	0.000748	2.80	365.51	75.87	0.20
Main	6441.7	3000.00	181.49	196.33	188.65	196.43	0.000360	2.99	2206.75	1135.72	0.15
Main	6441.7	6000.00	181.49	199.41	191.58	199.44	0.000141	2.18	7554.11	1353.66	0.10
Main	6441.7	10000.00	181.49	201.53	195.07	201.56	0.000155	2.49	10484.45	1419.24	0.11
Main	6441.7	10500.00	181.49	201.54	195.54	201.57	0.000170	2.61	10502.83	1419.55	0.11
Main	6441.7	20000.00	181.49	203.58	197.64	203.65	0.000300	3.74	13463.88	1476.18	0.15
Main	6441.7	25000.00	181.49	204.50	198.46	204.58	0.000355	4.20	14831.87	1507.19	0.16
Main	6441.7	36000.00	181.49	206.15	199.34	206.26	0.000465	5.06	17375.27	1592.00	0.19
Main	6441.7	40000.00	181.49	206.67	199.34	206.80	0.000501	5.33	18215.60	1601.90	0.20
Main	6441.7	60000.00	181.49	208.95	199.86	209.13	0.000658	6.52	21913.52	1662.95	0.23
Main	6199.2	100.00	181.44	185.06	183.14	185.09	0.000612	1.24	80.82	42.74	0.16
Main	6199.2	300.00	181.44	186.97	184.10	187.01	0.000586	1.63	184.61	62.57	0.17
Main	6199.2	500.00	181.44	188.24	184.71	188.29	0.000540	1.83	282.57	92.69	0.17
Main	6199.2	1000.00	181.44	190.48	185.82	190.55	0.000423	2.21	518.79	124.74	0.16
Main	6199.2	3000.00	181.44	196.28	188.32	196.36	0.000227	2.55	2319.95	666.71	0.13
Main	6199.2	6000.00	181.44	199.29	190.52	199.39	0.000270	3.23	3915.39	1138.75	0.15
Main	6199.2	10000.00	181.44	201.41	193.06	201.51	0.000297	3.70	7770.71	1503.47	0.16
Main	6199.2	10500.00	181.44	201.41	193.15	201.52	0.000327	3.89	7772.08	1503.50	0.17
Main	6199.2	20000.00	181.44	203.39	196.93	203.57	0.000525	5.31	10850.23	1590.88	0.22
Main	6199.2	25000.00	181.44	204.29	197.91	204.49	0.000592	5.81	12290.55	1614.97	0.23
Main	6199.2	36000.00	181.44	205.90	200.05	206.15	0.000730	6.80	14905.13	1650.42	0.26
Main	6199.2	40000.00	181.44	206.41	200.29	206.68	0.000774	7.11	15757.45	1671.21	0.27
Main	6199.2	60000.00	181.44	208.62	202.43	208.97	0.000965	8.47	19557.93	1750.63	0.30
Main	5971	100.00	180.44	185.00	182.15	185.01	0.000173	0.82	122.53	46.55	0.09
Main	5971	300.00	180.44	186.89	183.08	186.92	0.000294	1.35	223.47	72.83	0.12
Main	5971	500.00	180.44	188.15	183.69	188.19	0.000313	1.65	323.10	86.61	0.13
Main	5971	1000.00	180.44	190.39	184.78	190.46	0.000329	2.18	533.76	117.29	0.14
Main	5971	3000.00	180.44	196.13	187.57	196.29	0.000353	3.34	1297.90	424.07	0.16
Main	5971	6000.00	180.44	199.14	189.99	199.31	0.000394	4.06	4021.10	1179.16	0.18
Main	5971	10000.00	180.44	201.21	192.50	201.42	0.000482	4.88	7019.91	1661.29	0.20
Main	5971	10500.00	180.44	201.19	192.78	201.42	0.000537	5.14	6982.81	1660.81	0.21
Main	5971	20000.00	180.44	203.08	198.52	203.40	0.000853	6.93	10175.80	1719.07	0.27
Main	5971	25000.00	180.44	203.96	199.58	204.31	0.000939	7.48	11693.27	1723.68	0.29
Main	5971	36000.00	180.44	205.52	200.78	205.93	0.001124	8.59	14401.88	1741.22	0.32
Main	5971	40000.00	180.44	206.02	202.04	206.45	0.001185	8.96	15270.72	1750.20	0.33
Main	5971	60000.00	180.44	208.17	203.61	208.70	0.001435	10.47	19075.15	1783.46	0.37
Main	5873.3	100.00	181.86	184.90	183.64	184.96	0.001760	1.99	50.27	28.45	0.26
Main	5873.3	300.00	181.86	186.71	184.60	186.83	0.001700	2.77	108.33	35.68	0.28
Main	5873.3	500.00	181.86	187.93	185.28	188.10	0.001681	3.25	153.89	38.89	0.29
Main	5873.3	1000.00	181.86	190.08	186.54	190.34	0.001647	4.15	244.92	47.74	0.30
Main	5873.3	3000.00	181.86	195.53	189.71	196.10	0.001525	6.19	555.51	273.96	0.32
Main	5873.3	6000.00	181.86	197.50	193.17	198.89	0.003146	9.89	1110.07	740.20	0.48
Main	5873.3	10000.00	181.86	200.67	199.33	201.23	0.001576	8.08	4911.16	1633.94	0.35
Main	5873.3	10500.00	181.86	200.38	199.56	201.16	0.002107	9.23	4438.30	1615.22	0.40
Main	5873.3	20000.00	181.86	202.62	201.36	203.20	0.002003	9.81	8202.63	1703.50	0.40
Main	5873.3	25000.00	181.86	203.60	201.88	204.12	0.001917	9.93	9878.26	1709.41	0.40
Main	5873.3	36000.00	181.86	205.24	202.80	205.75	0.001985	10.67	12685.23	1728.62	0.41
Main	5873.3	40000.00	181.86	205.75	203.09	206.27	0.002021	10.94	13574.68	1736.70	0.42
Main	5873.3	60000.00	181.86	207.94	204.29	208.50	0.002198	12.17	17409.62	1766.36	0.44
Main	5837.2	Bridge									

HEC-RAS Plan: TW_CC River: Crane Creek Reach: Main (Continued)

Reach	River Sta	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
		(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
Main	5781	100.00	182.80	184.57	183.96	184.67	0.004666	2.61	38.39	30.47	0.41
Main	5781	300.00	182.80	186.52	184.75	186.64	0.001969	2.78	107.74	39.65	0.30
Main	5781	500.00	182.80	187.76	185.38	187.91	0.001714	3.15	158.92	43.28	0.29
Main	5781	1000.00	182.80	189.78	186.51	190.02	0.001871	3.89	256.99	54.91	0.31
Main	5781	3000.00	182.80	194.28	189.58	194.79	0.001808	5.74	526.12	217.46	0.34
Main	5781	6000.00	182.80	198.38	192.37	198.68	0.000931	5.24	2880.49	1180.44	0.26
Main	5781	10000.00	182.80	199.44	195.10	199.90	0.001467	6.95	4346.14	1573.46	0.33
Main	5781	10500.00	182.80	199.69	195.42	200.12	0.001384	6.84	4746.50	1647.00	0.32
Main	5781	20000.00	182.80	202.44	198.97	202.71	0.001039	6.68	9581.75	1768.91	0.29
Main	5781	25000.00	182.80	203.42	200.48	203.69	0.001034	6.93	11322.06	1778.63	0.29
Main	5781	36000.00	182.80	205.05	201.36	205.33	0.001124	7.66	14215.23	1790.71	0.31
Main	5781	40000.00	182.80	205.55	201.63	205.85	0.001159	7.91	15126.14	1797.88	0.31
Main	5781	60000.00	182.80	207.71	202.77	208.07	0.001335	9.10	19041.88	1844.78	0.34
Main	5715.5	100.00	181.85	184.42	183.12	184.48	0.001619	2.00	50.10	25.93	0.25
Main	5715.5	300.00	181.85	186.41	184.07	186.53	0.001561	2.79	107.59	31.77	0.27
Main	5715.5	500.00	181.85	187.61	184.77	187.79	0.001756	3.38	147.95	35.23	0.29
Main	5715.5	1000.00	181.85	189.54	186.13	189.86	0.002261	4.52	221.27	40.90	0.34
Main	5715.5	3000.00	181.85	193.71	189.62	194.54	0.002919	7.45	488.38	323.16	0.42
Main	5715.5	6000.00	181.85	196.79	193.61	198.23	0.003792	10.22	849.50	869.62	0.51
Main	5715.5	10000.00	181.85	199.46	196.77	199.72	0.001121	6.31	5623.25	1634.34	0.28
Main	5715.5	10500.00	181.85	199.70	197.06	199.95	0.001079	6.26	6030.75	1703.43	0.28
Main	5715.5	20000.00	181.85	202.42	198.65	202.60	0.000915	6.41	10975.95	1836.49	0.26
Main	5715.5	25000.00	181.85	203.40	199.53	203.58	0.000929	6.69	12773.85	1841.64	0.27
Main	5715.5	36000.00	181.85	205.01	200.66	205.22	0.001037	7.46	15752.78	1848.52	0.29
Main	5715.5	40000.00	181.85	205.52	200.93	205.73	0.001081	7.74	16689.05	1858.68	0.29
Main	5715.5	60000.00	181.85	207.67	202.06	207.94	0.001279	8.97	20749.79	1914.73	0.33
Main	5307.5	100.00	180.98	183.89	182.22	183.93	0.001121	1.65	60.70	28.92	0.20
Main	5307.5	300.00	180.98	185.84	183.15	185.93	0.001348	2.31	130.09	43.10	0.23
Main	5307.5	500.00	180.98	187.03	183.89	187.14	0.001380	2.68	187.18	53.66	0.25
Main	5307.5	1000.00	180.98	188.93	185.23	189.12	0.001352	3.50	305.29	69.53	0.26
Main	5307.5	3000.00	180.98	193.13	188.18	193.56	0.001599	5.52	808.03	211.88	0.31
Main	5307.5	6000.00	180.98	196.45	190.80	197.00	0.001655	6.82	1777.32	675.94	0.33
Main	5307.5	10000.00	180.98	198.59	194.71	199.15	0.001730	7.71	3436.47	1019.18	0.35
Main	5307.5	10500.00	180.98	198.84	194.90	199.40	0.001716	7.77	3638.64	1184.11	0.35
Main	5307.5	20000.00	180.98	201.89	198.43	202.20	0.001200	7.32	9219.95	1766.48	0.30
Main	5307.5	25000.00	180.98	202.88	199.61	203.18	0.001191	7.55	10975.40	1770.15	0.30
Main	5307.5	36000.00	180.98	204.46	200.96	204.78	0.001315	8.35	13765.90	1778.10	0.32
Main	5307.5	40000.00	180.98	204.94	201.26	205.28	0.001361	8.63	14635.69	1781.94	0.33
Main	5307.5	60000.00	180.98	207.02	202.49	207.41	0.001568	9.84	18339.59	1791.32	0.36
Main	4986.6	100.00	180.68	183.45	181.97	183.50	0.001602	1.90	52.53	26.20	0.24
Main	4986.6	300.00	180.68	185.31	182.95	185.42	0.001879	2.67	112.15	37.77	0.27
Main	4986.6	500.00	180.68	186.45	183.73	186.61	0.001998	3.14	159.42	44.72	0.29
Main	4986.6	1000.00	180.68	188.34	185.10	188.60	0.001933	4.07	257.98	61.16	0.31
Main	4986.6	3000.00	180.68	192.59	188.16	193.02	0.001791	5.75	936.35	315.74	0.32
Main	4986.6	6000.00	180.68	196.14	192.35	196.48	0.001272	5.96	2208.17	441.37	0.29
Main	4986.6	10000.00	180.68	198.12	194.13	198.61	0.001673	7.50	3099.08	893.90	0.34
Main	4986.6	10500.00	180.68	198.36	194.31	198.85	0.001696	7.63	3255.96	1058.55	0.34
Main	4986.6	20000.00	180.68	201.53	196.95	201.83	0.001252	7.43	8820.15	1771.01	0.30
Main	4986.6	25000.00	180.68	202.53	198.25	202.82	0.001230	7.62	10598.13	1773.81	0.30
Main	4986.6	36000.00	180.68	204.07	200.60	204.39	0.001365	8.44	13332.14	1778.75	0.32
Main	4986.6	40000.00	180.68	204.55	200.91	204.87	0.001414	8.72	14179.16	1779.94	0.33
Main	4986.6	60000.00	180.68	206.56	202.12	206.95	0.001641	9.97	17766.93	1785.72	0.36
Main	4515	100.00	180.11	182.69	181.32	182.74	0.001620	1.87	53.41	27.72	0.24
Main	4515	300.00	180.11	184.36	182.24	184.48	0.002119	2.77	108.14	37.79	0.29
Main	4515	500.00	180.11	185.42	182.96	185.59	0.002326	3.30	151.58	43.63	0.31
Main	4515	1000.00	180.11	187.29	184.27	187.55	0.002566	4.13	241.84	53.04	0.34
Main	4515	3000.00	180.11	191.42	187.37	192.02	0.002559	6.31	564.92	185.66	0.38
Main	4515	6000.00	180.11	195.26	190.02	195.80	0.001783	6.73	1611.39	555.56	0.34
Main	4515	10000.00	180.11	197.47	194.09	197.91	0.001526	6.95	3444.85	743.53	0.32
Main	4515	10500.00	180.11	197.72	194.29	198.15	0.001500	6.97	3643.71	831.59	0.32
Main	4515	20000.00	180.11	200.94	197.00	201.31	0.001365	7.57	7936.29	1616.35	0.31
Main	4515	25000.00	180.11	201.96	197.93	202.31	0.001338	7.78	9600.69	1625.23	0.31
Main	4515	36000.00	180.11	203.44	199.39	203.83	0.001529	8.73	11996.74	1633.00	0.34
Main	4515	40000.00	180.11	203.89	200.56	204.30	0.001598	9.06	12732.04	1634.67	0.35
Main	4515	60000.00	180.11	205.78	201.82	206.28	0.001914	10.50	15828.08	1640.32	0.39
Main	4072.4	100.00	179.15	180.32	180.32	180.74	0.036542	5.22	19.14	22.77	1.00
Main	4072.4	300.00	179.15	181.25	181.25	182.06	0.029994	7.23	41.48	25.52	1.00
Main	4072.4	500.00	179.15	181.94	181.94	183.02	0.027880	8.34	59.96	27.89	1.00
Main	4072.4	1000.00	179.15	183.28	183.28	184.81	0.025145	9.94	100.58	32.77	1.00
Main	4072.4	3000.00	179.15	186.57	186.57	189.33	0.020785	13.33	227.58	44.22	0.99
Main	4072.4	6000.00	179.15	190.93	190.93	193.96	0.011178	14.32	553.22	174.82	0.80
Main	4072.4	10000.00	179.15	194.21	194.21	196.51	0.007350	14.04	1577.26	394.15	0.68
Main	4072.4	10500.00	179.15	194.31	194.31	196.74	0.007744	14.49	1618.06	401.98	0.70

HEC-RAS Plan: TW_CC River: Crane Creek Reach: Main (Continued)

Reach	River Sta	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
		(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
Main	4072.4	20000.00	179.15	197.18	197.18	199.94	0.008607	17.39	2845.64	488.29	0.76
Main	4072.4	25000.00	179.15	198.93	198.93	201.11	0.006890	16.66	4277.70	1218.53	0.69
Main	4072.4	36000.00	179.15	200.63	200.63	202.58	0.006721	17.47	6667.18	1475.73	0.69
Main	4072.4	40000.00	179.15	200.98	200.98	202.99	0.007064	18.13	7190.32	1476.52	0.71
Main	4072.4	60000.00	179.15	202.42	202.42	204.74	0.008631	20.98	9309.06	1479.71	0.80

APPENDIX D

ACB AND TRM CALCULATIONS

Schnabel ENGINEERING

CALCULATION COVER SHEET

Project	Project Number
Woodlake Dam	17C21008

Title

ACB and TRM Calculations

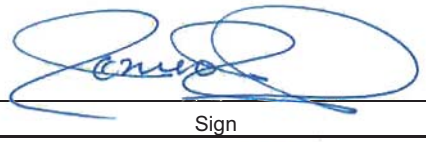
Computer Programs Used	Version/Release No.
HEC-RAS	5.0.3

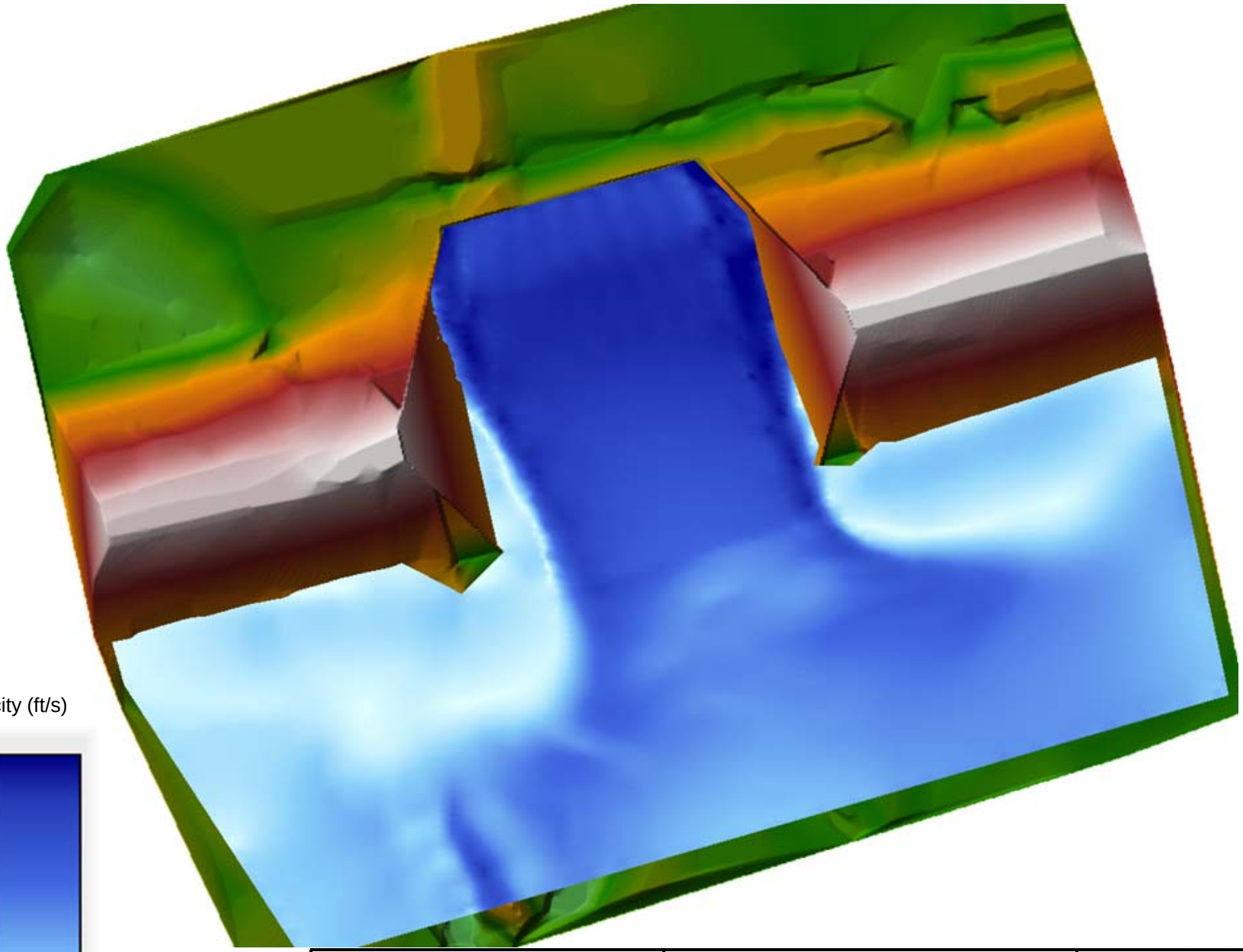
Purpose and Objective

To calculate the velocity going through the breach section using the 2D version of the HEC-RAS model, calculate the factor of safety for the ACBs, and select the appropriate ACB and TRM based on the results.

Summary of Conclusions

The velocity through the breach section varies between 10ft/s and 16ft/s. Using a velocity of 20ft/s and 4.75-inch, open celled, tapers blocks, the factor of safety is 3. The TRM selected can withstand velocities of 25 ft/s once vegetated.

Originator			
Maridee Romero-Graves			May 1, 2017
Print	Sign		Date
Checked			
Laura Shearin-Feimster			Apr 30, 2017
Print	Sign		Date



Schnabel ENGINEERING
SCHNABEL ENGINEERING SOUTH, P.C.

