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June 27, 2017

Hand Delivery

Ms. Melanie D. Davenport
Virginia Department of Environmental Quality
Director, Water Permitting Division
P.O. Box 1105
Richmond, VA 23218

Re: Virginia DEQ Comments on Dominion Energy Transmission, Inc., Atlantic Coast Pipeline – May 31, 2017 Response to Virginia Department of Environmental Quality Request for Information for Developing and Evaluating Additional Conditions for Section 401 Water Quality Certification for Interstate Natural Gas Infrastructure Project

Dear Ms. Davenport:

Enclosed is a CD containing minor revisions to the updated response delivered to you June 23, 2017 for the above referenced matter. Atlantic Coast Pipeline, LLC (Atlantic) is submitting this updated information to assist VDEQ in review of the proposed Atlantic Coast Pipeline Project under the Commonwealth of Virginia's 401 Water Quality Certification program.

Atlantic appreciates your review of this information. Please contact Richard Gangle at (804) 273-2814 or Richard.B.Gangle@dominionenergy.com, if there are questions regarding this submittal.

Please direct written responses to:

Richard Gangle
Dominion Energy Services, Inc.
5000 Dominion Boulevard
Glen Allen, Virginia 23060

Sincerely,

Robert M. Bisha
Technical Advisor, Atlantic Coast Pipeline

cc: Richard Gangle, Dominion Energy

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Glen Allen, VA 23060
DominionEnergy.com

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Ms. Melanie D. Davenport
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Re: Virginia DEQ Comments on Dominion Energy Transmission, Inc., Atlantic Coast Pipeline – May 31, 2017 Response to Virginia Department of Environmental Quality Request for Information for Developing and Evaluating Additional Conditions for Section 401 Water Quality Certification for Interstate Natural Gas Infrastructure Project

Dear Ms. Davenport:

Enclosed is a CD containing the updated response to your May 19, 2017 "Request for Information for Developing and Evaluating Additional Conditions for Section 401 Water Quality Certification for Interstate Natural Gas Infrastructure Project", which addresses the Virginia Department of Environmental Quality (VDEQ) comments dated June 15, 2017. Atlantic Coast Pipeline, LLC (Atlantic) is submitting this updated information to assist VDEQ in review of the proposed Atlantic Coast Pipeline Project under the Commonwealth of Virginia's 401 Water Quality Certification program. Also attached is annotated version of your comments to help facilitate your review of the updated submittal.

Atlantic appreciates your review of this information. Please contact Richard Gangle at (804) 273-2814 or Richard.B.Gangle@dominionenergy.com, if there are questions regarding this submittal.

Please direct written responses to:

Richard Gangle
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Glen Allen, Virginia 23060

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Sincerely,

Robert M. Bisha

Robert M. Bisha
Technical Advisor, Atlantic Coast Pipeline

cc: Richard Gangle, Dominion

Atlantic Coast Pipeline

DEQ Review Comments - Request for Additional Information

In accordance with Guidance Memo No. GM17-2003, Interstate Natural Gas Infrastructure Projects - Procedures for Evaluating and Developing Additional Conditions for Section 401 Water Quality Certification Pursuant to 33 USC Section 1341, on May 19, 2017 the Department of Environmental Quality (DEQ) requested information from Atlantic Coast Pipeline (ACP) in order to evaluate whether additional 401 water quality conditions are necessary to ensure the protection of water quality. On June 1, 2017 ACP submitted its response, dated May 2017 and prepared on behalf of ACP by ERM. In addition to reviewing the ACP response document, DEQ also considered other available project information specifically the Federal Energy Regulatory Commission's (FERC) draft Environmental Impact Statement (EIS) and the Commonwealth of Virginia's comments on the draft EIS (dated April 6, 2017), submittals and regulatory requirements associated with the development of Annual Standards and Specifications and stormwater and erosion and sediment control plans as they relate to appropriate site specific best management practices and the US Army Corps of Engineers Nationwide Permit 12. Finally, on June 7-8, 2017 DEQ convened a two day meeting in Lexington, Virginia to discuss the ACP response document. Attachment A to this document contains the agenda, attendee list and notes from this meeting.

Please provide responses and revised documents as appropriate to the following comments:

Section 2.0 - Project-related Upland Ground-disturbing Activities within 50 feet of Surface Waters

No additional information needed.

Section 3.0 - Identification of Perennial Surface Waters

1. A complete list of perennial water bodies that may be affected should be included rather than only a list of priority streams (see comment 3 in section 11.0).

Response: A complete list of waterbodies within 50 feet of project workspace, but not crossed, was included as Table 3.0-1 in Atlantic's May 2017 response to the VDEQ's Section 401 Certification Request for Information. The table inclusively identifies waters and unnamed tributaries of waters that are of the type of which VDEQ requested closer evaluation. (See pages 7 and 8)

Section 4.0 - Permanent Right-of-Way (ROW) Maintenance Measures

1. Include a description of any ROW maintenance and inspection measures to be used in areas of slopes greater than 30 percent.

Response: See Section 13 (pages 30 through 34) for more details on inspections. The

planned inspection schedule exceeds the VA standards and will be followed for all slope categories.

Section 5.0 - Plan to Protect Water Quality from Acid Forming Materials (AFM)

1. The plan should include details on field testing procedures to be followed by environmental inspectors if warranted.

Response: Added to the Information Request Response Document. (See page 15)

2. The plan references Section 6.6.8 of Resource Report 6. Relevant information from Report 6 should be incorporated into the plan.

Response: All the relevant text from Section 6.6.8 of Resource Report 6 was included in Atlantic's May 2017 response to the VDEQ's Section 401 Certification Request for Information.

3. Provide information regarding the source and appropriate composition of topsoil to be used in the event replacement topsoil used if different than FERC's Upland Erosion Control, Revegetation and Maintenance Plan.

Response: Added to the Information Request Response Document. (See page 15)

Section 6.0 - Hydrostatic Testing and Dust Control Protection Measures

Surface water withdrawals for hydrostatic testing of water tight containers, pipelines, and vessels from non-tidal waters and tidal waters are excluded from VWP Permit regulations (9VAC25-210-310A.6.b) regardless of the volume withdrawn. However, 9VAC25-210-310.B allows the Board to require a permit if the withdrawal is found to cause impairment, adversely affect beneficial uses, or violate water quality standards. To avoid an adverse effect or impairment, the withdrawals for hydrostatic testing should be managed so that:

- No more than 10% of the instantaneous flow rate from the channel is removed;
- The intake screens shall be designed so that screen openings are not larger than 1 Millimeter and;
- The screen face intake velocities are not greater than 0.25 feet per second.

Provide a discussion of what steps the applicants and its contractors will take during the hydrostatic testing to meet these requirements. The plan should describe the screen type and pump used to meet these requirements.

1. Provide maps showing the location of each prefabricated water impoundment structure. Include the latitude and longitude of the impoundment and the intake placed in the stream channel from which the water will be withdrawn. Explain if the impoundments will also

be used to store water withdrawals for HDD and dust control throughout the project or just for hydrostatic testing. Discuss the typical daily operation of pumps to withdraw water to fill the impoundments.

Response: The requested mapping is provided as Appendix C to the Information Request Response Document.

2. Provide a drawing showing the proposed location of discharge areas for hydrostatic testing water.

Response: The requested mapping is provided as Appendix D to the Information Request Response Document.

3. ACP states all hydrostatic test water discharges will be sheet flow in uplands. ACP should state that discharge monitoring will be in accordance with the 9VAC25-120-80 et. seq.

Response: Added to the Information Request Response Document (See pages 16 and 17)

Water Withdrawal for Dust Control and Horizontal Directional Drilling (HDD)

4. Prior to construction, applicant should provide DEQ with FERC required documents related to the proposed or potential sources of water used for dust control and HDD, anticipated quantities of water to be appropriated from each source, and the measures that will be implemented to ensure water sources and aquatic biota are not adversely affected by the appropriation activity.

Response: Added to the Information Request Response Document (See pages 16 through 18)

5. Surface water withdrawals for all purposes, including dust control and HDD, of less than 10,000 gallons per day from non-tidal waters and less than 2 million gallons from tidal waters per day are excluded from VWP Permit requirements (9VAC25-210-310.A.11).

Response: Added to the Information Request Response Document (See pages 16 through 18)

6. 9VAC25-210-310.B allows the Board to require a permit if the withdrawal is found to, cause an impairment, adversely affect beneficial uses, or violate water quality standards. To avoid an adverse effect or impairment, the withdrawals for dust control and HDD should be managed so that:

    - No more than 10% of the instantaneous flow rate from the channel is removed;
    - The intake screens shall be designed so that screen openings are not larger than 1 Millimeter and;
    - The screen face intake velocities are not greater than 0.25 feet per second.

Provide a discussion in the plan of what steps the applicants and its contractors will take during withdrawals for dust control or HDD to meet these requirements. The plan should identify the screen type and the pump used.

Response: Added to the Information Request Response Document (See pages 16 through 18)

7. Describe the construction spreads, when different parts of the pipeline will be constructed, and where water will be obtained for each construction spread. Provide calculations for the estimated maximum daily amount of water that will be needed for dust control and HDD activities for each construction spread. Discuss if each construction spread can separately meet the VWP exclusions for surface water withdrawals under 9VAC25-210-310. A for HDD and dust control surface after withdrawals. In addition, include the location of withdrawals for each construction spread and distribution across separate stream reaches to meet withdrawal recommendations.

Response: Added to the Information Request Response Document (See pages 16 through 18)

8. If daily withdrawals exceed 10,000 gallons per day from non-tidal waters and 2 million gallons from tidal waters per day, a VWP Permit in accordance with 9VAC25-210 et. seq. is required.

Response: Added to the Information Request Response Document (See page 16)

<u>General comments to all types of water withdrawals</u>

1. Include procedures in the plan to notify DEQ within 30 days prior to initiating a withdrawal for hydrostatic testing, dust control or HDD including when and where withdrawals are to occur. Withdrawals should avoid typically lowest flow periods for nearly all stream channels. DEQ recommends adjusting the location and timing of withdrawals where possible to coincide with higher streamflow periods and/or redirect withdrawals to larger flowing channels.

Response: Added to the Information Request Response Document (See page 16)

2. Provide plans and procedures that will be put in place to review nearby stream gauges and drought scenarios during water withdrawal activities to ensure that withdrawals are not occurring during low flow conditions that could cause impairment or affect other beneficial uses.

Response: Added to the Information Request Response Document (See page 16)

3. Discuss the impact of any water withdrawals on downstream water users, particularly during low flow periods.

Response: Added to the Information Request Response Document (See page 16)

4. Include plans to record and track the daily volumes of water withdrawn and where those records will be kept and reported to DEQ as needed.

Response: Added to the Information Request Response Document (See page 16)

Section 7.0 - Riparian Buffer Protection

1. Evaluate the ability to reduce the construction limit of disturbance (LCD) in upland areas approaching waterbody and wetland crossings from 125 feet to 75 feet and where possible this reduced LOD width should be extended 50 feet from each side of the stream or wetland crossing as an additional upland buffer.

Response: Added to the Information Request Response Document (See pages 19 and 20)

2. Evaluate moving construction laydown/contractor yard area away from Hamilton Branch Creek.

Response: Added to the Information Request Response Document (See page 21)

3. Evaluate requiring a 100 foot buffer from of any perennial, intermittent, or ephemeral surface waters for fueling, maintenance, parking and hazardous material storage activities (ATWS).

Response: Added to the Information Request Response Document (See page 19)

4. ACP should state that removal of riparian buffers not directly associated with the project construction activities is prohibited. Disturbance and removal of riparian buffers from project related upland ground disturbing activities that would occur within 50 feet of any perennial, intermittent, or ephemeral surface waters should be avoided where possible, and minimized if 50 feet is not possible. Removal of riparian buffers shall not be allowed where stream bank stability under normal flow conditions would be compromised.

Response: Added to the Information Request Response Document (See page 19)

Section 8.0 - Spill Prevention Control and Countermeasure (SPCC) Plan

1. The SPCC Plan prepared by ERM dated July 18, 2016 in response to the 401 Request for Information does not appear to have been revised to include DEQ comments provided on the DEIS by letter dated April 6, 2017. Relevant comments from the DEQ April 6, 2017 letter are provided in comments 2 through 4 below.

2. SPCC Plan p.2 - Section 4.0.A. See text below. The statutory requirements for making notifications in the event of an oil spill are "immediately upon learning of the discharge". The language below suggests a process that may result in a delay in reporting.

3. Section S.O.A.l.j., page 4 - This should state immediate reporting to DECL EPA and others. The language below suggests a process that may result in a delay in reporting.

4. Section 7.C.3.a and b., page 8. These oil spill reporting requirements do not specify a timeframe for reporting. These reporting requirements should clearly indicate that spills should be reported "immediately upon learning of the discharge". The cited sections of Virginia water control law specify that spillers must notify the *"director or coordinator of emergency services...for the political subdivision in which the discharge occurs and any other political subdivision reasonably expected to the affected by the discharge, and the appropriate federal authorities..."*. This is not addressed in the spill reporting section of the plan.

Response: The updated SPCC plan is provided as Appendix E to the Information Request Response Document.

Section 9.0 - Specific Engineering and Best Management Practices to be used in areas of Steep Slopes and Slide Prone Areas

1. The plan should include notification to DEQ prior to initiating construction activity in areas with greater than 30 percent slopes. The notice should include at a minimum, the anticipated start date, location and duration of activity.

Response: Added to the Information Request Response Document (See page 27)

2. Include procedures and notifications to be implemented in the event a slide results in an impact to state waters.

Response: Added to the Information Request Response Document (See page 27)

Section 10.0 - Blasting Plan

1. Confirm the reference to Karst Monitoring and Mitigation Plan on page 8, Section 8.0 of the Blasting Plan prepared by ERM dated November 1, 2016 is referencing the blasting

procedures in the Karst Terrain Assessment, Construction, Monitoring and Mitigation Plan (Appendix E) prepared by GeoConcepts dated January 2017.

Response: Yes, the Karst Monitoring and Mitigation Plan on page 8, Section 8.0 of the Blasting Plan prepared by ERM dated November 1, 2016 is referencing the blasting procedures in the Karst Terrain Assessment, Construction, Monitoring and Mitigation Plan (now Appendix H) prepared by GeoConcepts dated January 2017.

Section 11.0 - Water Quality Monitoring Plan

1. The narrative states that 8 sites were selected, but Table 3.0-1 (Appendix D, page 5) only lists 6 sites. Also, only 6 sites are depicted in the maps in WQM Plan, Appendix A. Please provide info on the 2 additional stations. See comments below for DEQ's recommended station locations.

Response: The revised Water Quality Monitoring (WQM) Plan includes seven sites. These sites are listed in Appendix A of the WQM Plan. A copy of the revised WQM Plan is included as Appendix F to the Information Request Response Document.

2. Actual proposed monitoring sites were not included on the provided maps. It is therefore difficult to determine if the sites are appropriately located. Lat/long coordinates of the above-, adjacent-to- and below-construction sites along each selected reach should be provided as soon as possible. An estimate of the distances from monitoring sites to activity areas would be beneficial for evaluating the overall study design.

Response: Maps depicting the recommended seven streams and associated upstream, adjacent, and downstream monitoring locations are included in Appendix A of the WQM Plan (see Appendix F to the Information Request Response Document). A table including latitude, longitude, and distance from the Project workspace is included as an inset with each map.

3. A complete list of perennial water bodies that may be affected should be included in section 3.0, rather than only a list of priority streams. Specifically, it appears that the proposed plan does not identify several Class VI wild trout waters that may be impacted by upland construction. These waters are important not only for the trout populations themselves, but because they exhibit sufficiently high water quality and ecological integrity necessary to support wild trout. The agency asks that the following Class VI streams be evaluated for potential impacts due to upland construction. If confirmed, these streams should be identified in section 3.0 (Table 3.0-1).

    - Vicinity of MP8.5.4: There appears to be upland construction activity near Lick Run and Townsend Draft, both designated as Class VI "Good" Wild Trout stream. Please confirm.

- Vicinity of MP86.9: Erwin Draft is included in the Plan, but the plan does not note that this stream is designated as a Class VI Wild Trout Water ("good"). Please confirm.
- Vicinity of MP87.9: There appears to be upland construction activity near Back Creek X-Trib which is designated as Class VI "Good" Wild Trout stream. Please confirm.
- Vicinity of MP94.1: There appears to be upland construction activity near Laurel Run which is designated as Class VI "Good" Wild Trout stream. Please confirm.
- Vicinity of MP113.5 and 114.1: Upland construction appears to impact Ramsey's Draft, which is designated as Class VI "Exploited" Wild Trout stream. Please confirm.

Response: A complete list of waterbodies within 50 feet of project workspace was include as Table 3.0-1 in Atlantic's May 2017 response to the VDEQ's Section 401 Certification Request for Information. As requested by the VDEQ, streams that are crossed by the Project are not included. Using the selection criteria described in Section 2.0 and 3.0 of the WQM Plan, Table 3.0-1 of the WQM Plan identifies the streams for monitoring where landowner access or public access is available (see Appendix F to the Information Request Response Document).

4. If confirmed that upland construction will occur within 50 feet of these Class VI streams (identified above), the agency requests that the monitoring plan include at least one monitoring station to evaluate impacts to Class VI trout waters, preferably on Erwin Draft (near MP86.9, and identified as a water of concern in Table 3.0-1).

Response: As discussed in the WQM Plan, Ewing Draft has been proposed for monitoring to evaluate impacts to Class VI trout waters (see Appendix F to the Information Request Response Document)

5. The station(s) cited to evaluate impacts to wild trout streams should include a method to check wild trout populations before, during and after construction.

Response: Atlantic is evaluating chemical and biological parameters before, during, and after construction according to the enclosed Water Quality Monitoring Plan (WQMP). Aquatic biota will be monitored according to the family-level benthic macroinvertebrate sampling approach described in the WQMP, which will provide necessary data to monitor biological stream health before, during, and after construction without need to rely on more transient fish populations that may or may not occur within the trout streams that will be monitored.

6. 3 of 6 sites in table 3.0-1 include threatened or endangered species. The monitoring plan should include a method to check threatened or endangered species populations before, during and after construction.

Response: These three streams were included as potential T&E resource waters based on the intention to identify high quality waters for sampling. Atlantic identified an Unnamed Tributary to Mill Creek and Unnamed Tributary to the Appomattox River as proposed sampling locations based on the connection to potential T&E waters. Neither of these streams are potential T&E water, thus no surveys are proposed. Surveys within the South River have been completed and determined that no federally listed species were present, therefore no follow-up surveys are proposed for the South River.

7. There are two public water supply intakes on Jennings Branch and Middle River (MP 129.2 & 130.4) that appear to be in the vicinity of upland construction. Monitoring before/after construction is needed to ensure that no contamination reaches these public water supply intakes.

Response: There are no public water supply sources associated with streams within 50 feet of the workspace that are not crossed by the Project.

8. The plan does not provide Standard Operating Procedures or Quality Assurance Project Plan that covers the parameters to be monitored. For example, how will the field probes be calibrated and what standards will be used? The offered "according to manufacturer instructions" is insufficient detail on how staff will perform operation and calibration of equipment. Please provide an SOP and QAPP.

Response: The manufacturer specifications that will be used to operate and calibrate the proposed field equipment are included in Appendix B of the WQM Plan (Appendix F to the Information Request Response Document). Appendix B also includes a Calibration Work Sheet and Directions that summarizes how the proposed field equipment will be calibrated by staff to satisfy the need for a SOP and QAPP.

9. The plan does not include the name of the laboratory which will perform macroinvertebrate identifications. The name of the laboratory and documentation that it can perform the VSCI protocol, such as a DEQ approved QAPP, is needed.

Response: As discussed in Section 6.0 of the WQM Plan (see Appendix F to the Information Request Response Document), Atlantic has identified Civil and Environmental Consultants, Inc (CEC) and REI Consultants as companies with labs and individuals with experience in macroinvertebrate sampling and identification, with appropriate qualifications in Virginia. One of these companies, or a similarly qualified lab, will be contracted to complete the laboratory identification of macroinvertebrates.

10. The proposed monitoring frequency for chemical parameters is far less than normally relied on to make water quality determinations. One reading for DO, pH, conductivity, and turbidity done before, during, and after construction is insufficient to determine if there is an actual water quality impairment. To make such determinations, the agency

prefers continuous monitoring of these parameters for a duration of one month to occur before, during, and after construction. However, DEQ requests that, at a minimum, three grab samples be collected at each site before, during, and after construction (total of nine samples per site). The grab samples should be collected at least one week apart.

Response: Added to the Information Request Response Document (See page 28)

11. There is no detail on how far apart benthic monitoring will occur during the project. For benthic parameters, changes to the community will happen over time. DEQ recommends that benthic sampling be conducted one month before, immediately after, and at least a month after actual construction.

Response: Added to the Information Request Response Document (See page 28)

12. The document specifies that duplicate chemical/physical sampling via two staff collecting samples at the same time and location will occur. Does this mean every sample will be collected in this manner? If not, please specify the frequency of duplicate sampling.

Response: Added to the Information Request Response Document (See page 28)

13. DEQ requests that the agency be notified to enable observation of at least one sampling event to document performance of the sampling teams. In addition, DEQ requests that the contracted laboratory provide two randomly selected samples, as selected by DEQ, including all identified organisms and material from which they were sorted, in order to verify identification accuracy and sorting efficiency. This is a routine procedure when the agency evaluates submitted data.

Response: Added to the Information Request Response Document (See page 28)

14. DEQ staff can provide guidance on adherence to Standard Operating Procedures for all aspects of the proposed monitoring, as requested by the contractors.

Response: Added to the Information Request Response Document (See page 28 and Appendix F to the Information Request Response Document)

15. DEQ requests that all raw data be provided in electronic form (the plan implies that benthic data may only be provided on laboratory bench sheets).

Response: Added to the Information Request Response Document (See page 28)

Section 12.0 - Karst Mitigation Plan

1. Submit the Karst Survey Report filed with FERC on February 24, 2017 as part of the response to DEQ's May 19, 2017 Request for Information.

Response: The Karst Survey Report is provided as Appendix G to the Information Request Response Document.

2. Submit Resource Report 2, Section 2. 1.6 Groundwater Construction Related Impacts and Mitigation as part of the response to DEQ's May 19, 2017 Request for Information.

Response: The Section 2.1.6 of Resource Report 2 is provided as Appendix I to the Information Request Response Document.

3. All field surveys for identification of karst features and associated documentation shall be completed and submitted to DEQ at least 14 days prior to initiation of land disturbance activities in those areas.

Response: Added to the Information Request Response Document (See page 30)

4. Provide clarification regarding field investigation procedures occurring between tree clearing and initiation of construction activity.

Response: Added to the Information Request Response Document (See page 30)

5. The plan should include notification to DEQ prior to initiating construction activity in areas with karst terrain. The notice should include at a minimum, the anticipated start date, location and duration of activity.

Response: Added to the Information Request Response Document (See page 30)

6. To further evaluate flow paths for significant karst features in the vicinity of the project, ACP shall develop a Karst Dye Tracing Plan to be submitted and approved prior to initiation of land disturbance activities in karst terrain. See Attachment B.

Response: Atlantic will provide a Karst Dye Trace Plan to VDEQ for approval prior to the initiation of land disturbance activities in Karst Terrain. (See page 30)

Section 13.0 - Description of Onsite Environmental Monitoring and Inspection Measures to be Implemented During Construction

1. The plan should state that the environmental inspectors will ensure the requirements required under ESC Inspection Requirements 9 VAC2 5-840-60, § 62. 1-44.15:58) and SWM Inspection Requirements (9VAC25-870-114, § 62. 1-44.15:37) will be followed.

Response: Added to the Information Request Response Document (See page 32)

ATLANTIC COAST PIPELINE, LLC
ATLANTIC COAST PIPELINE
Docket Nos. CP15-554-000 & CP15-554-001

Section 401 Certification Request for Information: Virginia Department of Environmental Quality

June 2017

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LIST OF ACRONYMS AND ABBREVIATIONS

ACP	Atlantic Coast Pipeline
Atlantic	Atlantic Coast Pipeline, LLC
ATWS	Additional temporary workspace
BIC	Atlantic's Best-in-Class Program
BMP	Best Management Practices
COM Plan	Construction, Operation and Maintenance Plan
DETI	Dominion Energy Transmission, Inc.
EI	Environmental Inspector
EPA	U.S. Environmental Protection Agency
ESC	Erosion and Sediment Control
ETS	Endangered, Threatened and Special Concern
FERC	Federal Energy Regulatory Commission
IC	Incremental Control
LOD	limits of disturbance
Plan	*Upland Erosion Control, Revegetation, and Maintenance Plan*
Procedures	*Wetland and Waterbody Construction and Mitigation Procedures*
Project	Atlantic Coast Pipeline
QA/QC	quality assurance and quality control
SPCC	Spill Prevention, Control, and Countermeasures Plan
SSD	Site-specific Designs
SWPPP	Stormwater Pollution Prevention Plan
TDs	Typical Designs
TMDL	Total Maximum Daily Load
VAC	Virginia Administrative Code
VDEQ	Virginia Department of Environmental Quality

1.0 INTRODUCTION

This document has been updated from Atlantic Coast Pipeline's June 1, 2017 submittal to the Virginia Department of Environmental Quality (VDEQ) in response VDEQ's request for additional information dated June 15, 2017. The June 1, 2017 submittal was in response to VDEQ's "Request for Information for Developing and Evaluating Additional Conditions for Section 401 Water Quality Certification for Interstate Natural Gas Infrastructure Project," dated May 19, 2017. The following information is provided with the intention to provide details on actions that will be implemented to ensure that the Atlantic Coast Pipeline Project (ACP or Project) activities occurring in upland areas do not result in a discharge or otherwise contribute to an exceedance of the Commonwealth of Virginia (Commonwealth) Water Quality Standards. Atlantic Coast Pipeline, LLC[1] (Atlantic) understands that any conditions developed and included in a draft 401 Certificate will be separate and in addition to any other requirements established by the Virginia Water Protection Permit Program, U. S. Army Corps of Engineers permits, stormwater and erosion and sediment control requirements, and any conditions imposed by the Federal Energy Regulatory Commission (FERC).

Atlantic has submitted additional detailed information regarding proposed construction, restoration, and operation measures to the FERC docket (number CP15-554-000). This information is available for viewing on the FERC website (http://www.ferc.gov). Using the "eLibrary" link, select "General Search" from the eLibrary menu and enter the docket number excluding the last three digits in the "Docket No." field (i.e., CP15-554).

The following sections have been organized to address the specific requests of the VDEQ, including:

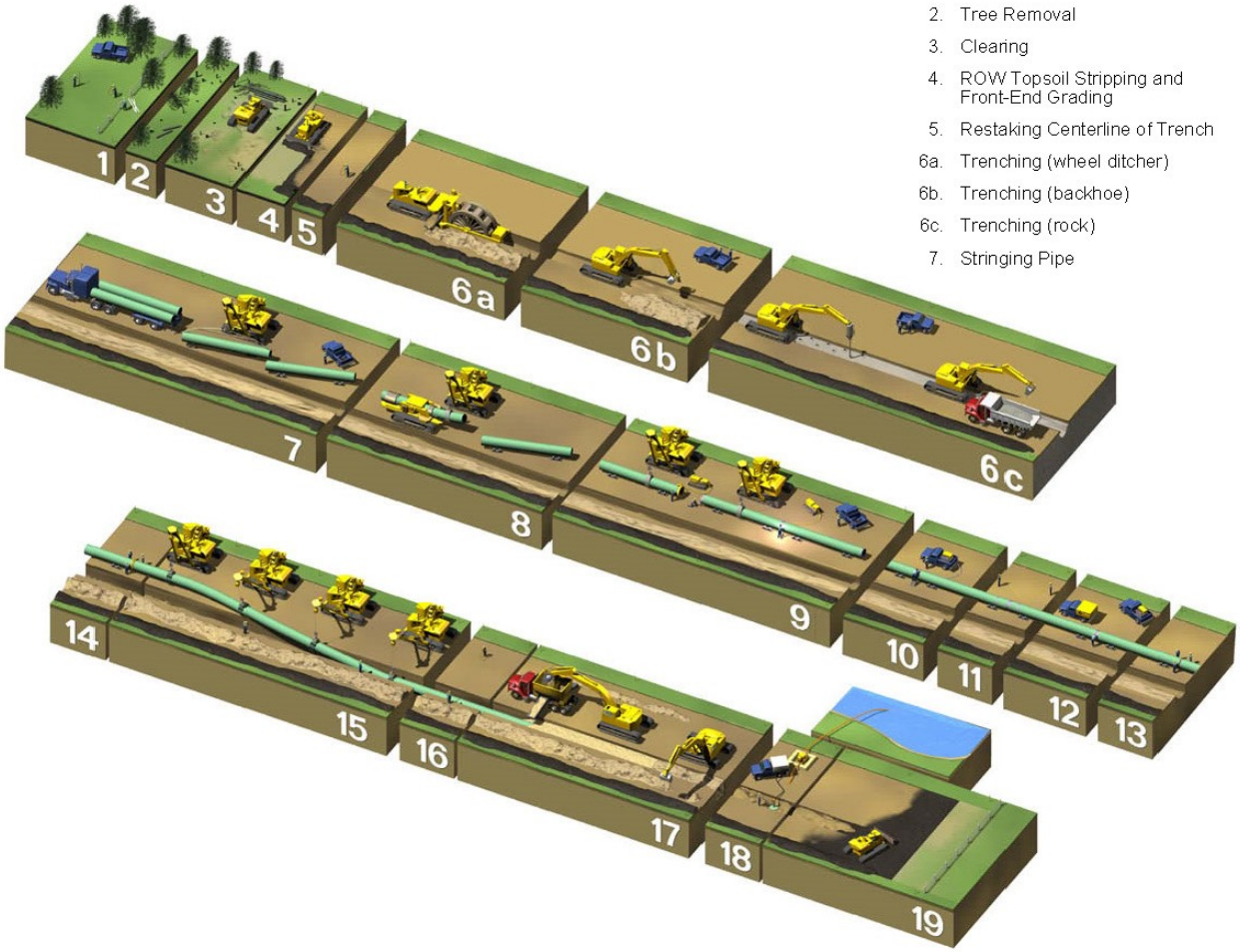
- A complete listing of the types of project-related upland ground-disturbing activities that would occur within 50 feet of any perennial, intermittent, or ephemeral surface waters.
- Identification of all perennial surface waters within 50 feet of the limit of disturbance (LOD) that are (a) designated as wild/stocked trout streams, (b) identified as endangered/threatened species waters, (c) designated for public water supply, (d) classified as Tier 3 streams, and/or (e) subject to an established total maximum daily load (TMDL) (identifying the pollutant of concern, including sediment, nutrients, or other).
- Permanent right-of-way maintenance measures relevant to minimizing erosion or other water quality impacts.
- A plan detailing measures to be used to protect water quality from acid forming materials.

[1] Atlantic Coast Pipeline, LLC (Atlantic) is a company formed by four major U.S. energy companies—Dominion Energy, Inc. (Dominion Energy); Duke Energy Corporation; Piedmont Natural Gas Co., Inc.; and Southern Company Gas, Inc. Dominion Energy Transmission, Inc. has been contracted by Atlantic to construct and operate the project.

- Protections to be employed to prevent any potential impacts associated with hydrostatic testing or dust control activities.
- A plan addressing how riparian buffers will be protected to the extent feasible during construction for additional protection of water quality.
- A Spill Prevention Control and Countermeasures (SPCC) Plan.
- Specific engineering and best management practices (BMPs) to be used in areas of steep slopes and slide prone areas.
- A Blasting Plan detailing measures to be used to protect water quality in connection with blasting activities.
- A Water Quality Monitoring Plan detailing measures to monitor potential impacts to water quality from upland ground-disturbing activities, including a discussion of (a) criteria to identify select critical areas for monitoring with consideration of wild/stocked trout streams, endangered/threatened species waters, public water supplies, TMDL watersheds, Tier 3 streams, or areas near acidic soils; (b) a proposed monitoring schedule (e.g., before, during and after construction activity); (c) chemical monitoring parameters (e.g., temperature, dissolved oxygen, specific conductance, pH, and turbidity) and biological monitoring using VDEQ-approved methods; (d) sample collection, handling and analytical quality QA/QC procedures; and (e) reporting procedures.
- A Karst Terrain Assessment, Construction, Monitoring and Mitigation Plan including discussion of measures to (a) identify known karst features within areas of land disturbance activities for construction of a pipeline and related access roads and appurtenances; (b) minimize the potential for any impacts to surface waters including water supply sources; (c) evaluate subsurface flow paths; (d) propose monitoring activities during the period of construction; and (e) mitigation measures applicable in the event of any impacts.
- Description of onsite environmental monitoring and inspection measures to be implemented during construction.

2.0 PROJECT RELATED GROUND DISTURBING ACTIVITIES

Construction of the ACP will follow industry-standard practices and procedures as described below. In a typical scenario, construction involves a series of discrete activities conducted in a linear sequence. These include survey and staking; clearing and grading; trenching; pipe stringing, bending, and welding; lowering-in and backfilling; hydrostatic testing; final tie-in; commissioning; and right-of-way cleanup and restoration. Figure 1.1-1 illustrates each of the steps in a typical construction sequence. Of these construction activities, ground disturbance that will occur within 50 feet of any perennial, intermittent, or ephemeral surface waters includes clearing and grading, access road improvements or construction, trenching, lowering in and backfilling, and right-of-way cleanup and restoration. A description of these ground disturbing activities is provided below.



1. Survey and Staking
2. Tree Removal
3. Clearing
4. ROW Topsoil Stripping and Front-End Grading
5. Restaking Centerline of Trench

6a. Trenching (wheel ditcher)
6b. Trenching (backhoe)
6c. Trenching (rock)

7. Stringing Pipe
8. Field Bending Pipe
9. Line-Up, Initial Weld
10. Fill & Cap, Final Weld
11. As-Built Footage
12. X-Ray Inspection, Weld Repair
13. Coating Field Welds
14. Inspection & Repair of Coating
15. Lowering Pipe into Trench
16. As-Built Survey
17. Pad, Backfill, Rough Grade
18. Hydrostatic Testing, Final Tie-in
19. Replace Topsoil, Final Clean-Up, Full Restoration

For environmental review purposes only.

Atlantic Coast Pipeline

Dominion Energy

Atlantic Coast Pipeline and Supply Header Project
Figure 1.1-1
Typical Pipeline Construction Sequence

ERM

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Clearing and Grading

To the extent feasible, Atlantic will minimize tree removal during construction. Cleared vegetation and stumps will either be burned, chipped (except in wetlands), or hauled offsite to a commercial disposal facility. No chips, mulch, or mechanically cut woody debris will be stockpiled in wetlands, and no upland woody debris will be disposed of in wetlands. Non-merchantable timber will not be disposed of by placing it off the right-of-way without landowner approval. No woody debris disposal will be allowed in agricultural areas or wetlands. Burning of non-merchantable wood will be allowed only where the contractor has acquired all applicable permits and approvals (e.g., agency and landowner) and in accordance with Commonwealth and local regulations, and only with site-specific approval from Atlantic.

Following clearing, the construction right-of-way and additional temporary workspace (ATWS) will be graded where necessary to provide a level work surface to allow safe passage of construction equipment and emergency vehicles. More extensive grading will be required in steep side slope or vertical areas and where necessary to prevent excessive bending of the pipelines.

Typically, topsoil will be segregated from subsoil in non-saturated wetlands, cultivated or rotated croplands, managed pastures, hayfields, residential areas, and in other areas requested by the landowner or land managing agency unless Atlantic is instructed by a landowner or land managing agency not to do so or Atlantic import topsoil in accordance with FERC's *Upland Erosion Control, Revegetation, and Maintenance Plan* (Plan). Topsoil will be segregated in accordance with the Plan and *Wetland and Waterbody Construction and Mitigation Procedures* (Procedures), where required. The depth of topsoil removed will depend on soil conditions and landowner requests or land managing agency requirements. In accordance with the Plan, and in areas where topsoil segregation is required, Atlantic will segregate at least 12 inches of topsoil in deep soils (more than 12 inches of topsoil) and the entire topsoil layer in shallow soils (less than 12 inches of topsoil).

If the ground is relatively flat and does not require topsoil segregation or grading, the existing vegetative mat will be peeled and removed similar to topsoil and stockpiled along the right-of-way for use in restoration.

Access Roads

Atlantic has identified roads that will be used to provide access to the Project construction right-of-way, permanent easement, and other facilities during construction and operation of the ACP. Atlantic will utilize existing roads to the extent practicable, but some new roads may need to be built in remote areas. Additionally, new roads will need to be built to provide access to aboveground facility sites (i.e., compressor and M&R stations, valves, and pig launcher/receiver assemblies) during operations. In some cases, existing roads will require improvement (such as grading, gravelling, replacing or installing culverts, minor widening, and/or clearing of overhead vegetation) to safely accommodate construction equipment and vehicles. A sufficient number of roads with regular spacing are needed to minimize congestion of construction vehicles and equipment on the right-of-way, having fewer access roads would

increase the duration of construction and create unsafe work conditions for workers. If any existing roads are damaged during construction, Atlantic will restore these roads to preconstruction condition or better.

Along temporary access roads temporary timber construction mats, temporary bridges, culverts, or temporary rip rap will be utilized as a temporary means to stabilize access roads for use during construction. Permanent access roads however may require improvements, such as placement of culverts or widening of the roadbed that will remain in place for operation of the pipeline and associated facilities. Where new culvert placement is required or replacement of existing culverts will occur, Atlantic will design culverts and embed culverts according to the appropriate design parameters per USACE general and regional conditions, or state requirements. Details pertaining to the required improvement of access roads will be provided as engineering designs are completed.

Trenching

Pipe trench will be excavated by rotary trenching machines, track-mounted backhoes, or other similar equipment. Trench spoil will be deposited adjacent to the trench within the construction right-of-way. The trench for each pipeline will be excavated to a depth that provides sufficient cover over the pipeline after backfilling. The typical dimensions of each pipeline trench will vary depending on a number of factors, such as the diameter of the pipe being installed and the substrate in the vicinity of the trench (see Table 2.0-1). The bottom width of the trench will be sufficient to accommodate the diameter of the pipeline and sufficient pad material around it (typically approximately one foot on either side of the pipeline). The top width will vary to allow the sides of the trench to be adapted to local soil conditions at the time of construction.

If trench dewatering is required within or off of the construction right-of-way, it will be conducted in accordance with the Plan and Procedures and applicable permits in a manner that will not cause erosion or result in silt-laden water flowing into a wetland or waterbody. In areas of topsoil segregation, subsoil from trench excavations will be placed adjacent to the topsoil in a separate pile to allow for proper restoration of the soil during backfilling and restoration.

When rock or rocky formations are encountered, hydraulic hammers, tractor-mounted mechanical rippers or rock trenchers will be used for breaking up the rock prior to excavation. In areas where mechanical equipment or other means cannot be used to break up or loosen boulders or shallow bedrock, blasting will be required (see Section 10.0 and Appendix A for additional information).

TABLE 2.0-1

Typical Trench Dimensions for the Atlantic Coast Pipeline

Pipeline	Outside Diameter	Cover	Top Width (feet)	Depth (feet)	Typical Depth of Cover (feet)
Atlantic Coast Pipeline					
AP-1	42-inch	Non-agricultural upland	10–15	7.5	3
		Agricultural	10–15	8.5	4
		Wetland	15–20	7.5	3
		Road, railroad, and waterbody crossings	15–20	9.5	5 or more
		Steep terrain	30	13.5	7 or more
AP-2	36-inch	Non-agricultural upland	10–15	7	3
		Agricultural	10–15	8	4
		Wetland	15–20	7	3
		Road, railroad, and waterbody crossings	15–20	9	5 or more
AP-3	20-inch	Non-agricultural upland	5–10	6	3
		Agricultural	5–10	7	4
		Wetland	10–15	6	3
		Road, railroad, and waterbody crossings	10–15	8	5 or more
AP-4	16-inch	Non-agricultural upland	5–10	6	3
		Agricultural	5–10	7	4
		Wetland	10–15	6	3
		Road, railroad, and waterbody crossings	10–15	8	5 or more
AP-5	16-inch	Non-agricultural upland	5–10	6	3
		Agricultural	5–10	7	4
		Wetland	10–15	6	3
		Road, railroad, and waterbody crossings	10–15	8	5 or more

Lowering-in and Backfilling

Prior to lowering-in, the trench will be inspected to confirm it is free of rocks and other debris that could damage the pipe or its protective coating. Dewatering may be necessary to inspect the bottom of the trench in areas where water has accumulated. If dewatering is required, it will be conducted in accordance with the Plan and Procedures and applicable permits in a manner that will not cause erosion or result in silt-laden water flowing into a wetland or waterbody.

The pipe will be lifted from the temporary supports and lowered into the trench using side-boom tractors. As necessary, trench breakers (stacked sand bags or foam) will be installed in the trench around the pipe in steeply sloped areas to prevent movement of subsurface water along the pipeline.

After lowering-in, the pipe will be padded and the trench will be backfilled with previously excavated materials using bladed equipment or backhoes. If the material excavated from the trench is rocky, the pipeline will be protected with a rock shield or covered with other suitable fill (i.e., crushed limestone rock or screened sand). Excavated rock will then be used to backfill the trench to the top of the existing bedrock profile in the trench, except that large rock will be buried on the working side of the two-tone cut where the contractor levels the ground for construction. This will prevent large rocks from migrating into the pad material in the trench and

making contact with the pipe. Additionally, excavated rock may be crushed with a rock pulverizer and incorporated into fill or used as gravel to upgrade access roads. Excavated material not required for backfill will be removed and disposed of at approved upland disposal sites.

Final Clean-Up and Restoration

Final cleanup will begin after backfilling and as soon as weather and site conditions permit. Final cleanup (including final grading and installation of permanent erosion control devices) will be completed within timeframes required by permits, in accordance with landowner requests, as required by the Plan and Procedures, or as approved by the appropriate agencies. Construction debris will be collected and taken to an approved disposal facility. Preconstruction contours will be restored as closely as practicable. Segregated topsoil will be spread over the surface of the right-of-way, and permanent erosion controls will be installed.

Revegetation measures will be implemented in accordance with the Plan and Procedures or as directed by the appropriate land managing agency. Disturbed, non-cultivated work areas will be stabilized and seeded as soon as possible after final grading, weather and soil conditions permitting, subject to the recommended seeding dates for the seed mixes used to revegetate different areas along the pipelines. Seeding will stabilize the soil, improve the appearance of the area disturbed by construction, and in some cases, restore native flora.

3.0 IDENTIFICATION OF PERENNIAL SURFACE WATERS

Table 3.0-1 identifies perennial surface waters within 50 feet of the LOD which do not cross the project workspace:

TABLE 3.0-1

Perennial Waterbodies Within 50 feet of Workspace Not Crossed by Workspace along the Atlantic Coast Pipeline in Virginia [a]

Pipeline Segment/County/ City	Milepost	Feature ID	Waterbody Name	Trout Waters	Potential T&E Species	TMDL Watershed (Impairment) [b]
AP-1						Total N, Total P, TSS
Highland County	86.9	shiy001	Erwin Draft			Total N, Total P, TSS
Bath County	99.3	sbaz007	Gibson Hollow			Total N, Total P, TSS
Bath County	99.3	sbaz005	UNT to Gibson Hollow			Total N, Total P, TSS
Bath County	103.1	sbar007	UNT to Mill Creek		UNT to Potential Freshwater Mussels Water	Total N, Total P, TSS
Augusta County	157.4	saua400	UNT to South Fork Back Creek	UNT to Class I-IV Trout Water,		Sediment, Total N, Total P, TSS, Mercury, PCB, E.Coli

TABLE 3.0-1

Perennial Waterbodies Within 50 feet of Workspace Not Crossed by Workspace along the Atlantic Coast Pipeline in Virginia [a]

Pipeline Segment/County/ City	Milepost	Feature ID	Waterbody Name	Trout Waters	Potential T&E Species	TMDL Watershed (Impairment) [b]
Nelson County	161.1	snex005	UNT to Spruce Creek	UNT to Class I-IV Trout Water,		Total N, Total P, TSS, E. Coli
Nelson County	163.1	snex006	Spruce Creek	Class I-IV Trout Water		Total N, Total P, TSS, E. Coli
Nelson County	184.5	snea407	UNT to James River		UNT to Potential Freshwater Mussels Water	Total N, Total P, TSS
Buckingham County	203.7	sbul002	UNT to Willis River			Total N, Total P, Fecal Coliform
Cumberland County	213.1	scuk003	UNT to Little Willis River			Total N, Total P, Fecal Coliform
Highland County	Contract or Yard	shic100	UNT to Jackson River			Total N, Total P, TSS
City of Suffolk	56.5	ssup025	UNT to Cohoon Creek			Total N, Total P, TSS, Fecal Coliform, Enterococci
City of Chesapeake	57.9	ssuo104	UNT to Western Branch Reservoir			Total N, Total P, TSS, Fecal Coliform, Enterococci
City of Chesapeake	71.7	schr012	UNT to East Ditch			Total N, Total P, TSS, Enterococci
City of Chesapeake	74.6	schr002	UNT to Dismal Swamp			Total N, Total P, TSS, Enterococci
City of Chesapeake	78.6	scho011	UNT to Deep Creek			Total N, Total P, TSS, Enterococci
City of Chesapeake	78.9	scho006	UNT to Deep Creek			Total N, Total P, TSS, Enterococci
City of Chesapeake	79.4	scho007	UNT to Deep Creek			Total N, Total P, TSS, Enterococci

[a] There are no Tier 3 streams or designated public water supply sources associated with streams within 50 feet of the workspace but not crossed by the Project.

[b] Impairment abbreviations for watersheds with total maximum daily load (TMDL) include: Total Nitrogen = Total N; Total Phosphorus = Total P; Total Suspended Solids = TSS; Mercury in Fish Tissue = Mercury; Polychlorinated biphenyl in Fish Tissue = PCB; remaining entries are bacteriological nomenclature.

4.0 PERMANENT RIGHT-OF-WAY MAINTENANCE MEASURES

Atlantic will stabilize the permanent right-of-way through the use of industry-standard construction and maintenance practices, such as restorative grading, soil compaction mitigation, and revegetation, as well as implementation of Atlantic's Best-in-Class (BIC) Program in steep slope terrain. Atlantic will restore the right-of-way to meet the VDEQ's stormwater management regulatory requirements (9 Virginia Administrative Code [VAC] 25-870 et seq.).

Atlantic is providing the VDEQ a quantitative evaluation that includes an analysis of water quality and quantity and demonstrates that post-construction runoff characteristics for ACP will remain hydrologically equivalent to pre-construction runoff characteristics.

Successful management of post-construction runoff from the right-of-way will include the following non-structural BMPs: proper grading to minimize concentrated flow and restore pre-construction flow patterns; mitigation of soil compaction to improve infiltration and decrease runoff volume; and establishment of permanent vegetation. Annual maintenance and inspection programs for the right-of-way will be implemented to provide long-term vegetation management and runoff control.

Through the implementation of these non-structural BMPs, post-construction runoff characteristics of the land surface after the completion of construction and final stabilization will be equivalent to pre-construction conditions. Calculations which demonstrate hydrologic equivalency of the post-construction condition with the pre-construction condition and compliance with Virginia's water quality and quantity criteria as set forth in 9 VAC 25-870-63 and 9 VAC 25-870-66, respectively, and related VDEQ guidance have been prepared and are included in the Virginia ACP *Stormwater Pollution Prevention Plan* (SWPPP) submission. Restoration and maintenance methods used to meet water quality and quantity design criteria and compliance standards of the VDEQ regulatory program are summarized as below.

Grading

Atlantic is required by FERC to restore the ground surface as closely as practicable to original contours to restore natural overland water flow patterns, aquifer recharge, and drainage patterns. FERC has an established process to review and approve any changes to this requirement in advance while in the field. The FERC variance request process will be included in the SWPPP to be submitted to the VDEQ.

Restoration of the right-of-way will begin after pipeline construction activities have been completed. Restoration measures include the re-establishment of final grades and drainage patterns as well as the installation of permanent erosion and sediment control measures to minimize post-construction erosion and to control post-construction stormwater runoff. Grading will be conducted prior to construction where necessary to provide a reasonably level work surface. Upon completion of construction, Atlantic will:

- restore the ground surface as closely as practicable to original contours to restore natural overland water flow patterns, aquifer recharge, and drainage patterns;
- re-contour disturbed areas in a fashion designed to stabilize slopes, remove ruts and scars, and support successful revegetation; and
- restore, to original or better condition, drainage ditches and culverts that are diverted or damaged during construction.

Additionally, in areas with slope inclinations equivalent to or greater than 30 percent and a slope length greater than 100 feet, restoration of steep terrain may include:

- grading to the natural conditions;
- installation of permanent erosion control devices (i.e., slope breakers) designed to reduce runoff velocity, divert water from the surface of the right-of-way, and encourage retention of soils;
- the use of additional structural materials (e.g., rock or woody debris) to provide an anchor for revegetation and deposition of soil; and
- the use of grading practices such as stair-stepping or grooving slopes or leaving slopes in a roughened condition by not fine-grading in accordance with Virginia Erosion and Sediment Control Handbook Std & Spec 3.29 (Surface Roughening) on slopes with an inclination exceeding 3 horizontal to 1 vertical (3:1) or that have received final grading but will not be stabilized immediately.

Atlantic will develop and implement other site-specific measures, where warranted, to address land movement, surface erosion, backfill erosion, soil stability, and restoring of the right-of-way in steep slope areas. Specifically, Atlantic is committed to employing measure from the BIC Program to protect the environment in steep slope areas. These measures are the most efficient and protective design or configuration with the least environmental impact while providing reliable construction and operations.

The following special design and construction mitigation measures will be implemented during construction in steep slope areas:

- targeted management and diversion of surface water around landslide sites, including the use of ditches, berms, slope breakers, and/or grading;
- mitigation of surface erosion by armoring or otherwise stabilizing surface soils using riprap, coir cloth, hydroseeding, mulching, and/or tracking;
- targeted management of water sources along the trench, including the use of trench breakers and/or added drainage piping in the trench;
- targeted mitigation of seeps, springs, or other subsurface water encountered along the right-of-way using subsurface drains or other special drainage measures;
- engineering of the backfill around or within steep slope areas to dry the backfill, facilitate compaction, improve backfill soil strength, and reduce saturation;
- installation of targeted structures to stabilize backfill using engineered fill, retaining walls, sack-crete placements, key trenches, and/or shear trenches; and
- reduction in surcharge on steep slope areas by reducing excess or saturated backfill.

Soil Compaction Mitigation

Atlantic will minimize impacts by implementing the mitigation measures for compaction and rutting as described in the FERC Plan and the ACP SWPPP and approved Erosion and

Sediment Control (ESC) plans. Soil compaction resulting from construction activities may reduce the potential for successful revegetation as well as decrease infiltration capability thereby increasing runoff potential. Fine-textured soils with poor internal drainage that are moist or saturated during construction are the most susceptible to compaction and rutting.

Compaction impacts will be mitigated through the use of tillage equipment during restoration activities such as a paraplow or similar implement. In areas where topsoil segregation occurs, plowing with a paraplow or other deep tillage implement to alleviate subsoil compaction will be conducted before replacement of the topsoil. In rocky or heavily rooted soils, compaction may be impossible to measure and rectify without additional damage. If compaction testing is impeded by rock or roots, Atlantic may conclude that there is a suitable amount of large material in the soil to rectify potential compaction. Soil compaction will be remediated prior to re-spreading of salvaged topsoil. Mitigation of soil compaction will improve infiltration, decrease runoff volume, and improve growing conditions for vegetation. A description of soil compaction mitigation will be included in the SWPPP to be submitted to the VDEQ.

Atlantic will test for soil compaction using penetrometers or other appropriate devices:

- in residential and agricultural areas (e.g., active croplands, pastures, nurseries, and orchards) disturbed by construction activities;
- in other areas requested by the land managing agency or landowner;
- in undisturbed areas adjacent to the construction workspace with the same soil type under similar moisture conditions to approximate preconstruction conditions; and
- in areas identified by the environmental inspectors (EI), who will be responsible for conducting subsoil and topsoil compaction testing and determining the need for corrective measures.

Where appropriate, such as in steep slope areas, compaction of the soil may be used intentionally to prevent surface erosion and slope instability in the form of landslides, landslips, or surficial slumping. A detailed evaluation and selection of control measures, including mechanical compaction of disturbed slopes, will be implemented in areas of steep terrain in accordance with the BIC Program. A description of soil compaction mitigation will be included in the SWPPP to be submitted to the VDEQ.

Revegetation

A Restoration and Rehabilitation Plan has been prepared for the ACP to address post-construction restoration and rehabilitation activities. The Restoration and Rehabilitation Plan describes seedbed preparation, seed mix selection, seeding methods, lime and fertilizer application, mulching, and supplemental planting. Permanent vegetative cover will be initiated within the timeframes set forth in the Virginia Minimum Standards (9 VAC 25-840-40) and will be considered successfully established when vegetation is uniform, mature enough to survive and

will inhibit erosion. The Restoration and Rehabilitation Plan will be appended to the SWPPP to be submitted to the VDEQ.

In accordance with Virginia Minimum Standards (MS-1), permanent or temporary soil stabilization will be applied to denuded areas within seven (7) days after final grade is reached on any portion of the site. Temporary soil stabilization will be applied within seven (7) days to denuded areas that may not be at final grade but will remain dormant for longer than 14 days. Permanent stabilization will be applied to areas that are to be left dormant for more than one (1) year. A permanent vegetative cover will be established on denuded areas not otherwise permanently stabilized. Per Virginia Minimum Standards (MS-3), permanent stabilization is achieved when vegetation is established that is uniform, mature enough to survive and will inhibit erosion.

Maintenance and Inspection

Post-construction maintenance and inspections will be used to monitor the success of the right-of-way restoration and control of stormwater runoff. Atlantic will inspect disturbed areas after the first and second growing seasons to determine the success of revegetation. In agricultural areas, revegetation will be considered successful when the area has been revegetated and is similar to adjacent undisturbed areas of the same field. In all other non-forested areas, revegetation will be considered successful when the density and cover of non-nuisance vegetation is similar to adjacent areas that were not disturbed by construction activities. In addition, routine operations inspections include visually inspecting the right-of-way once a year.

Following construction, a 50-foot-wide permanent easement will be maintained for operation of the pipeline. Property will be restored as close to its pre-construction condition as practical. In accordance with the FERC Plan and the ACP SWPPP, in non-cultivated uplands, a 10-foot-wide herbaceous corridor will be established and may be maintained annually, as needed. In addition, trees and brush will be cleared over the entire width of the permanent right-of-way on an as-needed basis not to exceed once every three years. In accordance with the Virginia Runoff Reduction Method Instructions and Documentation, dated 28 March 2011, utility rights-of-way that will be left in a natural vegetated state, including areas that will be bush hogged no more than four times per year, are considered hydrologically equivalent to forest/open space.

In wetlands and riparian areas, the FERC Procedures allow a 10-foot-wide corridor centered over pipelines to be permanently maintained in an herbaceous state. The Procedures also allow for cutting and removing trees greater than 15 feet in height within 15 feet of pipelines in wetlands.

Permanent Slope Breakers

In addition to non-structural BMPs, Atlantic will install permanent slope breakers during the construction phase of the Project. The permanent slope breakers will be constructed in accordance with FERC Plan requirements and the ESC Plans. Installed primarily as an erosion control measure, the slope breakers also provide incremental benefit to stormwater management

in the near-term post-construction period by preventing erosive flows from exiting the right-of-way.

Permanent slope breakers will be installed during final grading, except in cultivated areas and lawns (unless requested by the landowner), using spacing as shown on the construction alignment sheets. Spacing for permanent slope breakers will be congruent with the FERC Plan requirements and are shown in Table 4.0-1.

Table 4.0-1

Recommended Spacing for Permanent Slope Breakers

Trench Slope	Distance (feet)
5-15	300
>15-30	200
>30	100

NOTE: Slope breaker spacing in areas of steep terrain may be decreased as a result of the steep slopes BIC Program. Accordingly, this table may be revised to reflect more stringent spacing requirements.

The use of permanent slope breakers will shorten the drainage path, reduce runoff velocity, and direct water off the right-of-way to a stable well-vegetated area as sheet flow. In the absence of a stable well-vegetated area, an energy dissipating device, such as riprap outlet protection, will be installed at the end of the slope breaker.

Permanent Right-of-Way Maintenance - Conclusion

After the completion of construction and final stabilization, post-construction runoff characteristics will remain hydrologically equivalent to pre-construction runoff characteristics. Atlantic's proposed restoration and maintenance practices meet the relevant Virginia Stormwater Management Program regulatory requirements. In addition, the use of the proposed industry-standard practices is consistent with those required by FERC, and they have been successfully implemented in similar FERC-licensed projects in the Commonwealth.

5.0 PLAN TO PROTECT WATER QUALITY FROM ACID FORMING MATERIALS

The exposure of potentially acid-producing rock or soil materials during excavation can result in the oxidation of iron sulfide minerals in the subsoil or bedrock, thereby producing sulfuric acid. Introduction of sulfuric acid to an adjacent wetland or waterbody could potentially increase the acidity of the water and have negative impacts on aquatic or terrestrial vegetation and wildlife. In addition, incorporation of these materials into the surface could affect revegetation in areas disturbed during construction.

Based on a review of available mapping and agency consultations, several of the geologic formations underlying the ACP are known to contain acid-producing sulfide materials. These formations include consolidated bedrock (e.g., shale and slate) along the inland portions of the Project and unconsolidated marine sediments in the Coastal Plain. A summary of the crossing

lengths of these formations by the proposed ACP pipeline facilities is provided in Table 5.0-1. Appendix B includes a more detailed table with the milepost range for each of these units.