WOODLAKE DAM
WOODLAKE CC CORP.
MOORE COUNTY, NORTH CAROLINA
PROJECT NO. 17c21008.00

HEC-RAS 2D MODEL
VELOCITY THROUGH SPILLWAY
DATE: 04/28/2017

TEK 11-12
Factor of Safety Calculations
NCMA ACB Design Calculations

ACF Environmental
2831 Cardwell Road
Richmond, VA 23234
Phone: 1-800-271-2363

Project Design Parameters

V	20	Velocity (ft/sec)
τ	6.4	Design Shear (lb/ft^2)
S_b	0.02	Bed Slope (ft/ft)
SS	2	Side Slope (_H:1V)

Block Properties

ℓ_1	0.198	ft
ℓ_2	0.971	ft
ℓ_3	0.317	ft
ℓ_4	0.971	ft
W_b	65	lb
b	1.292	ft
τ_c	25.9	lb/ft^2
S_c	2.2	Sp. Gr.
ΔZ	0	in
SS	0.500	ft/ft
K_b	1	
L	1.45	ft
ρ	1.94	slugs/ft^3

θ_0 - Channel Bed Slope = 1.146 deg 0.020 rad

θ_1 - Channel Side Slope = 26.565 deg 0.464 rad

W_s - Submerged Block Weight

$W_s = W_b*(S_c-1)/S_c =$ 35.455 lbs

η_0 - Stability Number Horizontal Surface

$\eta_0 = \tau / \tau_c =$ 0.247

$F_D = F_L$ - Additional Lift & Drag Forces from ΔZ

$F_L = F_D = 0.5*\Delta Z*b*\rho*V^2 =$ 0.000 lbs

$a_\theta = (\cos^2(\theta_1) - \sin^2(\theta_0))^{0.5}$

$a_\theta =$ 0.894

$\theta = \arctan((\sin(\theta_0) * \cos(\theta_1))/(\sin(\theta_1)*\cos(\theta_0)$

$\theta =$ 2.291 deg 0.040 rad

$\beta = \text{Arctan}((\cos(\theta_0+\theta)/((\ell_4/\ell_3+1)*(1-a_\theta^2)^{0.5}/(\eta_0*\ell_2/\ell_1)+\sin(\theta_0+\theta))$

$\beta =$ 32.599 deg 0.569 rad

$\eta_1 = (\ell_4/\ell_3+\sin(\theta_0+\theta+\beta))/(\ell_4/\ell_3+1))*\eta_0$ = Stability Number for Sloped Surface

$\eta_1 =$ 0.222

$\delta = 90 - \beta - \theta$ - Angle between F_D and Block Motion

$\delta =$ 55.11 deg 0.962 rad

Factor of Safety

$FOS = (\ell_2/\ell_1*\theta_0) / ((1-a_\theta^2)^{0.5} * \cos(\beta) + \eta_1 * (\ell_2/\ell_1) + (\ell_3*F_D*\cos(\delta) + \ell_4 * F_L)/(\ell_1*W_s))$

FOS = **3.0**

Unit Recommended = SD 475 OCT

SHORETEC™ LLC
Preserving Our Natural Resources

PYRAMAT®

Product Data

PYRAMAT® 75 HPTRM

PYRAMAT® 75 high performance turf reinforcement mat (HPTRM) is a three-dimensional, lofty, woven polypropylene geotextile that is available in green or tan which is specially designed for erosion control applications on steep slopes and vegetated waterways. The matrix is composed of polypropylene monofilament yarns featuring X3® technology woven into a uniform configuration of resilient pyramid-like projections. The material exhibits very high interlock and reinforcement capacity with both soil and root systems, demonstrates superior UV resistance, and enhances seedling emergence.

PYRAMAT® 75 conforms to the property values listed below[1] and is manufactured at a Propex facility having achieved ISO 9001:2008 certification. Propex performs internal Manufacturing Quality Control (MQC) tests that have been accredited by the Geosynthetic Accreditation Institute – Laboratory Accreditation Program (GAI-LAP).

PROPERTY	TEST METHOD	ENGLISH	METRIC
ORIGIN OF MATERIALS			
% U.S. Manufactured		100%	100%
PHYSICAL			
Mass/Unit Area [2]	ASTM D-6566	13.5 oz/yd²	458 g/m²
Thickness [2]	ASTM D-6525	0.40 in	10.2 mm
Light Penetration (% Passing) [3]	ASTM D-6567	10%	10%
Color	Visual	Green or Tan	
MECHANICAL			
Tensile Strength [2]	ASTM D-6818	4000 x 3000 lbs/ft	58.4 x 43.8 kN/m
Elongation [2]	ASTM D-6818	40 x 35 %	40 x 35 %
Resiliency [2]	ASTM D-6524	80%	80%
Flexibility [4]	ASTM D-6575	0.534 in-lb	616,154 mg-cm
ENDURANCE			
UV Resistance % Retained at 3,000 hrs [4]	ASTM D-4355	90%	90%
UV Resistance % Retained at 6,000 hrs [4]	ASTM D-4355	90%	90%
PERFORMANCE			
Velocity (Vegetated) [4, 5]	Large Scale	25 ft/sec	7.6 m/sec
Shear Stress (Vegetated) [4, 5]	Large Scale	16 lb/ft²	766 Pa
Manning's n (Unvegetated) [4, 6]	Calculated	0.028	0.028
Seedling Emergence [4]	ASTM D-7322	296%	296%
ROLL SIZES		8.5 ft x 120 ft 15.0 ft x 120 ft	2.6 m x 36.6 m 4.6 m x 36.6 m

NOTES:

1. The property values listed above are effective 02/08/2017 and are subject to change without notice.
2. Minimum average roll values (MARV) are calculated as the typical minus two standard deviations. Statistically, it yields a 97.7% degree of confidence that any samples taken from quality assurance testing will exceed the value reported.
3. Maximum Average Roll Value (MaxARV), calculated as the typical plus two standard deviations. Statistically, it yields a 97.7% degree of confidence that any sample taken during quality assurance testing will meet to the value reported.
4. Typical Value.
5. Maximum permissible velocity and shear stress has been obtained through vegetated testing programs featuring specific soil types, vegetation classes, flow conditions, and failure criteria. These conditions may not be relevant to every project nor are they replicated by other manufacturers. Please contact Propex for further information.
6. Calculated as typical values from large-scale flexible channel lining test programs with a flow depth of 6 to 12 inches.

Propex GEOSOLUTIONS

ENGINEERED EARTH ARMORING SOLUTIONS™

www.propexglobal.com

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WOODLAKE DAM BREACH

PREPARED FOR

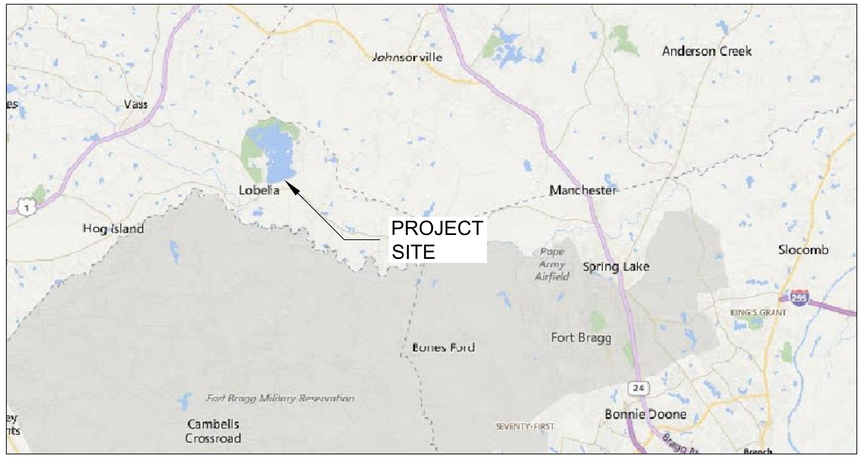
WOODLAKE CC CORP

VASS, NORTH CAROLINA

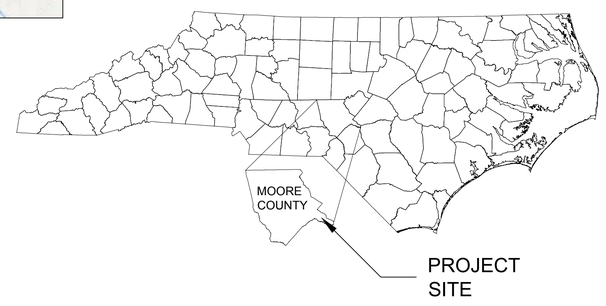
PREPARED BY

SCHNABEL ENGINEERING SOUTH, PC

VICINITY MAP



LOCATION MAP



REV	DESCRIPTION	DATE

DESIGNED BY: RTI
DRAWN BY: AYA
CHECKED BY: RTI

ROBERT T. INDRI, P.E.
DATE:
STATE PROFESSIONAL ENGINEER 037419

NORTH CAROLINA PROFESSIONAL SEAL 037419 ENGINEER ROBERT T. INDRI

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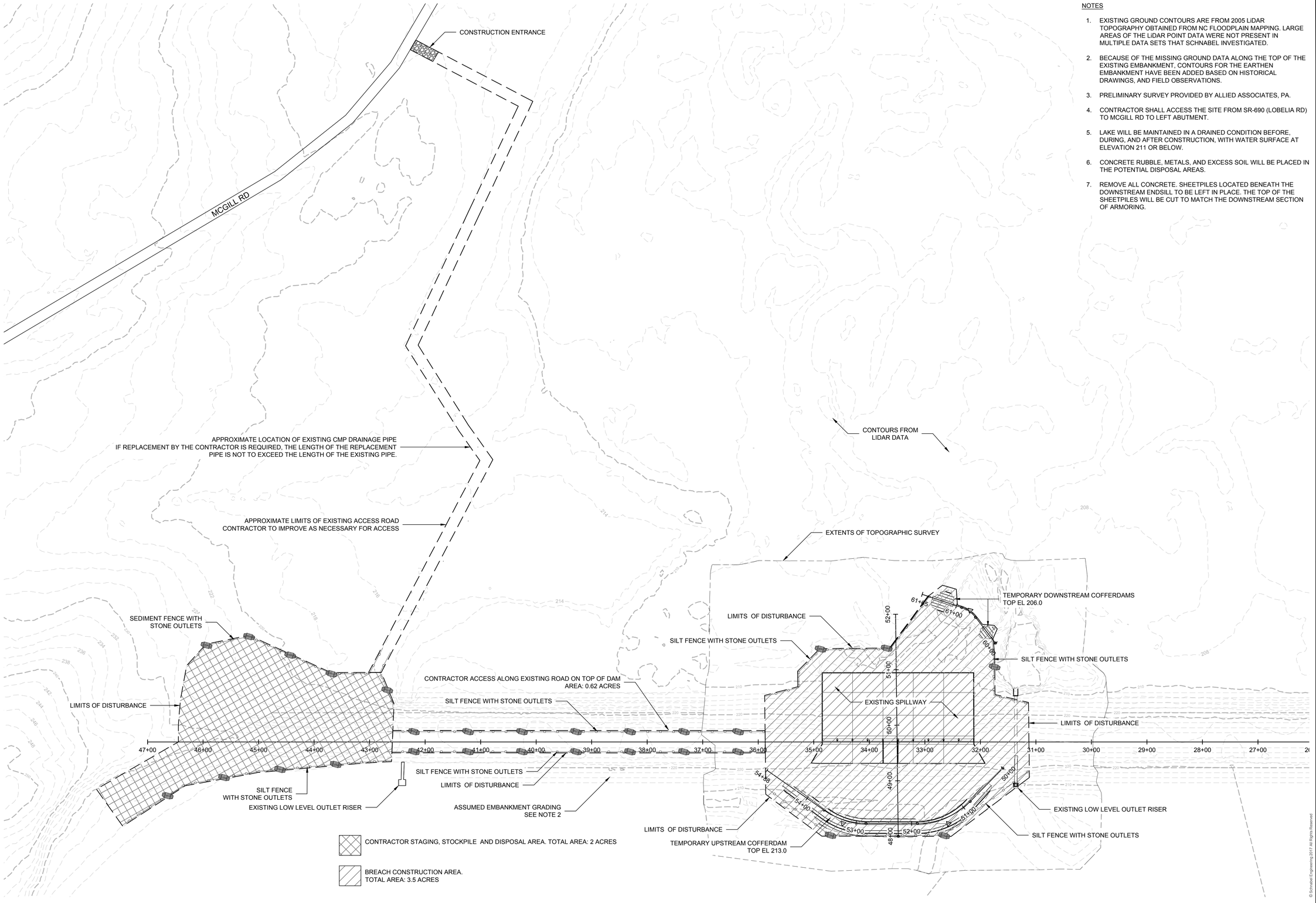
WOODLAKE DAM BREACH
WOODLAKE CC CORP
VASS, NC

COVER SHEET

PROJECT: 17C21008.00
DATE: MAY 2017
DRAWING NO. 01
SHEET 1 OF 7



NOTES

1. EXISTING GROUND CONTOURS ARE FROM 2005 LiDAR TOPOGRAPHY OBTAINED FROM NC FLOODPLAIN MAPPING. LARGE AREAS OF THE LiDAR POINT DATA WERE NOT PRESENT IN MULTIPLE DATA SETS THAT SCHNABEL INVESTIGATED.
2. BECAUSE OF THE MISSING GROUND DATA ALONG THE TOP OF THE EXISTING EMBANKMENT, CONTOURS FOR THE EARTHEN EMBANKMENT HAVE BEEN ADDED BASED ON HISTORICAL DRAWINGS, AND FIELD OBSERVATIONS.
3. PRELIMINARY SURVEY PROVIDED BY ALLIED ASSOCIATES, PA.
4. CONTRACTOR SHALL ACCESS THE SITE FROM SR-690 (LOBELIA RD) TO MCGILL RD TO LEFT ABUTMENT.
5. LAKE WILL BE MAINTAINED IN A DRAINED CONDITION BEFORE, DURING, AND AFTER CONSTRUCTION, WITH WATER SURFACE AT ELEVATION 211 OR BELOW.
6. CONCRETE RUBBLE, METALS, AND EXCESS SOIL WILL BE PLACED IN THE POTENTIAL DISPOSAL AREAS.
7. REMOVE ALL CONCRETE. SHEETPILES LOCATED BENEATH THE DOWNSTREAM ENDSILL TO BE LEFT IN PLACE. THE TOP OF THE SHEETPILES WILL BE CUT TO MATCH THE DOWNSTREAM SECTION OF ARMORING.

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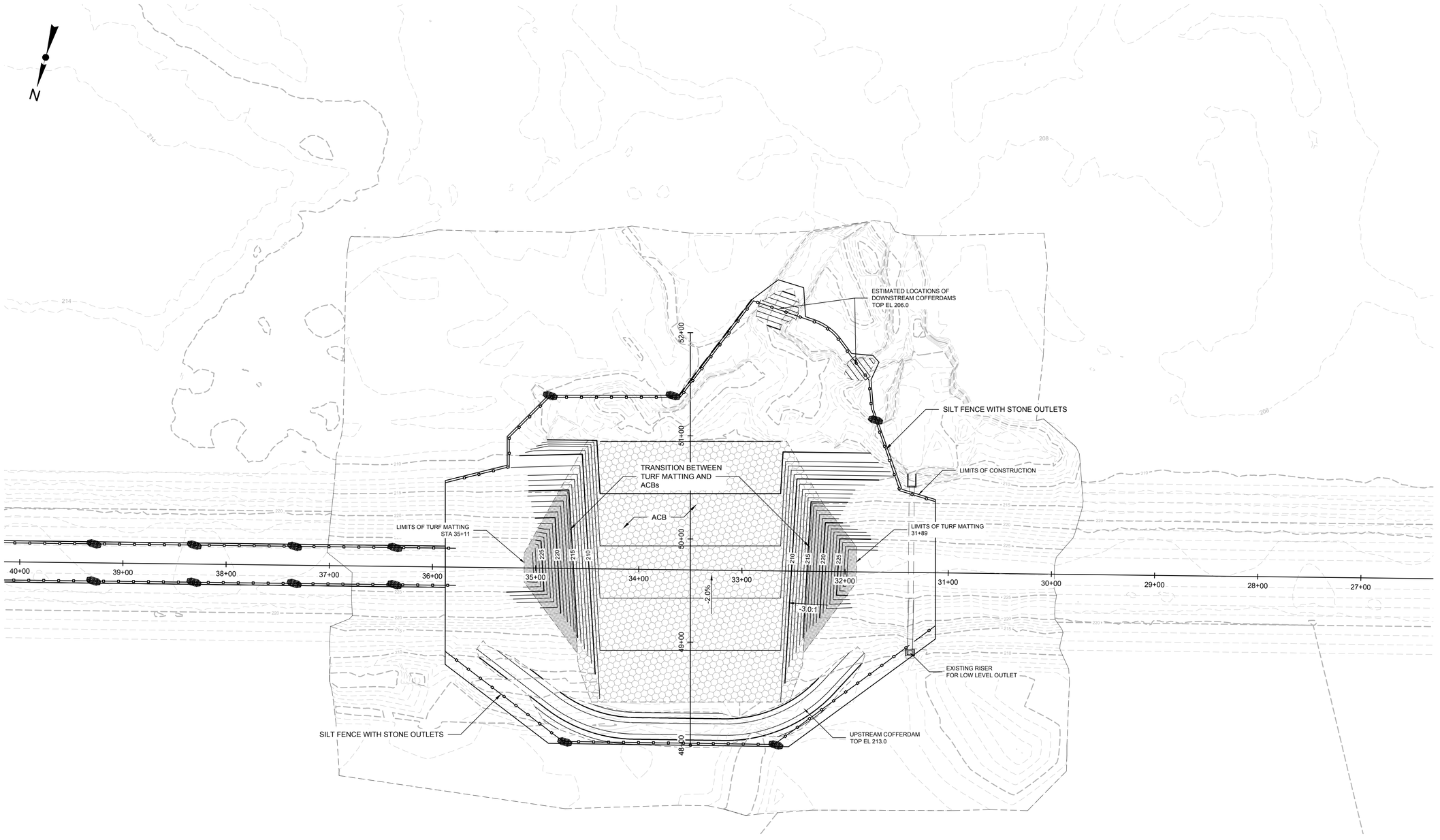
WOODLAKE DAM BREACH
WOODLAKE CC CORP
VASS, NC

SITE ACCESS AND EROSION AND SEDIMENT CONTROL

PROJECT: 17C21008.00
DATE: MAY 2017
DRAWING NO. 02
SHEET 2 OF 7



1 BREACH PLAN

SCALE: 1"=50'

0 50' 100'

ARTICULATED CONCRETE BLOCK EXTENTS

TURF MATTING EXTENTS

REV	DESCRIPTION	DATE

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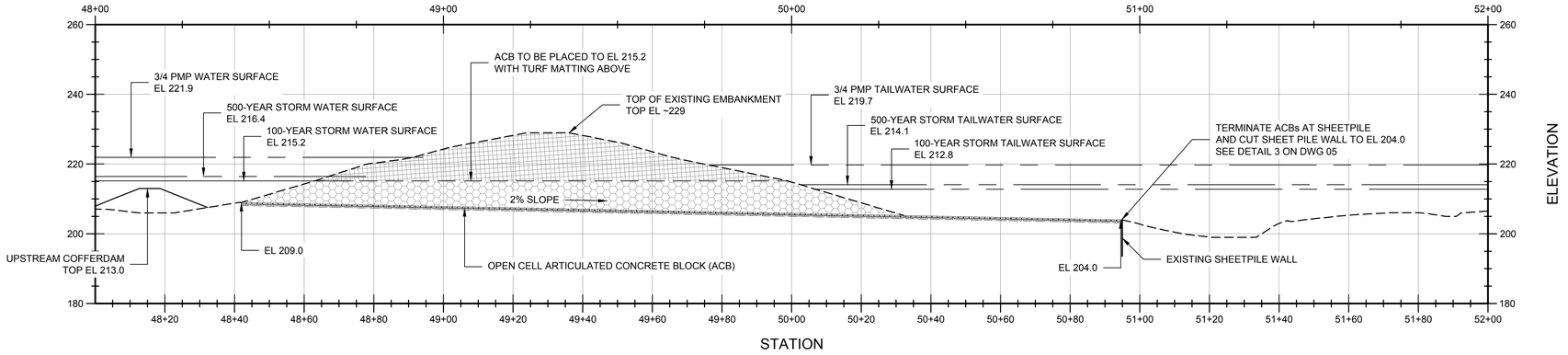
WOODLAKE DAM BREACH
WOODLAKE CC CORP
VASS, NC