TABLE 5.0-1

Geologic Units Containing Potentially Significant Acid-Producing Sulfide Minerals

Project or Physiographic Province or Unit/Formation	Crossing Length (miles)
ATLANTIC COAST PIPELINE	
Virginia	
Alligator Back Formation	2.1
Ashe Formation	2.3
Candler Formation	4.9
Chesapeake Group	2.8
Millboro Shale and Needmore Formation	9.2
Tabb Formation	13.5
TOTAL	**34.8**

Atlantic will implement a number of measures to avoid or minimize potential impacts resulting from construction activities in areas containing acid-producing rocks or soils. These include the following:

- segregating the top 12 inches of topsoil or all of the soil to the top of an acid producing layer in the trench, whichever is reached first;
- segregating rock or soil from the top of the acid-producing layer to the bottom of the acid-producing layer or to the bottom of the trench, whichever is reached first;
- segregating rock or soil below the acid-producing layer to the bottom of the trench;
- backfilling the trench with acid-producing materials first to a maximum of 12 inches below the surface;
- placing a cover of sand or other clean material around and over the pipe to avoid corrosion; and/or
- applying lime to the topsoil or replacing a minimum of 12 inches of acid-free topsoil.

Atlantic will attempt to limit the duration of stockpiled materials to 30 days or less in areas that contain acid-producing rock or soils. This will reduce the likelihood that these materials are oxidized and acidic drainage is produced. In addition, implementation of the measures outlined in the Plan and Procedures, the ACP SWPPP, and the ESC Plans, such as erosion and sediment controls, will prevent tracking of acid-producing materials along the right-of-way and minimize or avoid impacts on sensitive resources in these areas.

As part of the environmental training, which will be conducted prior to the start of construction, field personnel will be provided the descriptions and potential locations of the geologic formations that could contain significant acid-producing sulfide minerals (e.g., dark subsoils in the Coastal Plain with a sulfurous odor).

The EIs will survey work areas prior to construction for signs of acid-producing materials including sparse vegetation and/or red iron discharges or staining on side slopes. During construction, the EIs will monitor excavation activities and open trenches to identify potential acid-producing formations. The EIs will also monitor stockpiled materials for signs of oxidation and acid drainage. If acid-producing materials are suspected, the EIs will conduct field pH (pH_F) and field pH peroxide (pH_{FOX}) tests, which will indicate the existing and potential acidity levels in the material. If these tests indicate a potential for acid forming materials, Atlantic will implement the measures outlined above. In the event that replacement topsoil is needed, imported topsoil will be obtained from a local supplier and certified by the supplier to be free of any contaminates. The EIs will ensure that the replacement topsoil is not acid-producing soil, but is of the same general type as the soils in areas adjacent to where it will be deposited.

6.0 HYDROSTATIC TESTING, HDD AND DUST CONTROL PROTECTION MEASURES

Water for horizontal directional drills and for hydrostatic testing will be withdrawn and discharged in accordance with Commonwealth regulations and required permits. To minimize impacts of short duration, larger volume withdrawals of water from streams, Atlantic will construct pre-fabricated aboveground water impoundment structures adjacent to several of the water withdrawal points. Use of the water holding areas will allow for a longer duration of withdrawal at lower rates to minimize impacts on stream flows. Extending the timeframe for withdrawal of water and complying with Commonwealth regulations and permit requirements will minimize impacts on the aquatic resources within streams used for water withdrawal.

Information on water requirements and withdrawal locations for horizontal directional drills (i.e., water requirements and sources for hydrostatic testing of HDD segments and mixing of drilling mud) is provided in Table 6.0-1. Information on hydrostatic testing of the pipeline system (including locations and volumes of water withdrawals and locations of discharges) is provided in Table 6.0-2. Maps showing the location of the pre-fabricated impoundments are provided in Appendix C. Maps depicting discharge locations for hydrostatic testing of the pipeline system are provided in Appendix D.

The needs for dust control water will vary based on site conditions and weather conditions. Water for dust control will be obtained in relatively small volumes spread throughout the duration of construction and restoration. Based on assumptions of one 2,000 gallon water truck per mile, for use two days each week, and for a total of 16 weeks during construction of the spread, Atlantic estimated water needs by spread and estimates the volume provided above. Water sources will vary based on availability of surface water and potential for municipal water use.

Water for dust control and Horizontal Directional Drill (HDD) needs will be met by municipal water sources and in some cases a combination of municipal water and water withdrawals. Surface water withdrawals for the purposes of dust control and HDD would be limited to less than 10,000 gallons per day from non-tidal waters and less than 2 million gallons from tidal waters in order to meet the exclusion from VWP Permit requirements (9VAC25-210-310. A. 11). However, Atlantic recognizes that 9VAC25-210-310. B allows the State Water Control Board to require a permit if the withdrawal is found to, cause an impairment, adversely effect beneficial uses, or violate water quality standards. To avoid an impairment, adverse effect or water quality standards violation, the withdrawals for dust control and HDD's will be managed so that:

- No more than 10% of the instantaneous flow rate from the channel is removed;
- The intake screens shall be designed so that screen openings are not larger than 1 Millimeter and;
- The screen face intake velocities are not greater than 0.25 feet per second.

Atlantic will plan to withdraw water during higher streamflow conditions and, where practicable, from larger flowing channels. On-site personnel will monitor flow rates of streams being used by the project for withdrawal to ensure that none of the triggering conditions in 9VAC25-210-310. B occur. Daily flow rates as well as withdrawal rates will be documented and kept on site for review. USGS flow data for the nearest upstream and downstream locations will be monitored to ensure that no more than 10% of the instantaneous flow rate is withdrawn. If drought conditions are such that a withdrawal of 10% of the instantaneous flow could cause harm to benefical instream uses, then the withdrawal will be discontinued and another water source will be obtained until flow conditions improve. Atlantic will maintain the protection of downstream withdrawals/users during low flow conditions; however, with withdrawals limited to 10% of the stream flow the likelihood of harming downstream users is very remote.

A Water Use Plan will be submitted to VDEQ for approval prior to the start of construction. The Plan will provide procedures for notification of DEQ prior to initiating withdrawals including when and where withdrawals are to occur and record keeping. The Plan will describe the construction spreads, when different parts of the pipeline will be constructed, and where water will be obtained for each construction spread. It will also provide calculations for the estimated maximum daily amount of water that will be needed for each construction spread.

Secondary containment will be used on all pumps.

Once hydrostatic testing is complete, the test water will be discharged to well-vegetated upland areas, which will eliminate the translocation of invasive aquatic species that may be present. In addition, this practice will also prevent transporting water from impaired streams (i.e., 303d listed waters) to other waterbodies. Water discharged over land will be directed through containment structures such as hay bales and/or filter bags. The discharge rate will be regulated using valves and energy dissipation devices to prevent erosion. Water will be

discharged at a rate commensurate with agency consultations and permit requirements, but will typically range from 1,500 to 2,500 gallon per minute in accordance with the 9VAC25-120-80 et. seq.

TABLE 6.0-1

Water Requirements for Horizontal Directional Drills for the Atlantic Coast Pipeline in Virginia

Project/HDD	County or City / State or Commonwealth	Pipeline Segment / Milepost	Approximate Water Requirement for Hydro-testing (thousands of gallons)	Approximate Water Requirement for Drilling Mud (thousands of gallons)	Locations of Water Withdrawals [a]
ATLANTIC COAST PIPELINE					
Blue Ridge Parkway/ Appalachian National Scenic Trail	Augusta County, Virginia	AP-1 Mainline/ MP 158.2	325	4,517	James River
James River	Nelson and Buckingham Counties, Virginia	AP-1 Mainline/ MP 184.7	208	1,486	James River
Nottoway River	Southampton, Virginia	AP-3 Lateral/ MP 32.6	26	286	Municipal Water Source
Blackwater River	Southampton County and City of Suffolk, Virginia	AP-3 Lateral/ MP 38.6	34	380	Blackwater River
Prince Lake	City of Suffolk, Virginia	AP-3 Lateral/ MP 61.0	30	332	Lake Prince
Western Branch Reservoir	City of Suffolk, Virginia	AP-3 Lateral/ MP 62.4	22	250	Western Branch Reservoir
Western Branch Nansemond River	City of Suffolk, Virginia	AP-3 Lateral/ MP 63.6	52	584	Municipal Water Source
Nansemond River	City of Suffolk, Virginia	AP-3 Lateral/ MP 64.4	62	700	Municipal Water Source
Route 58	Suffolk County, Virginia	AP-3 Lateral/MP 71.5	40	442	Municipal Water Source
I-64 Crossing	City of Chesapeake, Virginia	AP-3 Lateral/ MP 77.8	31	346	Unnamed Pond at 36° 45’ 52” 76° 20’ 29”
US Route 17	City of Chesapeake, Virginia	AP-3 Lateral/ MP 78.6	45	501	Unnamed Pond at 36° 45’ 54” 76° 20’ 17”
South Branch Elizabeth River	City of Chesapeake, Virginia	AP-3 Lateral/ MP 81.8	26	295	Municipal Water Source

[a] Atlantic and DTI continue to review waterbodies for supply capacity.

TABLE 6.0-2

Water Requirements for Hydrostatic Testing for the Atlantic Coast Pipeline in Virginia

State or Commonwealth/ Spread	Approximate Water Requirement (Millions of Gallons) [a]	Locations of Water Withdrawals (Milepost)	Locations of Discharges (Milepost) [b]
Virginia			
Spread 3A	2.8	Back Creek (MP 87.2)	79.2; 87.2; 91.4
Spread 3A and 4	2.6	Jackson River (MP 91.5)	87.2; 91.4; 95.7
Spread 4	3.6	Municipal Water Source	91.4; 95.7; 97.8; 103.8
Spread 4A	2.5	Calfpasture River (MP 111.4)	103.8; 107.9; 112.2; 123.6; 125.9
Spread 5	3.2	Jennings Branch (MP 129.2)	125.9; 129.1; 130.8; 134.1; 137.7; 139.7; 140.9; 146.9; 154.0; 156.3
Spread 5	1.6	Municipal Water (MP 134.2)	156.3; 158.7
Spread 5	3.6	South Fork Rockfish River (MP 163.7)	158.7; 162.0; 163.8; 164.1; 169.5; 172.6; 178.9; 183.3
Spread 6	8.5	James River (MP 184.7)	183.3; 184.4; 184.8; 184.8; 199.8; 202.5; 214.3
Spread 6	6.5	Appomattox River (MP 220.8)	214.3; 228.7; 239.6
Spread 7 and 12	8.25	Municipal Water Source	239.6; 245.8; 247.5; 260.5; 272.3; 279.8; 282.4; 284.4; 291.6; 300.1
Spread 11	3.5	Blackwater River (MP 38.6)	0.0; 15.9; 17.1; 32.1; 32.5; 37.9; 38.3; 38.8; 39.0; 56.2; 57.3; 59.3; 66.3; 71.2; 71.9; 76.6
Spread 11	0.055	Municipal Water Source	60.7; 60.9
Spread 11	0.1	Western Branch Reservoir (MP 62.4)	62.0; 62.3
Spread 11	0.055	Municipal Water Source	63.2; 63.5
Spread 11	0.1	Municipal Water Source	65.1; 65.9
Spread 11	1.0	Municipal Water Source	76.6; 77.2; 77.5; 78.1; 78.6; 82.1; 82.2; 82.7

[a] Atlantic and DTI continue to review waterbodies for supply and discharge capacity.
[b] Discharge locations will be to upland locations a minimum of 300 feet from these sensitive waterbodies.

No chemicals will be added to the test water during hydrostatic testing. Water will be tested prior to introducing it in the pipeline. The water will be tested again prior to discharge once the hydrostatic test is complete. The water will then be discharged in accordance with the Plan and Procedures, the ACP SWPPP, and the ESC Plans and applicable permits through containment structures such as hay bales and/or filter bags to remove turbidity or suspended sediments (i.e., dirt left in the pipe during construction) and to prevent scour and erosion. Alternatively, the water will be hauled offsite for disposal at an approved location.

Atlantic will not use water from sensitive waterbodies for dust control water or for restoration and revegetation activities. Implementation of the construction and operational practices for FERC-regulated projects (i.e., Plan and Procedures), will also reduce the potential for impacts on listed species. Water used to control dust will be applied at a low rate in order to prevent runoff.

7.0 RIPARIAN BUFFER PROTECTION

In routing the pipeline and selecting crossing methods for waterbodies, Atlantic attempted to minimize the number and lengths of crossings, as well as potential impacts on wildlife, vegetation, and water quality. Atlantic will minimize impacts on riparian buffers by

following the Procedures, site-specific modifications to the Procedures requested by Atlantic and approved by the FERC, and additional requirements identified in Federal or Commonwealth wetland and waterbody crossing permits.

During the clearing and grading phase of construction, temporary bridges will be installed across waterbodies in accordance with the Procedures to allow construction equipment and personnel to cross. The bridges may include clean rock fill over culverts, timber mats supported by flumes, railcar flatbeds, flexi-float apparatuses, or other types of spans. Construction equipment will be required to use the bridges, except that the clearing and bridge installation crews will be allowed one pass through waterbodies before bridges are installed. The temporary bridges will be removed when construction and restoration activities are complete.

Atlantic will not disturb or remove riparian buffers that are not directly associated with the project construction activities. Disturbance and removal of riparian buffers from project related upland ground disturbing activities that would occur within 50 feet of any perennial, intermittent, or ephemeral surface waters will be avoided where possible, and minimized if 50 feet is not possible.

ATWS will be required on both sides of waterbody crossings to stage construction equipment, fabricate the pipeline, and store construction materials. ATWS will be located at least 50 feet away from the water's edge at each waterbody (with the exception of site-specific modifications as requested by Atlantic and approved by the FERC). Atlantic will maintain a 100 foot setback from of any perennial, intermittent, or ephemeral surface waters for fueling, maintenance, parking and hazardous material storage activities.

Reducing the construction limit of disturbance in upland areas approaching waterbody and wetland crossings from 125 feet to 75 feet for a total of 50 feet on either side of the crossing is not practicable. Atlantic's proposed construction corridor in the approaches to wetland and waterbody crossings is consistent with the FERC's *Wetland and Waterbody Construction and Mitigation Procedures*, which describe industry standard best management practices for reducing impacts in these areas, including locating additional temporary workspace (ATWS) at least 50 feet from the edges of the waterbody or wetland. Maintaining this setback and reducing the width of the construction corridor on either side of the crossing would result in additional impacts due to the following:

- An increase in vehicle and equipment traffic to relay spoil from the narrowed construction corridor to the ATWS on either side of the crossing;
- An increase in the duration of construction across the waterbody or wetland due to the additional vehicle and equipment traffic;
- An increase in the chances of a rain event and erosion occurring due to the additional time required to complete the crossing;
- Additional safety risks to construction personnel due to equipment moving and working in multiple directions (including relaying spoil back from the crossing) in a narrowed corridor; and,

- Insufficient space to build a bridge to get across the steam and excavate the trench while the bridge is in place.

Clearing adjacent to waterbodies will involve the removal of trees and brush from the construction right-of-way and ATWS areas. Woody vegetation within the construction right-of-way will be cleared to the edge of each waterbody. Sediment barriers will be installed at the top of the bank if no herbaceous strip exists. Initial grading of the herbaceous strip will be limited to the extent needed to create a safe approach to the waterbody and to install temporary bridges. Silt fence and/or straw bales (weed-free) located across the working side of the right-of-way will be removed during the day when vehicle traffic is present, and will be replaced each night. Alternatively, drivable berms may be installed and maintained across the right-of-way in lieu of silt fences and/or straw bales (weed-free). Waterbodies that will be crossed by the horizontal directional drill method (HDD) will avoid impacts to riparian buffers. For the ACP, the HDD method is currently being evaluated for the following six river crossings in Virginia pending the results of geotechnical investigations and final engineering:

- the James River crossing approximately at MP 184.7 of the AP-1 mainline at the Nelson/Buckingham County line in Virginia;
- the Nottoway River crossing approximately at MP 32.6 of the AP-3 lateral in Southampton County, Virginia;
- the Blackwater River crossing approximately at MP 38.6 of the AP-3 lateral at the Southampton County/City of Suffolk line in Virginia;
- the Western Branch Nansemond River crossing approximately at MP 63.6 of the AP-3 lateral in the City of Suffolk, Virginia;
- the Nansemond River crossing approximately at MP 64.4 of the AP-3 lateral in the City of Suffolk, Virginia; and
- the Southern Branch Elizabeth River crossing (part of the Intracoastal Waterway) approximately at MP 81.8 of the AP-3 lateral in the City of Chesapeake, Virginia.

Following construction and initial stream bank stabilization, Atlantic will restore the banks of waterbodies to preconstruction contours to the extent practicable. In steep-slope areas, re-grading may be required to reestablish stable contours capable of supporting preconstruction drainage patterns. Riparian areas will be revegetated with native species across the entire width of the construction corridor. Restoration of riparian areas will be designed to:

- restore stream bank integrity, including both shore crossings up to the ordinary high water mark;
- withstand periods of high flow without increasing erosion and downstream sedimentation; and
- include temporary erosion control fencing, which will remain in place until stream bank and riparian restoration is complete.

Permanent bank stabilization and erosion control devices (e.g., natural structures, rock riprap, and/or large woody debris) will be installed as necessary on steep banks in accordance with permit requirements to permanently stabilize the banks and minimize sediment deposition into waterbodies.

All disturbed banks and riparian work areas will be seeded as soon as possible after final grading, weather and soil conditions permitting and subject to the recommended seeding dates for the area. Seeding is intended to stabilize the soil, improve the appearance of the area disturbed by construction, and restore native flora.

Atlantic is evaluating options to move the contractor yard in the Deerfield area of Augusta County due to concerns expressed by VDEQ, but options are very limited. However, Atlantic is confident that measures detailed in ACP Erosion and Sediment Control Plans, and the Karst Terrain Assessment, Construction, Monitoring and Mitigation Plan will protect the karst features near this contractor yard and prevent any release of contaminants into a karst feature that may feed Hamilton Branch Creek. The proposed yard is at approximately 200 feet away from Hamilton Branch Creek, across Deer Valley Road.

8.0 SPILL PREVENTION, CONTROL, AND COUNTERMEASURES (SPCC) PLAN

To minimize the potential impact of hazardous material spills on water resources during construction and operation of the ACP, Atlantic has prepared and will implement an SPCC Plan. The SPCC Plan is included as Appendix E.

9.0 STEEP SLOPES AND SLIDE PRONE AREAS

The westernmost portion of the proposed AP-1 mainline in Virginia will be constructed in steep, mountainous terrain. Slope instability in the form of landslides, landslips, or surficial slumping can present a significant hazard to pipeline routing, design, construction, and operation in steep slope areas if proper planning and mitigation are not considered in advance. When routing the ACP, the goal was to do so perpendicularly to topographic contours and to minimize routing on steep slopes to the extent practicable, in accordance with Atlantic's program for steep slopes, which includes considerations for slips associated with pipeline construction during routing as well as engineering design, pre-construction planning, construction, and post-construction. Steep slopes have been avoided during routing to the maximum extent practicable and are limited to approximately 46 miles of slopes with an inclination of 30 percent or greater and a length of 100 feet or greater. The BIC Program was designed to proactively address slopes greater than 30 percent and identify mitigation measures beyond standard practices. Details of the BIC Program are provided below and are included in Atlantic's SWPPP.

Atlantic recognizes the increased risk of instability associated with pipeline construction, particularly while traversing steep slopes. As a baseline, Atlantic developed a program for use on projects within steep terrain. The program outlines the following engineering design methods which will apply to slip prevention and correction during construction:

- drainage improvement that may include providing subsurface drainage at seep locations through granular fill and outlet pipes, incorporating drainage into trench breakers using granular fill, and/or intercepting groundwater seeps and diverting them from the right-of-way;
- buttressing slopes with sack-crete trench breakers;
- changing slope geometry;
- benching and re-grading with controlled backfill;
- using alternative backfill;
- chemical stabilization of backfill;
- geogrid reinforced slope that consists of benching existing slope, installing subsurface drains, and incorporating geogrid reinforcement into compacted backfill; and/or
- retaining structures.

Selection of the most appropriate engineered prevention measure or combination is dependent on the individual site conditions and constraints.

For the ACP Project, Atlantic is also committed to identifying mitigation measures beyond standard practices through a BIC Program. The focus of the BIC Program is to proactively address steep slopes (defined as slopes with an inclination greater than 30 percent and greater than 100 feet in length) and landslide hazards related to pipeline construction, compressor stations, and metering and regulation facilities that could potentially impact environmental resources, in particular streams, wetlands, and waterbodies. The BIC Program is intended to incorporate the permit requirements from West Virginia, Virginia, and North Carolina, and then exceed these regulatory standards in order to mitigate for potential erosion and sediment discharges related to steep slope and landslide hazards.

The ultimate goal of the BIC Program is to develop project-specific engineering mitigation recommendations and thereby support preparation of steep slope control measures and site-specific ESC Plans for the ACP Project; these plans will be included in the SWPPP. The BIC Program has achieved this by assembling a team of internal Dominion Energy Transmission, Inc. (DETI) stakeholders, along with supporting external subject matter experts, to develop project-specific mitigation recommendations, by using a process-based approach that includes hazard identification and assessment (i.e., find and then understand the hazard), engineering mitigation design (i.e., targeted design measures that mitigate the hazard), monitoring (i.e., track performance to understand if additional mitigation is needed), and operational measures (i.e., monitor and maintain and operate the system, as needed).

The BIC Program Team convened in a series of design workshops to examine the identified hazards and supporting information along the pipeline alignment. The hazards were initially identified by studies such as the Geohazards Assessment or the karst study, and/or from other targeted studies such as the Order 1 Soil Survey. These studies identify and assess or support the review of the hazard, provide a basis to select the appropriate mitigation response to minimize or eliminate the hazard, and then monitor the hazard through ongoing operations.

The conceptual work-flow process of the BIC Program is organized around four general steps, briefly described as follows:

- Hazard Identification – Geologic hazards are systematically identified during the Geohazards Analysis Program through desktop analysis and field reconnaissance as well as by supporting evaluations (e.g., karst studies and soil surveys). Refer to Figure 9-1 for the conceptual work-flow process diagram describing the general approach.

- Hazard Characterization, Assessment, and Threat Classification – As part of the Geohazards Analysis Program, the nature of the geohazards and their potential impacts on the pipeline and environmental resources are assessed. A semi-quantitative ranking of hazard threat level to the proposed pipeline from various geohazards is used to identify areas for further investigation to determine where appropriate mitigation and monitoring measures may need to be designed and implemented during construction. Refer to Figure 9-1 for the conceptual work-flow process diagram describing the general approach.

- Hazard Mitigation – Areas for mitigation are selected based upon potential risk to the pipeline, environment, and operation and maintenance. Overall hazard reduction techniques may include BIC Program construction practices and/or BMPs. Site and hazard specific plans are being developed based on the recommendations of the Geohazards Analysis Program and mitigation techniques selected by a team of experts. The site and hazard specific plans address the specific geologic hazard (e.g., slip, stream scour, ground displacement) with mitigation measures, as applicable, for construction and/or operation of the Project. Atlantic will incorporate these mitigation measures on ESC Plans in the SWPPP submitted to VDEQ. Additional site-specific design drawings will be submitted to VDEQ staff at a later date once finalized. Refer to Figure 9-2 for the conceptual work-flow process diagram.

- Hazard Monitoring – Atlantic will monitor mitigation techniques to assess their effectiveness and the need for further mitigation, if appropriate. Refer to Figure 9-3 for a conceptual work flow process diagram.

As one of the initial steps in the BIC Program, Atlantic implemented a comprehensive Geohazards Analysis Program to assess potential geohazards, including slope failures, along the proposed pipeline route. The study for slope failures included:

- a desktop analysis to prepare an inventory of and categorize potential slope hazards along the proposed routes;
- a field program to verify the locations and limits of slope hazards along the routes;
- a risk analysis of slope hazards along the routes; and
- recommendations for landslide and landslip mitigation, if and where warranted.

Figure 9-1 Hazard Identification and Assessment

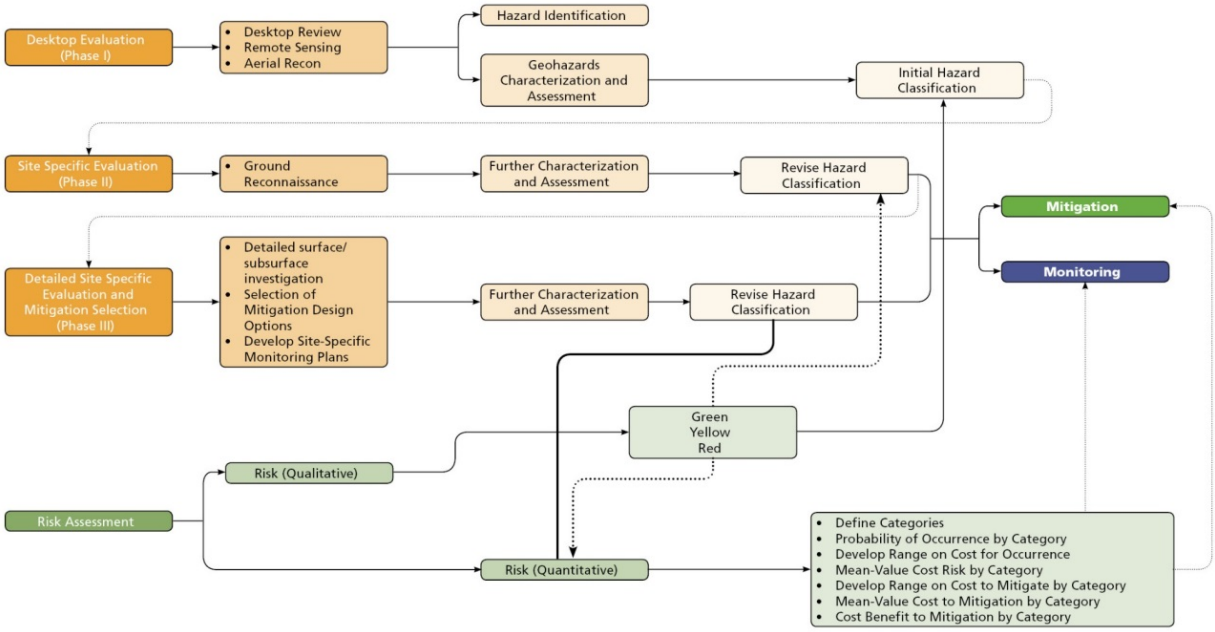


Figure 9-2 Hazard Mitigation

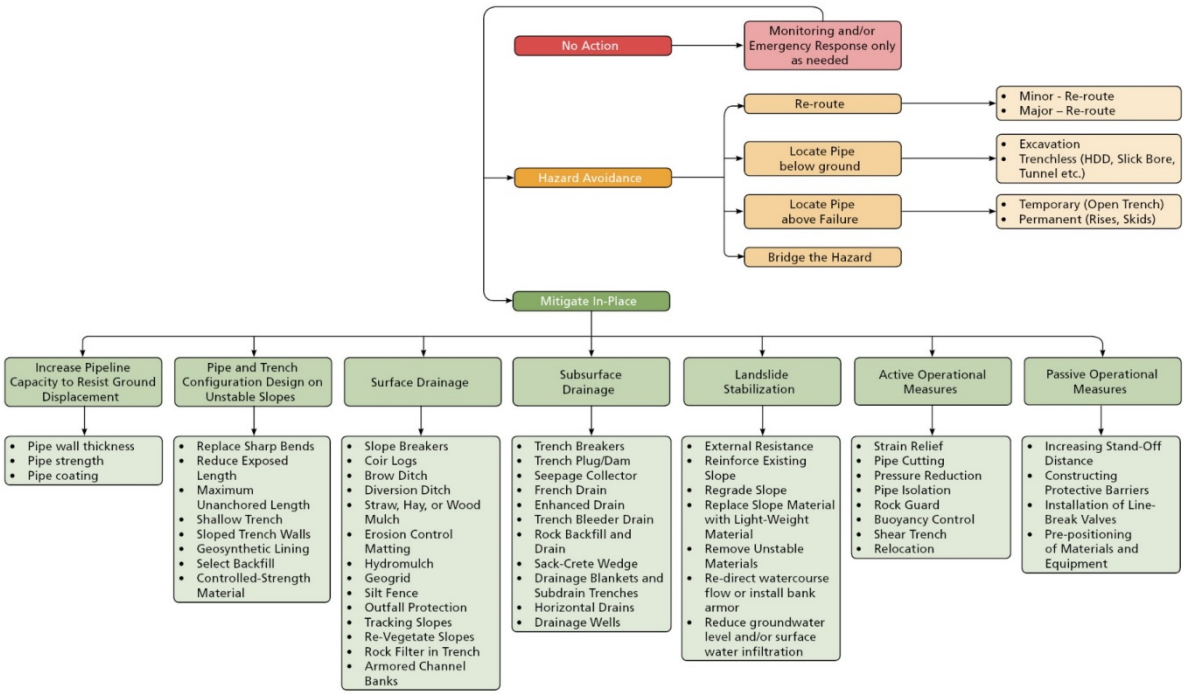
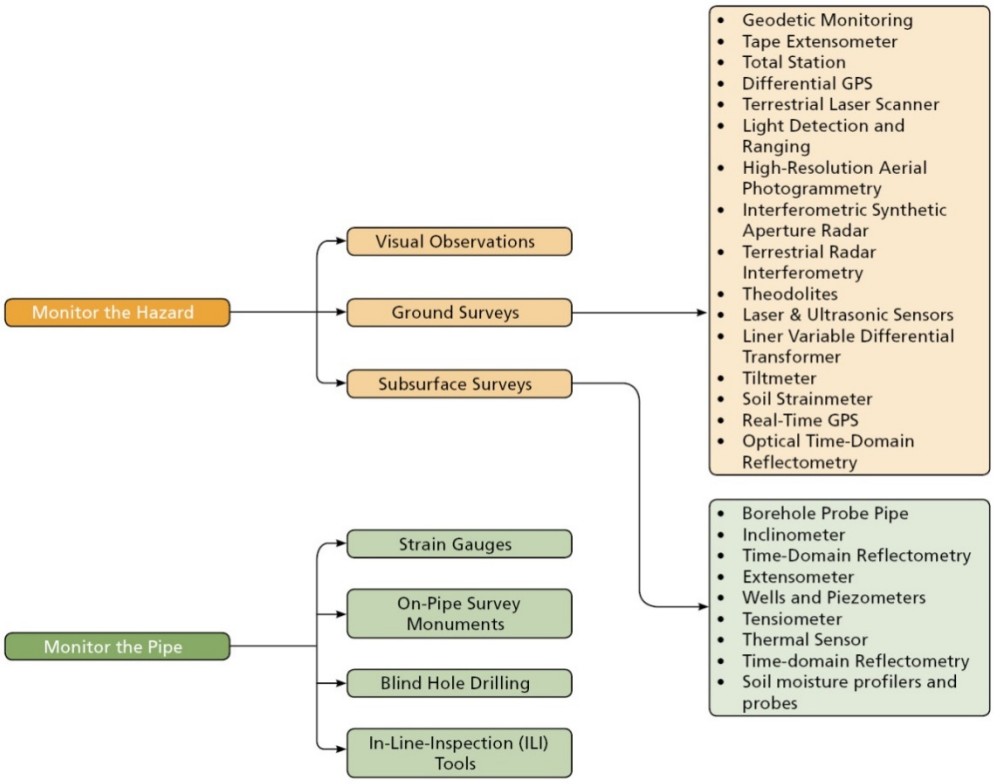


Figure 9-3 Hazard Monitoring



Atlantic has completed the desktop and field reconnaissance portion of the Geohazards Analysis Program and filed a final report to FERC. The final report provided recommendations on geological hazards and potential risks to be mitigated during construction and operation of the proposed ACP facilities. Through desktop study and field verification, the Geohazards Analysis Program identified six recurring typical steep slope hazard scenarios that collectively encompass the majority of the steep slopes identified along the ACP alignment. Some sites may have the characteristics of more than one typical scenario type, particularly those that contain sensitive resources at the slope's toe or where previously modified by cutting and filling.