BREACH PLAN AND ARMORING

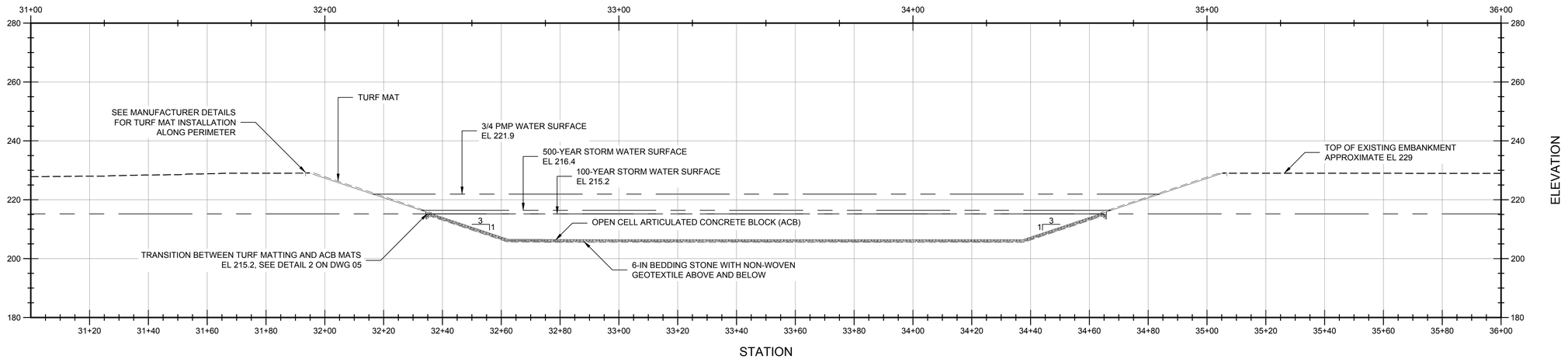
PROJECT: 17C21008.00
DATE: MAY 2017
DRAWING NO. 03
SHEET 3 OF 7



1/03 BREACH PROFILE

SCALE: 1"=20'

0 20' 40'



2/03 SECTION AT CENTERLINE OF EXISTING EMBANKMENT

SCALE: 1"=20'

0 20' 40'

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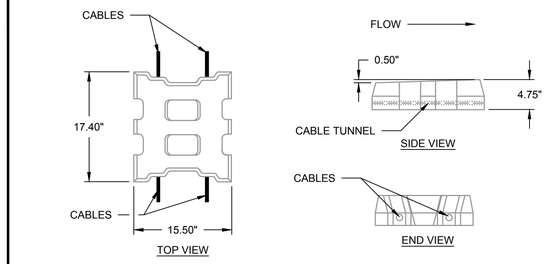
WOODLAKE DAM BREACH
WOODLAKE CC CORP
VASS, NC

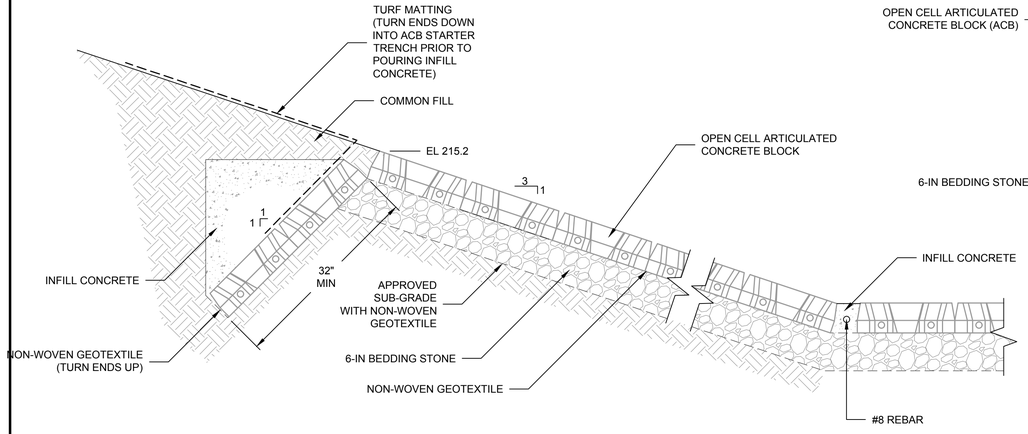
BREACH PROFILE AND SECT

PROJECT: 17C21008.00
DATE: MAY 2017
DRAWING NO. 04
SHEET 4 OF 7



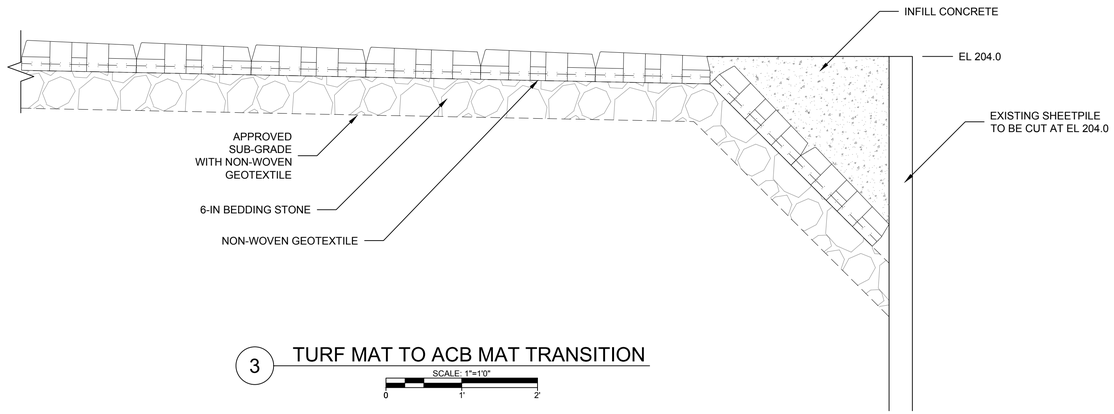
1 OPEN CELL ARTICULATED BLOCK (ACB)

SCALE: 1"=1'0"



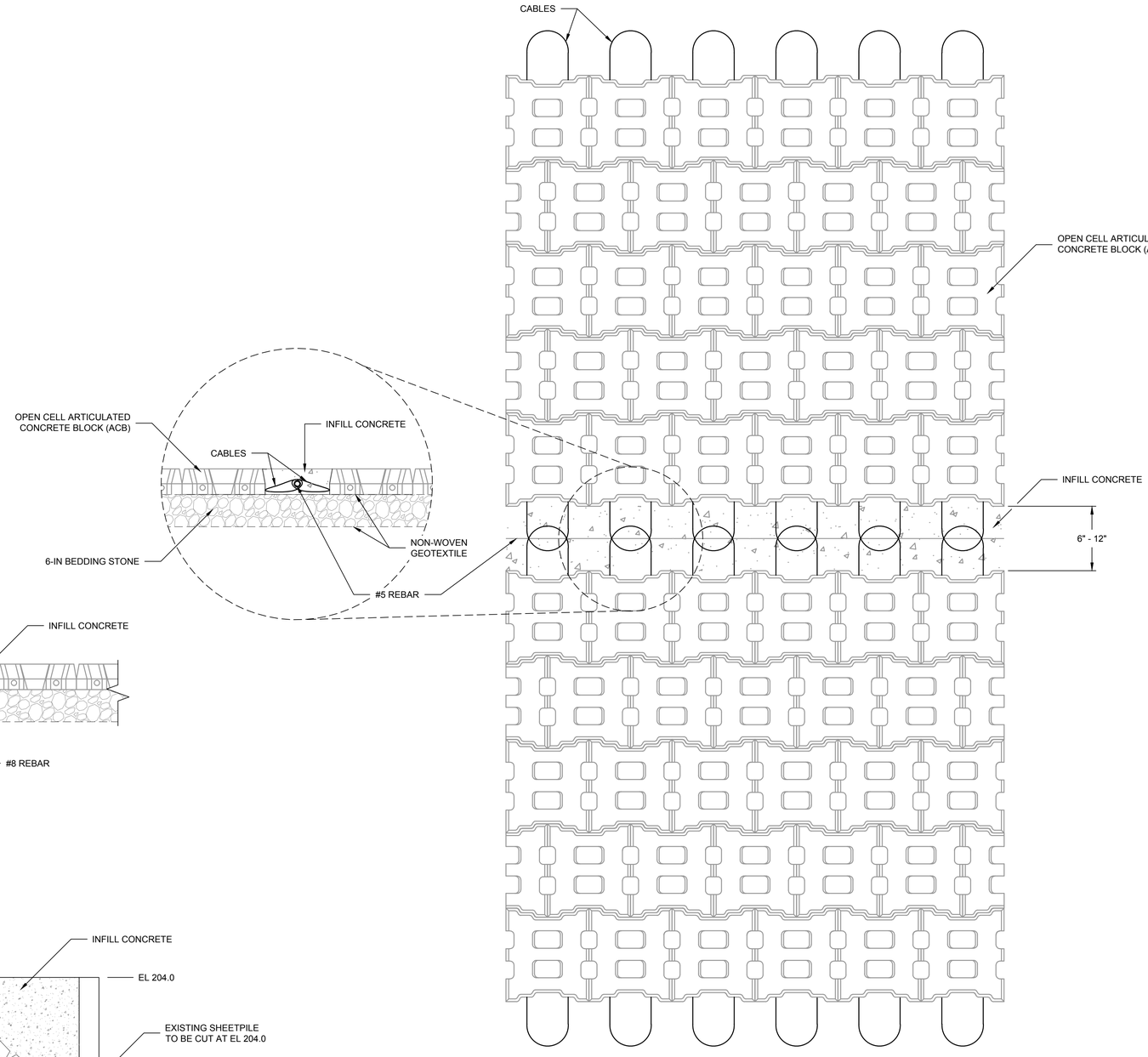
2 TURF MAT TO ACB MAT TRANSITION

SCALE: 1"=1'0"



3 TURF MAT TO ACB MAT TRANSITION

SCALE: 1"=1'0"



4 MAT TO MAT CONNCECTION

SCALE: 1"=1'0"

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WOODLAKE DAM BREACH
WOODLAKE CC CORP
VASS, NC

ARTICULATED CONCRETE BLOCK DETAILS

PROJECT: 17C21008.00
DATE: MAY 2017
DRAWING NO. 05
SHEET 5 OF 7

GROUND STABILIZATION TIMELINE REQUIREMENTS

SITE AREA DESCRIPTION	STABILIZATION TIME FRAME	STABILIZATION TIME FRAME EXCEPTIONS
PERIMETER DIKES, SWALES, DITCHES AND SLOPES	7 DAYS	NONE
HIGH QUALITY WATER (HQW) ZONES	7 DAYS	NONE
SLOPES STEEPER THAN 3:1	7 DAYS	IF SLOPES ARE 10-FT OR LESS IN LENGTH AND ARE NOT STEEPER THAN 2:1, 14 DAYS IS ALLOWED.
SLOPES 3:1 OR FLATTER	14 DAYS	7-DAYS FOR SLOPES GREATER THAN 50 FEET IN LENGTH
ALL OTHER AREAS WITH SLOPES FLATTER THAN 4:1	14 DAYS	NONE (EXCEPT FOR PERIMETERS AND HQW ZONES)

THIS CHART WAS INTERPRETED FROM *STATE OF NORTH CAROLINA DEPARTMENT OF ENVIRONMENT AND NATURAL RESOURCES DIVISION OF WATER QUALITY GENERAL PERMIT - NCG 010000.* PERSON(S) RESPONSIBLE FOR EROSION CONTROL WILL REFER TO *GENERAL PERMIT - NCG 01000.*

GENERAL SEEDING NOTES:

1. IF WORK IN DISTURBED AREAS STOPS FOR MORE THAN 7 WORKING DAYS ON THE DAM SLOPES OR 14 WORKING DAYS ON THE DAM CREST, TEMPORARY SEEDING SHALL BE APPLIED TO STABILIZE THE AREA.
2. COMPLETE GRADING BEFORE PREPARING SEEDBEDS, AND INSTALL ALL NECESSARY EROSION CONTROL PRACTICES SUCH AS, DIKES, WATERWAYS, AND BASINS. MINIMIZE STEEP SLOPES BECAUSE THEY MAKE SEEDBED PREPARATION DIFFICULT AND INCREASE THE EROSION HAZARD.
3. TILL OR DISC THE PREPARED AREAS TO BE SEEDED TO A MINIMUM DEPTH OF FOUR (4) INCHES. REMOVE ALL STONES LARGER THAN THREE (3) INCHES ON ANY SIDE, STICKS, ROOTS, AND OTHER EXTRANEOUS MATERIALS AT THE SURFACE DURING THE BED PREPARATION.
4. RECOMPACT THE AREA USING A CULTIPACKER ROLLER. THE FINISHED GRADE SHALL BE A SMOOTH, EVEN SOIL SURFACE WITH A LOOSE, UNIFORMLY FINE TEXTURE. ALL RIDGES AND DEPRESSIONS SHALL BE REMOVED AND FILLED TO PROVIDE THE APPROVED SURFACE DRAINAGE. SEEDING OF GRADED AREAS IS TO BE DONE IMMEDIATELY AFTER FINISHED GRADES ARE OBTAINED AND SEEDBED PREPARATION IS COMPLETED
5. REFERTILIZE IF GROWTH IS NOT FULLY ADEQUATE. RESEED, REFERTILIZE AND MULCH IMMEDIATELY FOLLOWING REPAIR OF EROSION DAMAGE.

TEMPORARY SEEDING:

LIME: BASED ON SOIL TEST OR 1 TO 1.5 TONS/ACRE ON COARSE TEXTURED SOILS OR 2-3 TONS ON FINE-TEXTURED SOILS. APPLY LIMESTONE UNIFORMLY AND INCORPORATE INTO THE TOP 4-6 INCHES OF SOIL. SOILS WITH A PH OF 6 OR HIGHER NEED NOT BE LIMED.

FERTILIZER: BASED ON SOIL TESTS. APPLY 10-10-10 GRADE FERTILIZER AT 700-1000 LBS/ACRE AND INCORPORATE INTO THE TOP 4-6 INCHES OF SOIL. IF A HYDRAULIC SEEDER IS USED, DO NOT MIX SEED AND FERTILIZER MORE THAN 30 MINUTES BEFORE APPLICATION.

MULCH: MULCH SHALL BE CLEAN STRAW AT 4000LBS/ACRE STRAW. ANCHORED WITH TACKING AGENT APPROVED BY CONTRACTOR. APPROVED METHODS ARE ASPHALT, NETTING, OR A MULCH ANCHORING TOOL. A DISK WITH BLADES SET NEARLY STRAIGHT CAN BE USED AS AN ANCHORING TOOL.

LATE WINTER AND EARLY SPRING	DATES:	SEED TYPES:	SEEDING RATE:
MOUNTAINS (> 2500 FT)	FEB 15-MAY 15	RYE GRAIN	120 LBS/AC
MOUNTAINS (< 2500 FT)	FEB 1-MAY 1	ANNUAL LESPEDEZA*	50 LBS/AC
PIEDMONT	JAN 1 - MAY 1		
COASTAL PLAIN	DEC 1-APR 15		
SUMMER	**DATES:**	**SEED TYPES:**	**SEEDING RATE:**
MOUNTAINS	MAY 15-AUG 15	GERMAN MILLET	40 LBS/AC
PIEDMONT	MAY 1-AUG 15		
COASTAL PLAIN	APR 15-AUG 15		
FALL	**DATES:**	**SEED TYPES:**	**SEEDING RATE:**
MOUNTAINS	AUG 15 - DEC 15	RYE (GRAIN)	120 LBS/AC
PIEDMONT	AUG 15 - DEC 30		
COASTAL PLAIN	AUG 15 - DEC 30		

*KOBE IN PIEDMONT AND COASTAL PLAIN, KOREAN IN MOUNTAINS

MAINTENANCE

REFERTILIZE IF GROWTH IS NOT FULLY ADEQUATE. RESEED AND MULCH AREAS WHERE SEEDLING EMERGENCE IS POOR, OR WHERE EROSION OCCURS, AS SOON AS POSSIBLE. DO NOT MOW. PROTECT FROM TRAFFIC AS MUCH AS POSSIBLE.

PERMANENT SEEDING:

LIME: BASED ON SOIL TEST OR 2 TONS/ACRE

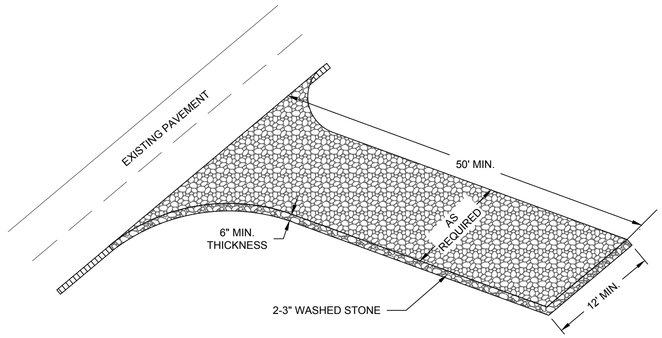
FERTILIZER: BASED ON SOIL TEST OR 1000 LBS/ACRE OF 5-10-10 FERTILIZER

SEED TYPES:	SEEDING DATES:	SEEDING RATES: (POUNDS/ACRE):
TALL FESCUE	SEP 30 - MAR 15	100
RED TOP		5
GERMAN MILLET	APRIL 15 - AUG 15	10
RYE (GRAIN)	AUG 15 - APR 15	40

MULCH:

TYPE AND RATE OF APPLICATION: CLEAN STRAW AT 2 TONS/ACRE

METHOD OF ANCHORING: ANCHORED WITH TACKING AGENT APPROVED BY OWNER.



1 CONSTRUCTION ENTRANCE
NOT TO SCALE

CONSTRUCTION NOTES:

1. CLEAR THE ENTRANCE AND EXIT AREA OF ALL VEGETATION, ROOTS, AND OTHER OBJECTIONABLE MATERIAL AND GRADE PROPERLY.
2. PLACE FILTER FABRIC OVER CLEARED AREA.
3. PLACE WASHED STONE TO THE SPECIFIC GRADE AND DIMENSIONS SHOWN ON THE PLANS AND SMOOTH IT.
4. PROVIDE DRAINAGE TO CARRY WATER TO A SUITABLE OUTLET.

MAINTENANCE NOTES:

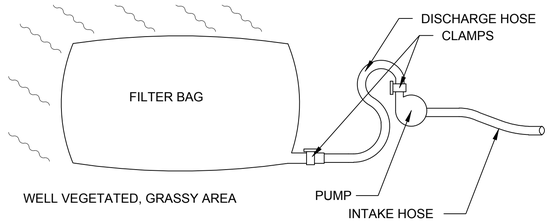
1. MAINTAIN THE STONE PAD IN A CONDITION TO PREVENT MUD OR SEDIMENT FROM LEAVING THE CONSTRUCTION SITE. THIS MAY REQUIRE PERIODIC TOP DRESSING WITH 2-INCH STONE.
2. AFTER EACH RAINFALL, INSPECT ANY STRUCTURE USED TO TRAP SEDIMENT AND CLEAN IT OUT AS NECESSARY.
3. IMMEDIATELY REMOVE ALL OBJECTIONABLE MATERIALS SPILLED, WASHED, OR TRACKED ONTO PUBLIC ROADWAYS.

NOTES

1. COARSE AGGREGATE: 2-3 INCH WASHED STONE
2. MINIMUM THICKNESS: 6 INCHES
3. MINIMUM LENGTH: 50 FEET
4. MINIMUM WIDTH: 25 FEET
5. GEOTEXTILE: REQUIRED TO SEPARATE COARSE AGGREGATE FROM SUBGRADE
6. MAINTAIN TO PREVENT TRANSPORT OF SEDIMENT ONTO PUBLIC ROADS. PLACE ADDITIONAL COARSE AGGREGATE AS CONDITIONS DEMAND.

FILTER BAG NOTES:

1. USE FILTER BAGS AS NECESSARY TO TREAT WATER PUMPED FROM EXCAVATION.
2. PLACE FILTER BAGS IN WELL VEGETATED AREAS UPSTREAM OF ADDITIONAL EROSION AND SEDIMENT CONTROL MEASURES SUCH AS SEDIMENT TRAPS.



2 SEDIMENT FILTER BAG DETAIL
NOT TO SCALE

NOTIFICATION OF LAND RESOURCES SEDIMENT AND EROSION CONTROL SELF-INSPECTION PROGRAM:

THE SEDIMENTATION POLLUTION CONTROL ACT WAS AMENDED IN 2006 TO REQUIRE THAT PERSONS RESPONSIBLE FOR LAND-DISTURBING ACTIVITIES INSPECT A PROJECT AFTER EACH PHASE OF THE PROJECT TO MAKE SURE THAT THE APPROVED EROSION AND SEDIMENTATION CONTROL PLAN IS BEING FOLLOWED. RULES DETAILING THE DOCUMENTATION OF THESE INSPECTIONS TOOK EFFECT OCTOBER 1, 2010. THE SELF-INSPECTION PROGRAM IS SEPARATE FROM THE WEEKLY SELF-MONITORING PROGRAM OF THE NPDES STORMWATER PERMIT FOR CONSTRUCTION ACTIVITIES. THE FOCUS OF THE SELF-INSPECTION REPORT IS THE INSTALLATION AND MAINTENANCE OF EROSION AND SEDIMENTATION CONTROL MEASURES ACCORDING TO THE APPROVED PLAN. THE INSPECTIONS MUST BE CONDUCTED AFTER EACH PHASE OF THE PROJECT, AND CONTINUED UNTIL PERMANENT GROUND COVER IS ESTABLISHED IN ACCORDANCE WITH NCGS 113A-54.1 AND 15A NCAC 4B.0131. THE SELF-INSPECTION REPORT FORM IS AVAILABLE AS AN EXCEL SPREADSHEET FROM HTTP://PORTAL.NCDENR.ORG/WEB/LR/EROSION.