The six typical scenarios are identified by letters A through F, and each are generally described as follows:

Primary Scenarios

A. steep slopes without evidence of previous movement;

B. steep slopes with evidence of active movement;

C. steep slopes with increased potential to become unstable after construction disturbance; and

D. steep slopes near narrow ridge tops.

Secondary Scenarios

A. steep slopes with a sensitive resource at toe (e.g., streams, wetlands, roads); and

B. steep slopes previously modified by cutting and filling.

Project-specific steep slope geohazard mitigation Typical Designs (TDs) for each of the six typical scenarios were developed as part of the BIC Program. Additionally, Site-specific Designs (SSDs) were developed for those locations with unique geohazard concerns and/or a greater potential for instability. The TDs are included in the SWPPP submitted to VDEQ. The locations where the BIC Program will be implemented are identified on the construction alignment sheets and on plans developed for a select group of the most challenging and unique steep slopes requiring SSDs. The SSDs are currently being prepared and will be provided to VDEQ upon completion.

The TD packages are intended to provide a comprehensive and programmatic approach to address the hundreds of locations along the pipeline alignment. TD packages include Incremental Control (IC) measures (i.e., Typical Details) that provide targeted mitigation for steep slope related hazards that are above and beyond the standard ESCs necessary to meet regulatory requirements. The TDs list ICs that are available for use at a site. The host of ICs for each typical scenario provides options to the field team to respond to site-specific field conditions. These ICs will be implemented in addition to the standard ESC measures which are shown on the alignment sheets. Detailed drawings of the ICs are also provided in the SWPPP to be submitted to VDEQ.

SSD packages are site-specific steep slope mitigation plans that address specialized steep slope or related hazards and conditions at targeted sites, and require geotechnical, hydro-technical engineering, or geologic technical support to develop the design package. SSD packages typically include detailed engineering drawing sets, showing plan and profile and section views of the intended design, supported by details and specifications, and may require specialized work plans. Incremental controls proposed for SSDs are the same as used for the TDs. There are currently 15 locations along the ACP pipeline (9 are located within Virginia), identified through the Geohazards Analysis Program, that were addressed with a SSD. These design plans are currently being prepared and will be provided to VDEQ upon completion.

Atlantic will provide specific employee training that has been developed from the steep slope program. Atlantic personnel with responsibility for pipeline routing, construction, or operation must be trained in this procedure on an annual basis. The training may be completed by an online learning management system module or may be conducted by Energy Infrastructure Environmental Services personnel or Atlantic Engineering Management. At a minimum, the following personnel will be trained:

- engineering Directors and Managers;

- design and construction engineers;
- operations Directors, Managers and Supervisors;
- construction supervisors; and
- construction and operations Environmental Construction Coordinators.

The training must include the following:

- types and causes of slope failures;
- routing avoidance and desktop methods;
- field reconnaissance;
- risk prioritization;
- pipeline design and engineering to prevent slope failures;
- addressing slope failures during construction;
- addressing slope failures post-construction; and
- reporting requirements.

Atlantic's commitment to address steep slope areas is demonstrated by the up-front reconnaissance to identify steep slope and slide prone areas, and proactively identifying and addressing these areas within project documents submitted as part of the FERC environmental review process, and according to construction stormwater permitting documents, such as the SWPPP, that will be implemented during construction.

At least 30 days prior to the start of construction for a spread with slopes greater than 30% and over 100 foot long, ACP will notify VDEQ. The notification will include the anticipated start date, location based on mileposts, and estimated during of the construction activities for that spread. VDEQ will be notified upon discovery of a slip/slide that impacts state waters should this occur. Atlantic will also notify FERC, DGIF, EPA, FWS and downstream public water intakes, as appropriate. Remedial actions will occur simultaneously to ensure all materials are removed from the waters and the slope failure repaired.

10.0 BLASTING PLAN

If consolidated rock is encountered during construction, Atlantic's preferred procedure will be to fracture and excavate the bedrock using standard construction equipment. Blasting of bedrock will only be required in areas where hard, crystalline bedrock is encountered and the bedrock cannot be removed by conventional excavation methods. Atlantic has prepared and will implement a *Blasting Plan* which will identify blasting procedures, including the use, storage, and transportation of explosives. The *Blasting Plan* is included as Appendix A.

11.0 WATER QUALITY MONITORING PLAN

Atlantic has prepared a Water Quality Monitoring Plan in response to the VDEQ "Request for Information for Developing and Evaluating Additional Conditions for Section 401 Water Quality Certification for Interstate Natural Gas Infrastructure Project," dated May 19, 2017.

This plan is provided with the intention to provide details on actions that will be implemented to evaluate potential indirect effects on water quality by the Project activities occurring in upland adjacent to ground disturbing activities along the construction right-of-way. The Water Quality Monitoring Plan is included in Appendix F.

Atlantic will conduct three monitoring events, separated by a minimum of a week for chemical and physical parameters as outlined in Section 4.0 of the WQM Plan (see Appendix F) at each site prior to construction, once during active construction, and once after stabilization (i.e., seeding and mulching of the construction right-of-way). For the biological monitoring (benthic parameter), sampling will occur at least one month before and after construction during either the fall or spring index period. Atlantic will notify a point of contact, to be assigned by VDEQ, in advance of pre-construction monitoring events, which will provide VDEQ an opportunity to coordinate requested site visits for quality assurance review, as agreed by both parties.

Atlantic will solicit guidance from VDEQ regarding adherence to Standard Operating Procedures for all aspects of monitoring. In addition, biological sampling will be performed in the field with laboratory analysis (i.e., sample sorting and identification) as necessary to follow VDEQ sampling protocols. The sampling and laboratory analyses will be completed under the supervision of scientists with Scientific Collectors Permits and experienced in the performance the Virginia Stream Condition Index (VSCI) analytical methodology and the U.S. Environmental Protection Agency (EPA) Rapid Bioassessment Protocols (RBPs) for both field and laboratory analysis. Duplicate chemical and physical sampling will be collected by two staff collecting samples at the same time and location using separate equipment to validate each measurement.

Within four weeks of completing each sampling event the data (chemical parameter sampling results, bench sheets, metrics, and Virginia Stream Condition Index (VSCI) scores) will be provided to VDEQ in electronic format via email. All data will be provided in PDF and Microsoft Excel file formats. Photographic information will be provided in a PDF and Microsoft Word file formats. VDEQ is requested to specify the recipients of the email information. Emails will be sent with a "read receipt" to confirm delivery.

12.0 KARST MANAGEMENT PLAN

Atlantic completed field surveys for karst features in the vicinity of proposed land disturbing activities. Atlantic filed an updated Karst Survey Report with FERC on February 24, 2017. The Karst Survey Report is provided as Appendix G.

In addition, Atlantic has prepared and will implement a *Karst Terrain Assessment, Construction, Monitoring and Mitigation Plan* and ESC plans identify measures for avoiding or minimizing impacts on karst features during construction. The *Karst Terrain Assessment, Construction, Monitoring and Mitigation Plan* is included as Appendix H. This plan outlines procedures for monitoring activities for karst features during construction. Based on karst features identified in the vicinity of proposed construction activities, Project ESC plans within the SWPPP that Atlantic is submitting to VDEQ provide the necessary protections of karst features to protect surface water and water supply sources.

To further evaluate flow paths for significant springs in the vicinity of the project, Atlantic is also developing a program in conjunction with Virginia Department of Conservation and Recreation to evaluate subsurface flow paths for significant springs.

Finally, mitigation measures in the event of any impacts are detailed in Atlantic's Resource Report 2, submitted to FERC, within Section 2.1.6. Groundwater Construction Related Impacts and Mitigation. In summary, Atlantic has worked to identify karst features that have an opening into the subsurface bedrock and have the potential to provide a conduit for impacts to groundwater through initial desktop assessments, avoidance of features during routing, and completing more detailed field survey for karst features, as described above in this section. In addition to implementing the measures outlined in the *Karst Terrain Assessment, Construction, Monitoring and Mitigation Plan, SPCC Plan, and Blasting Plan*, specific to conditions in karst areas, Atlantic plans to monitor groundwater quality and yield for public and private supply wells and springs proximate to the Project area, as described in more detail below. Groundwater inventory and sample collection will be conducted before and after construction to determine whether water supplies have been affected by pipeline construction activities. Atlantic and DETI will establish baseline groundwater conditions prior to construction of the Projects through investigative field surveys and a sampling protocol. The surveys will include a groundwater inventory of all wells or springs within 500 feet of the proposed pipeline in karst areas and within 150 feet of the construction workspace along the remainder of the proposed pipeline. In order to conduct these inventories, landowner permission will need to be obtained first.

With landowner permission, water samples will be obtained prior to construction to establish water quality and yield baselines during the varying seasons. These samples will be tested for pH, total suspended solids, total dissolved solids, conductivity, alkalinity, acidity, sulfates, oil/grease, phenolic, iron, manganese, aluminum, fecal coliform, copper, lead, nickel, silver, thallium, zinc, chromium, arsenic, mercury, selenium, cyanide, calcium magnesium, hardness, chlorides, antimony, cadmium, and beryllium. Sampling methods will adhere to the prevailing U.S. Environmental Protection Agency (EPA) and VDEQ sampling, analytical and data quality assurance and quality control procedures. The samples will be analyzed using EPA-approved methods and the analysis will be performed by a certified laboratory.

Any well damage claim will be investigated for cause; during this investigation a temporary potable water source will be supplied to the well owner. This temporary potable water source will be supplied by a potable water storage device and/or a temporary water treatment system to restore potable water.

In the event the damage claim investigation yields positive results that construction activities caused or contributed to well damage. Atlantic or DETI will provide a permanent potable water source. This will be supplied by a permanent water treatment system and/or a new well drilled to a deeper aquifer.

Attached as Appendix I is the Groundwater Construction Related Impacts and Mitigation from Section 2.1.6 of Resource Report 2.

Atlantic will provide a Karst Dye Trace Plan to VDEQ for approval prior to the initiation of land disturbance activities in karst terrain. Following tree clearing and prior to ground disturbing activities a karst specialist will walk the temporary construction right-of-way in karst terrain areas to look for any karst features that may not have been visible with tree cover.

Prior to the start of construction for a spread with karst terrain, Atlantic will notify VDEQ of the anticipated start date, construction spread, and expected duration of construction for the spread.. In addition, Atlantic will notify VDEQ upon discovery of any newly identified karst feature not previously evaluated.

13.0 ENVIRONMENTAL MONITORING

Atlantic is committed to constructing and operating the ACP in a manner that will minimize environmental impacts and comply with applicable permits and approvals, the Plan and Procedures, and other environmental plans or requirements. Atlantic will train company and contractor personnel to familiarize them with environmental plans, permit requirements, and other conditions. EIs will be hired to monitor compliance during the construction and restoration phases of the Project. Atlantic will be responsible for ensuring the implementation of and compliance with environmental requirements during construction of the Project.

Additionally, Atlantic will adopt various BIC technologies and work practices in the areas of slip prevention on steep slopes, air emissions from compressor turbines, and methane leaks from equipment and pipeline components. BIC for natural gas transmission systems means industry-proven, most efficient and/or protective design/configuration, with the least environmental impact providing reliable operations.

Environmental Compliance

Atlantic will incorporate relevant environmental requirements and environmental mitigation plans into the construction bid documents for the Project. Additionally, Atlantic will review these materials with prospective contractors in a pre-bid meeting. The contractor(s) selected for the Project will be required to comply with all relevant requirements regardless of whether they were described in bid documents or discussed at the meeting.

Atlantic will conduct environmental training prior to commencement of construction activities so that contractors are aware of the environmental requirements of the Project. During construction, if a contractor does not comply with the environmental requirements, Atlantic will

direct the contractor to comply and may take other corrective actions as necessary, including issuing stop-work orders, until the contractor is in compliance.

Environmental Training

Prior to construction, Atlantic will conduct environmental training for all company and contractor personnel. The training program will focus on the Plan and Procedures, the Plan of Development or Construction, Operation and Maintenance (COM) Plans, Certificate and permit conditions, and construction, restoration, and mitigation plans. In addition, Atlantic will provide large-group training sessions before each work crew begins construction. Periodic follow-up training for groups of newly assigned personnel will be provided as necessary by the EIs. Besides training rosters, which will be kept to verify that personnel have been trained, Atlantic will issue hardhat stickers to be placed on each worker's hardhat as field verification that the worker has completed the training.

Environmental Inspection

Atlantic will assign an appropriate number of EIs per construction spread with additional inspectors, as necessary, to monitor environmental compliance during construction. The EIs will have peer status with other inspectors and will report directly to the spread chief inspector. EIs will have the authority to stop activities that violate environmental conditions of Federal or Commonwealth environmental permits and landowner agreements and to order appropriate corrective action. EIs will be responsible for:

- ensuring compliance with the requirements of the Certificate as well as Federal and Commonwealth permits, clearances, and other approvals; the Plan and Procedures; Atlantic's construction, restoration, and mitigation plans; and environmental requirements identified in landowner easement agreements;
- evaluating the construction contractor's implementation of environmental mitigation measures;
- act as liaisons between Atlantic and field representatives of environmental regulatory agencies that visit the ACP Project area during construction;
- identifying, documenting, and overseeing corrective actions, as necessary, to bring an activity back into compliance;
- verifying that the limits of authorized construction work areas and locations of access roads are visibly marked before clearing;
- verifying the location of restoration sites, and maintaining appropriate signage for boundaries of sensitive resource areas, waterbodies, wetlands, farm improvements (i.e., repair of fences, drain tiles, irrigation systems, or structures), or areas with special restoration requirements;
- monitoring erosion and sediment control devices and soil stabilization measures in construction areas, and identifying additional needs for new controls or maintenance of existing controls;

- verifying that dewatering activities are properly monitored and do not result in the deposition of sand, silt, and/or sediment into sensitive environmental resource areas, including but not limited to wetlands, waterbodies, cultural resource sites, and sensitive species habitats;
- ensuring that subsoil and topsoil are tested in agricultural and residential areas to measure compaction and determine the need for corrective action;
- advising the Construction Inspector when environmental conditions (such as wet or frozen soils) make it advisable to restrict or delay construction activities to avoid topsoil mixing or excessive compaction;
- ensuring restoration of contours and topsoil;
- verifying that soils imported for agricultural or residential use have been certified as free of invasive species and soil pests, unless otherwise approved by the landowner;
- determining the need for and ensuring that erosion controls are properly installed, as necessary, to prevent sediment flow into wetlands, waterbodies, sensitive areas, and onto roads;
- keeping records of compliance or non-compliance with conditions of environmental regulatory permits and approvals, including activities that could result in decertification of organic farms; and
- identifying areas that will require special attention to ensure stabilization and restoration success.

Additional monitoring details are included in Section 11.0 Water Quality Monitoring Plan.

Inspection Frequency

The EIs will ensure the requirements required under ESC Inspection Requirements 9 VAC2 5-840-60, § 62. 1-44.15:58) and SWM Inspection Requirements (9VAC25-870-114, § 62. 1-44.15:37) will be followed.

Spring, Summer, and Fall

Routine inspections will be conducted by DETI or designated personnel, trained in stormwater controls and BMPs. Inspection frequency requirements are stipulated by both the FERC Plan and the Commonwealth of Virginia Stormwater Management Act, the Virginia Erosion and Sediment Control Law and associated regulations, where applicable.:

Virginia Inspection Frequency (**without** discharge to exceptional waters or waters impaired for sediment):

- At least once every 5 business days; or

- At least once every 10 business days and no later than 48 hours following a measurable storm event. In the event that a measurable storm event occurs when there are more than 48 hours between business days, the inspection must be conducted no later than the next business day.

Virginia Inspection Frequency (**with** discharge to exceptional waters or waters impaired for sediment, sediment-related parameter, or nutrients):

- At least once every 4 business days; or
- At least once every 5 business days and no later than 48 hours following a measurable storm event. In the event that a measurable storm event occurs when there are more than 48 hours between business days, the inspection must be conducted on the next business day.

FERC Inspection Frequency:

- On a daily basis in areas of active construction or equipment operation;
- On a weekly basis in areas with no construction or equipment operation; and
- Within 24 hours of each stormwater event (runoff from precipitation, snowmelt, and surface runoff and drainage, including rainfall events resulting in 0.5-inch or more).

EIs will perform inspections of all temporary ESC measures in accordance with FERC requirements and will record the results of the inspections on a Daily Report. In addition, inspections will be performed in accordance with Virginia Stormwater Management Act, the Virginia Erosion and Sediment Control Law, and associated regulations. Rain gauges will be located on site to identify measurable storm events. Rain gauge data will also be included on the Virginia inspection form.

<u>Winter</u>

According to Virginia Stormwater Management Act, the Virginia Erosion and Sediment Control Law, and associated regulations, where applicable, where areas have been temporarily stabilized or land-disturbing activities will be suspended due to continuous frozen ground conditions and stormwater discharges are unlikely:

- The inspection frequency may be reduced to **once per month**. If weather conditions (such as above-freezing temperatures or rain or snow events) make discharges likely, the operator will immediately resume the regular inspection frequency.

DETI will also follow additional inspection protocol as outline in the *Winter Construction Plan* submitted to FERC:

Following pipeline construction activities and prior to the resumption of restoration activities the following Spring, DETI will inspect the condition of erosion control devices **within 48 hours of a significant rain or snow melt event,** if accessible and weather permitting, to ensure that the devices remain in place and are effective in controlling snow melt and Spring runoff.

Third-Party Compliance Monitoring

In addition to the EIs, Atlantic will participate in a third-party compliance monitoring program during construction of the ACP. Under this program, Atlantic will fund a third-party contractor, to be selected and managed by FERC staff, to provide environmental compliance monitoring services for the Project. The third-party contractor will provide regular reports to FERC staff on compliance issues and assist FERC staff in screening and processing variance requests during construction.

ATLANTIC COAST PIPELINE, LLC
ATLANTIC COAST PIPELINE

Response to Virginia Department of Environmental Quality Request for Information for the Section 401 Water Quality Certification

APPENDIX A

Blasting Plan

ATLANTIC COAST PIPELINE, LLC
ATLANTIC COAST PIPELINE
Docket No. CP15-554-000
CP15-554-001

and

DOMINION TRANSMISSION, INC
SUPPLY HEADER PROJECT
Docket No. CP15-555-000

Blasting Plan

Updated, Rev. 3

Prepared by

ERM

November 1, 2016

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LIST OF ACRONYMS AND ABBREVIATIONS

ACP	Atlantic Coast Pipeline
Atlantic	Atlantic Coast Pipeline, LLC
DTI	Dominion Transmission, Inc.
GPS	global positioning system
PPV	peak particle velocity
Project	Atlantic Coast Pipeline
SHP	Supply Header Project

1.0 INTRODUCTION

Atlantic Coast Pipeline, LLC (Atlantic) – a company formed by four major energy companies - Dominion Resources, Inc.; Duke Energy Corporation; Piedmont Natural Gas Co., Inc.; and AGL Resources, Inc. – proposes to construct and operate approximately 600 miles of natural gas transmission pipelines and associated aboveground facilities in West Virginia, Virginia, and North Carolina. This Project, referred to as the Atlantic Coast Pipeline (ACP), will deliver up to 1.5 million dekatherms per day of natural gas from supply areas in the Appalachian region to demand areas in Virginia and North Carolina. Atlantic has contracted with Dominion Transmission, Inc. (DTI), a subsidiary of Dominion Resources, Inc., to construct and operate the ACP on behalf of Atlantic.

In conjunction with the ACP, DTI proposes to construct and operate approximately 37.5 miles of pipeline loop and modify existing compression facilities in Pennsylvania and West Virginia. This Project, referred to as the Supply Header Project (SHP), will enable DTI to provide firm transportation service to various customers, including Atlantic.

2.0 PURPOSE

Based on an analysis of the Natural Resource Conservation Service's Soil Survey Geographic Database, approximately 26 percent (155.8 miles) of the proposed ACP and SHP pipeline routes will cross areas with bedrock at depths of less than 60 inches. More than half (81.7 miles) of this bedrock are considered paralithic (soft) and may not require blasting during construction. The remaining areas will cross soils with a lithic contact (hard bedrock) within 60 inches of the surface that may require blasting or other special construction techniques during installation of the proposed pipelines.

This *Blasting Plan* outlines the procedures and safety measures that Atlantic's and DTI's construction contractors (referred to as the Contractor below) will adhere to while conducting blasting activities required for the construction of the ACP and SHP. Before blasting, a site-specific Blasting Specification Plan, which is consistent with the provisions in this *Blasting Plan*, will be submitted by the Contractor to Atlantic or DTI for approval. Approval of a site-specific Blasting Specification Plan does not relieve the Contractor from responsibility or liability.

3.0 GENERAL REQUIREMENTS

Blasting for grade or trench excavation will be used where deemed necessary by the Contractor, and approved by an Atlantic or DTI representative, after examination of the site. To the extent practical on USFS lands, rock trenching will be accomplished using mechanical means such as rippers, rock hammers, John Henry drills, etc.

Blasting operations will be conducted by or under the direct and constant supervision of personnel legally licensed and certified to perform such activity in the jurisdiction where blasting occurs. Prior to any blasting activities, the Contractor will provide Atlantic or DTI with appropriate information documenting the experience, licenses, and permits associated with blasting personnel.

Blasting-related operations will comply with applicable Federal, State/Commonwealth, and local regulations, permit conditions, and the construction contract. These operations include: obtaining, transporting, storing, handling, loading, detonating, and disposing of blasting material; drilling; and ground-motion monitoring.

4.0 PRE-BLASTING REQUIREMENTS

Prior to the initiation of blasting operations, the Contractor will comply with the following:

- The Contractor will obtain all required Federal, State/Commonwealth, and local permits relating to the transportation, storage, handling, loading, and detonation of explosives.
- The Contractor will be responsible for the protection of existing underground facilities.
- Before performing any work on, or accessing the construction right-of-way, the Contractor will verify with an Atlantic or DTI representative that all property owners have been notified of the upcoming construction activities. The Contractor will notify all such parties at least 48 hours prior to blasting.
- The Contractor will submit to Atlantic or DTI its site-specific Blasting Specification Plan for approval prior to the execution of blasting activity.

5.0 SITE-SPECIFIC BLASTING PLANS

For each area determined to require blasting, a site-specific Blasting Specification Plan will be prepared by the Contractor. This plan will include, at a minimum, the following information:

- blaster's name, company, copy of license, and statement of qualifications;
- seismograph company, names, equipment and sensor location;
- site location (milepost and stationing), applicable alignment sheet numbers, and associated rock type and geological structure (solid, layered, or fractured);
- copies of all required Federal, State/Commonwealth, and local permits;
- methods and materials, including explosive type, product name and size, weight per unit, and density; stemming material; tamping method; blasting sequence; use of non-electrical initiation systems for all blasting operations; and magazine type and locations for storage of explosives and detonating caps;
- site dimensions, including explosive depth, distribution, and maximum charge and weight per delay; and hole depth, diameter, pattern, and number of holes per delay;
- Global positioning system (GPS) coordinates of blasting location(s), distance and orientation to nearest aboveground and underground structures, and dates and hours blasting will be conducted;

- blasting procedures for:
  - storing, handling, transporting, loading, and firing explosives;
  - prevention of misfires, fly-rock, fire prevention, noise, and stray current accidental-detonation;
  - signs, flagmen, and warning signals prior to each blast;
  - locations where the pipeline route:
    - parallels or crosses an electrical transmission corridor, cable, or pipeline;
    - parallels or crosses a highway or road;
    - approaches within 500 feet of a water well or within 150 feet of an oil and gas well; or
    - approaches within 1,000 feet of any residence, building, or occupied structure;
  - local notification;
  - inspections after each blast;
  - disposal of waste blasting material; and
  - blasting on steep slopes.

6.0 MONITORING

During blasting operations, the Contractor will be required to monitor operations in the following manner:

- The Contractor will provide seismographic equipment to measure the peak particle velocity (PPV) of all blasts in the vertical, horizontal, and longitudinal directions.
- The Contractor will measure the PPV at any existing pipelines, domestic structures, water supply wells, oil and gas wells, electrical transmission tower footings, and other utilities within 150 feet of the blasting. If none of these structures/facilities are present, the Contractor will measure the PPV at the edge of the construction right-of-way.
- The Contractor will complete a Blasting Log Record immediately after each blast and submit a copy to an Atlantic or DTI representative upon completion of blasting activities at each blasting site.

7.0 SAFETY

7.1 Protection of Aboveground and Underground Structures

Where blasting is determined to be required, Atlantic and DTI will identify any municipal water mains proposed for crossing, and will consult the local water authority. Reports of

identified crossings will include location by milepost, owner, and status and results of contacts with the water authority.

The Contractor will exercise control to prevent damage to aboveground and underground structures including pipelines, domestic structures, water supply wells, oil and gas wells, electrical transmission tower footings, measures to minimize blasting impacts on steep slopes, and other utilities. The Contractor will implement the following procedures:

- If blasting occurs within 500 feet of an identified water well, water flow performance and water quality testing will be conducted before blasting. If the water well is damaged, the well will be repaired or otherwise restored or the well owner will be compensated for confirmed damages. Atlantic and DTI will provide an alternative potable water supply to the landowner until repairs occur.
- If blasting occurs within 150 feet of any aboveground structures, the Contractor and an Atlantic or DTI representative will inspect and photograph the structures before blasting. In the event that blasting damage to the aboveground structure is confirmed, the owner will be compensated.
- The Contractor will be responsible for the ultimate resolution of all damage claims resulting from blasting. Such liability is not restricted by the 150-foot inspection requirement cited above.
- Blasting will not be allowed within 15 feet of an existing pipeline, unless specifically authorized by an Atlantic or DTI representative.
- Holes that have contained explosive material will not be re-drilled. Holes will not be drilled where danger exists of intersecting another hole containing explosive material.
- Blasting mats or padding will be used on all shots where necessary to prevent scattering of loose rock onto adjacent property and to prevent damage to nearby structures and overhead utilities.
- Blasting will not begin until occupants of nearby buildings, stores, residences, places of business, places of public gathering, and farmers have been notified by the Contractor in advance to protect personnel, property, and livestock. The Contractor will notify all such parties at least 48 hours prior to blasting.
- Blasting in or near environmentally sensitive areas, such as streams and wildlife areas, may include additional restrictions. When blasting in streams, the following additional measures may be implemented, in consultation with the appropriate agencies, to avoid or minimize impacts on fisheries, aquatic resources, and habitats:
    - Prior to the initiation of the designed blast and following audible warning signals, a single cap will be initiated in the stream to alert fish to move away from blasting area.
    - Removing fish from blasting area and relocating them downstream, this will only be used in smaller streams.

- In larger streams a boat can be used both up and down stream to alert fish to move away from blasting area. This tactic can be used only if the operators of the boat can retreat a safe distance from the blast zone as determined by the Blaster in Charge.