IF YOU HAVE QUESTIONS OR CANNOT ACCESS THE FORM, PLEASE CONTACT THIS OFFICE AT (910) 433-3300..

SUMMARY OF DISTURBED AREAS	
DISTURBED AREA	AREA (AC)
CONSTRUCTION STAGING, STOCKPILE, AND DISPOSAL AREA	2 AC
CONSTRUCTION ACCESS ALONG EXISTING ROAD AND TOP OF DAM	0.62 AC
BREACH CONSTRUCTION AREA	3.5 AC
TOTAL	6.12 AC

GENERAL NOTE:

1. THESE SPECIFICATIONS WERE REFERENCED FROM THE NC EROSION AND SEDIMENT CONTROL PLANNING AND DESIGN MANUAL, REVISED 2013.

DATE | DESCRIPTION | REV

DESIGNED BY: RTI
DRAWN BY: AYA
CHECKED BY: RTI

ROBERT T. INDRI, P.E.
DATE:
STATE PROFESSIONAL ENGINEER 037419

NORTH CAROLINA PROFESSIONAL SEAL 037419 ENGINEER ROBERT T. INDRI

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WOODLAKE DAM BREACH
WOODLAKE CC CORP
VASS, NC

EROSION & SEDIMENT CONTROL DETAILS - 1 OF 2

PROJECT: 17C21008.00
DATE: MAY 2017
DRAWING NO. 06
SHEET 6 OF 7

MATERIALS:

1. USE A SYNTHETIC FILTER FABRIC OF AT LEAST 95% BY WEIGHT OF POLYOLEFINS OR POLYESTER, WHICH IS CERTIFIED BY THE MANUFACTURER OR SUPPLIER AS CONFORMING TO THE REQUIREMENTS IN ASTM D 6461, WHICH IS SHOWN IN PART BELOW. SYNTHETIC FILTER FABRIC SHOULD CONTAIN ULTRAVIOLET RAY INHIBITORS AND STABILIZERS TO PROVIDE A MINIMUM OF 6 MONTHS OF EXPECTED USABLE CONSTRUCTION LIFE AT A TEMPERATURE RANGE OF 0 TO 120°F.

TEMPORARY SILT FENCE MATERIAL PROPERTY REQUIREMENTS

	TEST MATERIAL	UNITS	SUPPORTED[1] SILT FENCE	UNSUPPORTED[1] SILT FENCE	TYPE OF VALUE
GRAB STRENGTH	ASTM D 4632	N (LBS)			
MACHINE DIRECTION			400	550	MARV
			(90)	(90)	
X-MACHINE DIRECTION			400	450	MARV
			(90)	(90)	
PERMITTIVITY[2]	ASTM D 4491	SEC-1	0.05	0.05	MARV
APPARENT OPENING SIZE[2]	ASTM D 4751	MM	0.60	0.60	MAX. ARV[3]
		(US SIEVE #)	(30)	(30)	
ULTRAVIOLET STABILITY	ASTM D 4355	% RETAINED STRENGTH	70% AFTER 500 HOURS OF EXPOSURE	70% AFTER 500 HOURS OF EXPOSURE	TYPICAL

1 SILT FENCE SUPPORT SHALL CONSIST OF 14 GAUGE STEEL WIRE WITH A MESH SPACING OF 150 MM (6 INCHES), OR PREFABRICATED POLYMER MESH OF EQUIVALENT STRENGTH.
2 THESE DEFAULT VALUES ARE BASED ON EMPIRICAL EVIDENCE WITH A VARIETY OF SEDIMENT. FOR ENVIRONMENTALLY SENSITIVE AREAS, A REVIEW OF PREVIOUS EXPERIENCE AND/OR SITE OR REGIONALLY SPECIFIC GEOTEXTILE TESTS IN ACCORDANCE WITH ASTM D 5141 SHOULD BE PERFORMED TO CONFIRM SUITABILITY OF THESE REQUIREMENTS.
3 AS MEASURED IN ACCORDANCE WITH ASTM D 4632.

2. POSTS FOR SEDIMENT FENCES SHALL BE 1.33 LB/LINEAR FT STEEL WITH A MINIMUM LENGTH OF 5 FT. POSTS SHALL HAVE PROJECTIONS TO FACILITATE FASTENING THE FABRIC.

3. FOR REINFORCEMENT OF STANDARD STRENGTH FILTER FABRIC, USE WIRE FENCE WITH A MINIMUM 14 GAUGE AND A MAXIMUM MESH SPACING OF 6 INCHES.

CONSTRUCTION NOTES:

1. ENSURE THAT THE HEIGHT OF THE SEDIMENT FENCE DOES NOT EXCEED 24 INCHES ABOVE THE GROUND SURFACE.

2. CONSTRUCT THE FILTER FABRIC FROM A CONTINUOUS ROLL CUT TO THE LENGTH OF THE BARRIER TO AVOID JOINTS. WHEN JOINTS ARE NECESSARY, SECURELY FASTEN THE FILTER FABRIC ONLY AT A SUPPORT POST WITH 4 FEET MINIMUM OVERLAP TO THE NEXT POST.

3. SUPPORT STANDARD STRENGTH FILTER FABRIC BY WIRE MESH FASTENED SECURELY TO THE UPSLOPE SIDE OF THE POSTS USING TIE WIRES. EXTEND THE WIRE MESH SUPPORT TO THE BOTTOM OF THE TRENCH. FASTEN THE WIRE REINFORCEMENT, THEN FABRIC ON THE UPSLOPE SIDE OF THE FENCE POST. WIRE OR PLASTIC ZIP TIES SHALL HAVE A MINIMUM 50-POUND TENSILE STRENGTH.

4. SPACE POSTS A MAXIMUM OF 6 FT FOR UNSUPPORTED SEDIMENT FENCE AND 8 FT FOR SUPPORTED SEDIMENT FENCE. SUPPORT POSTS SHOULD BE DRIVEN SECURELY INTO THE GROUND TO A MINIMUM OF 24 INCHES.

5. INSTALL STONE OUTLETS IN ALL LOW LYING AREAS AND SWALES AND AT A MINIMUM SPACING OF EVERY 100 FT OTHERWISE.

6. EXCAVATE A TRENCH APPROXIMATELY 4 INCHES WIDE AND 8 INCHES DEEP ALONG THE PROPOSED LINE OF POSTS AND UPSLOPE FROM THE BARRIER.

7. PLACE 12 INCHES OF THE FABRIC ALONG THE BOTTOM AND SIDE OF THE TRENCH.

8. BACKFILL THE TRENCH WITH STONE PLACED OVER THE FILTER FABRIC AND COMPACT.

9. DO NOT ATTACH FILTER FABRIC TO EXISTING TREES.

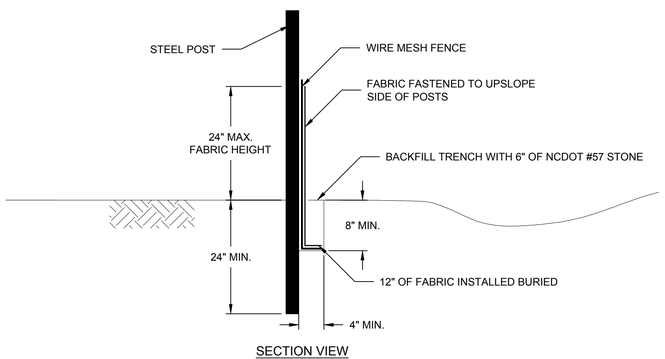
MAINTENANCE NOTES:

1. INSPECT SEDIMENT FENCES AT LEAST ONCE A WEEK AND AFTER EACH SIGNIFICANT RAINFALL EVENT (1/2 INCH OR GREATER). MAKE ANY REQUIRED REPAIRS IMMEDIATELY.

2. SHOULD THE FABRIC OF A SEDIMENT FENCE COLLAPSE, TEAR, DECOMPOSE OR BECOME INEFFECTIVE, REPLACE IT PROMPTLY.

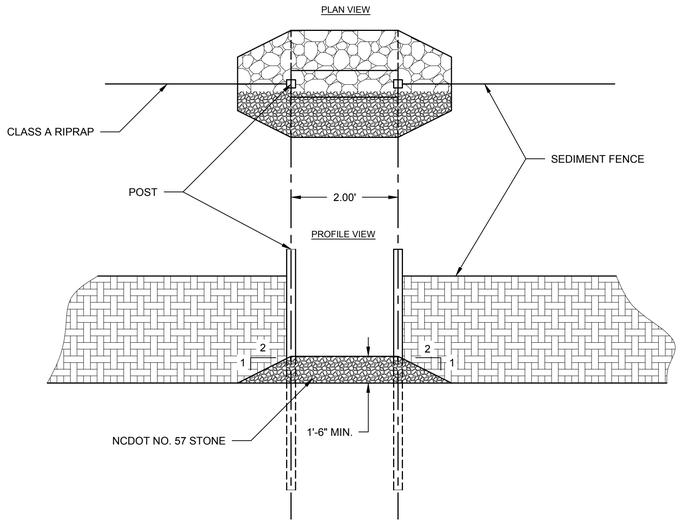
3. REMOVE SEDIMENT DEPOSITS AS NECESSARY TO PROVIDE ADEQUATE STORAGE VOLUME FOR THE NEXT RAIN AND TO REDUCE PRESSURE ON THE FENCE. TAKE CARE TO AVOID UNDERMINING THE FENCE DURING CLEANOUT.

4. REMOVE ALL FENCING MATERIALS AND UNSTABLE SEDIMENT DEPOSITS AND BRING THE AREA TO GRADE AND STABILIZE IT AFTER THE CONTRIBUTING DRAINAGE AREA HAS BEEN PROPERLY STABILIZED WITH SEED AND MULCH.



SECTION VIEW

1 TYPICAL SEDIMENT FENCE DETAIL (SF)
NOT TO SCALE



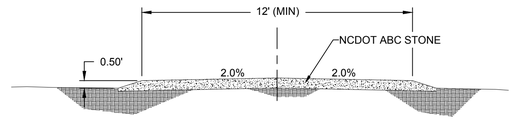
SEDIMENT FENCE OUTLET MAINTENANCE NOTES:

1. INSPECT SEDIMENT FENCE OUTLETS WEEKLY AND AFTER EACH SIGNIFICANT (1/2 INCH OR GREATER) RAINFALL EVENT AND REPAIR IMMEDIATELY.

2. CLEAN OUT SEDIMENT, STRAW, LIMBS OR OTHER DEBRIS THAT COULD CLOG THE SEDIMENT FENCE OUTLET WHEN HALF OF THE SEDIMENT FENCE OUTLET IS COVERED.

3. REPLACE STONE AS NEEDED TO ENSURE DEWATERING.

2 SEDIMENT FENCE OUTLET DETAIL
NOT TO SCALE



3 TEMPORARY ACCESS ROAD DETAIL
NOT TO SCALE

GENERAL NOTE:

1. THESE SPECIFICATIONS WERE REFERENCED FROM THE NC EROSION AND SEDIMENT CONTROL PLANNING AND DESIGN MANUAL, REVISED 2013.

DESCRIPTION | DATE | REV

DESIGNED BY: RTI
DRAWN BY: AYA
CHECKED BY: RTI

ROBERT T. INDRI, P.E.
DATE:
STATE PROFESSIONAL ENGINEER 037419

NORTH CAROLINA PROFESSIONAL SEAL 037419 ENGINEER ROBERT T. INDRI

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WOODLAKE DAM BREACH
WOODLAKE CC CORP
VASS, NC

EROSION & SEDIMENT CONTROL DETAILS - 2 OF 2

PROJECT: 17C21008.00
DATE: MAY 2017
DRAWING NO. 07
SHEET 7 OF 7

TECHNICAL SPECIFICATIONS

Woodlake Dam Breach
Vass, North Carolina

Project No. 17C21008
May 1, 2017

TECHNICAL SPECIFICATIONS
Woodlake Dam Breach
Vass, North Carolina

Project No. 17C21008
May 1, 2017

The signee below is responsible for the following specifications:

DIVISION 01 - GENERAL REQUIREMENTS

01 57 50	Surveying
01 57 60	Control of Water

DIVISION 02 - EXISTING CONDITIONS

02 41 16	Structure Demolition

DIVISION 03 - CONCRETE

03 30 01	Cast-in-Place Concrete for Minor Structures

DIVISION 31 - EARTHWORK

31 05 13	Soils for Earthworks
31 05 16	Aggregates for Earthworks
31 05 19	Geosynthetics for Earthwork
31 23 16	Excavation
31 23 23	Fill Placement
31 25 13	Erosion and Sedimentation Control
31 35 19.16	Turf Reinforcement
31 35 23	Articulating Concrete Block Revetments

Robert Indri, PE
NC Professional Engineer No. 037419

SECTION 01 57 50

SURVEYING

PART 1 GENERAL

1.1 SUMMARY

A. This Section addresses the requirements for surveying, including:
   1. Bench Marks and Primary Control
   2. Temporary Baselines and Controls
   3. Construction Surveys and Staking

B. Related Sections:
   1. Section 31 23 16 – Excavation

1.2 REFERENCES

A. Survey control will be provided by the ENGINEER.

1.3 SUBMITTALS

A. Prior to commencement of work requiring CONTRACTOR performed surveys, the CONTRACTOR shall submit in writing to the ENGINEER for approval the name, qualifications and experience of the individuals to be assigned to the survey tasks.

B. Record Survey Data in fully identified, standard hard-bound engineering survey field notebooks with consecutively numbered pages.

C. Include in Field notes and printed data the purpose or description of the work, the date the work was performed, weather data, sketches, personnel who performed and checked the work, and instruments used with serial numbers.

D. Electronically generated survey data and computations shall be bound, page numbered and cross referenced in a bound field notebook containing the index for all survey data.

E. Survey records shall be available at all times during the progress of the work for examination and use by the ENGINEER and copies shall be made available upon request.

F. Provide complete documentation of computations and supporting data for progress payments.

1.4 QUALITY REQUIREMENTS

A. All work shall follow recognized professional practice and the standards of the industry unless otherwise specified in this specification.

B. The work shall be performed to the accuracy and detail as indicated herein.

C. Notes, sketches, and other data shall be complete, recorded neatly, legible, reproducible and organized in a manner that will allow reproduction of copies for job documentation.

D. All computations shall be mathematically correct.

E. Computations shall include information to identify the bid item, date, and who performed, checked and approved the computations.

F. Computations shall be legible, complete and clearly document the source of all information used including assumptions and measurements made.

G. If a computer program is used to perform the computations, the CONTRACTOR shall provide the ENGINEER with the software identification, vender's name, version number, and other pertinent data, prior to beginning survey work.

H. Computer generated computations shall show all input data including values assigned and assumptions made.

I. All points shall be located with respect to the Datum specified on Construction Drawings.

J. The elevations of permanent and temporary bench marks shall be determined and recorded to the nearest 0.01 foot.

K. Vertical control surveys shall be of such precision that the error of vertical closure in feet shall not exceed 0.1 times the square root of the number of miles run from the reference datum.

L. Linear measurements shall be accurate to within 1.0 foot in 10,000 feet, unless otherwise specified in this specification.

M. The angular error of closure for transit traverses shall not exceed 20 seconds times the square root of the number of angles turned.

N. Unless otherwise specified, measurements for stationing and establishing the location of structures shall be made to the nearest 0.1 of a foot.

O. Elevations for concrete work, pipes and gate shall be determined and recorded to the nearest 0.01 foot.

P. Elevations for earth work shall be determined and recorded to the nearest 0.1 foot.

1.5 QUALIFICATIONS

A. All surveys shall be completed by professional staff licensed to practice surveying in the State of North Carolina.

PART 2 PRODUCTS

2.1 GENERAL

A. The CONTRACTOR shall be responsible for calculation of the quantity of required equipment, materials and supplies based on the Construction Drawings and other factors as identified by the CONTRACTOR.

B. The CONTRACTOR shall be responsible for all costs associated with delays or material quantity shortfalls due to miscalculations, or required re-work resulting from not meeting material or placement specifications.

2.2 EQUIPMENT AND SUPPLIES

A. CONTRACTOR shall be responsible for all equipment and supplies required for completion of the Work.

B. Ensure that equipment for construction surveys is of a quality and condition to provide the required accuracy.

C. Maintain equipment in good working order and in proper adjustment at all times.

D. Records of calibration tests, accuracy checks and adjustments shall be maintained and be available for inspection by the ENGINEER.

E. Material includes all the necessary field notebooks, stakes, templates, platforms, equipment, spikes, steel pins, tools, and all other items necessary to perform the work specified.

PART 3 EXECUTION

3.1 EXAMINATION

A. Verify condition of equipment and supplies.

3.2 PREPARATION

A. Determine location of benchmarks, baselines and other primary control points indicated on Construction Drawings or other documentation.

B. Plan installation of temporary control points on site in locations that will not interfere with or be damaged by construction activities.

C. Establish and coordinate marking and flagging systems with CONTRACTOR and ENGINEER to minimize confusion and miscommunication between various site activities.

3.3 PROTECTION

A. Ensure that control points are clearly identified in the field and adequate measures are taken to protect such points during the construction activities.

3.4 BENCHMARKS AND PRIMARY CONTROL POINTS

A. The benchmarks for primary control, necessary to establish lines and grades needed for construction will be provided to the CONTRACTOR.

B. These baselines and benchmarks shall be used as the origin of all surveys, layouts, and measurements to establish construction lines and grades. The CONTRACTOR shall take all necessary precautions to prevent the loss or damage of primary control points. Any stakes or control points lost or damaged by construction activity will be reestablished by the CONTRACTOR or at CONTRACTOR'S expense.

C. The CONTRACTOR shall rectify all Work improperly installed because of not maintaining, not protecting, or removing without authorization established reference points, stakes, marks, and monuments at no cost to the OWNER.

3.5 TEMPORARY BASELINES AND CONTROL POINTS

A. Temporary benchmarks, baselines, etc. shall be tied to the primary control points.

3.6 CONSTRUCTION SURVEYS

A. CONTRACTOR performed surveys shall consist of all work necessary for:
   1. Establishing lines and grades.
   2. Setting stakes as described in 3.7 below.
   3. Performing interim (post excavation), and final surveys for quantity determinations.
   4. Performing quantity surveys, measurements, and computations for progress payment if needed.
   5. Perform record survey drawings/verification. Record surveys shall be provided to ENGINEER upon Substantial Completion. CONTRACTOR shall maintain an on-going Record Drawing file and available to the ENGINEER for inspection. A final Record Drawing will be required for approval of Substantial Completion and Final Completion.
   6. Other surveys as needed.

B. Quantity surveys for measurement of excavation and fill placement quantities shall include surveyed cross-sections at the end of each area surveyed and spaced no more than 50 feet apart, at all changes in slope. Each cross-section shall have points located at the top and bottom of slopes, at all slope break lines, and intermediate points to ensure an accurate quantity survey.

3.7 STAKING

A. Prior to the commencement of work on any item the construction staking required for that item shall be completed.

B. Construction staking shall be completed as indicated herein, or as otherwise indicated on Construction Drawings or as directed by the ENGINEER.

C. Construction staking for excavation and backfill:
   1. Slope stakes shall be placed at the intersection of the specified slopes and ground line.
   2. Slope stakes or the reference stakes for slopes shall be marked with the stationing, required cut or fill, slope ratio and horizontal distance.
   3. Offset reference stakes and hubs shall be placed on at least one side of specified excavations and backfill.

D. Construction staking structures:
   1. Centerline and offset reference line stakes for location, alignment and elevation shall be placed for all structures.

END OF SECTION

SECTION 01 57 60

CONTROL OF WATER

PART 1 GENERAL

1.1 SUMMARY

A. This Section includes control of surface water as needed to perform the required construction, including:
   1. Designing, constructing, and maintaining a cofferdam to protect Spillway excavation and breach construction.
   2. Debris removal of Low Level Outlets prior to use in control of water.
   3. Furnishing, installing, operating, monitoring and maintaining all necessary pumps, piping and other facilities and equipment.
   4. Maintaining stream buffers, wetland protection, and turbidity requirements as defined in local, State, and Federal permits.
   5. Removing all temporary works and equipment after they have served their purposes.
   6. Complying with all applicable environmental protection laws and requirements in operating the components of the water control system and disposal of collected water and sediments.

B. Related Sections:
   1. Section 31 25 13 – Erosion and Sedimentation Control
   2. Section 31 23 16 – Excavation

1.2 DEFINITIONS
   1. none

1.3 DESIGN REQUIREMENTS

A. The CONTRACTOR shall construct cofferdams, to the elevations shown on the drawings.

1.4 PROJECT REQUIREMENTS AND CONSTRAINTS

A. Remove debris in front of the two low level outlets and check that gates are in a full open condition.

B. During construction of the breach, divert stream flows and stormwater runoff through the two low level outlets.

C. Remove debris that may accumulate in front of gates.

1.5 SUBMITTALS

none

1.6 QUALIFICATIONS

A. The Water Control Plan shall be completed by personnel with expertise in the appropriate technical disciplines.

B. The CONTRACTOR'S Engineer responsible for design of the Water Control Plan shall have at least 5 years of experience in responsible charge of Water Control Plan design that includes cofferdams and other diversion works similar in scope and size to the work specified herein.

PART 2 PRODUCTS

(NOT USED)

PART 3 EXECUTION

3.1 PROTECTION

A. Protect reservoir, creek and wetlands from any and all materials used or disturbed during the water control activities, including soils and sediment, fill, admixtures, oil and grease, loose debris, and chemicals.

B. The CONTRACTOR shall be solely responsible for any and all damage to the Work caused by floods, storms, cofferdam failure, dewatering device failure and/or floating debris and shall take every precaution to prevent any damage to the Work which may be caused by rain, floods, storms, and/or floating debris.

C. The CONTRACTOR shall be solely responsible for damages resulting from failure of cofferdams and diversion works, whether such failure is caused by overtopping, sliding, internal erosion, or any other mechanism.

D. In the event of flooding and consequent possibility of cofferdam or diversion structure overtopping or dewatering device failure, the CONTRACTOR shall implement measures to minimize damage to construction work.

E. Should overtopping occur, the CONTRACTOR shall dewater and clean out the affected areas and undertake all repairs to the construction work.

3.2 REMOVAL

A. After the diversion works have served their purpose, the CONTRACTOR shall remove, level, or grade such works to present an acceptable appearance, meet permit requirements, and to prevent any obstruction of the flow of water or any other interference with the operation of or access to the permanent works. Components of the

water control program will be either removed completely or trimmed to the elevations shown on the Drawings, or as directed by the ENGINEER.

B. Removal includes stockpiling, spoiling, re-use or disposal of materials. Under no conditions shall the CONTRACTOR be allowed to dispose of any such materials in the creek or wetlands.

C. On-site disposal shall be limited to placement in the approved disposal areas.

D. Non-soil materials to be disposed of may be stockpiled on site at locations approved by the OWNER.

END OF SECTION

SECTION 02 41 16

STRUCTURE DEMOLITION

PART 1 GENERAL

1.1 SUMMARY

A. This Section includes the following:

1. Demolition and removal of structures and/or site improvements.
2. Abandoning in place or removing below-grade construction.
3. Salvaging items for reuse by OWNER.

B. Demolition includes removal of reinforced concrete, steel gates and ancillary components of the existing overflow spillway at Woodlake Dam for construction of the breach though the same area.

C. Related Sections include the following:

1. Section 31 23 23 – Fill Placement

1.2 DEFINITIONS

A. Demolish: Completely remove and legally dispose of waste at approved on-site locations.

B. Recycle: Recovery of demolition waste for subsequent processing in preparation for reuse.

C. Remove: Detach items from existing construction and legally dispose of them off-site unless they are indicated to be removed and salvaged or removed and reinstalled.

D. Salvage: Carefully detach from existing construction, in a manner to prevent damage, allow for further use, and deliver to OWNER. Include fasteners or brackets needed for reattachment elsewhere.

1.3 MATERIALS OWNERSHIP

A. Unless otherwise indicated, demolition waste becomes the property of OWNER.

B. The following items shall be salvaged for the OWNER:
1. Concrete rubble.
2. Miscellaneous metals.

1.4 SUBMITTALS

A. Preconstruction Photographs or Video:
1. Show existing conditions of construction and site improvements, including finish surfaces that might be misconstrued as damage caused by demolition operations.

2. Provide photographs and/or video of conditions of items after stockpiled and salvaged.

1.5 QUALITY ASSURANCE

A. Regulatory Requirements: Comply with governing EPA notification regulations before beginning demolition. Comply with hauling and disposal regulations of authorities having jurisdiction.

1.6 PROJECT CONDITIONS

A. OWNER assumes no responsibility for structures to be demolished.

B. Hazardous Materials: Hazardous materials may be present in structures to be demolished. If a report on the presence of hazardous materials is on file for review and use, the CONTRACTOR may examine report to become aware of locations where hazardous materials are present.

1. Do not disturb hazardous materials or items suspected of containing hazardous materials except under procedures specified elsewhere in the Contract Documents.
2. OWNER will provide material safety data sheets for materials that are known to be present in structures to be demolished .
3. Presence of lead paint on gates, and other painted surfaces is unknown.

PART 2 PRODUCTS

2.1 GENERAL

A. CONTRACTOR shall be responsible for all equipment and supplies needed to accomplish the required demolition including turbidity curtains and oil booms, if needed.

PART 3 EXECUTION

3.1 EXAMINATION

A. Review Project Record Documents of existing construction provided by OWNER, if available. OWNER does not guarantee that existing conditions are same as those indicated in Project Record Documents.

B. Test for hazardous materials. Remediate hazardous materials before proceeding with demolition operations.

3.2 PROTECTION

A. Existing Facilities: Protect adjacent roadways during demolition operations. Maintain exits from existing structures.

B. Protect reservoir water from dust and debris during demolition activities.

C. Conform to permit requirements for environmental protection during demolition activities.

D. Remove temporary barriers and protections where hazards no longer exist. Where open excavations or other hazardous conditions remain, leave temporary barriers and protections in place.

3.3 DEMOLITION, GENERAL

A. CONTRACTOR shall be responsible for any required permits and for meeting all applicable federal and state requirements.

B. Reinforcing steel or other embedded materials may be encountered in portions of concrete to be removed and no additional compensation will be allowed for concrete demolition containing steel or embedded materials.

C. Demolish indicated existing structures completely. Use methods required to complete the Work within limitations of governing regulations and as follows:

1. Reinforcing steel shall not be left exposed on features to be only partially demolished.
2. Do not use cutting torches until work area is cleared of flammable materials. Maintain portable fire-suppression devices during flame-cutting operations.
3. Maintain fire watch during and for at least two hours after flame-cutting operations.
4. Maintain adequate ventilation when using cutting torches.

D. Provide surveyor's support to demolition work to ensure demolition is taken to the lines and grades as shown on Drawings or approved Shop Drawings.

E. During demolition, perform surveys to detect hazards that may result from demolition activities.

F. Site Access and Temporary Controls: Conduct demolition and debris removal operations to ensure minimum interference with roads and other adjacent occupied and operating facilities.

1. Do not close or obstruct streets or other adjacent occupied or operating facilities without permission from OWNER and authorities having jurisdiction. Provide alternate routes around closed or obstructed areas if required by OWNER or authorities having jurisdiction.
2. Use water mist and other suitable methods to limit spread of dust and dirt. Comply with governing environmental protection regulations. Do not use water when it may damage adjacent structures or create hazardous or objectionable conditions, such as ice, flooding, and pollution.

G. Removal of Concrete Surfaces and Structures: Concrete designated for removal, break into pieces and dispose of at designated locations.

H. Existing Utilities: Abandon existing utilities and below-grade utility structures if present.

3.4 SITE RESTORATION

A. Below-Grade Areas: Completely fill below-grade areas and voids resulting from demolition operations with satisfactory soil materials according to backfill requirements in Section 31 23 23 - Fill Placement.

B. Site Grading: Uniformly rough grade area of demolished construction to a smooth surface, free from irregular surface changes. Provide a smooth transition between adjacent existing grades and new grades. Eliminate areas where water may collect in depressions.

C. Remove temporary work.

3.5 DISPOSAL OF DEMOLISHED MATERIALS

A. General: Except for items or materials indicated to be recycled, reused, salvaged, reinstalled, or otherwise indicated to remain OWNER'S property, remove demolished materials from Project site and legally dispose of them in an approved landfill acceptable to authorities having jurisdiction.

3.6 CLEANING

A. Clean adjacent structures and improvements of dust, dirt, and debris caused by demolition operations. Return adjacent areas to condition existing before demolition operations began.

END OF SECTION

SECTION 03 30 01

CAST-IN-PLACE CONCRETE FOR MINOR STRUCTURES

PART 1 GENERAL

1.1 SUMMARY

A. This Section addresses products and placements for cast-in-place concrete constructing the concrete starter wall for the articulated concrete blocks.

B. Related Sections:
   1. Section 31 23 16 - Excavation
   2. Section 31 23 23 - Fill Placement

1.2 REFERENCES

A. American Concrete Institute:
   1. ACI 117 - Standard Specifications for Tolerances for Concrete Construction and Materials
   2. ACI 301 - Specifications for Structural Concrete
   3. ACI 304 - Guide for Measuring, Mixing, Transporting and Placing Concrete
   4. ACI 305 - Hot Weather Concreting
   5. ACI 306.1 - Standard Specification for Cold Weather Concreting
   6. ACI 308.1 - Standard Specification for Curing Concrete
   7. ACI 350 - Code Requirements for Environmental Engineering Concrete Structures

B. ASTM International:
   1. ASTM C33 - Standard Specification for Concrete Aggregates.
   2. ASTM C94/C94M - Standard Specification for Ready-Mixed Concrete.
   3. ASTM C150 - Standard Specification for Portland Cement.
   4. ASTM C260 - Standard Specification for Air-Entraining Admixtures for Concrete.
   5. ASTM C309 - Standard Specification for Liquid Membrane-Forming Compounds for Curing Concrete
   6. ASTM C441 - Standard Test Method for Effectiveness of Pozzolans or Ground Blast-Furnace Slag in Preventing Excessive Expansion of Concrete Due to the Alkali-Silica Reaction
   7. ASTM C494/C494M - Standard Specification for Chemical Admixtures for Concrete.
   8. ASTM C618 - Standard Specification for Coal Fly Ash and Raw or Calcined Natural Pozzolan for Use as a Mineral Admixture in Concrete.
   9. ASTM C685/C685M - Standard Specification for Concrete Made By Volumetric Batching and Continuous Mixing.
   10. ASTM C920 - Standard Specification for Elastomeric Joint Sealants
   11. ASTM C1017/C1017M - Standard Specification for Chemical Admixtures for Use in Producing Flowing Concrete.
   12. ASTM C1218 - Standard Test Method for Water-Soluble Chloride in Mortar and Concrete.

13. ASTM C1260 - Standard Test Method for Potential Alkali Reactivity of Aggregates (Mortar-Bar Method)
14. ASTM D1751 - Standard Specification for Preformed Expansion Joint Filler for Concrete Paving and Structural Construction (Nonextruding and Resilient Bituminous Types)

C. US Army Corps of Engineers (COE)
1. COE CRD-C 513 – Corps of Engineers Specifications for Rubber Waterstops
2. COE CRD-C 572 – Corps of Engineers Specifications for PVC Waterstops

1.3 SUBMITTALS

A. Prior to placement of concrete, the Contractor shall furnish the Engineer, for approval, a statement of the materials and mix proportions he intends to use. The statement shall include evidence satisfactory to the Engineer that the materials and proportions will produce concrete conforming to this specification. The materials and proportions so stated shall constitute the "job mix." After a job mix has been approved, neither the source, character or grading of the aggregates nor the type or brand of cement or admixture shall be changed without prior notice to the Engineer. If such changes are necessary, no concrete, containing such new or altered materials shall be placed until the Engineer has approved a revised job mix.

B. Delivery Tickets: Ready-mixed concrete producer shall furnish duplicate delivery tickets. Contractor shall retain one ticket and submit other ticket to Engineer at time of concrete delivery. Delivery tickets shall indicate delivery date, type of concrete, class, cement content, admixtures, and amount of water.

1.4 QUALITY REQUIREMENTS

A. Perform Work in accordance with ACI 301 and ACI 350 and all requirements of this Section and related sections of this specification.

B. Conform to ACI 305 when concreting during hot weather.

1.5 Conform to ACI 306.1 when concreting during cold weather.

1.6 DEFINITIONS

A. Construction Joint: A construction joint is defined as a planned joint where two placements of concrete meet, across which development and maintenance of bond are required, through which any reinforcement that may be present is not interrupted. Unless otherwise indicated on Drawings, construction joints in water bearing members shall be provided with a waterstop and/or sealant groove of the shape indicated.

B. Control Joint: Control joints serve to provide for volumetric shrinkage of monolithic concrete thus preventing the formation of objectionable shrinkage cracks elsewhere in the concrete. A control joint is defined as a planned joint where two placements of concrete meet, across which no bond is achieved, and through which some or all reinforcement that may be present is not interrupted. Unless otherwise indicated or specified, control joints in water bearing members shall be provided with a waterstop and/or sealant groove of the shape indicated.

C. Contraction Joint: A contraction joint is defined as a planned joint where two placements of concrete meet, across which no bond is achieved and through which no reinforcement passes. Contraction joints serve to provide for volumetric shrinkage of monolithic concrete and for movement between monolithic units at established joints, thus preventing the formation of objectionable shrinkage cracks elsewhere in the concrete. Unless otherwise indicated or specified, contraction joints in water bearing members shall be provided with a waterstop and/or sealant groove of the shape indicated.

D. Expansion or Isolation Joints: Expansion or isolation joints are defined as a planned joint that separates two adjacent concrete placements to allow the concrete to expand freely. Typically, a space is provided between the two placements by placing a filler joint material against the first pour, which acts as a form for the second pour.

E. Abrupt Surface Irregularities: Offsets and fins in formed concrete surfaces resulting from displaced, mismatched, or misplaced forms, sheathing, or liners or from defects in forming materials. Abrupt irregularities shall be measured within one inch of the irregularity.

F. Gradual Surface Irregularities: Irregularities in formed concrete surfaces resulting from warping and similar uniform variations from planeness or true curvature. Gradual surface irregularities shall be measured by determining gap between concrete and near surface along a five foot straightedge, measured between contact points.

PART 2 PRODUCTS

2.1 CONCRETE MATERIALS

A. Cement shall conform to ASTM C150, Type II, low alkali (LA) Portland type. Cement used throughout the work shall be uniform in color.

B. Coarse and Fine Aggregate shall meet ASTM C33. The maximum size aggregate shall be 1 inch for reinforced concrete.

C. Water shall be clean, potable and free from oil, salt, acid, alkali, organic matter, or other deleterious substances.

2.2 ADMIXTURES

A. Air Entrainment: Conform to ASTM C260 and be compatible with water reducing and any other admixture. If air-entraining cement is used, any additional air-entraining admixture shall be of the same type as that in the cement.

B. Water Reducing Admixtures: Conform to ASTM C494, Type A. Use water reducing admixture to increase workability of mix.

C. Set Retarders: ASTM C494, Type B, shall not be used in concrete, unless otherwise authorized in writing by Engineer.

D. Water Reducing Admixtures and Set Retarders: ASTM C494, Type D shall not be used in concrete, unless otherwise authorized in writing by Engineer.

E. High Range Water Reducing Admixtures: Conform to ASTM C494, Type F. Use HRWRA to increase workability of mix.

F. High Range Water Reducing Admixtures and Retarders: ASTM C494, Type G shall not be used in concrete, unless otherwise authorized in writing by Engineer.

G. Accelerating Admixtures: ASTM C494, Type C or E shall not be used in concrete, unless otherwise authorized in writing by Engineer.

2.3 FORMWORK

A. Forms shall be of wood, plywood, steel, or other approved material and shall be mortar tight. The forms and associated false work shall be substantial and unyielding and shall be constructed so that the finished concrete will conform to the specified dimensions and contours.

B. Form surfaces shall be smooth and free from holes, dents, sags or other irregularities. Forms shall be coated with a non-staining form release agent before set into place.

C. Metal ties or anchorages within the forms shall be equipped with cones, she-bolts, or other devices that permit their removal to a depth of at least one inch without injury to the concrete. Ties designed to break off below the surface of the concrete shall not be used without cones.

2.4 CONCRETE REINFORCEMENT

A. Quality.
1. Steel reinforcing bars shall conform to ASTM A 615, Grade 60. All bending shall be in accordance with standard practice and shall be performed by machine methods as approved. The reinforcement as delivered to the Site shall be free from loose, flaky rust, mill scale, and from oil, grease, mud, mortar, or other coating which might inhibit its bond with concrete or grout.

B. Identification.
1. Each bundle of steel shall be tagged at the mill with an identifying mill tag, showing the name of the mill and the melt or heat number. The mill shall certify that all reinforcing steel or welded wire fabric represented by that melt or heat number complies with the specification requirements. Reinforcing bars to be shipped to the jobsite are to have attached plastic or metal tags. Place on each tag the mark number of the rebar corresponding to the mark number indicated on the shop drawings. Mark numbers on tags to be so placed that the numbers cannot be removed by weather or other means.

C. Storage.
1. The materials should be stored off of the ground and protected from weathering if stored for any prolonged time to prevent rusting.

2.5 CONCRETE ACCESSORIES

A. Curing and Sealing Compound: Liquid membrane-forming compound for curing concrete, ASTM C309, clear type.

B. Bond Breaker: Asphalt impregnated felts, 15 pounds, polyethylene tape, coated paper, metal foil, or other approved material.

PART 3 EXECUTION

3.1 PLACING STEEL REINFORCEMENT

A. The placing of reinforcing steel shall conform to the applicable provisions of CRSI "Recommended Practice for Placing Reinforcing Bars" except as specified herein. Reinforcement bars shall be detailed to conform to the current standards. Reinforcing steel shall not be placed as concrete operations proceed or without definite means of holding it in its correct position. Once reinforcement is secured within forms, reinforcement shall be maintained clean until completely embedded in the concrete. All bending shall be in accordance with standard approved practice. Unless otherwise indicated, provide minimum 3-inch concrete protective covering for reinforcement.

B. Do not bend reinforcement after embedding in hardened concrete unless approved by the Engineer. Do not bend reinforcing bars by means of heat.

3.2 SPLICING

A. Except as otherwise specified herein, all splices, lengths of laps, locations, placement, and embedment of reinforcement shall conform to the applicable requirements of ACI 318. Staggering of splices may be required. In general, vertical bar splices shall not be spaced closer than 15 ft and horizontal splices not closer than 30 ft. Lapped ends of bars shall be placed in contact and securely wired or shall be separated sufficiently to permit the embedment of the entire surface of each bar in concrete.

B. Lapped or mechanical splices may be used. Reinforcement bars shall be tied securely at alternate intersections, except around the perimeter of a mat, in which case, every intersection shall be tied. Ties shall be made of No. 16 iron wire.

3.3 SUPPORTS

A. All reinforcement shall be secured in place by use of metal or concrete supports, spacers, or ties. Such supports shall be of sufficient strength to maintain the reinforcement in place throughout the concreting operation. The supports shall be used in such a manner that they will not be exposed or contribute in any way to the discoloration or deterioration of the concrete.

B. The use of broken stone, metal pipe or wooden blocks will not be permitted.

C. Provide supporting concrete blocks or use of other approved methods on the ground. Provide plastic coated metal chairs, runners, bolsters, spacers, hangers, and rebar supports as required on form work. Plastic coating shall meet the requirements stated in the Concrete Reinforcing Steel Institute "Manual of Standard Practice". Only the rebar support tips in contact with the forms need to be plastic coated.

3.4 MIXERS AND MIXING

A. Concrete shall be uniform and thoroughly mixed when delivered to the site. Variations in slump of more than 1 inch within a batch will be considered evidence of inadequate mixing and shall be corrected by increasing mixing time or other means.

B. For stationary mixers, the mixing time after all cement and aggregates are in the mixer drum shall be not less than 1-1/2 minutes. When concrete is mixed in a truck mixer, the number of revolutions of the drum or blades at mixing speed shall be not less than 70 nor more than 100.

C. Unless otherwise specified, volumetric batching and continuous mixing at the construction site will be permitted. The batching and mixing equipment shall conform to the requirements of ASTM Specification C 685 and shall be demonstrated prior to placement of concrete, by tests with the job mix, to produce concrete meeting the specified proportioning and uniformity requirements. Concrete made by this method shall be produced, inspected, and certified in conformance with Sections 6, 7, 8, 13, and 14 of ASTM Specification C 685.

D. No mixing water in excess of the amount called for by the job mix shall be added to the concrete during mixing or hauling or after arrival at the delivery point.

3.5 CONVEYING

A. Concrete shall be delivered to the site and discharged into the forms within 1-1/2 hours after the introduction of cement to the aggregates. In hot weather or under conditions contributing to quick stiffening of the concrete, the time between the introduction of the cement to the aggregates and discharge shall not exceed 45 minutes.

B. The Engineer may allow a longer time, provided the set time of the concrete is increased a corresponding amount by the addition of an approved set-retarding admixture. In any case, concrete shall be conveyed from the mixer to the forms as rapidly as predictable by methods that will prevent segregation of the aggregates or loss of mortar.

3.6 PLACING

A. Concrete shall not be placed until the subgrade, forms and steel reinforcement have been inspected and approved. No concrete shall be placed except in the presence of the Engineer. The Contractor shall give reasonable notice to the Engineer each time he intends to place concrete. Such notice shall be far enough in advance to give the Engineer adequate time to inspect the subgrade, forms, steel reinforcement and other preparations for compliance with the specifications.

B. The concrete shall be deposited as closely as possible to its final position in the forms and shall be worked into the corners and angles of the forms and all around the reinforcement and embedded items in a manner to prevent segregation of aggregates or excessive laitance. Formed concrete shall be placed in horizontal layers not more than 20 inches thick. Concrete shall not be dropped more than five feet vertically unless suitable equipment is used to prevent segregation. Hoppers and chutes, pipes or "elephant trunks" shall be used as necessary to prevent segregation and the splashing of mortar on the forms and reinforcing steel above the layer being placed.