- When blasting on steep slopes the following measures will be taken to minimize blasting impacts.
  - A safety berm may be created at the base of each shot to minimize the shot material movement down the slope after initiation if practical.
  - A catch berm may be created at the base of the hill to stop material from leaving the right-of way, if practical.
  - Berms may be constructed on the right-of-way to direct any rolling material away for the offside boundaries.
  - Shots will be initiated from the lowest elevation of the trench.
  - The blaster will conduct test blasts on areas without slope with a reduction of powder factor that will fracture the material while keeping it in place. Tight digging and higher vibrations may be associated with this adjustment.
  - Decking the holes may be considered to lower the pounds per delay.
  - Where multiple trench shots are to be initiated, the shot material will stay in place and remain muck bound. This will hold the following shots in place.
- All blasting will be subject to the following limitations:
  - Maximum PPV of 12.0 inches per second, or the maximum PPV in accordance with State/Commonwealth or local regulations, in any of three mutually perpendicular axes measured at the lesser distance of the nearest facility or the edge of the permanent easement.
  - Maximum drill size will be 2.5 inches unless otherwise approved by an Atlantic or DTI representative.
  - Maximum quantity of explosive per delay will be governed by the recorded measurements as influenced by the test blast program or a scaled distance formula.
  - Explosive agents and ignition methods will be approved by an Atlantic or DTI representative. Ammonium nitrate/fuel oil and other free flowing explosives and blasting agents are not acceptable and will not be used.
  - Drill holes will not be left loaded overnight.
  - Approved stemming material will be used in all holes.
- The drilling pattern will be set in a manner to achieve smaller rock fragmentation (maximum 1 foot in diameter) to use as much as possible of the blasted rock as backfill material after the pipe has been padded in accordance with the

specifications. The Contractor will submit the proposed drilling pattern to an Atlantic or DTI representative for approval.

- Under pipeline crossings and all other areas where drilling and blasting is required within 15 feet of existing facilities:
  - Drill holes will be reduced to a maximum of 2 inches or less in diameter.
  - The number of holes shot at one time will be limited to three unless otherwise approved by an Atlantic or DTI representative.
  - Appropriate delay between charges will be used to attain desired fragmentation.

7.2 Protection of Personnel

The Contractor will include in its procedures all Federal, State/Commonwealth, and local safety requirements for blasting. The Contractor's procedures will address, at a minimum, the following requirements:

- Blasting will be performed during daylight hours only.
- Only authorized, qualified, and experienced personnel will handle explosives.
- No explosive materials will be located where they may be exposed to flame, excessive heat, sparks, or impact. Smoking, firearms, matches, open flames, and heat- and spark-producing devices will be prohibited in or near explosive magazines or while explosives are being handled, transported, or used.
- A code of blasting signals will be established, posted in conspicuous places, and utilized during blasting operations. Employee training will be conducted on the use and implementation of the code.
- The Contractor will use every reasonable precaution including, but not limited to, visual and audible warning signals, warning signs, flag persons, and barricades to ensure personnel safety.
- Warning signs, with lettering a minimum of 4 inches in height on a contrasting background, will be erected and maintained at all approaches to the blast area.
- Flaggers will be stationed on all roadways passing within 1,000 feet of the blast area to stop all traffic during blasting operations.
- Both workers involved in the detonation and personnel not involved in the detonation will stand back at a distances determined by the person in charge from the time the blast signal is given until the "ALL CLEAR" is sounded.
- No loaded holes will be left unattended or unprotected. No explosives or blasting agent will be abandoned.
- In the case of a misfire, the blaster will provide proper safeguards for personnel until the misfire has been re-blasted or safely removed.

- The exposed areas of the blast will be matted wherever practicable. In cases where such a procedure is not deemed to be feasible, the Contractor will submit an alternative procedure for review by an Atlantic or DTI representative and the site in question will be visited and examined by the consultant before any approval is granted.
- Atlantic and DTI may employ two-way radios for communication between vehicles and office facilities. The Contractor will advise Atlantic or DTI and other pipeline contractors of any need to cease use of such equipment during blasting activities.
- All loading and blasting activity will cease and personnel in and around the blast area will retreat to a position of safety during the approach and progress of an electrical storm irrespective of the type of explosives or initiation system used. This is a major safety precaution and will always be observed. All explosive materials, all electrical initiation systems, and all non-electric initiation systems are susceptible to premature initiation by lightning.
- Previous blast areas must be inspected to verify the absence of misfires. No drilling may commence until such inspection occurs. If a misfire occurs adjacent to a hole to be drilled, the misfire will be cleared by the blaster using reasonable techniques required for the situation prior to commencement of drilling. If a misfire occurs at some distance from the drilling area, drilling may be stopped while clearing preparations are underway. When the misfire is to be cleared by re-shooting, drilling will be shut down and personnel evacuated to a place of safety prior to detonation.
- All transportation of explosives will be in accordance with applicable Federal, State/Commonwealth, and local laws and regulations. Vehicles used to transport explosives will be in good working condition and equipped with tight wooden or non-sparking metal floor and sides. If explosives are carried in an open-bodied truck, they will be covered with a waterproof and flame-resistant tarp. Wiring will be fully insulated to prevent short-circuiting and at least two fire extinguishers will be carried. The vehicle will be plainly marked to identify its cargo so that the public may be adequately warned. Metal, flammable, or corrosive substances will not be transported in the same vehicle with explosives. There will be no smoking, and unauthorized or unnecessary personnel will not be allowed in the vehicle. Competent, qualified personnel will load and unload explosives into or from the vehicle.
- No sparking metal tools will be used to open kegs or wooden cases of explosives. Metallic slitters will be used to open fiberboard cases, provided the metallic slitter does not come in contact with the metallic fasteners of the case. There will be no smoking, no matches, no open lights, or other fire or flame nearby while handling or using explosives. Explosives will not be placed where they are subject to flame, excessive heat, sparks, or impact. Partial cases or packages of explosives will be re-closed after use. No explosives will be carried in the pockets or clothing of personnel. The wires of an electric blasting cap will not be tampered with in any way. Wires will not be uncoiled. The use of electric blasting caps

will not be permitted during dust storms or near any other source of large charges of static electricity. Uncoiling of the wires or use of electric caps will not be permitted near radio-frequency transmitters. The firing circuit will be completely insulated from the ground or other conductors.

- No blast will be fired without a positive signal from the person in charge. This person will have made certain that all surplus explosives are in a safe place; all persons, vehicles, and/or boats are at a safe distance; and adequate warning has been given. Adequate warning of a blast will consist of, but not be limited to, the following:
  - notifying nearby homeowners and local agencies, if necessary;
  - stopping vehicular and/or pedestrian traffic near the blast site; and
  - signaling with an air horn, whistle, or similar device using standard warning signals.
- Only authorized and necessary personnel will be present where explosives are being handled or used.
- The condition of the hole will be checked with a wooden tamping pole prior to loading. Surplus explosives will not be stacked near working areas during loading. Detonating fans will be cut from spool before loading the balance of charge into the hole. No explosives will be forced into a bore hole past an obstruction. Loading will be done by a blaster holding a valid license or by personnel under his direct supervision.
- Fly-rock leaving the right-of-way will be collected immediately and disposed of at disposal sites approved by Atlantic or DTI. This work will not be left to the cleanup crew.

7.3 Lightning Hazard

A risk of accidental detonation caused by lightning strikes exists at any time the workplace is experiencing an electrical storm and there are loaded holes on site. If this hazard is judged to exist by an Atlantic or DTI representative, work will discontinue at all operations and workers will be moved to secure positions away from the loaded holes. Furthermore, workers will not return to the work site until the storm has passed and an Atlantic or DTI representative has indicated it is clear to return.

The Contractor will have on site an approved lightning instrument capable of measuring the degree of electrical activity as a storm approaches, and the distance to the storm front from the instrument on the right-of-way.

8.0 KARST

In accordance with Atlantic's and DTI's *Karst Monitoring and Mitigation Plan*, and in addition to the measures described above, the following procedures will be implemented in areas of karst terrain:

- Blasting will be conducted in a manner that will not compromise the structural integrity or alter the karst hydrology of known or presumed habitat for federally listed threatened and endangered species in the subterranean karst environment (e.g. Madison cave isopod).
- Excavations will be inspected for voids, openings or other tell-tale signs of solution (karst) activity.
- If rock removal intercepts an open void, channel, or cave, construction activities will cease in the vicinity of the void, channel, or cave until a remedial assessment is performed by a qualified geologist or engineer with experience in karst terrain.
- Use of explosives will be limited to low-force charges designed to transfer the explosive force only to the rock which is designated for removal (e.g., maximum charge of 2 inches per second ground acceleration).
- If the track drill used to prepare drill holes for explosive charges encounters a subsurface void larger than 6 inches within the first 10 feet of bedrock, or a group of voids totaling more than 6 inches within the first 10 feet of bedrock, then explosives will not be used until a subsurface exploration is conducted to determine if the voids have connectivity to a deeper karst structure. The subsurface exploration will be carried out with track drill probes, coring drill, electrical resistivity, or other techniques capable of resolving open voids in the underlying bedrock. If a track drill or coring rig is used, then all open holes will be grouted shut after the completion of the investigation.

9.0 STORAGE REQUIREMENTS

All explosives, blasting agents, and initiation devices will be stored in locked magazines that have been located, constructed, approved, and licensed in accordance with Federal, State/Commonwealth, and local regulations. Magazines will be dry, well ventilated, reasonably cool (painting of the exterior with a reflective color), bullet and fire resistant, and kept clean and in good condition.

Initiation devices will not be stored in the same box, container, or magazine with other explosives. Explosives, blasting agents, or initiation devices will not be stored in wet or damp areas; near oil, gasoline, or cleaning solvents; or near sources of heat radiators, steam pipes, stoves, etc. No metal or metal tools will be stored in the magazine. There will be no smoking, matches, open lights, or other fire or flame inside or within 50 feet of storage magazines or explosive materials.

Magazines will be constructed and located in accordance with Federal, State/ Commonwealth, and local regulations. Magazines will be marked in minimum 3-inch-high letters with the words “DANGER – EXPLOSIVES” prominently displayed on all sides and roof, and be kept locked at all times unless explosives are being delivered or removed by authorized personnel. Admittance will be restricted to the magazine keeper, blasting supervisor, or licensed blaster.

Accurate and current records will be kept of the explosive material inventory to ensure that oldest stocks are utilized first, satisfy regulatory requirements, and for immediate notification of any loss or theft. Magazine records will reflect the quantity of explosions removed, the amount returned, and the net quantity used at the blasting site.

When explosive materials are taken from the storage magazine, they will be kept in the original containers until used. Small quantities of explosive materials may be placed in day boxes, powder chests, or detonator boxes. Any explosive material not used at the blast site will be returned to the storage magazine and replaced in the original container as soon as possible.

ATLANTIC COAST PIPELINE, LLC
ATLANTIC COAST PIPELINE

Response to Virginia Department of Environmental Quality Request for Information for the Section 401 Water Quality Certification

APPENDIX B

Geologic Units Containing Potentially Significant Acid-Producing Sulfide Minerals Crossed by the Atlantic Coast Pipeline in Virginia

Appendix B

Geologic Units Containing Potentially Significant Acid-Producing Sulfide Minerals Crossed by the Atlantic Coast Pipeline in Virginia

Project/Commonwealth/ Component	Milepost Range		Unit Age	Geologic Unit	Primary Lithology	Secondary Lithology
AP-1	87.13	87.36	Devonian	Millboro Shale and Needmore Formation	black shale	shale
	90.94	92.02	Devonian	Millboro Shale and Needmore Formation	black shale	shale
	97.25	97.75	Devonian	Millboro Shale and Needmore Formation	black shale	shale
	101.76	102.17	Devonian	Millboro Shale and Needmore Formation	black shale	shale
	103.65	105.16	Devonian	Millboro Shale and Needmore Formation	black shale	shale
	108.37	108.94	Devonian	Millboro Shale and Needmore Formation	black shale	shale
	109.09	110.49	Devonian	Millboro Shale and Needmore Formation	black shale	shale
	115.23	115.34	Devonian	Millboro Shale and Needmore Formation	black shale	shale
	122.64	122.80	Devonian	Millboro Shale and Needmore Formation	black shale	shale
	177.09	179.20	Proterozoic Z	Ashe Formation - Biotite gneiss	biotite gneiss	N/A
	179.20	179.74	Proterozoic Z-Cambrian	Alligator Back Formation - Feldspathic metagraywacke	meta-argillite	schist
	180.00	180.87	Proterozoic Z-Cambrian	Alligator Back Formation - Feldspathic metagraywacke	meta-argillite	schist
	181.24	183.15	Cambrian	Candler Formation - Phyllite and schist	phyllite	schist
	183.37	184.04	Proterozoic Z-Cambrian	Alligator Back Formation - Feldspathic metagraywacke	meta-argillite	schist
	184.04	184.17	Cambrian	Candler Formation - Phyllite and schist	phyllite	schist
	184.82	186.91	Cambrian	Candler Formation - Phyllite and schist	phyllite	schist
	188.70	189.24	Cambrian	Candler Formation - Phyllite and schist	phyllite	schist
AP-3	34.37	38.01	Quaternary	Tabb Formation; Sedgefield Member	sand	N/A
	38.54	39.24	Quaternary	Tabb Formation; Sedgefield Member	sand	N/A
	55.26	55.52	Tertiary	Chesapeake Group	sand	silt
	55.84	56.44	Tertiary	Chesapeake Group	sand	silt
	57.43	58.06	Tertiary	Chesapeake Group	sand	silt
	60.57	61.27	Tertiary	Chesapeake Group	sand	silt
	61.94	62.26	Tertiary	Chesapeake Group	sand	silt
	62.37	62.67	Tertiary	Chesapeake Group	sand	silt
	65.08	65.23	Quaternary	Tabb Formation; Sedgefield Member	sand	N/A

ATLANTIC COAST PIPELINE, LLC
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Response to Virginia Department of Environmental Quality Request for Information for the Section 401 Water Quality Certification

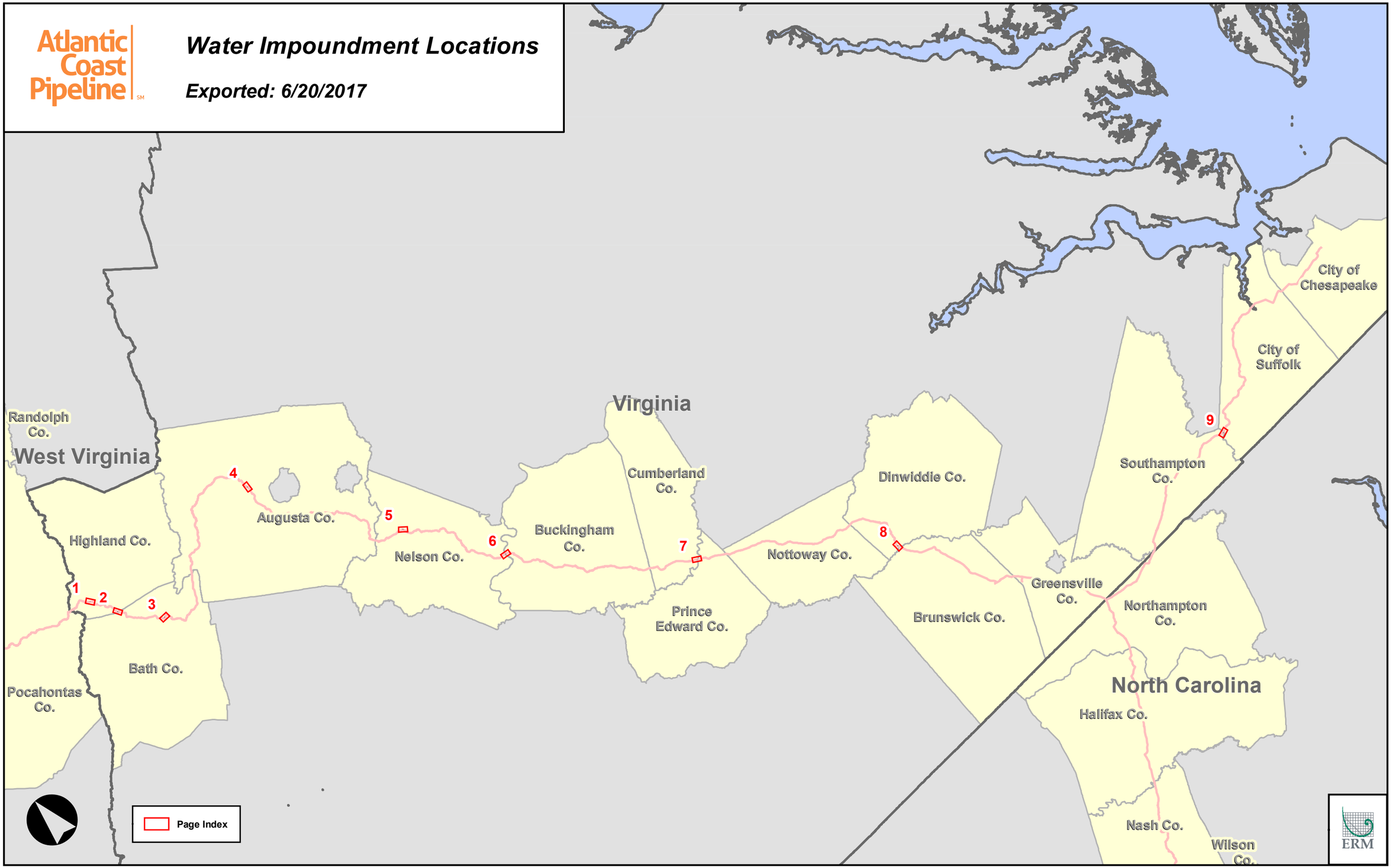
APPENDIX C

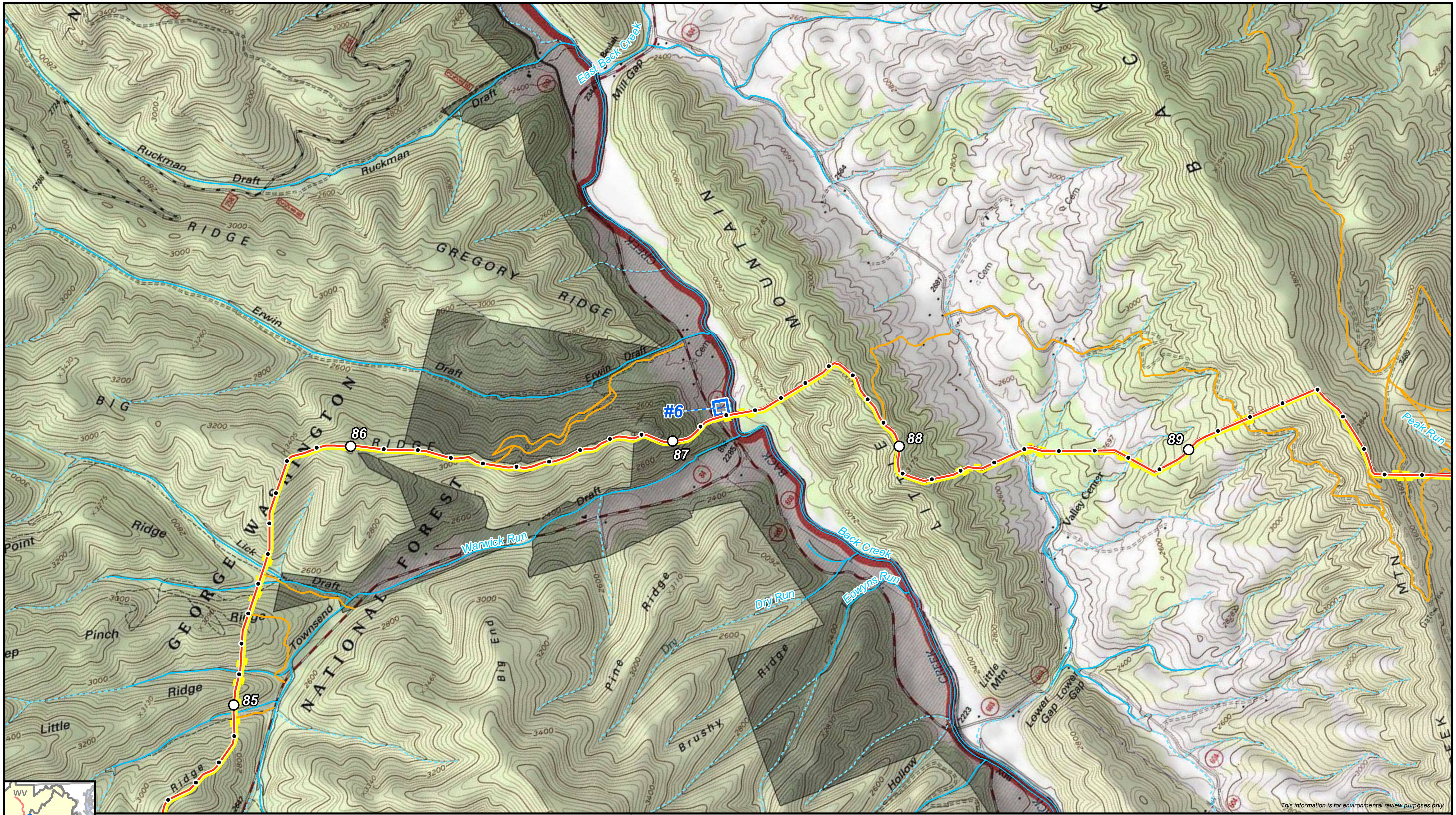
Maps Depicting Locations of Water Impoundments

Atlantic Coast Pipeline SM

Water Impoundment Locations

Exported: 6/20/2017





0 1,000 2,000
Feet

1:24,000 | 1 inch = 2,000 feet

- Proposed Centerline
- Milepost
- Water Impoundment
- Permanent Workspace
- Temporary Workspace
- Access Road

Atlantic Coast Pipeline

Atlantic Coast Pipeline
Water Impoundment Locations
Highland County, Virginia

Page 1 of 9

ERM

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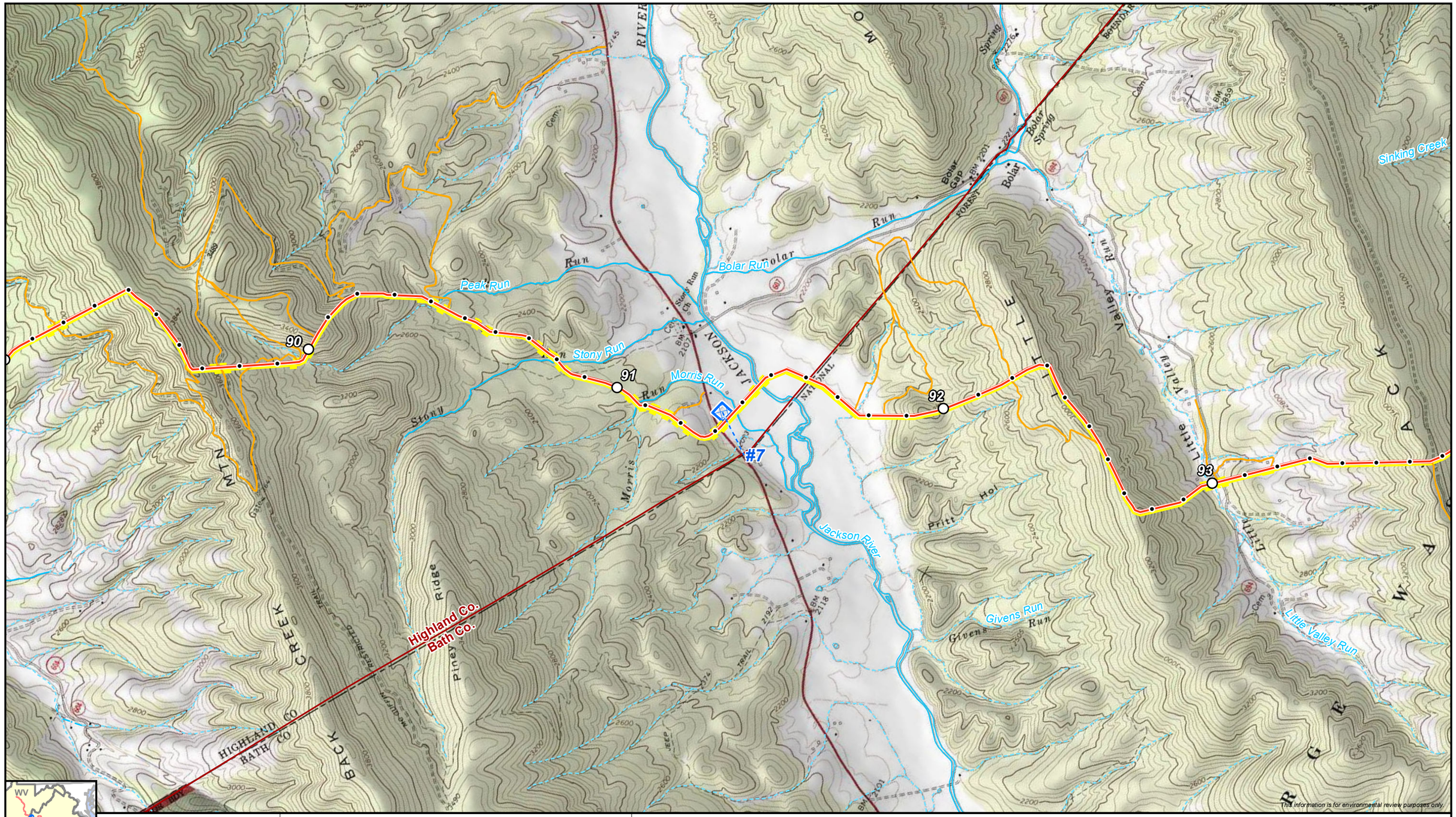

Atlantic Coast Pipeline

Water Impoundment Locations

Bath County, Virginia

Page 2 of 9

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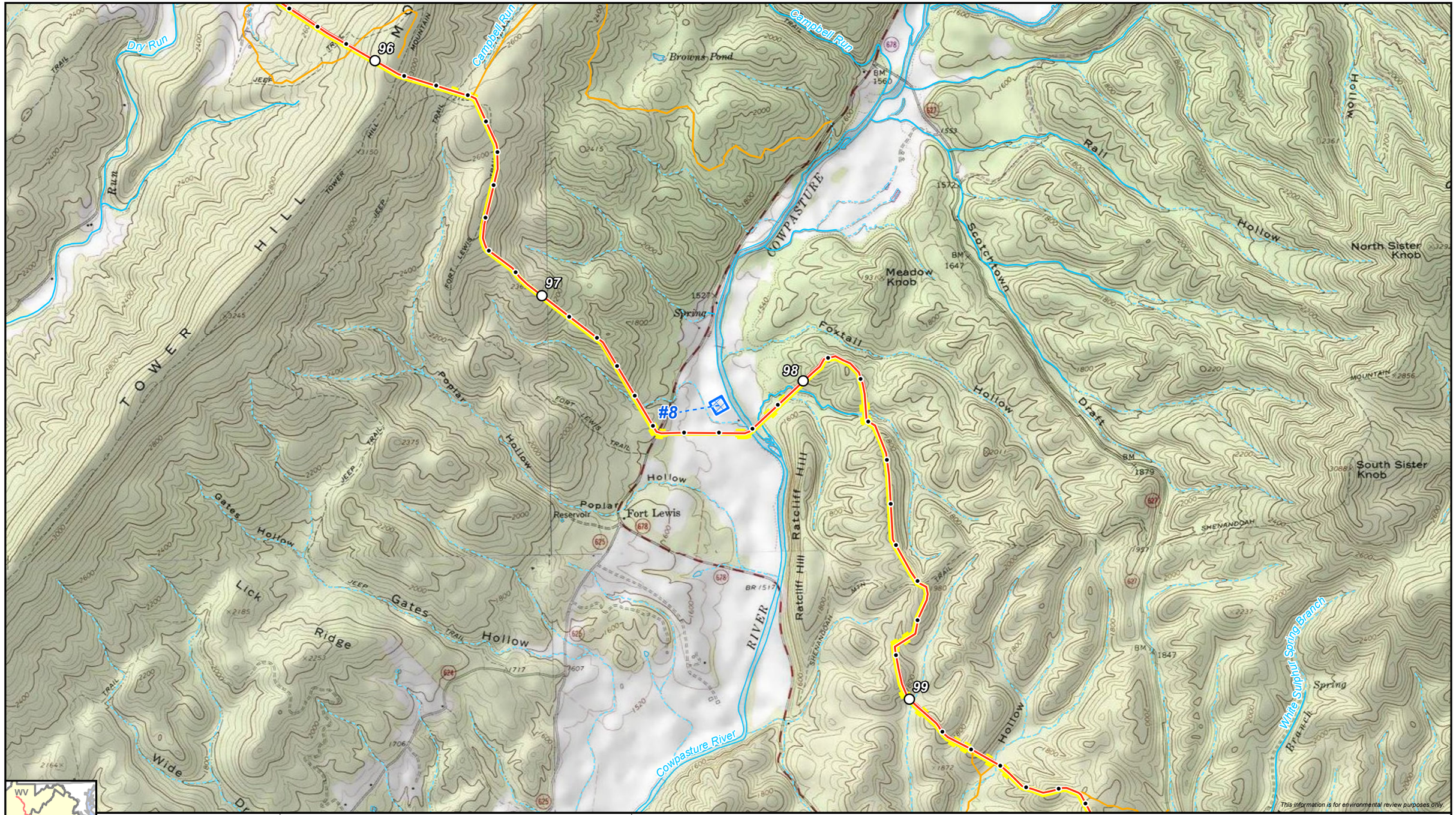