C. Immediately after the concrete is placed in the forms, it shall be consolidated by spading, hand tamping, or vibration as necessary to insure smooth surfaces and dense concrete. Each layer shall be consolidated to insure monolithic bond with the preceding layer. If the surface of a layer of concrete in place sets to the degree that it will not flow and merge with the succeeding layer when spaded or vibrated, the Contractor shall discontinue placing concrete and shall make a construction joint according to the procedure specified in Subpart 3.8, Construction Joints.

D. If placing is discontinued when an incomplete horizontal layer is in place, the unfinished end of the layer shall be formed by a vertical bulkhead.

3.7 CONSTRUCTION JOINTS

A. Construction Joints shall be made at the locations shown on the drawings. If construction joints are needed which are not shown on the drawings, they shall be placed in locations approved by the Engineer.

B. Where a featheredge would be produced at a construction joint, as in the top surface of a sloping wall, an insert form shall be used so that the resulting edge thickness on either side of the joint is not less than 6 inches.

C. Steel tying and form construction adjacent to concrete in place shall not be started until the concrete has cured at least 12 hours. Before new concrete is deposited on or against concrete that has hardened, the forms shall be retightened. New concrete shall not be placed until the hardened concrete has cured at least 12 hours.

3.8 REMOVAL OF FORMS

A. Forms shall not be removed without the approval of the Engineer.

B. Forms shall be removed in such a way as to prevent damage to the concrete. Supports shall be removed in a manner that will permit the concrete to take the stresses due to its own weight uniformly and gradually.

3.9 FINISHING FORMED SURFACES

A. Immediately after the removal of forms:
   1. All fins and irregular projections shall be removed from exposed surfaces.
   2. The holes produced on all surfaces by the removal of the form ties, cone-bolts, and she-bolts shall be cleaned, wetted and filled with a dry-pack mortar consisting of one part Portland cement, three parts sand that will pass a No. 16 sieve, and just sufficient water to produce a consistency such that the filling is at the point of becoming rubbery when the material is solidly packed.

3.10 FINISHING UNFORMED SURFACES

A. All exposed surfaces of the concrete shall be accurately screeded to grade and then float finished, unless specified otherwise.

B. Excessive floating or troweling of surfaces while the concrete is soft will not be permitted.

C. The addition of dry cement or water to the surface of the screeded concrete to expedite finishing will not be allowed.

D. Joints and edges on unformed surfaces that will be exposed to view shall be chamfered or finished with molding tools.

3.11 CURING

A. Concrete shall be prevented from drying for a curing period of at least 7 days after it is placed. Exposed surfaces shall be kept continuously moist for the entire period, or until curing compound is applied as specified below. Moisture shall be maintained by sprinkling, flooding, or fog spraying or by covering with continuously moistened canvas, cloth mats, straw, sand or other approved material.

B. Wood forms left in place during the curing period shall be kept continuously wet. Formed surfaces shall be thoroughly wetted immediately after forms are removed and shall be kept wet until patching and repairs are completed. Water or covering shall be applied in such a way that the concrete surface is not eroded or otherwise damaged.

C. Concrete, except at construction joints, may be coated with approved curing compound in lieu of continued application of moisture, except as otherwise specified. The compound shall be sprayed on the moist concrete surfaces as soon as free water has disappeared, but shall not be applied to any surface until patching, repairs and finishing of that surface are completed. The compound shall be applied at a uniform rate of not less than one gallon per 150 square feet of surface and shall form a continuous adherent membrane over the entire surface. Curing compound shall be thoroughly mixed before applying and continuously agitated during application. Curing compound shall not be applied to surfaces requiring bond to subsequently placed concrete, such as construction joints, shear plates, reinforcing steel and other embedded items. If the membrane is damaged during the curing period, the damaged area shall be resprayed at the rate of application specified above. Surfaces covered by the membrane shall not be trafficked unless protected from wear.

3.12 REMOVAL AND REPLACEMENT OR REPAIR

A. When concrete is honeycombed, damaged or otherwise defective, the Contractor shall remove and replace the structure or structural member containing the defective concrete or, where feasible, correct or repair the defective parts. The Engineer will determine the required extent of removal, replacement, or repair.

B. Prior to starting repair work the Contractor shall obtain the Engineer's approval of his plan for affecting the repair. The Contractor shall perform all repair work in the presence of the Engineer.

3.13 CONCRETING IN COLD WEATHER

A. When atmospheric temperature is less than 40 degrees F at time concrete is delivered to work site, during placement, or at any time during the curing period, perform Work in accordance with ACI 306.1 – Cold Weather Concreting.

3.14 CONCRETING IN HOT WEATHER

A. When climatic or other conditions are such that temperature of concrete may reasonably be expected to exceed 90 degrees F at time of delivery at work site, during placement, or during first 24 hours after placement, perform Work in accordance with ACI 305R – Hot Weather Concreting.

END OF SECTION

SECTION 31 05 13

SOILS FOR EARTHWORK

PART 1 - GENERAL

1.1 SUMMARY

A. This Section includes the definition and material specifications of soil materials from on-site sources used for engineered backfill in breach construction as shown on the Drawings.

This section does not address the placement of soils for earthworks for dam construction, which is covered in Section 31 23 23, Fill Placement.

B. Related Sections:
1. Section 01 57 60 - Control of Water
2. Section 31 05 16 - Aggregates for Earthwork
3. Section 31 23 16 - Excavation
4. Section 31 23 23 - Fill Placement

1.2 REFERENCES

A. ASTM International:
1. ASTM D422 – Standard Method for Particle size Analysis of Soils.
2. ASTM D2216 – Test Method for Laboratory Determination of Water (Moisture) Content of Soil and Rock.
3. ASTM D2487 - Standard Classification of Soils for Engineering Purposes (Unified Soil Classification System).
4. ASTM D2488 – Practice for Description and Identification of Soils (Visual-Manual Procedure).
5. ASTM D4318 – Test Method for Liquid Limit, Plastic Limit, and Plasticity Index of Soils.
6. ASTM D4959-89 – Test Method for Determination of Water Content (Moisture) by Direct Heating Method.

1.3 SUBMITTALS

A. none

1.4 QUALITY ASSURANCE/QUALITY CONTROL

A. The CONTRACTOR shall be responsible for testing of moisture in all soils for earthwork as necessary to ensure the soils meet the moisture requirements as specified herein and in Section 31 23 23, Fill Placement.

The CONTRACTOR shall perform additional soil testing specified herein if they intend to use materials from other borrow areas not specified on the drawings. The ENGINEER will provide testing associated with approving soils to be used for backfill as needed to shape grades for the breach and to provide foundations for the articulated concrete blocks and rip rap.

PART 2- PRODUCTS

2.1 GENERAL

A. All borrow material shall come from the project work site in approved areas. CONTRACTOR shall not obtain borrow material from private landowners or offsite sources unless all onsite options have been exhausted.

B. The CONTRACTOR shall be responsible for calculation of the required volumes of each material type based on the Drawings, consultations with the ENGINEER, estimates of wastage during excavation, stockpiling, haulage and placement, required degree of compaction, experience with similar materials, and other factors as identified by the CONTRACTOR.

C. The CONTRACTOR shall be responsible for all costs associated with delays or material quantity shortfalls due to volume miscalculations or required rework or material wastage resulting from not meeting material or placement specifications, negligence in equipment operation or control of water, or contamination of soil materials.

2.2 USE OF ON-SITE BORROW MATERIALS

A. On-site soils from within the limits of work area shown on the Drawings shall be used for earthworks for breach.

B. The CONTRACTOR shall maintain a minimum offset of 25 feet from delineated wetlands during borrow area development and closure to prevent non-permitted impacts to wetlands.

C. ENGINEER shall evaluate the quality and availability of borrow soils within the work area as necessary to evaluate the quality and quantity of the material.

2.3 SOIL MATERIALS

A. Soils shall be an approved on-site excavated material from excavation of the Spillway, as shown on the Drawings, that are durable and free of debris, organic matter, and other deleterious materials.

B. Soils within excavation of the Spillway are variable and vary from cohesive to non-cohesive soils. The CONTRACTOR shall develop plans to use the variation of soil and that meets the specification requirements for their intended use.

C. Soils, topsoil, and organic material, grasses, brush, and trees, excavated from slopes of the Spillway shall be wasted and shall not be used for construction. The CONTRACTOR may use excavated material below the stripped topsoil and organics if he performs sufficient laboratory testing to demonstrate that the excavated soils meets the requirements of a defined soil material specified herein.

D. Soils designated for use as engineered fill for the Breach include:
   1. Common Fill

2.4 COMMON FILL

A. Common Fill is any backfill to be placed inside of the limits of the breach backfill or permanent roads, if needed.

B. Common fill shall not contain organic material. Common fill can be rock and weathered rock used for temporary access roads.

C. The plasticity index (PI) of the material passing the U.S. Standard No. 40 sieve shall be non-plastic to 25 when tested in accordance with ASTM D4318.

D. No particle size shall be greater than the 3 inches and at least 75% shall pass the 1-inch sieve and 15% shall pass the #200 sieve.

PART 3- EXECUTION

3.1 PREPARATION

A. Identify borrow from excavation of the breach. Stockpile in approved areas as needed.

3.2 PROTECTION

A. Direct surface water away from stockpile site(s) to prevent erosion or deterioration of materials.

B. Ensure that stockpile area(s) is above elevations of potential flooding.

C. Provide covers or other protection measures to inhibit erosion of stockpiles during rainfall.

3.3 STOCKPILE CLEANUP

A. For earthwork and remaining stockpile, grade and level as approved by ENGINEER, leave area in clean and neat condition.

3.4 QUALITY CONTROL AND QUALITY ASSURANCE TESTING

A. The minimum testing frequency for testing of soils from the excavation of the Spillway to be used in construction are provided in Schedule 2 below. The ENGINEER shall perform the required tests.

Schedule 2: Minimum Testing Requirements for Fill Soils from Excavation of Spillway

Laboratory Test Required	ENGINEER Minimum Test Frequency
Soil Classification (ASTM D2487)	1/2,000 cubic yards
Gradation (Mechanical) (ASTM D422)	1/2,000 cubic yards
Atterberg Limits	1/2,000 cubic yards

(ASTM D4318)	
Moisture Content (ASTM D2216)	1/1,000 cubic yards
Moisture Density Relationship Tests (ASTM D698)	1/1,000 cubic yards

END OF SECTION

SECTION 31 05 16

AGGREGATES FOR EARTHWORK

PART 1 GENERAL

1.1 SUMMARY

A. This section includes definition and material specifications for aggregates used in the Breach Design as Filter Sand (sand) and Filter Stone (stone), bedding stone in riprap areas, and riprap.

This Section does not address the placement of aggregates for earthwork, which is covered in Section 31 23 23 – Fill Placement

B. Related Sections:

1. Section 31 23 23 – Fill Placement

1.2 REFERENCES

A. NCDOT Standard Specifications For Roads and Structures - Section 1005, General Requirements for Aggregates, and Section 1042, Riprap.

1.3 SUBMITTALS

A. Submit NCDOT certified specification sheets for aggregates to be used in construction.

1.4 QUALITY REQUIREMENTS

A. Furnish each aggregate material from single source throughout the Work.

1.5 QUALIFICATONS (not used)

1.6 DEFINITIONS

A. Filter Sand is a fine natural quartz rich aggregate (sand) placed over or against compacted fill and natural subgrades to allow water to permeate through without carrying fine grained soil particles. This is a deposited sand typically mined along river banks. Manufactured sand from crushing operations is not allowed where Filter Sand is shown on the Drawings.

B. Manufactured Filter Sand – Sand that is produced from quarry operations typically from igneous or metamorphic rock that is blasted, crushed, washed and screened. Manufactured Filter Sand shall not be used as Filter Sand.

C. Filter Stone is a coarse aggregate used to collect and/or convey water that passes through Filter Sand.

D. Bedding Stone is coarse aggregate used as bedding for riprap.

E. Riprap is coarse rock material used for slope protection from surface water erosion and wave action.

PART 2 PRODUCTS

2.1 GENERAL

A. The CONTRACTOR shall be responsible for calculation of the required volumes of each material type based on the Drawings, consultations with the ENGINEER, estimates of wastage during delivery, stockpiling, haulage and placement, required degree of compaction, experience with similar materials, and other factors as identified by the CONTRACTOR.

2.2 FILTER SAND

A. FILTER SAND shall meet the requirements of ASTM C 33 or NCDOT #2S fine aggregate as specified in Section 1005 of the NCDOT Standard Specifications for Roads and Structures.

2.3 FILTER STONE

A. Filter Stone shall meet the requirements of NCDOT #78M coarse aggregate as specified in Section 1005 of the NCDOT Standard Specifications for Roads and Structures.

2.4 BEDDING STONE FOR RIPRAP

A. Bedding stone for riprap shall meet the requirements of NCDOT #57 coarse aggregate as specified in Section 1005 of the NCDOT Standard Specifications for Roads and Structures.

2.5 RIPRAP (IF USED)

A. Class 2 Riprap shall meet the requirements of NCDOT Class 2 PLAIN RIP RAP as specified in Section 1042 of the NCDOT Standard Specifications for Roads and Structures.

B. Class B Riprap shall meet the requirements of NCDOT Class B PLAIN RIP RAP as specified in Section 1042 of the NCDOT Standard Specifications for Roads and Structures.

C. Class A Riprap shall meet the requirements of NCDOT Class A PLAIN RIP RAP as specified in Section 1042 of the NCDOT Standard Specifications for Roads and Structures.

PART 3 EXECUTION (Not used)

END OF SECTION

SECTION 31 05 19

GEOSYNTHETICS FOR EARTHWORK

PART 1 GENERAL

1.1 SUMMARY

A. This Section includes material specifications for geosynthetics including geotextile for use in articulating concrete blocks as shown on the Drawings.

B. Related Sections:
   1. Section 31 23 23 – Fill Placement
   2. Section 31 35 23 – Articulating Concrete Block Revetments

1.2 REFERENCES

A. ASTM International (ASTM)
   1. ASTM D 123, Standard Terminology Relating to Textiles
   2. ASTM D 1683, Failure in Sewn Seams of Woven Fabrics
   3. ASTM D 3786, Hydraulic Bursting Strength of Geotextile Fabrics
   4. ASTM D 3884, Abrasion Resistance of Textile Fabrics (Rotary Platform, Double-Head Method)
   5. ASTM D 4491, Water Permeability of Geotextiles
   6. ASTM D 4533, Trapezoid Tearing Strength of Geotextiles
   7. ASTM D 4354, Sampling of Geosynthetic for Testing
   8. ASTM D 4355, Deterioration of Geotextile from Exposure to Ultraviolet light and Water (Xenon-Arc Type Apparatus)
   9. ASTM D 4632, Grab Breaking Load and Elongation of Geotextiles
   10. ASTM D 4751, Determining Apparent Opening Size of a Geotextile
   11. ASTM D 4833, Index Puncture Resistance of Geotextiles
   12. ASTM D 4873, Guide for Identification, Storage, and Handling of Geotextiles

1.3 SUBMITTALS

A. At least 10 days prior to delivery of the materials to the site, the CONTRACTOR shall inform the ENGINEER in writing of the source from which he intends to obtain material, and typical test results showing the material meets the specification requirements.

B. Approval by the ENGINEER of CONTRACTOR submittals shall not alleviate the CONTRACTOR'S responsibilities for completing the work as specified.

1.4 QUALITY REQUIREMENTS

A. Submit certification of the geosynthetic materials from the manufacturer.

1.5 QUALIFICATIONS

A. Purchase all materials from reputable suppliers to ensure sufficient quantities, delivery times, and quality of materials.

1.6 DEFINITIONS

A. Geotextile: Flexible, synthetic fabric made from polypropylene or polyester, in one of three basic forms: woven, needle punched, or heat bonded.

PART 2 PRODUCTS

2.1 GENERAL:

A. The CONTRACTOR shall be responsible for calculation of the required quantity of each material based on Project Drawings, consultations with the ENGINEER, estimates of waste during delivery, stockpiling, haulage and placement, required degree seam overlap, anchoring, experience with similar materials, and other factors as identified by the CONTRACTOR.

B. The CONTRACTOR shall be responsible for all costs associated with delays or material quantity shortfalls due to quantity miscalculations, unanticipated damage during handling or installation, or required rework resulting from not meeting material or placement specifications.

2.2 GEOTEXTILE

A. Geotextiles placed below the bedding stone for areas covered by articulating concrete block revetments, shall be a non-woven, needle-punched polypropylene fabric designed for use in filter applications such as Tencate/Mirafi 180N. The geotextile shall meet the following requirements listed in Table 1.

Table 1: Geotextile Physical Properties

Property	**Required Value**
Grab Strength	minimum 200 lbs
Grab Elongation	minimum 50%
Puncture Strength	minimum 500 lbs
Trapezoidal Tear Strength	minimum 80 lbs
Permittivity	minimum 1.0 sec^{-1}
Apparent Opening Size	Between U.S. Sieve Size No. 80 and U.S. Sieve Size No. 120

PART 3 EXECUTION

3.1 EXAMINATION

A. Check products upon delivery to assure that proper material is received and is undamaged.

3.2 PREPARATION

A. Identify area(s) for storage of material and obtain approval of the ENGINEER.

3.3 PROTECTION

A. All geosynthetic materials shall be labeled, shipped, stored, and handled in accordance with applicable standards. No hooks, tongs, or other sharp instruments shall be used for handling geosynthetics.

3.4 FIELD QUALITY CONTROL

A. At the time of installation, the geosynthetic material shall be rejected if it has defects, rips, holes, flaws, deterioration or damage incurred during manufacture, transportation or storage.

END OF SECTION

SECTION 31 23 16

EXCAVATION

PART 1 GENERAL

1.1 SUMMARY

A. The work covered in this specification includes:
   1. Unclassified excavation to the lines and grades as shown on the Drawings or as directed by the ENGINEER for the foundation of the breach.
   2. Control, collection, and removal of surface water and ground water in the areas of project excavations as needed to perform the required construction. Requirements for control and diversion of the reservoir levels and flow, and surface water run-off outside of excavations are covered in Section 01 57 60 - Control of Water.

B. Related Sections
   1. Section 01 57 60 - Control of Water
   2. Section 01 57 50 - Surveying
   3. Section 31 05 13 - Soils For Earthwork
   4. Section 31 23 23 - Fill Placement

1.2 SUBMITTALS

A. The CONTRACTOR shall provide the following Topographic Maps. These maps shall have a contour interval no greater than one (1) foot.
   1. Surveyed topographic map and sections of existing ground surface within the limits of construction.
   2. Surveyed topographic map and sections showing completed unclassified excavation (i.e., to foundation grades) for construction.
   3. The topographic map shall meet the following requirements and include:
      a. Scale: 1 inch equals 20 feet.
      b. Contour interval: 1 foot with 10-foot contours labeled.
      c. Northing and Easting coordinate system ticks and baseline data for the project.
      d. Dam axis.
      e. North arrow.
      f. Key natural and project reference features as required by the ENGINEER.
      g. All contours and features to be adequately labeled.
   4. Provide original maps on a reproducible medium, and a CD/diskette copy in an AutoCAD 2013 or later DXF data file. The DXF file shall be set to coordinates and shall be at elevation.

1.3 QUALITY REQUIREMENTS

A. Purchase all materials from reputable suppliers that can ensure sufficient quantities, delivery times, and quality of materials.

B. The CONTRACTOR shall assume sole responsibility for dewatering and surface water control systems and for loss or damage resulting from partial or complete failure of protective measures or erosion or resultant damage caused by ground water and surface water control operations.

C. The CONTRACTOR shall comply with authorities having jurisdiction for the following:
   1. Water discharge and disposal from pumping operations.

1.4 QUALIFICATIONS

A. Engage a land surveyor registered in the State of North Carolina to perform required land surveying services. Post-excavation surveys for quantity measurements will be required as stipulated in Section 01 57 50 - Surveying.

1.5 DEFINITIONS

A. Unclassified Excavation – Unclassified excavation includes all earth materials, including topsoil, soil, and rock. All boulders or detached pieces of solid rock less than one cubic yard in volume shall be unclassified.

B. Excavation Dewatering includes the following:
   1. Lowering of ground water table and intercepting ground water to prevent ground water from entering excavations.
   2. Diversion and/or capture of surface water run-off within open excavations.
   3. Disposing and treating (if needed) of removed water via discharge to permitted location(s).

PART 2 - PRODUCTS

2.1 GENERAL

A. The CONTRACTOR shall be responsible for calculation of the quantities, estimates of wastage during delivery and installation, experience with similar materials, and other factors as identified by the CONTRACTOR.

B. The CONTRACTOR shall be responsible for all costs associated with delays or material quantity shortfalls due to miscalculations or required rework resulting from not meeting material or placement specifications.

C. The CONTRACTOR shall be responsible for all costs associated with delays, permitting activities, fees, penalties, spills, clean-up, malfunctions or failures of any of the equipment associated with the dewatering program.

2.2 DEWATERING EQUIPMENT

A. Select dewatering equipment to meet specified performance requirements.

PART 3 - EXECUTION

3.1 EXAMINATION

A. Prior to commencing excavation, the CONTRACTOR shall confirm that the areas to be excavated have been adequately surveyed and marked.

3.2 PREPARATION

A. Identify required lines, levels, contours, and datum, as shown on the Drawings.

B. The CONTRACTOR is responsible for establishing stockpile locations. The CONTRACTOR is responsible for stabilizing these areas in accordance with state and local regulations and these specifications.

3.3 PROTECTION

A. Comply with all safety requirements of OSHA, state, and federal regulations. Where there is a conflict between the requirements of this section and the requirements of the publication Construction Safety Standards, the more stringent requirements shall govern.

B. Removal of water from excavations shall be accomplished in such a manner that erosion and the transmission of sediment and other pollutants are minimized. Diversion ditches shall be installed as required to prevent surface water and sediment from entering the excavated areas.

C. Protection of all pumping wells, monitoring wells, pumps, piping, and accessories from damage from construction activities shall be the sole responsibility of the CONTRACTOR.

3.4 EXCAVATION

A. The CONTRACTOR shall excavate and stockpile topsoil, demolition, and backfill material for reuse, if applicable.

B. Excavate soils to the lines and grades as shown on the Drawings or as directed by the ENGINEER. The lines and grades of rock line shown on the drawings are approximations based on inspections performed during design.

C. The CONTRACTOR shall assume all responsibility for sequencing excavation, and stabilizing slopes. The OWNER and ENGINEER do not represent that the excavation slopes shown can be performed to or maintained at the neat lines described in these Specifications or as shown on the Drawings.

D. Divert surface water and storm water run-off away from slopes and prevent drainage across excavations.

E. Maintain slopes during construction to keep the slopes in a safe condition.

F. The CONTRACTOR shall install safety barriers meeting all OSHA requirements at the top of all cut slopes.

3.5 EXCAVATION DEWATERING

A. Installation of Dewatering System

1. Install dewatering system to perform the excavation in a relatively dry state.
2. Maintain dewatering in order to place fill, aggregates and articulated concrete blocks.

Dewatering may consist of ditches, berms, sumps and pumps, and other devices to divert and drain surface and ground water from excavation areas.

2. Divert surface water within excavation areas into sumps and discharge water into a filter bag (Dirtbag or equivalent).
3. Control and remove surface and groundwater entering the excavation.

C. System Operation and Maintenance

1. Operate dewatering system continuously until backfilling is complete.
2. Provide appropriate supervision of dewatering system by personnel skilled in operation, maintenance, and replacement of system components.
3. Conduct daily observation of dewatering system and monitoring systems. Make required repairs and perform scheduled maintenance.
4. Fill fuel tanks before the fuel level in the tank falls below 25 percent capacity. Refilling during the night or on the weekends should be performed as appropriate to protect the work.

D. Water Disposal

1. Discharge water in accordance with the approved CONTRACTOR'S Excavation Dewatering Plan and the applicable requirements of Section 01 57 19 -Temporary Environmental Controls.

E. System Removal

1. Remove dewatering and surface water control systems after dewatering operations are discontinued.

END OF SECTION

SECTION 31 23 23

FILL PLACEMENT

PART 1 - GENERAL

1.1 SUMMARY

A. The work shall consist of placing compacted earth fill and aggregate fill associated with the construction of the breach and establishing final grades as required by the Drawings or as directed by the ENGINEER.

B. Placement of geosynthetic materials is discussed in Section 31 05 19, Geosynthetics for Earthwork.

C. Related Sections:
1. Section 31 05 13 - Soils for Earthwork
2. Section 31 05 16 - Aggregates for Earthwork
3. Section 31 05 19 - Geosynthetics for Earthwork
4. Section 31 23 16 - Excavation

1.2 REFERENCES

A. ASTM International:
1. ASTM D698 - Standard Test Method for Laboratory Compaction Characteristics of Soil Using Standard Effort (12,400 ft-lbf/ft3 (600 kN-m/m3))
2. ASTM D1556 - Standard Test Method for Density of Soil in Place by the Sand-Cone Method
3. ASTM D2216 - Laboratory Determination of Water (Moisture) Content of Soil, Rock, and Soil-Aggregate Mixtures
4. ASTM D2487 - Classification of Soils for Engineering Purposes (Unified Soil Classification System)
5. ASTM D2937 - Density of Soil In Place By The Drive-Cylinder Method
6. ASTM D4254 - Test Methods for Minimum Index Density and Unit Weight of Soils and Calculation of Relative Density
7. ASTM D6938 – Standard Test Method for In-Place Density and Water Content of Soil and Soil Aggregate by Nuclear Methods (Shallow Depth)

1.3 QUALITY REQUIREMENTS

A. Quality control and quality assurance shall be performed by the ENGINEER in accordance with requirements provided in this section.

B. The ENGINEER shall perform field quality assurance tests of density and water content of soil in place and associated one-point compaction tests, and perform other gradation or index tests to confirm that materials meet the specification requirements.

1.4 DEFINITIONS

A. Optimum water content - that water content which will result in a maximum dry unit weight of the soil when subjected to the ASTM D698 compaction test.

B. Percent compaction - Percent compaction is defined as follows:

$$\text{Percent compaction} = \frac{(\gamma d)\ IP \times 100\%}{(\gamma d)max}$$

Where: $(\gamma d)\ IP$ = the in-place dry density of a particular soil

$(\gamma d)max$ =the maximum dry density of that same soil, determined by compaction test according to ASTM procedure

For each in-place density test sample, the maximum dry density will be determined using a one-point compaction test performed for that particular sample and the results of full curve, ASTM D698, compaction tests performed for samples of similar soil. The one-point compaction test will be performed on either the field density test sample or soil from a location immediately adjacent to the field density test sample, using the ASTM D698 procedure, as appropriate. The results of the one-point tests will then be compared with the full compaction curves to estimate the maximum dry density applicable to the field density test sample. The frequency for making one-point compaction tests may be reduced if the results of the one-point compaction test show that the maximum dry unit weight does not vary more than 2 pcf between any two tests.

C. Coverage is defined as the requirement for successive trips of a piece of compaction equipment, which by means of sufficient overlap will ensure contact on the entire surface of the layer by the equipment.

PART 2 - PRODUCTS

2.1 EARTH FILL MATERIALS

A. Earth fill materials, including Common Fill shall be as specified in Section 31 05 13 – Soils for Earthwork.

2.2 AGGREGATE FILL MATERIALS

A. Aggregate fill materials, including Filter Sand, Filter Stone, and Bedding Stone, shall be as specified in Section 31 05 16 – Aggregates for Earthwork.

2.3 GEOSYNTHETIC MATERIALS

A. Geosynthetic materials shall be as specified in Section 31 05 19 – Geosynthetics for Earthwork.

2.4 WATER FOR MOISTURE CONDITIONING AND FILTER SAND

A. Water used for moisture control in soils shall be free of organic debris and ice.

B. Water used for compaction techniques in Filter Sand shall be free of organic debris, ice, and fines. Water used shall have a turbidity of no more than 10 Nephelometric Turbidity Units (NTU).

PART 3 - EXECUTION

3.1 EXAMINATION

A. Soils and aggregate shall not be placed until the required excavation and foundation preparation have been completed and the foundation has been inspected and approved by the ENGINEER.

B. Soils and aggregate shall not be placed on a previously placed and accepted lift that has become deteriorated due to construction traffic or exposure.

3.2 PREPARATION

A. Except as otherwise specified, earth foundation surfaces, shall be graded to remove surface irregularities and shall be scarified parallel to the axis of the dam or otherwise acceptably scored and loosened to a minimum depth of 2 inches. The moisture content of the loosened material shall be controlled as specified for the earth fill, and the surface materials of the foundation shall be compacted and bonded with the first layer of earth fill as specified for subsequent layers of earth fill.

B. Earth abutment surfaces and earthen slopes shall be free of loose, uncompacted earth in excess of two inches in depth normal to the slope and shall be at such moisture content that the earth fill can be compacted against them to affect a good bond between the fill and the abutments.

C. Surfaces on which geosynthetics shall be placed shall be prepared in accordance with Section 31 05 19 – Geosynthetics for Earthwork.

3.3 PROTECTION

A. CONTRACTOR shall protect integrity and maintain functionality of dewatering systems during all fill activities.

B. The geosynthetics shall be protected at all times during construction from contamination by surface runoff and any geosynthetics so contaminated shall be removed and replaced with uncontaminated geosynthetics. Any damage to the geosynthetics during installation or during placement of bedding materials and riprap shall be replaced by the CONTRACTOR at no cost to the OWNER. In no case shall any type of equipment be allowed on the unprotected geosynthetics.

C. Any areas previously compacted and approved that become saturated and compromised due to equipment traffic, operations, or exposure to weather shall also be repaired.

3.4 FIELD QUALITY CONTROL

A. During the course of the work, the ENGINEER shall perform such tests as are required to identify materials, to determine moisture content, and to determine the density of the in-place fill. These tests performed by the ENGINEER will be used to evaluate if the fills conform to the requirements of the specifications. Such tests are not intended to provide the CONTRACTOR with the information required by him for the proper execution of the work and their performance shall not relieve the CONTRACTOR of the necessity to perform tests for that purpose.

B. ENGINEER shall perform the following testing on the in-place earthwork materials:

Schedule 1 - Field Testing For Earthwork

Material	Test	Test Schedule
Common Fill	Visual observation of equipment passes; field density and moisture content	1 test per lift per 1,000 square feet
Filter Sand[(1)]	Visual observation of equipment passes; field density and moisture content	1 test per lift per 500 square feet

[(1)] The ENGINEER may reduce the frequency of required tests on Filter Sand once a standard number of equipment passes to achieve compaction has been established. The required testing frequency shall be reinstated at the discretion of the ENGINEER based on changes in compaction equipment, aggregate source, gradation, or other factors that affect placement and/or compaction.

C. Earth fill placed at densities lower than the specified minimum density or at moisture contents outside the specified acceptable range of moisture content or otherwise not conforming to the requirements of the specifications shall be reworked to meet the requirements or removed and replaced with acceptable fill.

D. Care shall be taken by the CONTRACTOR to prevent Filter Sand and Filter Stone from becoming contaminated with soil. If the Filter Sand or the Filter Stone becomes contaminated, the contaminated material shall be removed and replaced at no cost to the OWNER.

3.5 PLACEMENT OF SOILS FOR EARTHWORK

A. Earthfill shall not be placed upon a frozen surface, nor shall snow, ice, or frozen material be incorporated in the fill.

B. Fill shall be placed in approximately horizontal layers in rows parallel to the dam baseline axis. Materials placed by dumping in piles or windrows shall be spread uniformly to not

more than the specified thickness before being compacted. The compacted thickness of each layer compacted with large ride-on compactors shall not exceed 10 inches for Common Fill. The compacted thickness of each layer compacted with hand-operated power tampers shall not exceed 4 inches. Hand-operated power tampers shall be used only where space or loading restrictions prevent the use of large ride-on compactors, or as directed by the ENGINEER.

3.6 PLACEMENT OF AGGREGATES – FILTER SAND AND FILTER STONE

A. Filter Sand and Filter Stone shall be placed uniformly in layers not more than 10 inches thick before compaction. When compaction is accomplished by hand-operated or remote-controlled equipment, the layers shall be not more than 8 inches thick. The material shall be placed in a manner to avoid segregation of particle sizes and to ensure the continuity and integrity of all zones. No foreign materials shall be allowed to become intermixed with or otherwise contaminate the aggregate.

3.7 PLACEMENT OF AGGREGATES – BEDDING STONE

A. Bedding stone for riprap or articulated concrete block (ACB) revetments shall be placed on geosynthetics to the lines and grades shown on the Drawings and as directed by the ENGINEER. Bedding stone shall be placed such that aggregate does not tear or puncture underlying geosynthetics. Bulldozers shall not be used to spread the bedding stone.

B. The average thickness of the bedding stone layer shall not be less than the full thickness shown on the Drawings. Combing with a backhoe bucket or by hand work may be required to shape the bedding stone surface in preparation for placement of geosynthetics and ACB revetments or riprap.

3.8 CONTROL OF MOISTURE CONTENT

A. The moisture content of the materials being placed shall be maintained within the specified range during placement and compaction of fill.

B. Material that is too wet when deposited on the fill shall either be removed or be dried to the specified moisture content prior to compaction.

C. If the top surface of the preceding layer of compacted fill or a foundation or abutment surface in the zone of contact with the fill becomes dryer than its specified moisture range for compaction, it shall either be removed or scarified and moistened by sprinkling to an acceptable moisture content prior to placement of the next layer of fill.

3.9 COMPACTION

A. Compaction techniques and equipment shall be done in accordance with these specifications.

B. Each layer of earth or aggregate fill shall be compacted as necessary to make the density of the fill not less than the minimum density specified below.

C. Common Fill shall be compacted with ride-on compaction equipment such as a CAT CP68 padded vibrating drum roller.

D. Compaction by means of drop weights operating from a crane or hoist will not be permitted.

E. Filter Stone shall be compacted or consolidated by making at least four passes (coverages) with a ride-on vibratory drum roller unless the compacted thickness of the lift is 4 inches or less and then the lift can be compacted with at least four passes with a vibratory plate compactor.

F. Density and moisture content requirements for Soils for Earthwork and Aggregates for Earthwork for dam construction are presented in the following table:

Material and Use	ASTM Compaction Standard	Minimum Percent Compaction	Allowable Moisture Content Range[(1)]
Common Fill	D698	95%	-2.0% to +3.0%
Filter Sand	D698	4 coverages of compactor or as determined from test section for flooding in trenches	-2% to +3.5%

[(1)]Moisture Content Range is the allowable moisture content deviation from the soil's optimum moisture content as defined by the applicable ASTM Standard.

END OF SECTION

SECTION 31 35 19.16

TURF REINFORCEMENT

PART 1 GENERAL

1.1 SECTION INCLUDES

A. Erosion control material to protect newly constructed or excavated stable soil slopes to be seeded and vegetated.

1.2 REFERENCES

A. American Society for Testing and Materials (ASTM):
   1. D 570 - Standard Test Methods for Water Absorption of Plastics.
   2. D 6524 – Standard Test Method for Stiffness of Geosynthetics Used as Turf Reinforcement Mats.
   3. D 6525 - Standard Test Method for Measuring Nominal Thickness of Permanent Erosion Control Products.
   4. D 6575 – Test Method for Stiffness of Geosynthetics Used as Turf Reinforcements Mats (TRM's)
   5. D 4354 - Practice for Sampling of Geosynthetics for Testing.
   6. D 4355 - Test Method for Deterioration of Geotextiles from Exposure to Ultraviolet Light and Water (Xenon-Arc Type Apparatus).
   7. D 4439 - Terminology for Geotextiles.
   8. D 6818 - Test Method for Ultimate Tensile Properties of Turf Reinforcement Mats.
   9. D 4632 - Test Method for Grab Breaking Load and Elongation of Geotextiles.
   10. D 4759 - Practice for Determining the Specification Conformance of Geosynthetics.
   11. D 4873 - Guide for Identification, Storage, and Handling of Geotextiles.

B. Geosynthetic Accreditation Institute (GAI) - Laboratory Accreditation Program (LAP).

C. International Standards Organization (ISO) 9001:2008 - Quality System Certification.

1.3 DEFINITIONS

A. *Certificate of Compliance (COC):* An official document certified by an authorized representative within the manufacturer's company that the manufactured synthetic turf reinforcement mat product(s) meet designated property values as manufactured in a facility having achieved ISO 9001:2008 certification, and tested in accordance with GAI-LAP procedures.

B. *High Performance Turf Reinforcement Mat (HPTRM):* A long-term, non-degradable RECP composed of UV-stabilized, non-degradable, synthetic fibers, nettings and/or filaments processed into three-dimensional reinforcement matrices designed for permanent and critical hydraulic applications where design discharges exert velocities and shear stresses that exceed the limits of mature natural vegetation. HPTRMs provide sufficient thickness, strength and void space to permit soil filling and/or retention and the development of vegetation within the matrix. The HPTRM MARV tensile strength per ASTM D-6818 is 3000 lbs/ft in the weakest principle direction.

C. *Manufacturer:* Entity that produces synthetic turf reinforcement mats through a process directly utilizing obtained raw materials, in a facility owned and operated by said entity, using equipment and assemblies owned and operated by said entity, subject to a certified Manufacturing Quality Control (MQC) Program. Upon completion of production, the manufacturer may sell the turf reinforcement mat product(s) directly to the customer, or through a vendor entity.

D. *Manufacturing Quality Control (MQC) Program*: A certified and documented program initiated and operated by the manufacturer that outlines the operational techniques and activities which sustain a quality of the synthetic turf reinforcement mat product(s) that will satisfy given needs.

E. *Minimum Average Roll Value (MARV):* Property value calculated as typical minus two standard deviations. Statistically, it yields a 97.7 percent degree of confidence that any sample taken during quality assurance testing will exceed value reported.

F. *Rolled Erosion Control Product (RECP):* A temporary degradable or long-term non-degradable material manufactured or fabricated into rolls designed to reduce soil erosion and assist in the growth, establishment and protection of vegetation.

G. *Securing Pin:* A device designed to temporarily hold the HPTRM in place while either vegetation establishes, or the installation of the HPTRM occurs. The securing pin offers no long term value to permanent tie-down of the HPTRM in an armoring solution.

H. *Trilobal Monofilament Yarn:* A multi-dimensional polymer fiber consisting of a minimum of three points, providing increased surface area and grooves/channels along the fiber to capture additional moisture and sediment to enhance vegetative growth.

I. *Typical Roll Value:* Property value calculated from average or mean obtained from test data.

J. Vendor: An entity that provides synthetic turf reinforcement mat product(s) to a customer, on behalf of an independent manufacturer. A vendor does not manufacture the actual synthetic turf reinforcement mat product(s), and therefore is not subject to provisions of a certified MQC Program.

1.4 SUBMITTALS

A. Submit the following:

1. Certification:

1. The Contractor shall provide the Engineer a certificate stating the name of the HPTRM manufacturer, product name, style, chemical compositions of filaments or yarns and other pertinent information to fully describe the geotextile.
2. The Manufacturer is responsible for establishing and maintaining a Quality Control Program to assure compliance with the requirements of the specification. Documentation describing the quality control program shall be made available prior to the approval of the HPTRM for use on the project.
3. The manufacturer's Certificate of Compliance (COC) shall state that the furnished HPTRM meets MARV requirements of the specification as evaluated under the manufacturer's quality control program. The certificate shall be attested to by a person having legal authority to bind the Manufacturer.
4. The Contractor shall establish and maintain a quality control procedure to assure compliance of the armoring solution with the requirements of the specification. Documentation describing the quality control procedure shall be provided to the Engineer.

2. Manufacturing Quality Control (MQC) test results shall be provided by the manufacturer for the HPTRM prior to installation during the duration of the project as material is delivered to the jobsite.
3. Independent Performance Test Results shall be provided upon request.

1.5 DELIVERY, STORAGE, AND HANDLING

A. HPTRM labeling, shipment and storage shall follow ASTM D 4873.

B. Product labels shall clearly show the manufacturer or supplier name, style name, and roll number.

C. Each shipping document shall include a notation certifying that the material is in accordance with the manufacturer's certificate.

D. Each HPTRM roll shall be wrapped with a material that will protect the HPTRM from damage due to shipment, water, sunlight, and contaminants. (This will be waived for HPTRMs having a 90% retention of strength after 6000 hours of exposure per ASTM D-4355.)

E. The protective wrapping shall be maintained during periods of shipment and storage.

F. During storage, HPTRM rolls shall be elevated off the ground and adequately covered to protect them from the following: Site construction damage, extended exposure to ultraviolet (UV) radiation, precipitation, chemicals that are strong

acids or strong bases, flames, sparks, temperatures in excess of 71 deg C (160 deg F) and any other environmental condition that might damage the HPTRM.

1.6 QUALITY ASSURANCE SAMPLING, TESTING, AND ACCEPTANCE

A. HPTRM shall be subject to sampling and testing to verify conformance with this specification. Sampling for testing shall be in accordance with ASTM D 4354.

B. Acceptance shall be in accordance with ASTM D 4759 based on testing of either conformance samples obtained using Procedure A of ASTM D 4354, or based on manufacturer's certifications and testing of quality control samples obtained using Procedure B of ASTM D 4354.

C. Quality Assurance Sampling and Testing will be waived for ISO 9001:2008 Certified Manufacturing Facilities. Documentation of ISO 9001:2008 Certification shall be provided upon request.

PART 2 PRODUCTS

2.1 MANUFACTURERS

A. Approved Manufacturers:
   1. Propex Operating Company, LLC,4019 Industry Drive, Chattanooga, TN 37416, (800) 621-1273

2.2 Alternate HPTRM Manufacturers:

A. For consideration, alternate systems meeting the material specification must also have a documented history of HPTRM installations totaling more than 750,000 square yards and have been in the marketplace for more than five (5) years. Past project documentation will be required for submittal for evaluation to include project name, date of installation, owner's contact information and size of the project.