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Feet

1:24,000 | 1 inch = 2,000 feet

- Proposed Centerline
- Milepost
- Water Impoundment
- Permanent Workspace
- Temporary Workspace
- Access Road

Atlantic Coast Pipeline

Atlantic Coast Pipeline
Water Impoundment Locations
Bath County, Virginia
Page 3 of 9

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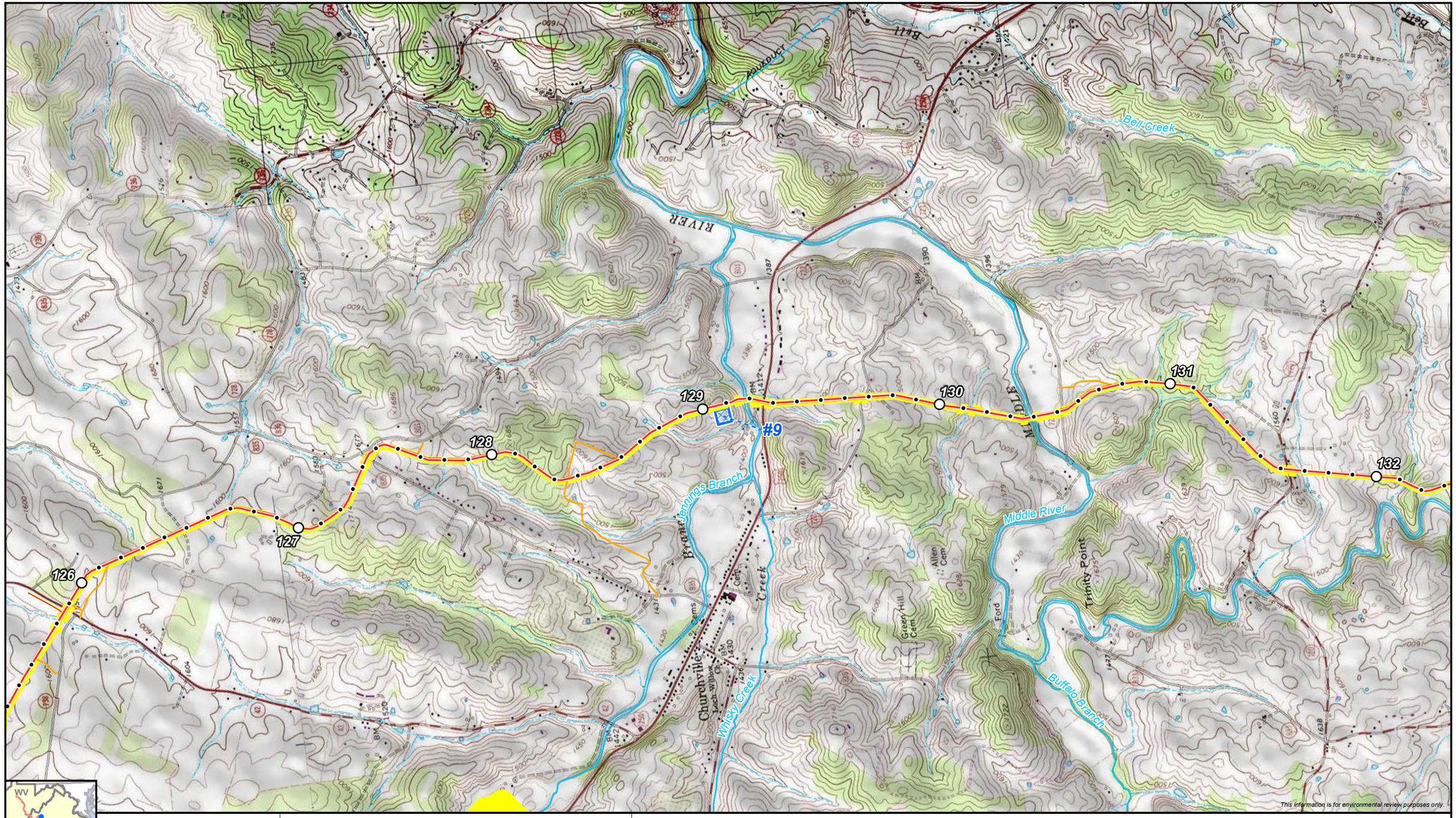

Atlantic Coast Pipeline

Water Impoundment Locations

Augusta County, Virginia

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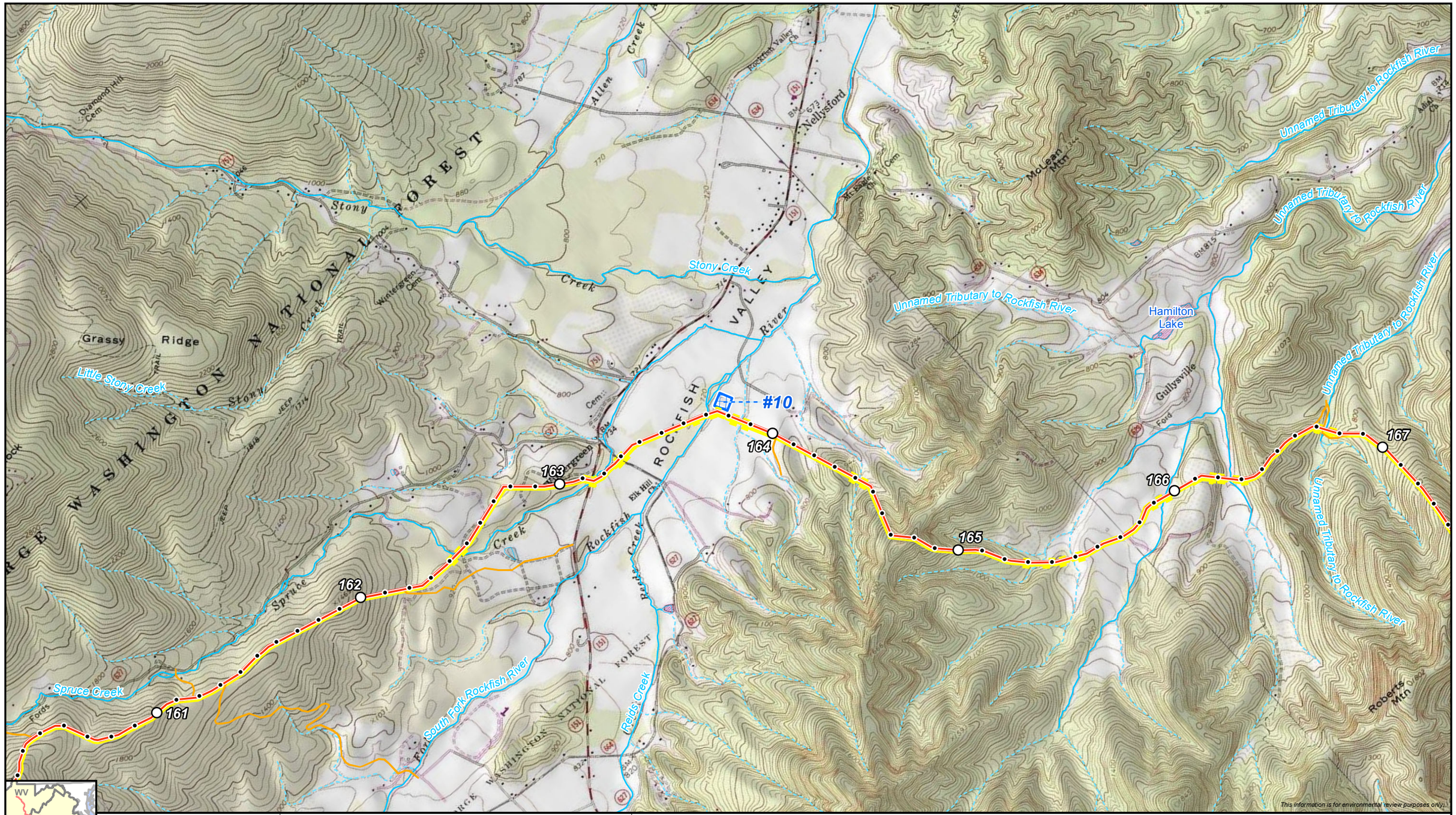
#10
163
164
165
166
167
162
161
Stony Creek
Unnamed Tributary to Rockfish River
Hamilton Lake
Nellysford
Grassy Ridge
Little Stony Creek
Spruce Creek
South Fork Rockfish River
Reids Creek
Rockfish Valley
Roberts Mtn
Gullysville
Wintergreen
Elk Hill
Diamond Hill Cem
McLean Mtn
Allen Creek
Spruce Creek
Rockfish Creek
Stony Creek
Creek
River
Ford
Cem
Trail
Jeep
Fork
Church
WV
VA
NC
0
1,000
2,000
Feet
1:24,000
1 inch = 2,000 feet
Proposed Centerline
Milepost
Water Impoundment
Permanent Workspace
Temporary Workspace
Access Road
Atlantic Coast Pipeline
This information is for environmental review purposes only.
Atlantic Coast Pipeline
Water Impoundment Locations
Nelson County, Virginia
Page 5 of 9
ERM
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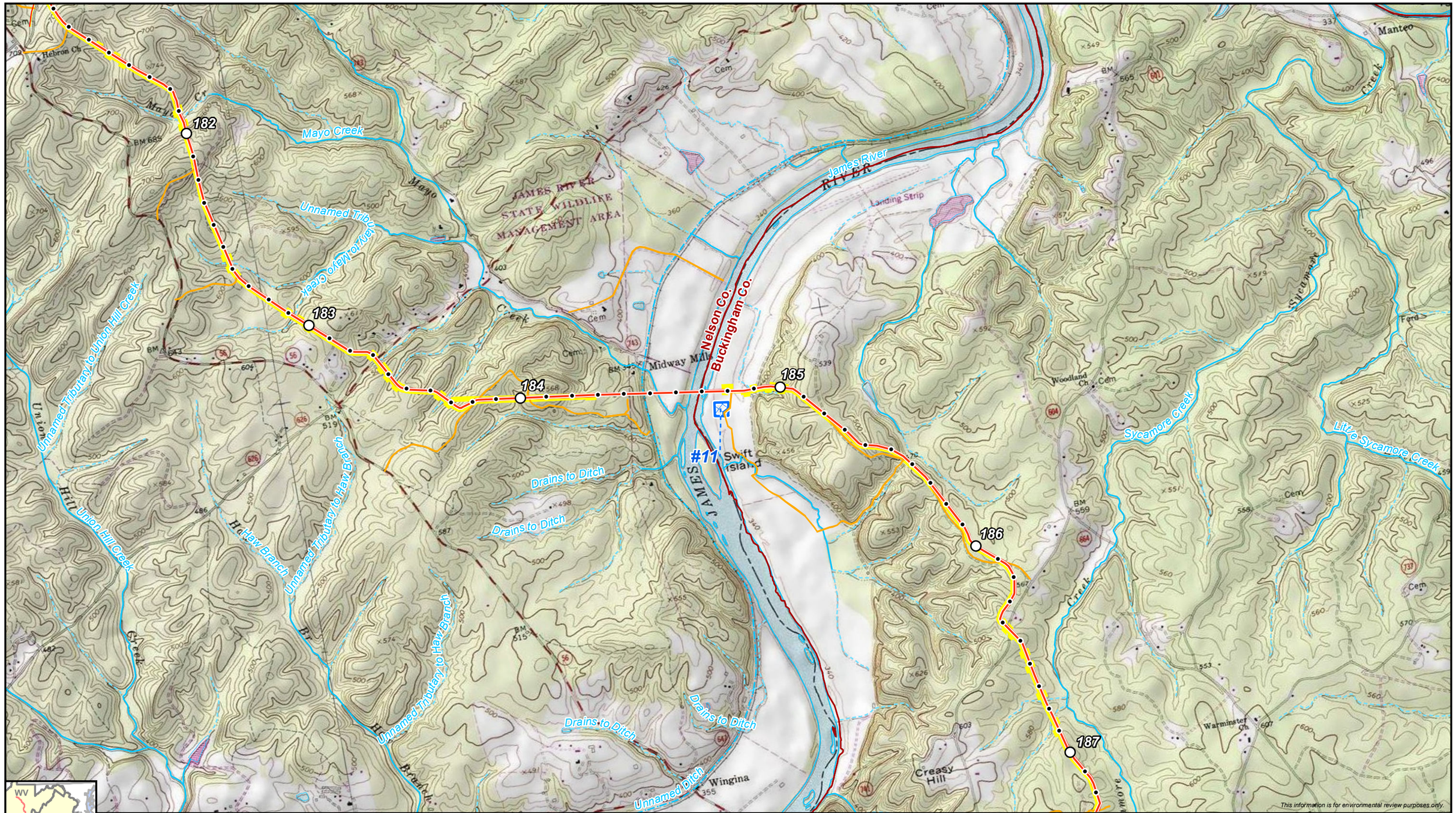

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Feet

1:24,000 | 1 inch = 2,000 feet

- Proposed Centerline
- Milepost
- Water Impoundment
- Permanent Workspace
- Temporary Workspace
- Access Road

Atlantic Coast Pipeline

Atlantic Coast Pipeline
Water Impoundment Locations
Nelson County, Virginia

ERM

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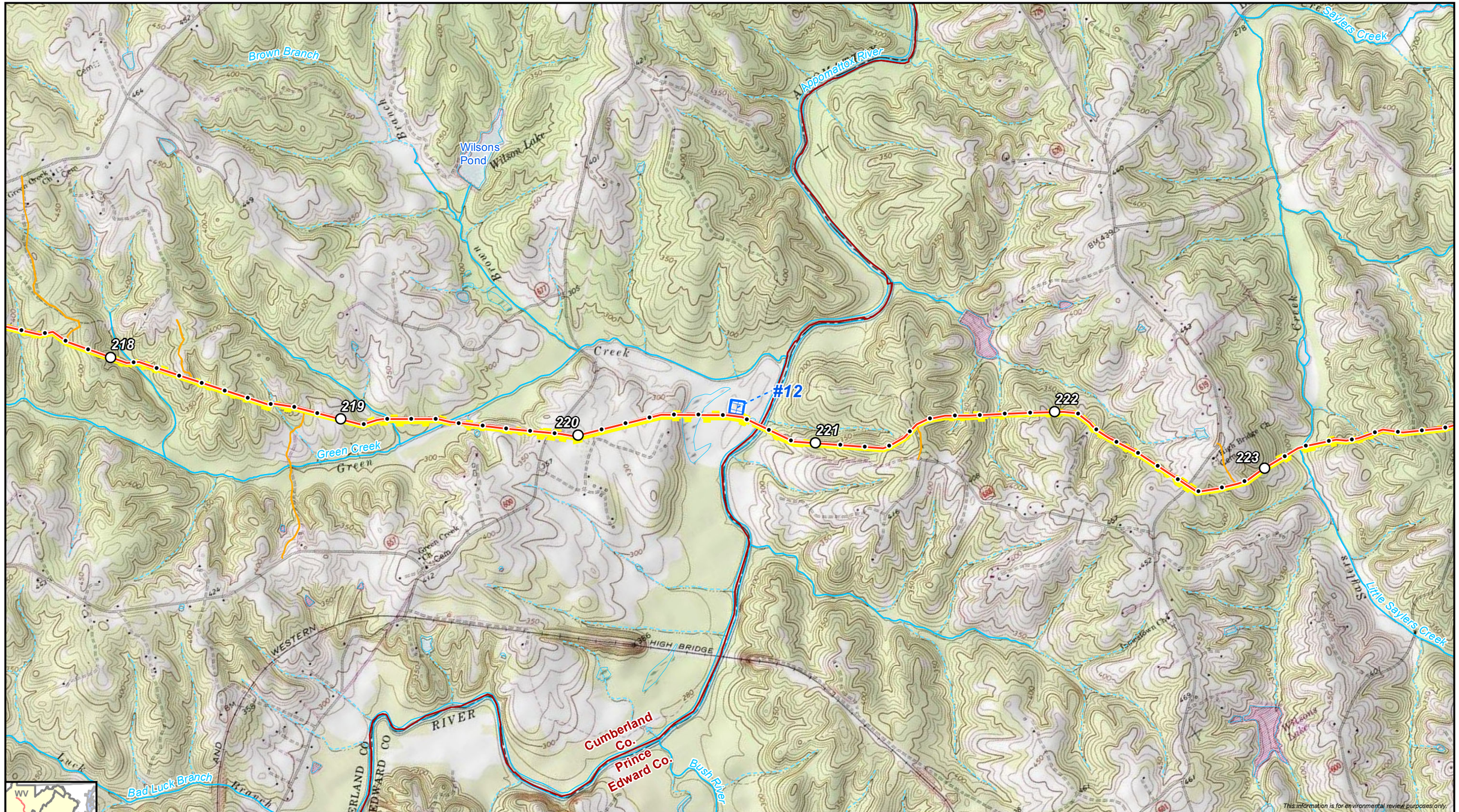

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Feet

1:24,000 | 1 inch = 2,000 feet

- Proposed Centerline
- Milepost
- Water Impoundment
- Permanent Workspace
- Temporary Workspace
- Access Road

Atlantic Coast Pipeline

Atlantic Coast Pipeline

Water Impoundment Locations

Prince Edward County, Virginia

Page 7 of 9

ERM

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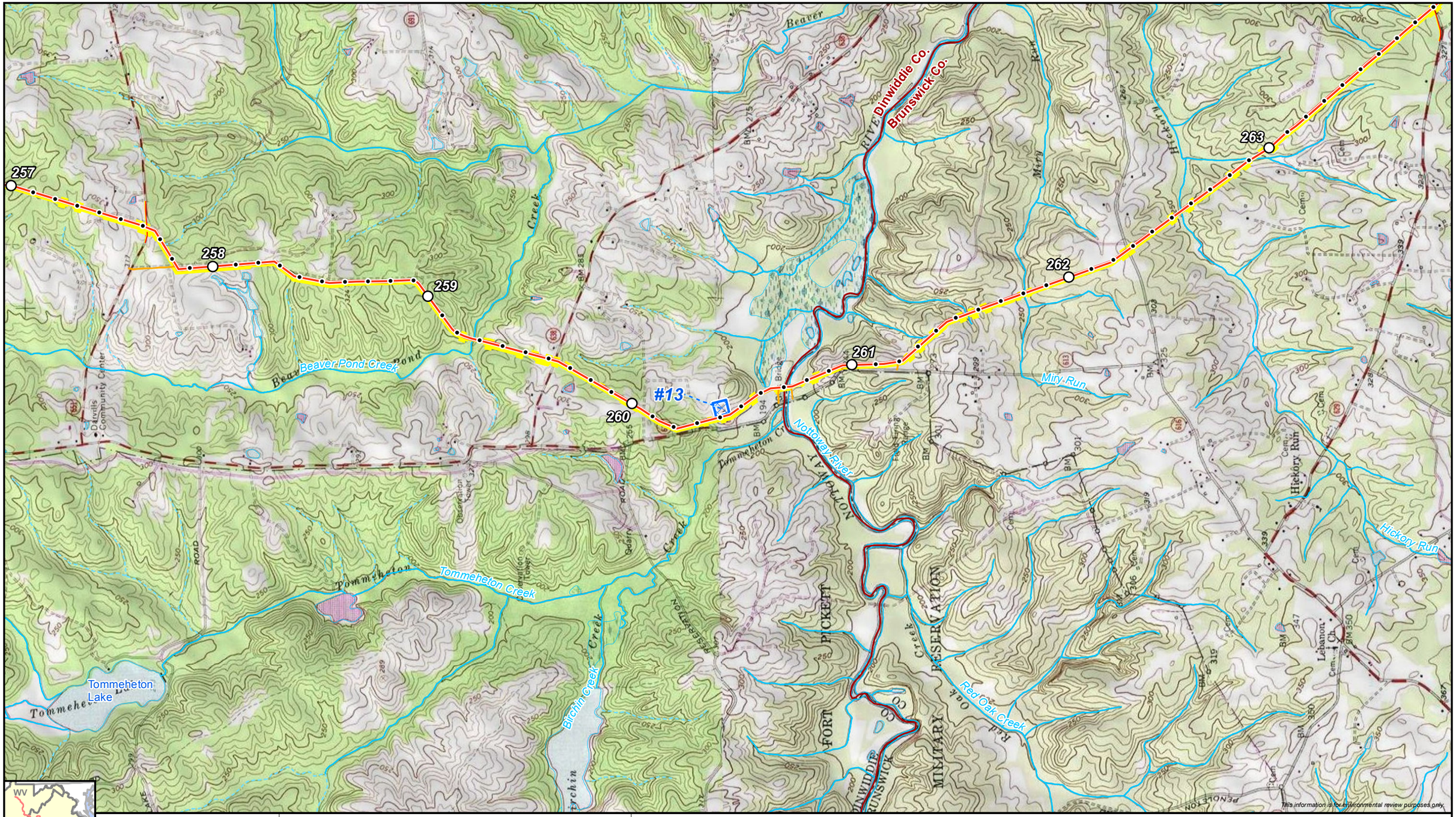

Atlantic Coast Pipeline

Water Impoundment Locations

Dinwiddie County, Virginia

ERM

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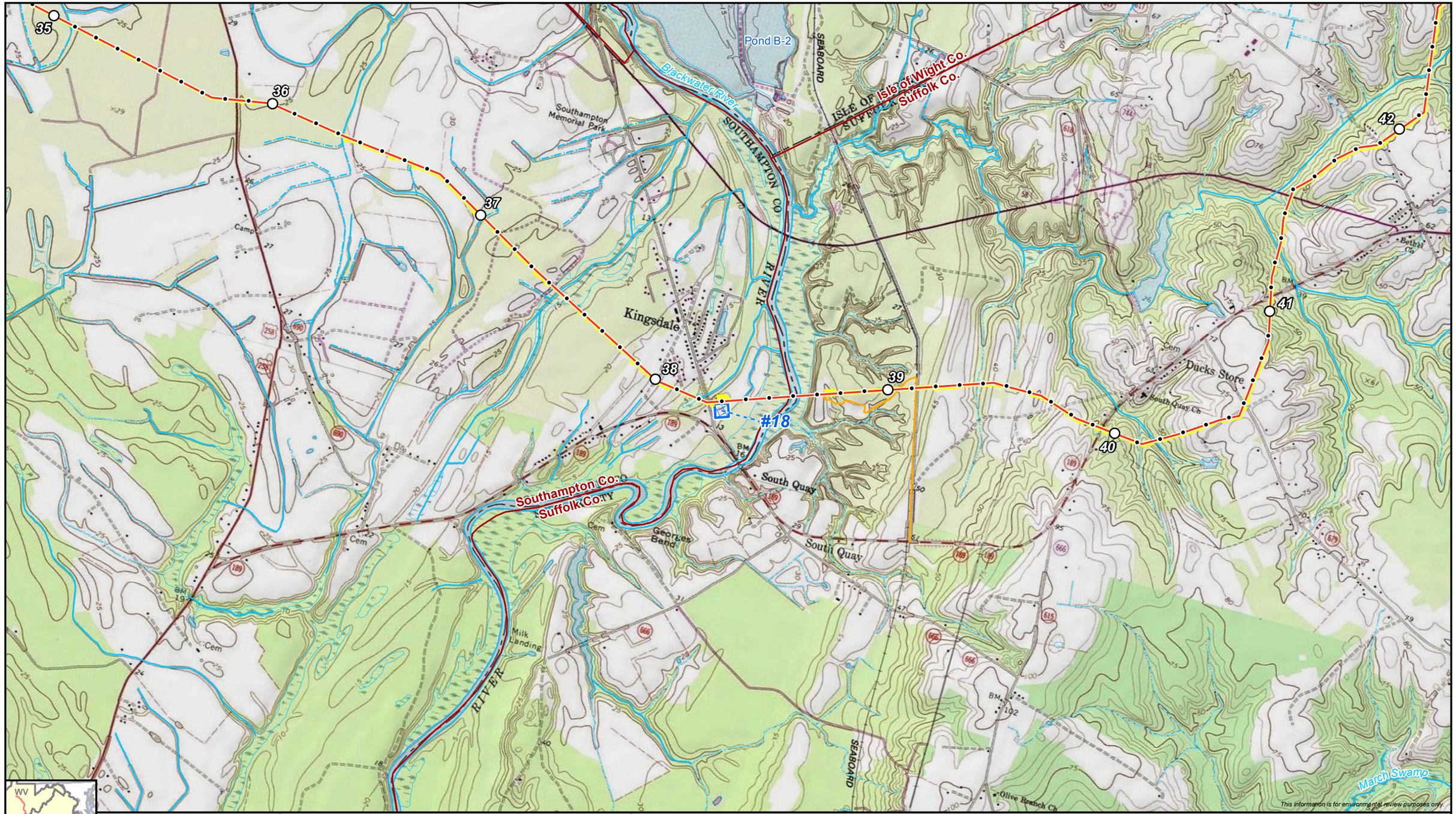

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Feet

1:24,000 | 1 inch = 2,000 feet

- Proposed Centerline
- Milepost
- Water Impoundment
- Permanent Workspace
- Temporary Workspace
- Access Road

Atlantic Coast Pipeline

Atlantic Coast Pipeline
Water Impoundment Locations
Suffolk County, Virginia
Page 9 of 9

ERM

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ATLANTIC COAST PIPELINE, LLC
ATLANTIC COAST PIPELINE

Response to Virginia Department of Environmental Quality Request for Information for the Section 401 Water Quality Certification

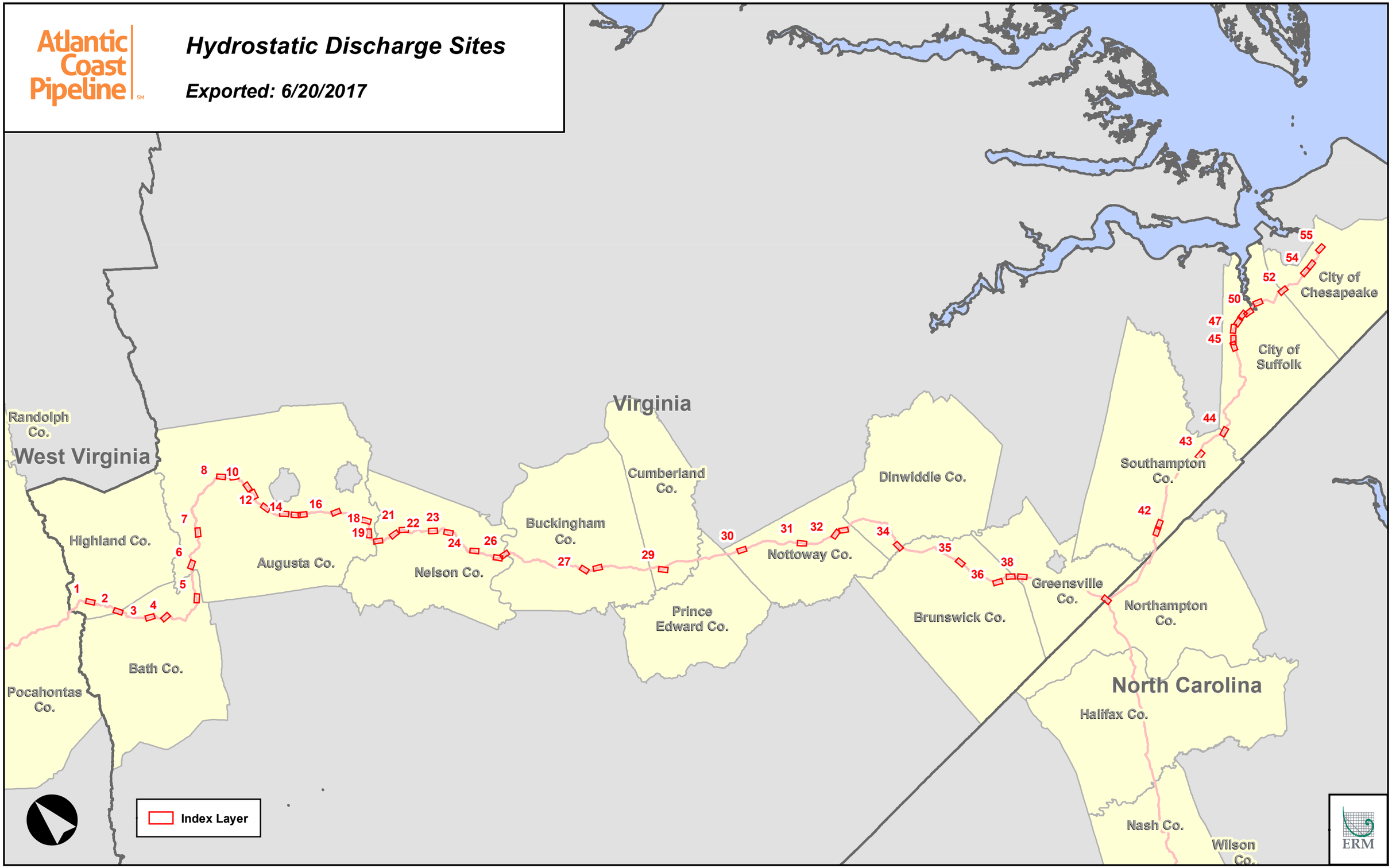
APPENDIX D

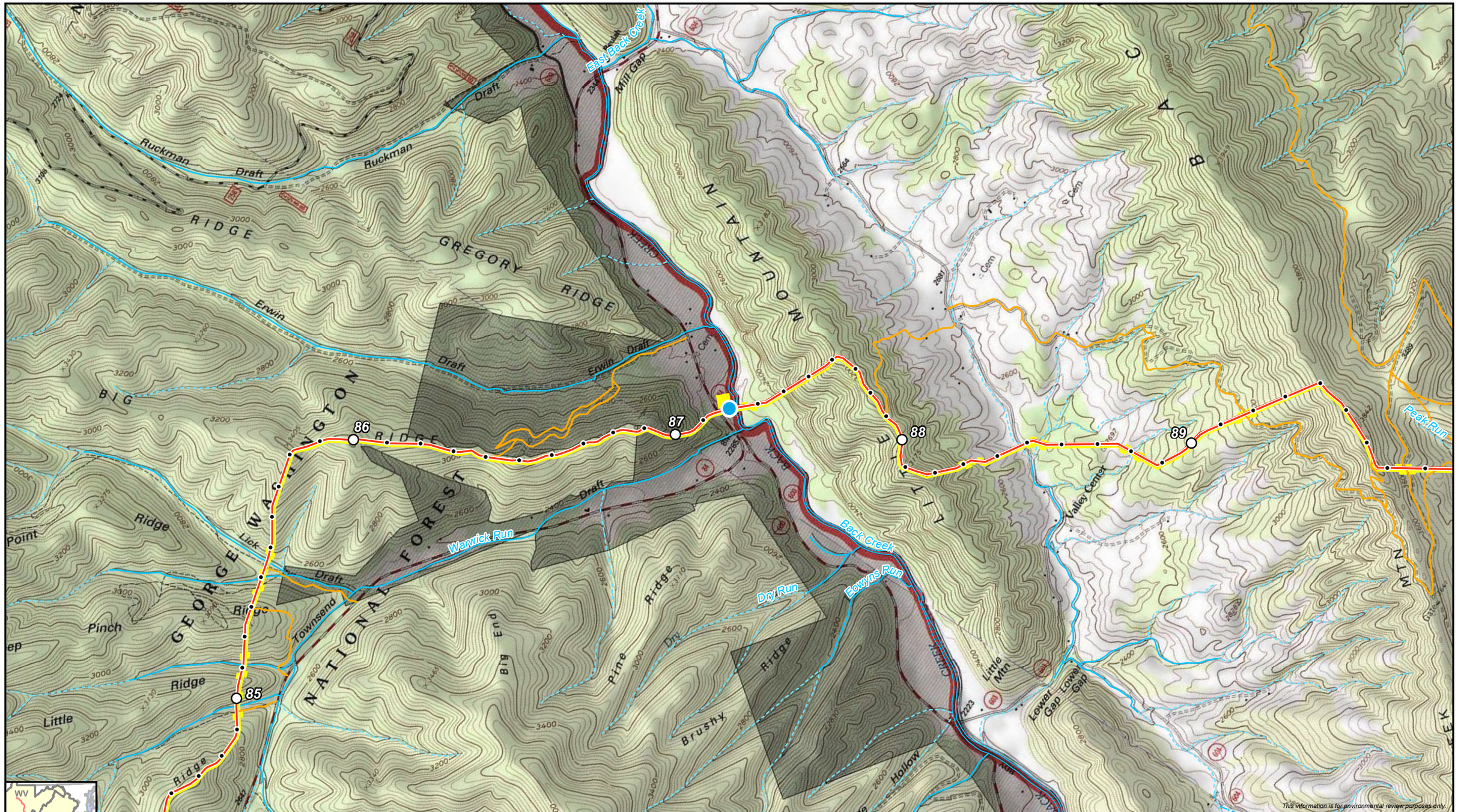
Maps Depicting Discharge Locations for Hydrostatic Test Water