B. Any alternate products seeking approval must be submitted to the Engineer. For acceptance on this project, any alternates seeking approval must meet the requirements outlined in this document. The alternate's product specifications and a product sample must be submitted to the Engineer for approval.

2.3 MATERIALS

A. PYRAMAT® 75 HPTRM:
   1. Three-dimensional, lofty woven polypropylene RECP specially designed for erosion control applications on levees, steep slopes, and vegetated waterways.
   2. Matrix composed of Trilobal monofilament yarns woven into uniform configuration of resilient pyramid-like projections that minimize watering requirements while enhancing vegetation establishment.

3. Must be a homogeneous matrix, and not comprised of layers, composites, or discontinuous materials, or otherwise loosely held together by stitched or glued netting.
4. The woven matrix of Trilobal yarns must be heat-set to improve interlock and minimize yarn displacement around anchors and pins, which also results in greater flexibility for improved conformance to uneven surfaces.
5. Material is to exhibit very high interlock and reinforcement capacity with both soil and root systems and demonstrate high tensile modulus.
6. The HPTRM should meet the following values:

Property	Test Method	Test Parameters	Units	Property Requirement
Thickness [1]	ASTM D-6525	Minimum	mm (in)	10 (0.40)
Light Penetration [1] (% Passing)	ASTM D-6567	Maximum	percent	10
Tensile Strength [1]	ASTM D-6818	Minimum	kN/m (lb/ft)	58 x 44 (4,000 x 3,000)
Tensile Elongation [1]	ASTM D-6818	Maximum	percent	40 x 35
Resiliency [1]	ASTM D-6524	Minimum	percent	80
Flexibility [2, 3]	ASTM D-6575	Maximum	mg-cm (in-lb)	615,000 (0.534)
UV Resistance [2]	ASTM D-4355	Minimum	percent	90 at 3,000 hrs [4] 90 at 6,000 hrs

Note:

1. Minimum Average Roll Value (MARV).
2. Typical Value.
3. A smaller value for flexibility denotes a more flexible material.
4. Third party / Independent Testing values must be provided showing UV resistance testing for two consecutive years including most recent year.

B. Performance Properties:

1. Flume Testing: In a vegetated state, the HPTRM must demonstrate acceptable performance (as defined by the Engineer) when subjected to at least 0.5 hrs of continuous flow producing the following conditions.
   1. Permissible velocity: 7.6 m/sec (25 ft/sec)
   2. Permissible tractive force (shear stress): 770 kPa (16 psf)
   3. Performance may be demonstrated by:
      a. Flume testing at an independent facility under conditions similar to this project provided that the manufacturer can demonstrate that the material tested is functionally equivalent to the material being supplied. This may be demonstrated by providing index property test results (listed in 2.2.A.4) from a GAI-LAP accredited laboratory for both the tested and supplied materials.

b. A documented case history of successful performance (as defined by the Engineer) at an installation similar to this project where (documented) hydraulic forces met or exceeded the requirements listed above provided that the manufacturer can demonstrate that the case history material is functionally equivalent to the material being supplied. This may be demonstrated by providing index property test results (listed in 2.2.A.4) from a GAI-LAP accredited laboratory for both the case history and supplied materials.

2. Wave Overtopping Testing: In a vegetated state, the HPTRM must demonstrate acceptable performance (as defined by the Engineer) when subjected to wave overtopping simulations, performed by Colorado State University (CSU), and authorized and directed by the U.S. Army Corps of Engineers (USACE).
   1. A single test shall be defined as one wave overtopping simulation down the flume on one set of trays (linear and angled sections) for 3 equivalent test hours at 4.0 cfs/ft. Passing this wave overtopping test is defined as surviving the 3 equivalent test hours without visible damage.
   2. Failure is defined by (0.06 m) 0.2 ft. or more of soil/grass erosion over a (0.37 m^2) 4 ft^2 area.
   3. Each type of HPTRM armoring product shall be subject to 1 wave overtopping test on each tray set at 4.0 cfs/ft for the duration equivalent to 3 test hours (~6 elapsed hours).
3. Functional Longevity: In addition to the UV resistance per ASTM D-4355 stated above, the HPTRM must have a documented installation showing a minimum retained tensile strength of 70% per ASTM D-6818 after a minimum of 10 years of exposure to a minimum solar radiation of 21.7 MJ/m2-day.

C. Manufacturing Quality Control: Testing shall be performed at a laboratory accredited by GAI-LAP for tests required for the geosynthetic, at frequency exceeding ASTM D 4354, with following minimum acceptable testing frequency:

Property	**Test Frequency m^2 (yd^2)**
Thickness	1/10,974 (1/13,125)
Light Penetration (% Passing)	1/10,974 (1/13,125)
Tensile Strength	1/10,974 (1/13,125)
Tensile Elongation	1/10,974 (1/13,125)
Resiliency	1/43,896 (1/52,500)
Flexibility	1/43,896 (1/52,500)
UV Resistance	Annually

2.4 ACCESSORIES

A. Securing Pins:

1. Securing pins should be at least 5 mm (0.2 in.) diameter steel with a 38 mm (1.5 in.) steel washer at the head of the pin. Securing pins should be driven flush to the soil surface.
2. Length: 300 to 600 mm (12 to 24 inches); sufficient ground penetration to resist pullout.
3. Placement: The pins provide for temporary tie-down of the HPTRM to the slope to aid with vegetation establishment. Locations of the pins along trenches are indicated in the drawings at the center of the 0.3 m x 0.3 m (1 ft x 1ft) trench spaced 0.3 m (1 ft) apart. Locations of the pins along the vertical overlaps are spaced 0.3 m (1 ft) apart. HPTRM rolls wider than 3.2 m (10.5 ft) must not have a pin spacing greater than 0.45 m (1.5 ft) in any direction to minimize wrinkling of the material common to wide roll width geosynthetics and the loss of intimate contact beneath the HPTRM.
4. Heavier metal stakes may be required in rocky soils
5. Stainless steel pins are required.

PART 3 EXECUTION

3.1 PREPARATION

A. Grade and compact areas to be treated with HPTRM (compacted as indicated or as directed by Engineer). Subgrade shall be uniform and smooth.

B. Remove large rocks, soil clods, vegetation, and other sharp objects so that the installed mat will have direct contact with the soil surface.

C. Prepare seedbed by loosening 50 to 75 mm (2 to 3 in) of soil above final grade. This may be accomplished with a rotary tiller on slopes 3H:1V or flatter.

D. Select and apply soil amendments, fertilizer, and seed, (in an amount equivalent to 50% of the total mixture required to be installed on the soil surface) to scarified surface prior to installation of HPTRM. Do not mulch areas where HPTRM is to be placed.

E. Keep areas moist as necessary to establish vegetation. When watering seeded areas, use fine spray to prevent erosion of seeds or soil. If as a result of rain, prepared seedbed becomes crusted or eroded, or if eroded places, ruts, or depressions exist for any reason, rework soil until smooth and reseed such areas.

F. Terminate the edges of the turf mat reinforcement per the Drawings and Manufacturers instructions.

3.2 INSTALLATION

A. Install HPTRM at elevation and alignment indicated.

B. Beginning at downstream end of the slope, place initial end of first roll of HPTRM into the TOS trench and secure with securing pins at 300 mm (12 in) intervals.

C. Unroll the HPTRM down the slope and secure the HPTRM end in the TOS trench with securing pins at 300 mm (12 in) intervals.

D. Position adjacent upstream rolls in same manner, overlapping preceding roll minimum 75 mm (3 in) until the armoring limits are completed.

E. Backfill and compact the trenches with specified soil or as directed by Engineer.

F. Secure HPTRM to the slope with securing pins at a frequency of 2.5 pins per square meter (2 pins per square yard). Increased anchoring frequency may be required if site conditions are such that the Engineer determines it necessary.

G. Alternate installation methods must be approved by Engineer prior to execution.

H. Soil fill and seed or sod the HPTRM:

1. Installed HPTRM shall be seeded (or re-seeded) and soil filled, OR sodded as required by the project documents.
2. Do not place excessive soil above material.
3. Broadcast additional seed or mulch above soil-filled mat and irrigate as necessary to establish/maintain vegetation.

I. Rubber-tired vehicles must be used, and sharp turns avoided. No heavy and/or tracked equipment or sharp turns are permitted on the installed HPTRM. Avoid ANY traffic over the HPTRM if loose or wet soil conditions exist.

END OF SECTION

SECTION 31 35 23

ARTICULATING CONCRETE BLOCK REVETMENTS

PART 1 GENERAL

1.1 SUMMARY

A. This section includes material and placement specifications for articulating concrete block (ACB), cables, and anchors for use as ersoion protection for the Breach through the spillway section of Woodlake Dam as shown on the Drawings.

This section does not address Geosynthetics for Earthwork (Section 31 05 19), which are required as part of the installation of the ACB.

B. Related Sections:
1. Section 31 05 16 – Aggregates for Earthwork
2. Section 31 05 19 - Geosynthetics for Earthwork

1.2 REFERENCES

A. ASTM International (ASTM)
1. ASTM C 33 Concrete Aggregates
2. ASTM C 140 Sampling and Testing Concrete Masonry Units
3. ASTM C 476 Grout for Masonry
4. ASTM C 1262 Freeze-Thaw Durability of Manufactured Concrete Masonry Units
5. ASTM D698 - Standard Test Method for Laboratory Compaction Characteristics of Soil Using Standard Effort (12,400 ft-lbf/ft3 (600 kN-m/m3))U.S. Federal Highway Administration (FHWA)
6. FHWA RD-89-199 Hydraulic Stability of Articulated Concrete Block Revetment Systems During Overtopping Flows

1.3 SUBMITTALS

A. Meet all requirements of Section 01 33 00 - Submittal Procedures: Requirements for Submittals.

B. ACB Revetment Construction Plan: Prior to commencing work, submit for approval by the ENGINEER a plan that consists of at least the following:
1. Product literature and descriptive technical data on blocks, cables, cable fittings, soil anchors, and geotextile. Include sufficient details and data to show that the proposed materials and products meet the requirements of this specification.
2. Shop drawings showing layout and details of ACB and geotextile installations. Show block patterns, anticipated locations of cast-in-place concrete joints, mattress junction details, layout sequence, grade change details, and proposed installation methods for void filling materials.
3. Test reports demonstrating that proposed ACB revetment system conforms to FHWA RD-89-199.

4. Copies of manufacturer's written instructions on material handling, storage and installation details.

1.4 QUALITY ASSURANCE

A. At least 15 days prior to delivery of the ACB and associated materials to the site, the CONTRACTOR shall inform the ENGINEER in writing of the source from which he intends to obtain such materials, and typical test results showing the material meets the specification requirements.

1.5 QUALIFICATIONS

A. Purchase all materials from reputable, long standing suppliers to ensure sufficient quantities, delivery times, and quality of materials.

1.6 DEFINITIONS

A. Articulating Concrete Block (ACB) Revetment System: A matrix of interconnected concrete block units for erosion protection.

B. Cable-tied articulating concrete block revetment units will be referred to as mattresses.

C. Joint Fill: Concrete grout to be used to fill the joints between the mattresses and against headwalls or other adjacent structures as shown on the Construction Drawings or as directed by the ENGINEER.

D. Block Fill: Soil materials to be used to fill voids spaces between the interconnected concrete blocks. Soils shall meet the requirement of Section 31 05 16 – Aggregates for Earthwork, or as directed by the ENGINEER.

PART 2 PRODUCTS

2.1 GENERAL

A. The CONTRACTOR shall be responsible for calculation of the required volumes of each material type based on Project Drawings, consultations with the ENGINEER, estimates of waste, loss and breakage during delivery, stockpiling, haulage and placement, experience with similar materials, and other factors as identified by the CONTRACTOR.

2.2 ARTICULATING CONCRETE BLOCK

A. ACB System Requirements
   1. Matrix Assembly: Cabled system, such as Shoreblock® SD-475-OCT, open-celled, tapered, manufactured by Shoretec, L.L.C., Houston TX, or equal.
   2. Mattresses shall be pre-manufactured as an assembly of concrete blocks connected into mattresses by the use of revetment cables. The assembled mattresses shall have a width of up to 8 feet and a length that is capable of being transported without special permitting.
   3. Thickness, minimum: 4.75 inches

B. The ACB product shall have been tested in a flume chamber in substantial conformance with FHWA RD-89-199. The flume test shall be based on conservative assumptions for field placement of the blocks (such as block orientation, and joint spacing within construction tolerances). The critical shear stress (and critical velocity) shall be indicated in the test report.

C. Block Structural Requirements

1. Blocks shall be either wet cast using concrete as specified herein, or formed by vibratory block forming machine (dry cast). Blocks shall be interlocking, and penetrations shall be included for revetment cables as necessary to bind the individual blocks into mattresses. Cable penetrations shall prevent any exposure of cables to potential UV degradation within the dimensions of the individual blocks. The blocks shall be closed cell, as shown on the Drawings, and capable of articulation when formed into mattresses.
2. Compressive Strength, minimum: 4000 psi; tested in accordance with ASTM C 140.
3. Concrete aggregate shall meet the requirements of ASTM C 33 except for grading. Aggregate grading shall be reasonably consistent and shall be well graded from the maximum size which can be conveniently handled with available equipment.
4. Water Absorption (dry cast units), maximum: 7%
5. Saturated Surface-Dry Density, minimum: 143 pcf
6. Air entrainment of wet cast concrete: 4-7%
7. Freeze-thaw durability tested in accordance with ASTM C 1262: either (1) weight loss of each of 5 specimens after 100 cycles shall not exceed 1 percent; or (2) weight loss of each of 5 specimens after 150 cycles shall not exceed 1.5 percent

2.3 CABLE

A. Provide cable and connectors sufficiently sized for the size/weight of the assembled mattresses such that the assembled mattresses can be placed in compliance with OSHA standards. The ACB revetment manufacturer shall be responsible for determining the minimum cable strength compatible with the mattress size for safe handling. Use a minimum factor of safety of five, and include appropriate reduction factors for mechanically crimped cable, and other fasteners.

B. Use rope manufactured from polyester, stainless steel wire, or galvanized steel wire. Fittings such as sleeves, stops, and washers shall be in accordance with the manufacturer's recommendations unless otherwise shown on the Drawings.

C. Polyester rope shall consist of high tenacity, low elongation, and continuous filament polyester fibers, with a core constructed of parallel fibers within an outer jacket or cover. The weight of the parallel core shall be between 65 to 70 percent of the total weight of the cable. Minimum nominal diameter shall be ¼ inch.

D. Cable shall be impervious to rot, mildew, and degradation associated with marine organisms. Materials used shall not be affected by continuous immersion in fresh water.

2.4 ANCHORS

A. ACB mattresses shall be anchored at the top and at the exposed sides of the ends of the revetment system by fastening the exposed revetment cables to the anchors driven into the anchor trench as recommended by the manufacturer.

B. Anchors shall have a minimum pull resistance of 2,000 pounds and shall be attached to the ACB revetment system in a manner that will achieve little or no slack in the revetment cable, and be compatible with the proposed ACB revetment system.

C. Anchors shall be of the helical or flexible type and shall be installed at intervals as recommended by the manufacturer. Material options for the anchors shall be cast aluminum, galvanized steel, or galvanized ductile cast iron.

2.5 GROUT

A. Grout for gaps in the concrete mattresses shall be coarse and proportioned in accordance with ASTM C 476. The quantity of the mixing water shall be the minimum necessary to obtain a uniform mixture and to permit placing.

PART 3 EXECUTION

3.1 EXAMINATION

A. Comply with all requirements of Section 01 40 00 - Quality Requirements: Testing and inspection services.

B. Grade tolerance: ±2 inches of specified finished grade, with no abrupt variations that would cause vertical projections of individual blocks of more than 1 inch beyond the adjacent blocks.

C. Check products upon delivery to assure that proper material is received and is undamaged.

3.2 PREPARATION

A. Stockpile materials in an area pre-approved by the Engineer.

B. Ensure that drainage materials and associated geotextile placements are in conformance with the requirements of the specifications and approved by the Engineer.

3.3 PROTECTION

A. To limit exposure of geotextile to UV light, place blocks within 7 days after placing geotextile, and block fill within 14 days after placing blocks.

B. Protect work from damage by subsequent operations. Remove and replace broken or displaced blocks in complete conformance with this section. Damaged materials shall not be incorporated in the work.

C. Equipment shall not be allowed on the ACB that could crack, cause abrasion, or otherwise damage the blocks. Vehicle traffic on the ACB shall be restricted to light weight rubber tired vehicles, and where intermittent access is necessary to accomplish the work. Routine haul routes shall not be established on the ACB. These allowances shall not waive the CONTRACTOR'S obligation to maintain the installation until acceptance, and verify that vehicle access does not crack, or in any way damage, the ACB.

3.4 FIELD QUALITY CONTROL

A. Provide services of manufacturer's technical representative for on-site consultation during installation.

B. Provide blocks free of defects that would interfere with proper placement or that would impair strength or durability of the installation.

C. Repair or replace any ACB units, mattresses, cables, anchors or related materials that, either before or after installation, are damaged or otherwise do not meet the requirements of this specification or at the direction of the ENGINEER. Repairs or replacements shall be the sole responsibility of the CONTRACTOR and shall be completed at no cost to the OWNER.

3.5 FOUNDATION PREPARATION

A. Areas on which filter fabric, drainage layer, and ACB mattresses are to be placed shall be constructed to the lines and grades shown on the Drawings. The subgrade shall be free of voids, pits, or depressions and shall be proof-rolled. Voids, pits, or depressions shall be brought to grade by backfilling in accordance with applicable portions of the specifications. All obstructions, such as roots and projecting stones larger than 1 inch remaining on the surface, shall be removed and all of the soft or low density pockets of material removed shall be filled with common material and compacted to a minimum of 95% of the ASTM D 698 density.

B. Excavation and preparation for anchor trenches, side trenches, and toe trenches or aprons shall be done in accordance to the lines, grades, and dimensions shown on the Drawings.

C. Immediately prior to placing the filter fabric, drainage layer, and mattresses, the prepared foundation area shall be inspected by the ENGINEER for approval.

3.6 PLACEMENT

A. Filter fabric shall be installed on the prepared subgrade prior to placement of the drainage layer and ACB mattresses, in accordance with Section 31 05 19 – Geosynthetics for Earthwork. Adjacent layers of filter fabric shall have a minimum of 2 feet of overlap. Fabric shall be secured with 6"x1"x6" pins.

B. Place granular drainage layer on filter fabric as shown on the Drawings. Materials shall be in accordance with Section 31 05 16 – Aggregates for Earthwork.

C. Place ACB mattresses in accordance with the manufacturer's written instructions and the CONTRACTOR'S approved shop drawings, within the limits shown on the Drawings.

D. Lift, align, and place ACB mattresses using a spreader bar designed for that purpose, in such a manner as to produce a relatively planar surface. The mattresses shall be placed side-by-side and/or end-to-end so that the mattresses abut each other. No overlapping of mattresses will be permitted.

E. Maximum block projections (vertical offset from adjacent blocks) for installation in the dry shall not exceed 1 inch. Typical block projections shall be less than half the maximum projection. The maximum space or gap between mattresses shall be 3 inches, except that local wider gaps may be accepted if the length of the gap is less than 3 feet and the entire gap is grouted.

F. Individual blocks that are hand-placed shall be subject to the spacing and level parameters specified above. Revetment cables shall be threaded into the blocks as the placement proceeds and fastened with approved sleeves, fittings, or fasteners.

3.7 GROUTED JOINTS

A. Use of grout shall be minimized to the extent practicable. Joints that shall require grout include:
   1. Joints between cable-tied mattresses where the joint is 3 inches wider than the nominal joint; and
   2. Abutments where the ACB meets headwalls, pipe penetrations, or other adjacent structures as shown on the Drawings and as directed by the ENGINEER.

B. All cable ties shall be completed prior to placing grout.

C. Abutments shall be constructed neatly, voids filled in with partial blocks, and the remaining gaps filled with grout. Grout shall be thoroughly compacted in place and struck off to adjacent surface.

D. Grout shall be continuously cured for a period beginning immediately after installation and continuing for seven days. Curing may be accomplished by wet curing, curing compound, or a combination thereof.

3.8 BLOCK FILL

A. Backfill interior open cells and voids between ACB blocks using filter stone as shown on the Drawings or as directed by the ENGINEER.

B. Backfilling shall be completed in a timely manner such that all mattresses are backfilled within the same day they are placed.

C. Place filter stone either by hand or using equipment in such a way as to ensure complete filling of voids and meeting the compaction requirements of applicable standards or as directed by the ENGINEER.

D. Place block fills so as to ensure no damage to ACB, seals, joints, cables or underlying geosynthetics or drainage layer. Any such materials damaged during the placement of block fills shall be repaired or replaced at the discretion of the ENGINEER.

E. Repair or replacement of damaged ACB or associated materials shall be the sole responsibility of the CONTRACTOR and shall be completed to the satisfaction of the ENGINEER at no cost to the OWNER.

END OF SECTION