Atlantic Coast Pipeline SM

Hydrostatic Discharge Sites

Exported: 6/20/2017





Atlantic Coast Pipeline

Atlantic Coast Pipeline
Hydrostatic Discharge Sites
Highland County, Virginia

ERM

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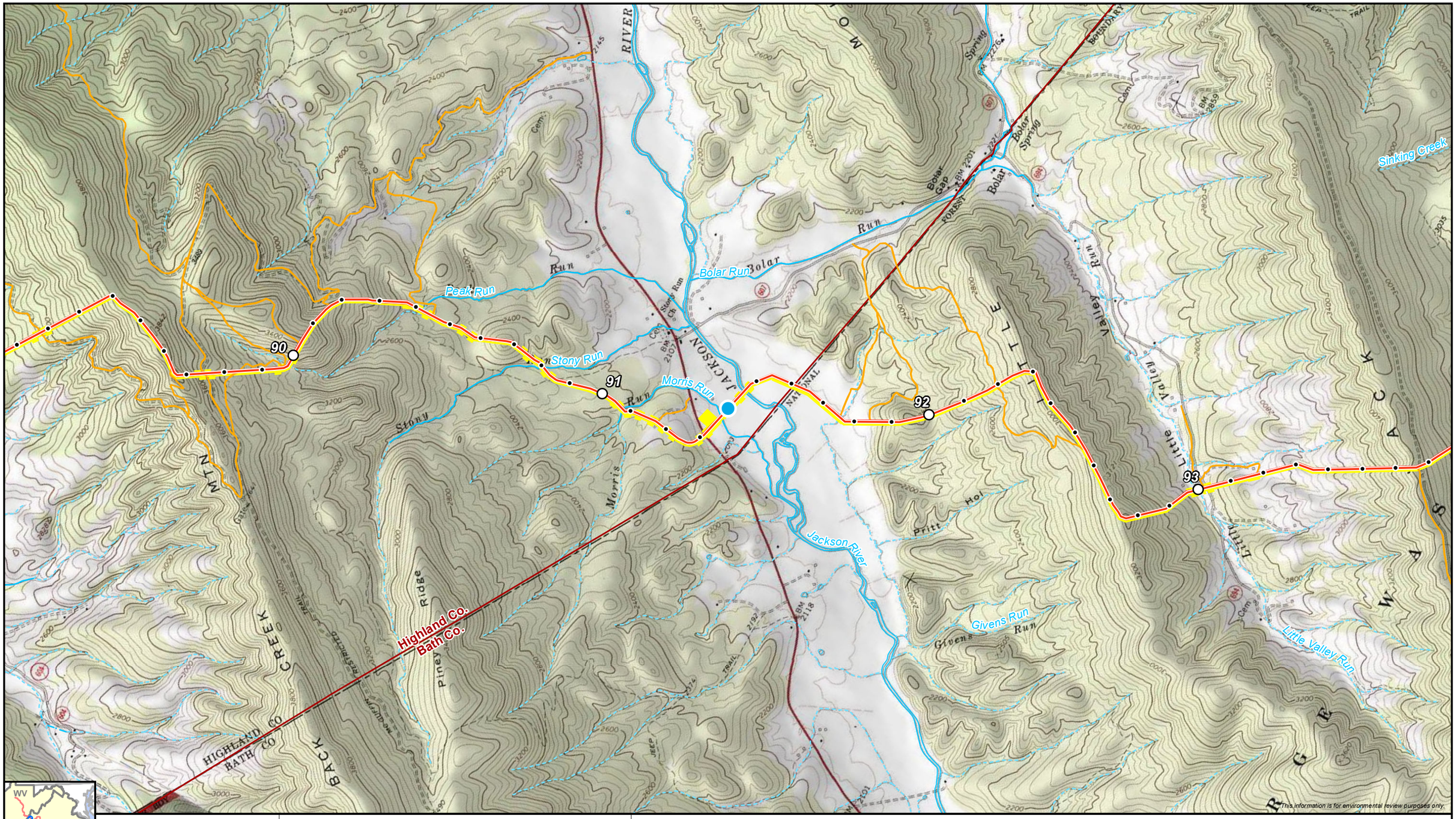

Atlantic Coast Pipeline

Hydrostatic Discharge Sites

Bath County, Virginia

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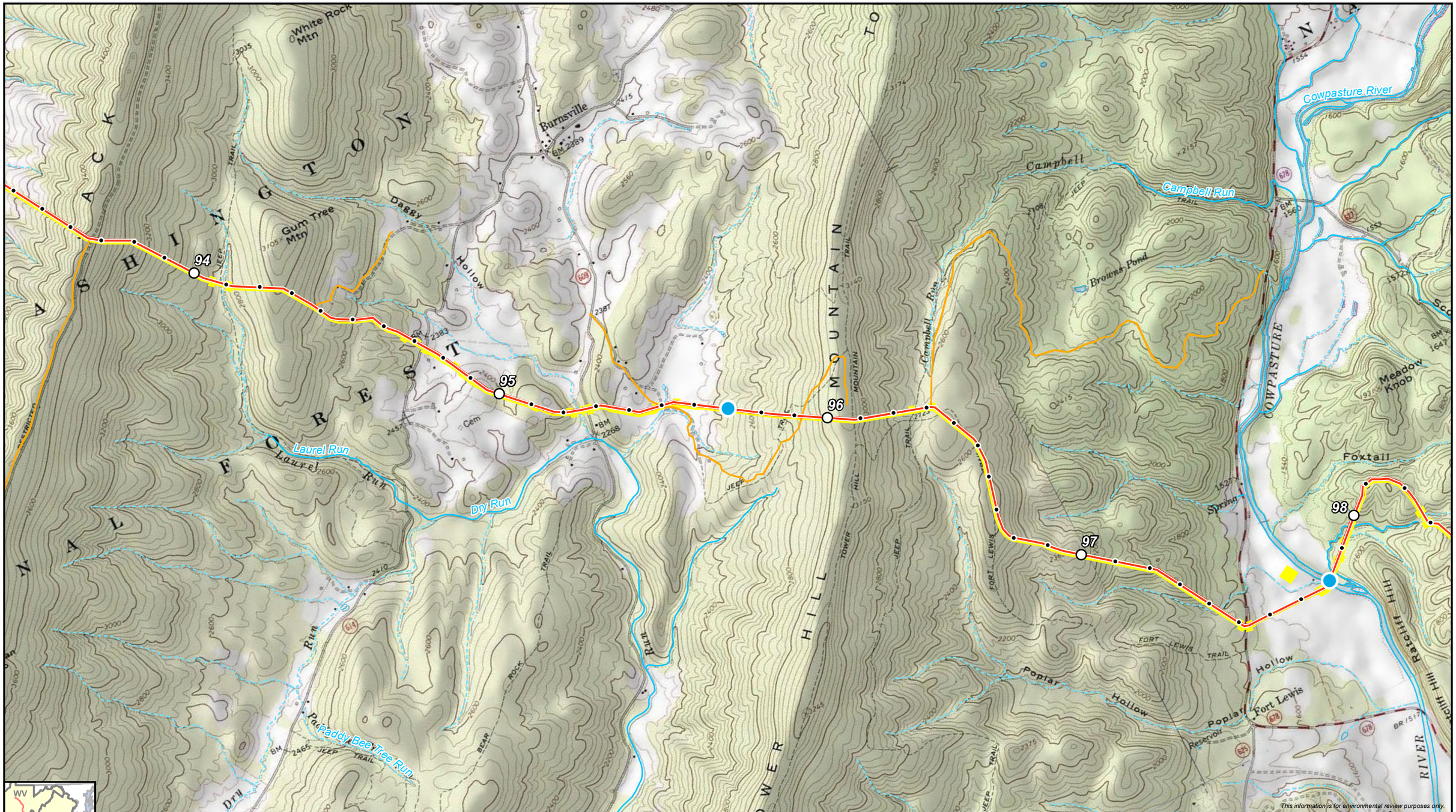

0 1,000 2,000
Feet

1:24,000 | 1 inch = 2,000 feet

Proposed Centerline
Milepost
Hydrostatic Discharge Sites
Temporary Workspace
Permanent Workspace
Access Road

Atlantic Coast Pipeline

Atlantic Coast Pipeline
Hydrostatic Discharge Sites
Bath County, Virginia

ERM

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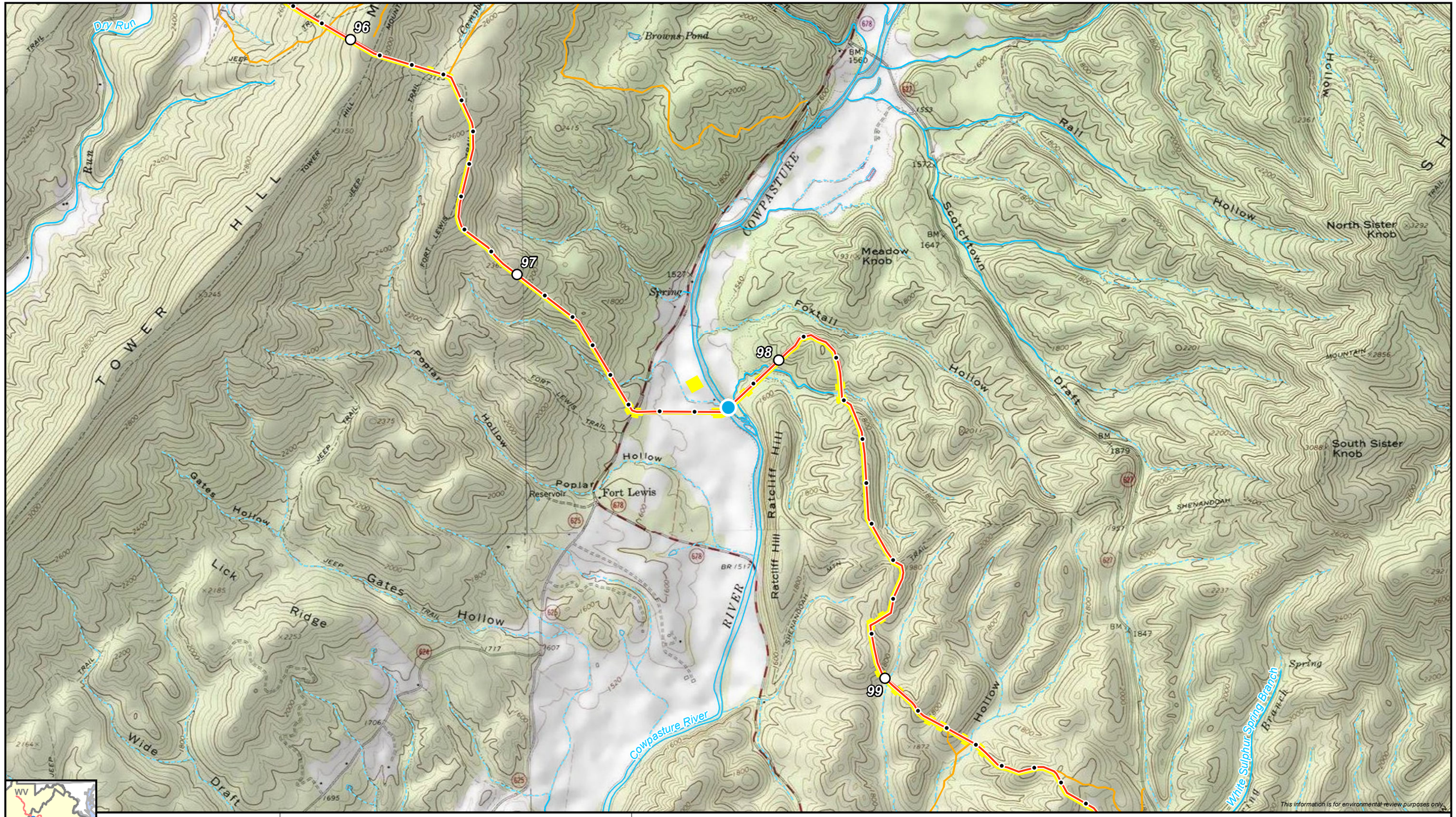

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Feet

1:24,000 | 1 inch = 2,000 feet

- Proposed Centerline
- Milepost
- Hydrostatic Discharge Sites
- Temporary Workspace
- Permanent Workspace
- Access Road

Atlantic Coast Pipeline

Atlantic Coast Pipeline

Hydrostatic Discharge Sites

Bath County, Virginia

ERM

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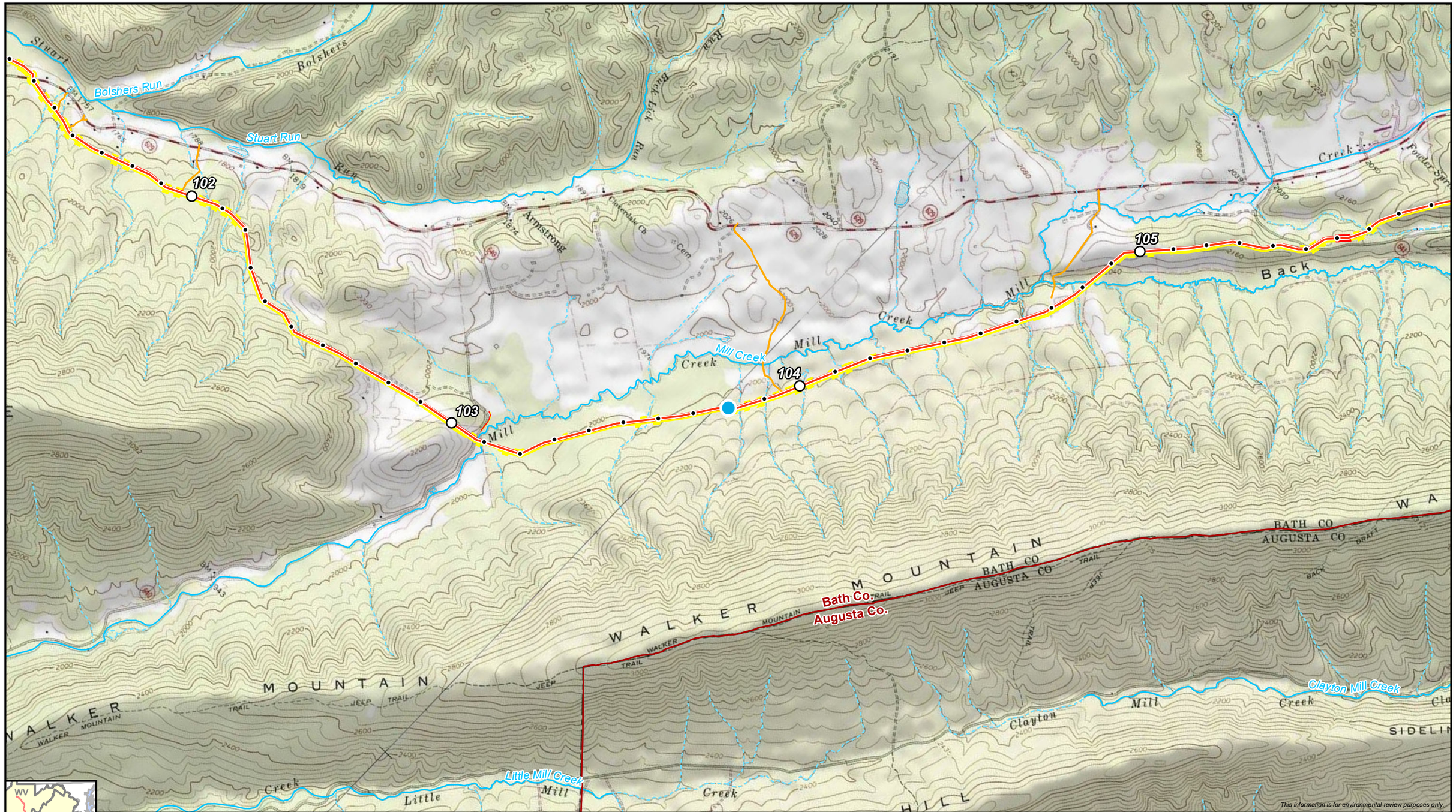

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Feet

1:24,000 | 1 inch = 2,000 feet

Proposed Centerline
Milepost
Hydrostatic Discharge Sites
Temporary Workspace
Permanent Workspace
Access Road

Atlantic Coast Pipeline

Atlantic Coast Pipeline
Hydrostatic Discharge Sites
Bath County, Virginia

ERM

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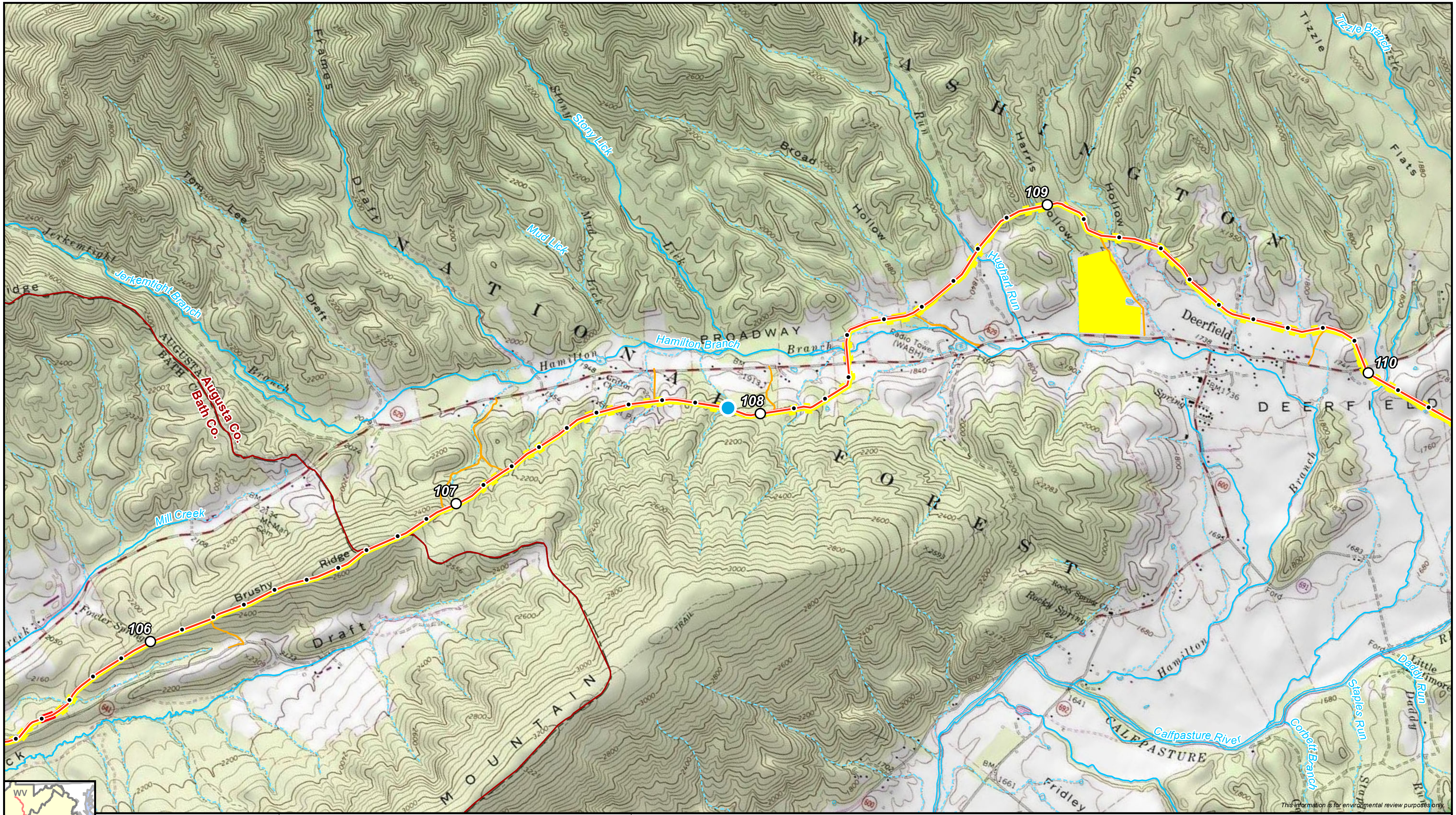

0 1,000 2,000
Feet

1:24,000 | 1 inch = 2,000 feet

Proposed Centerline
Milepost
Hydrostatic Discharge Sites
Temporary Workspace
Permanent Workspace
Access Road

Atlantic Coast Pipeline

Atlantic Coast Pipeline
Hydrostatic Discharge Sites
Augusta County, Virginia

ERM

M:\Clients\D-F\DOM\SRPP_ArcGIS\2017\06\19_VA_Rev12_Water_Imp_and_Discharge_Maps_Discharge_Site_Maps_DOM_SRP_VA_Sheet_Maps_Discharge.mxd, **REVISED:** 6/20/2017

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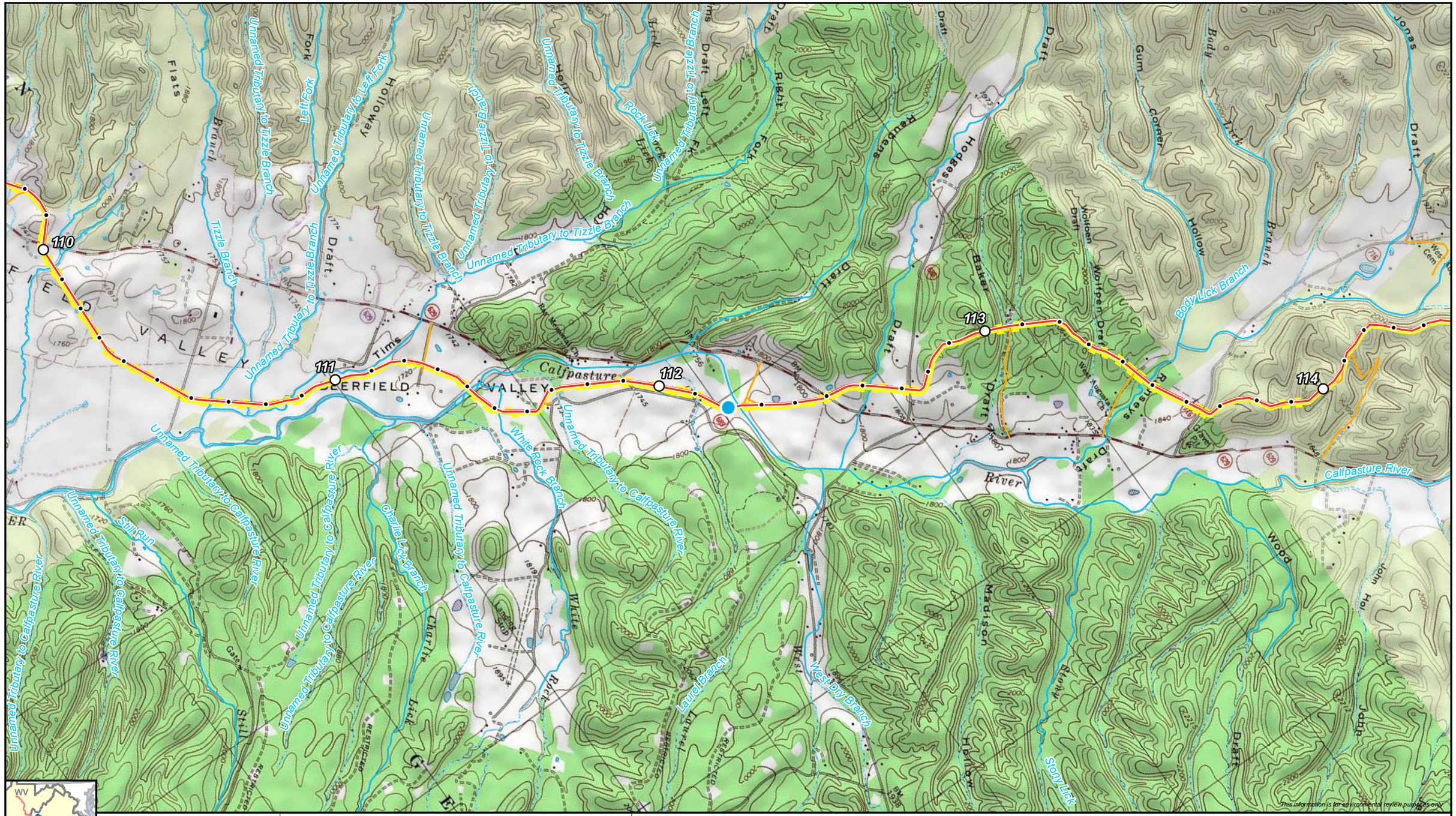
110
111
112
113
114
Tizzle Branch
Unnamed Tributary to Tizzle Branch
Unnamed Tributary to Left Fork
Left Fork
Unnamed Tributary to Tizzle Branch
Unnamed Tributary to Tizzle Branch
Unnamed Tributary to Tizzle Branch
Unnamed Tributary to Tizzle Branch
Unnamed Tributary to Tizzle Branch
Draft
Tims
Calfpasture
Unnamed Tributary to Calfpasture River
Unnamed Tributary to Calfpasture River
Unnamed Tributary to Calfpasture River
Unnamed Tributary to Calfpasture River
Unnamed Tributary to Calfpasture River
Still Run
Charlie Lick Branch
White Rock Branch
Laurel Branch
West Dry Branch
Body Lick Branch
Calfpasture River
Stony Lick
Hollow
Branch
Draft
Gum Corner
Jonas
Hodges
Baker
Wolfpen Draft
Reubens
Right Fork
Left Fork
Rock Lick Branch
Flats
Holloway
Madison
Woods
John Hol
Draft
Still
Gate
Landing Strip
RESTRICTED
Rest Memorial Ch
Wesleyan Ch
Wes Cem
VALLEY
ERFIELD
River
WV
VA
NC
0 1,000 2,000
Feet
1:24,000
1 inch = 2,000 feet
Proposed Centerline
Milepost
Hydrostatic Discharge Sites
Temporary Workspace
Permanent Workspace
Access Road
Atlantic Coast Pipeline
Atlantic Coast Pipeline
Hydrostatic Discharge Sites
Augusta County, Virginia
Page 7 of 55
ERM
This information is for environmental review purposes only.
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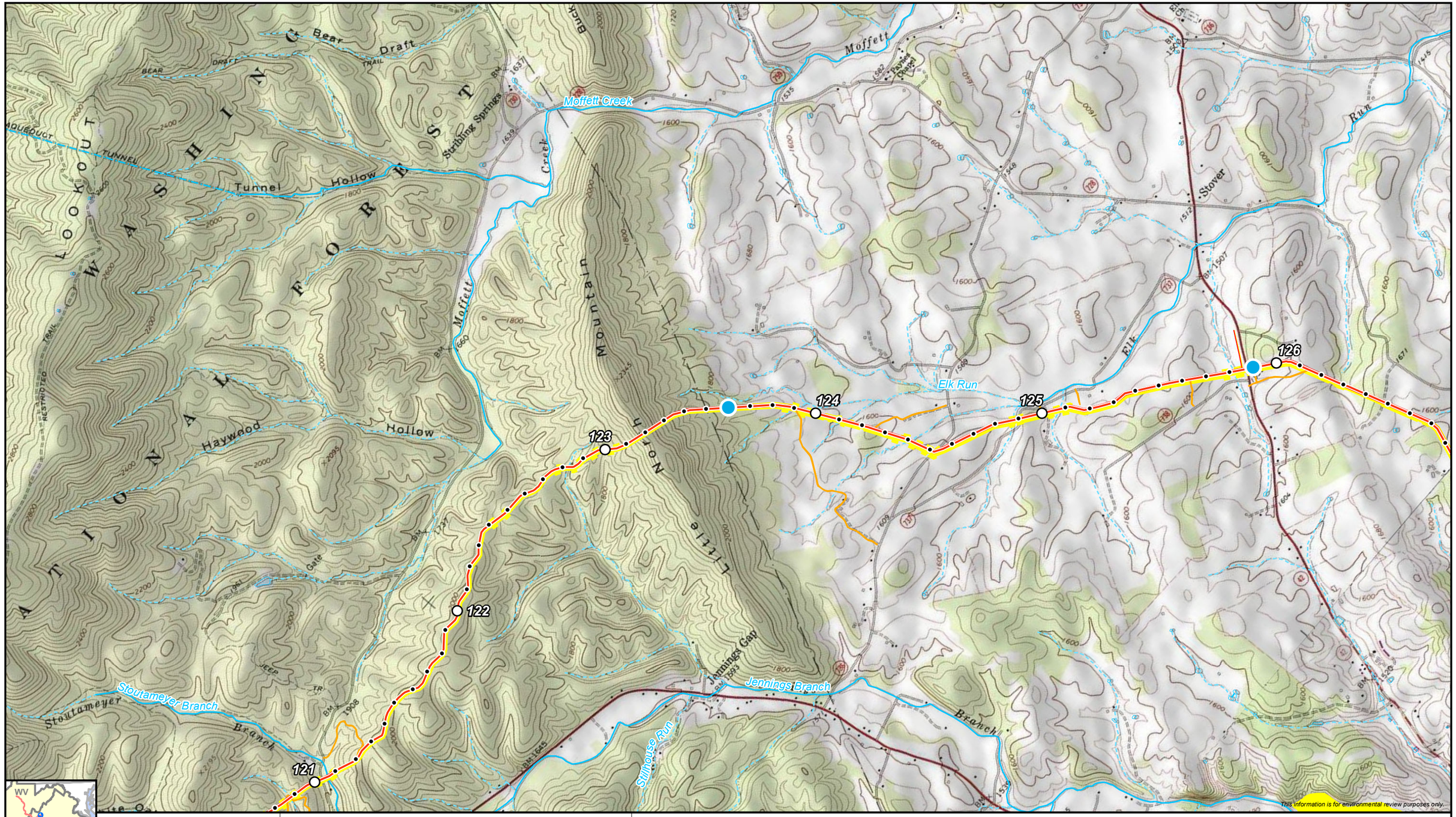

Atlantic Coast Pipeline

Hydrostatic Discharge Sites

Augusta County, Virginia

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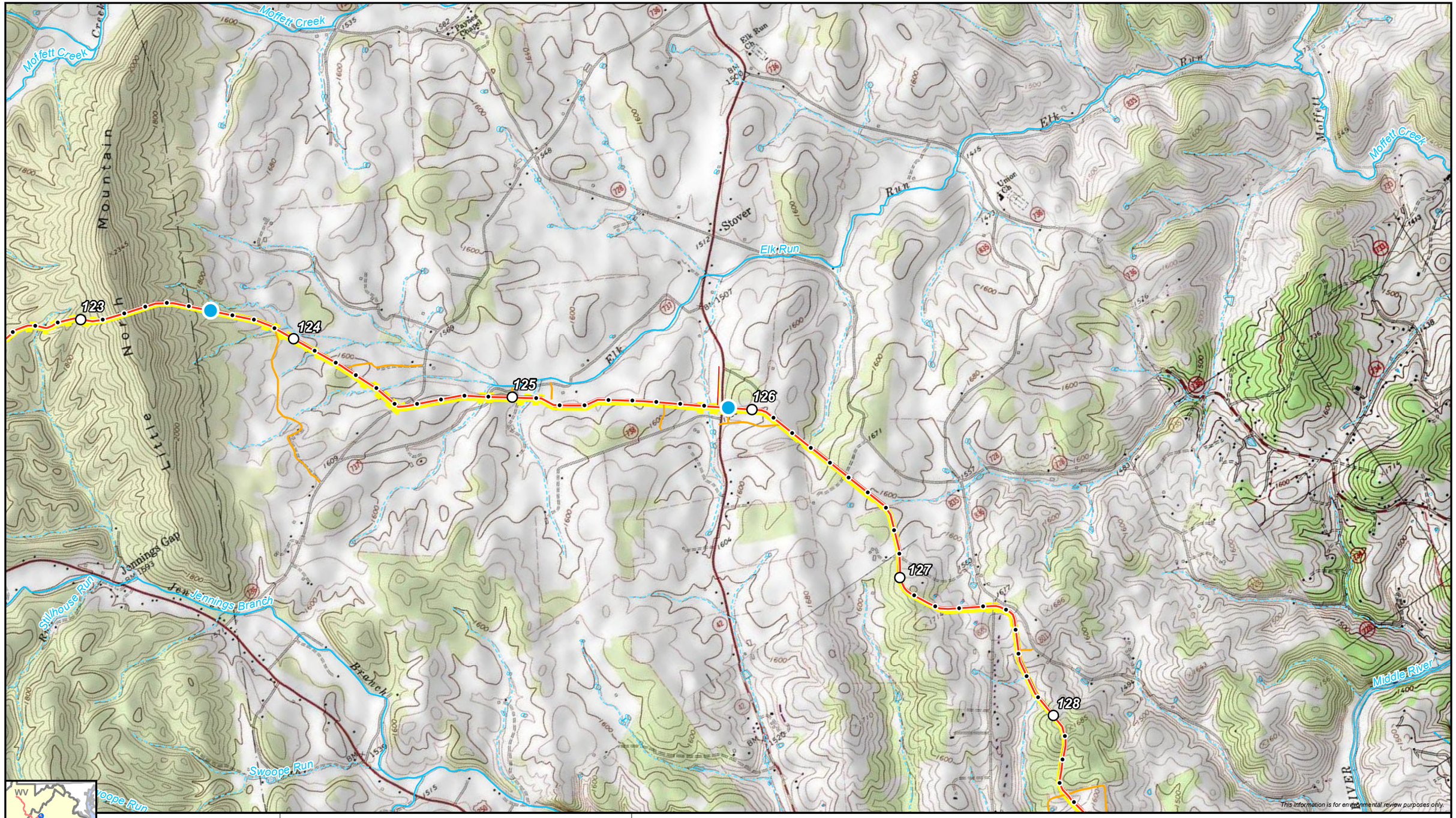

Atlantic Coast Pipeline

Hydrostatic Discharge Sites

Augusta County, Virginia

M:\Clients\D-F\DOM\SRPP_ArcGIS\2017\06\19_VA_Rev12_Water_Imp_and_Discharge_Maps_Discharge_Site_Maps_DOM_SRP_VA_Sheet_Maps_Discharge.mxd, **REVISED:** 6/20/2017

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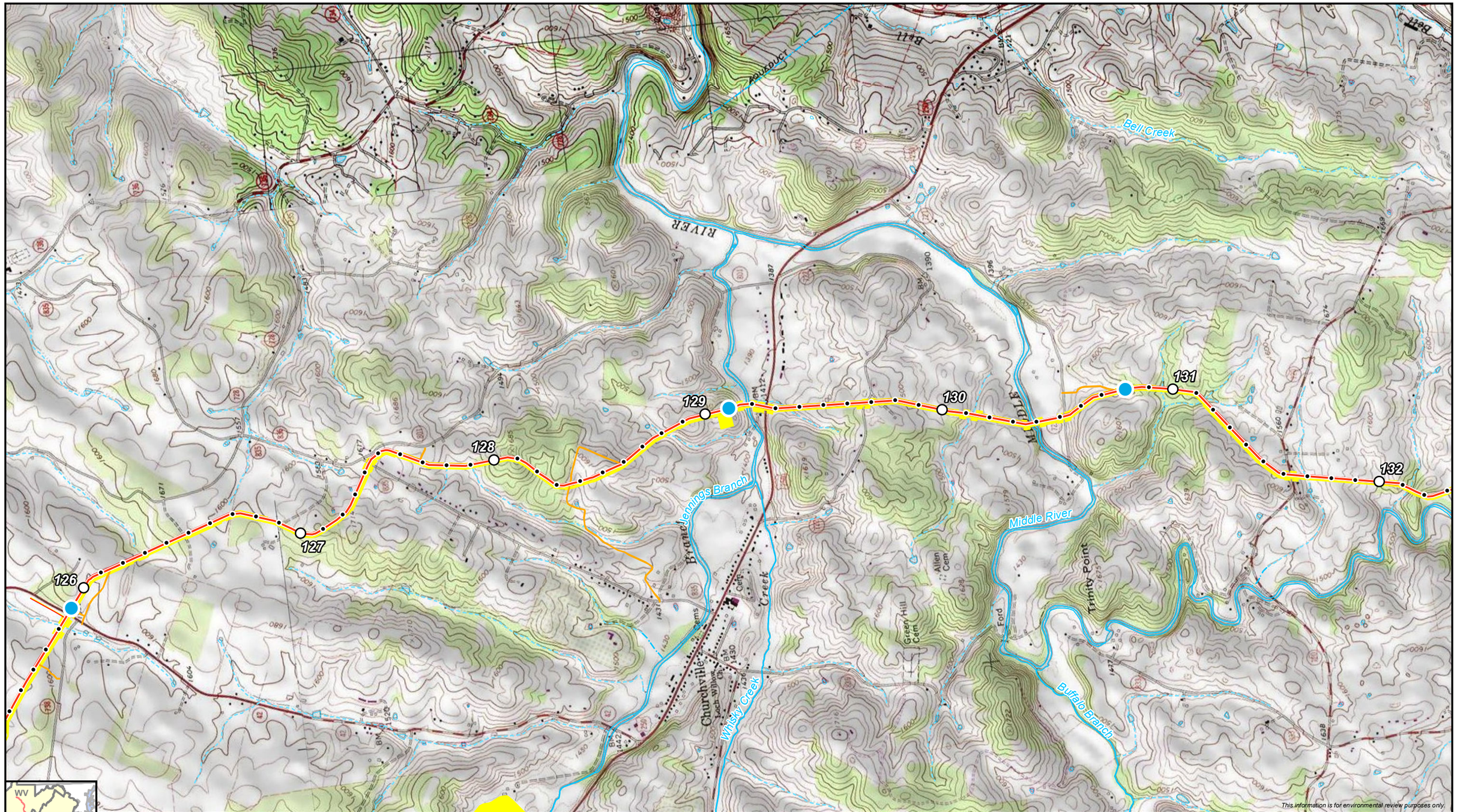

0 1,000 2,000

Feet

1:24,000 | 1 inch = 2,000 feet

Proposed Centerline
Milepost
Hydrostatic Discharge Sites
Temporary Workspace
Permanent Workspace
Access Road

Atlantic Coast Pipeline

Atlantic Coast Pipeline
Hydrostatic Discharge Sites
Augusta County, Virginia

ERM

M:\Clients\D-F\DOM\SRPP_ArcGIS\2017\06\19_VA_Rev12_Water_Imp_and_Discharge_Maps_Discharge_Site_Maps_DOM_SRP_VA_Sheet_Maps_Discharge.mxd, **REVISED:** 6/20/2017

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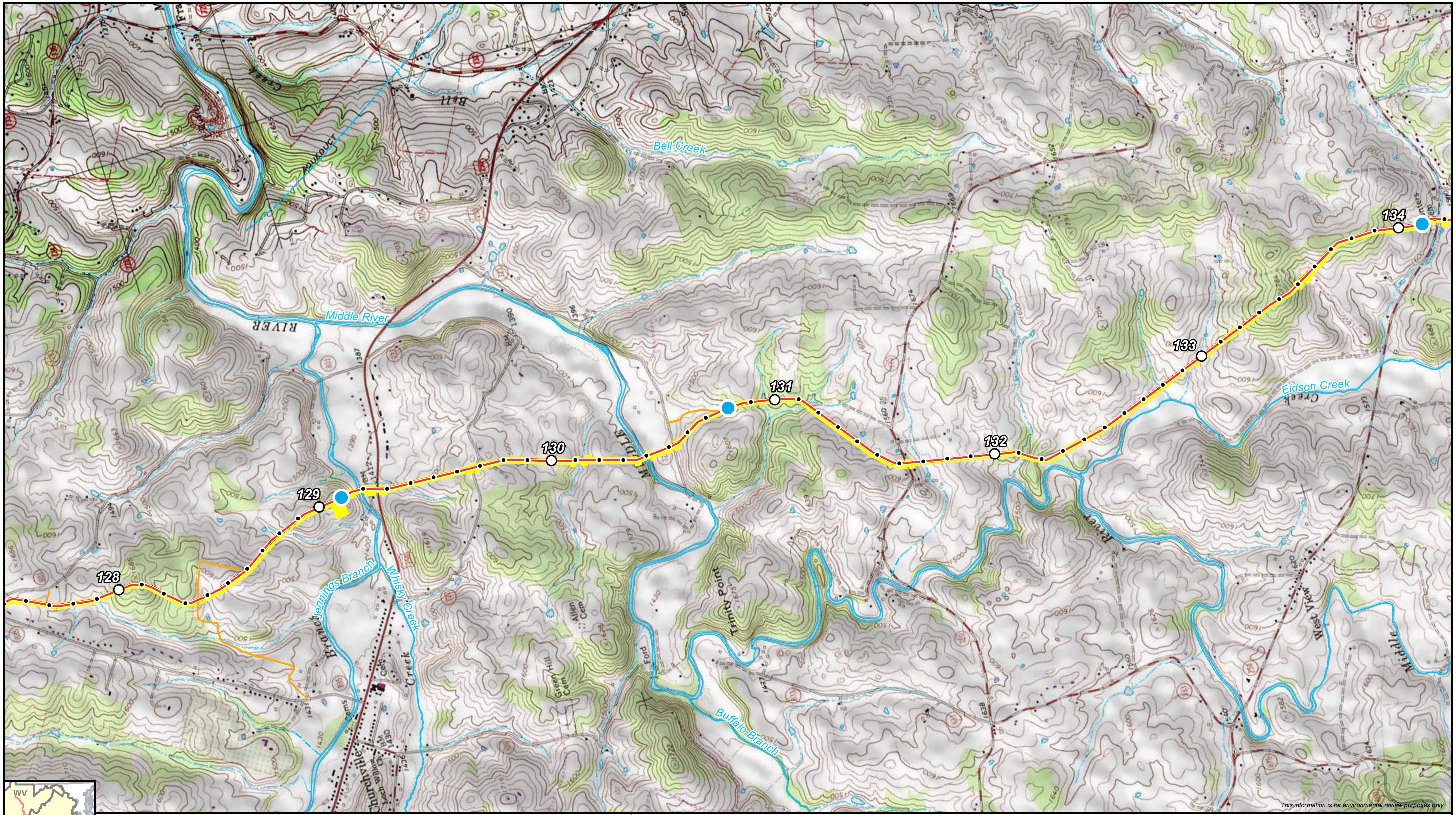

0 1,000 2,000
Feet

1:24,000 | 1 inch = 2,000 feet

Proposed Centerline
Milepost
Hydrostatic Discharge Sites
Temporary Workspace
Permanent Workspace
Access Road

Atlantic Coast Pipeline

Atlantic Coast Pipeline
Hydrostatic Discharge Sites
Augusta County, Virginia

ERM

M:\Clients\D-F\DOM\SRPP_ArcGIS\2017\06\19_VA_Rev12_Water_Imp_and_Discharge_Maps_Discharge_Site_Maps_DOM_SRP_VA_Sheet_Maps_Discharge.mxd, **REVISED:** 6/20/2017

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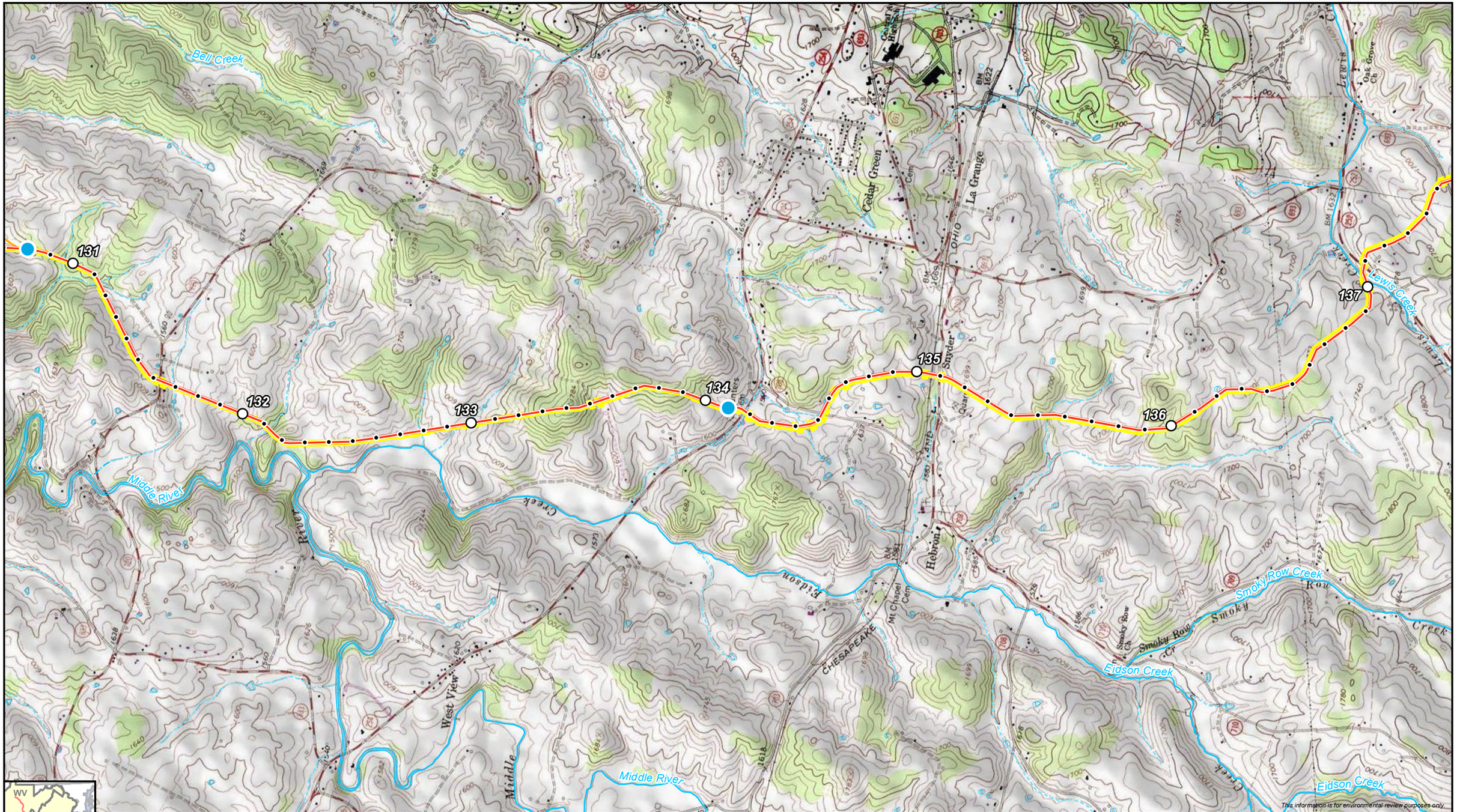

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Feet

1:24,000 | 1 inch = 2,000 feet

Proposed Centerline
Milepost
Hydrostatic Discharge Sites
Temporary Workspace
Permanent Workspace
Access Road

Atlantic Coast Pipeline

Atlantic Coast Pipeline
Hydrostatic Discharge Sites
Augusta County, Virginia

ERM

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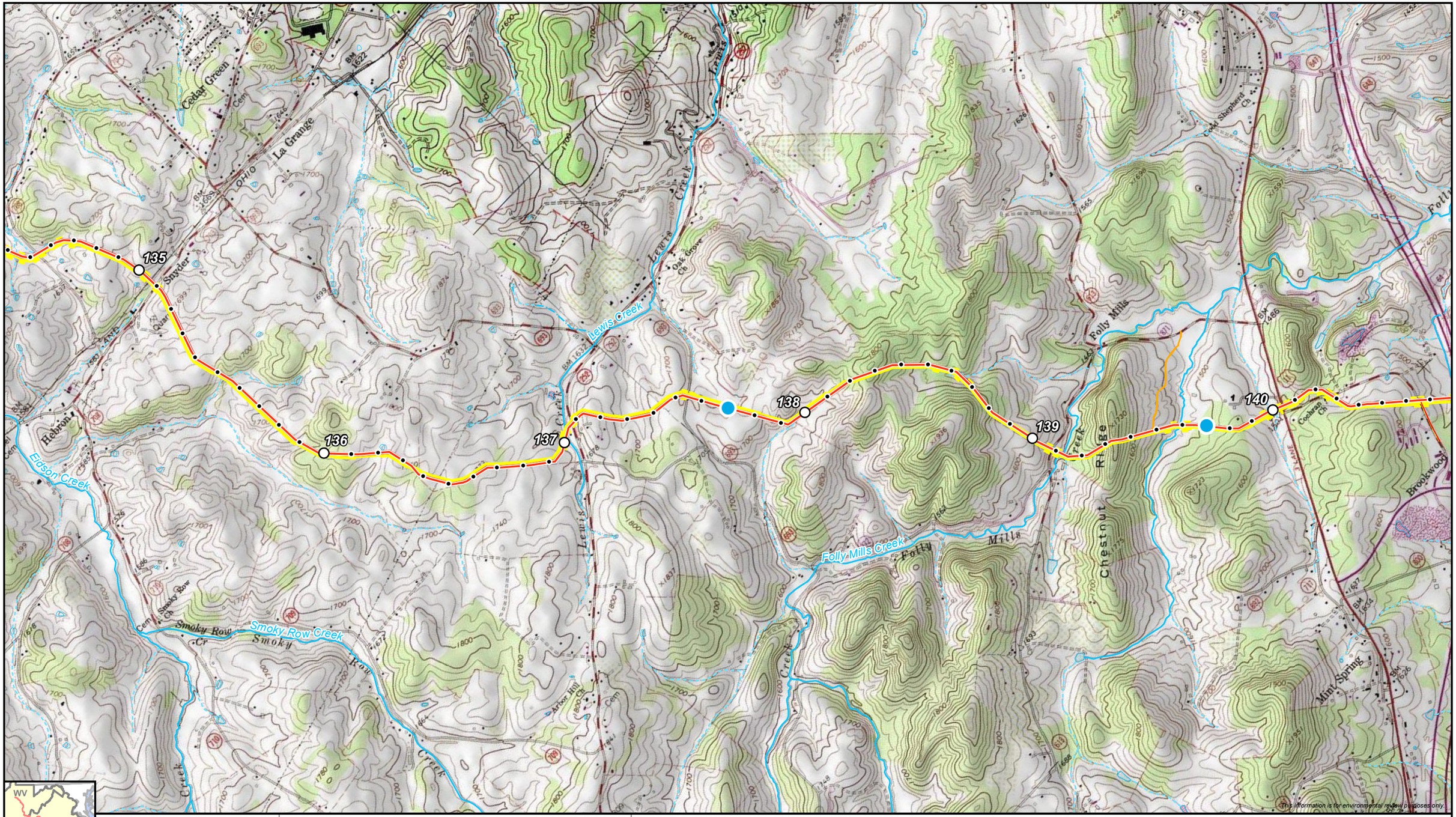

Atlantic Coast Pipeline

Hydrostatic Discharge Sites

Augusta County, Virginia

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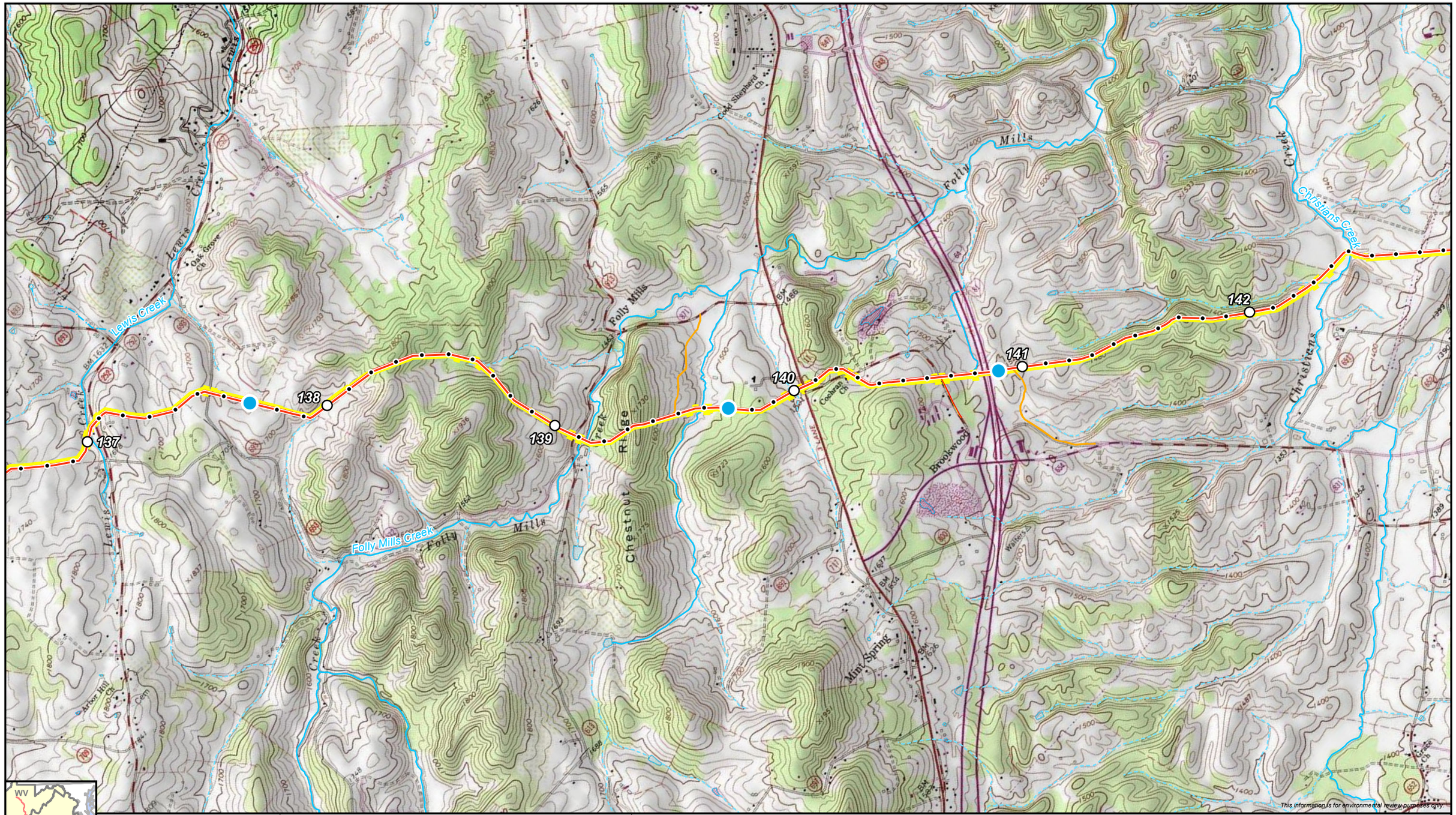

Atlantic Coast Pipeline

Atlantic Coast Pipeline

Hydrostatic Discharge Sites

Augusta County, Virginia

ERM

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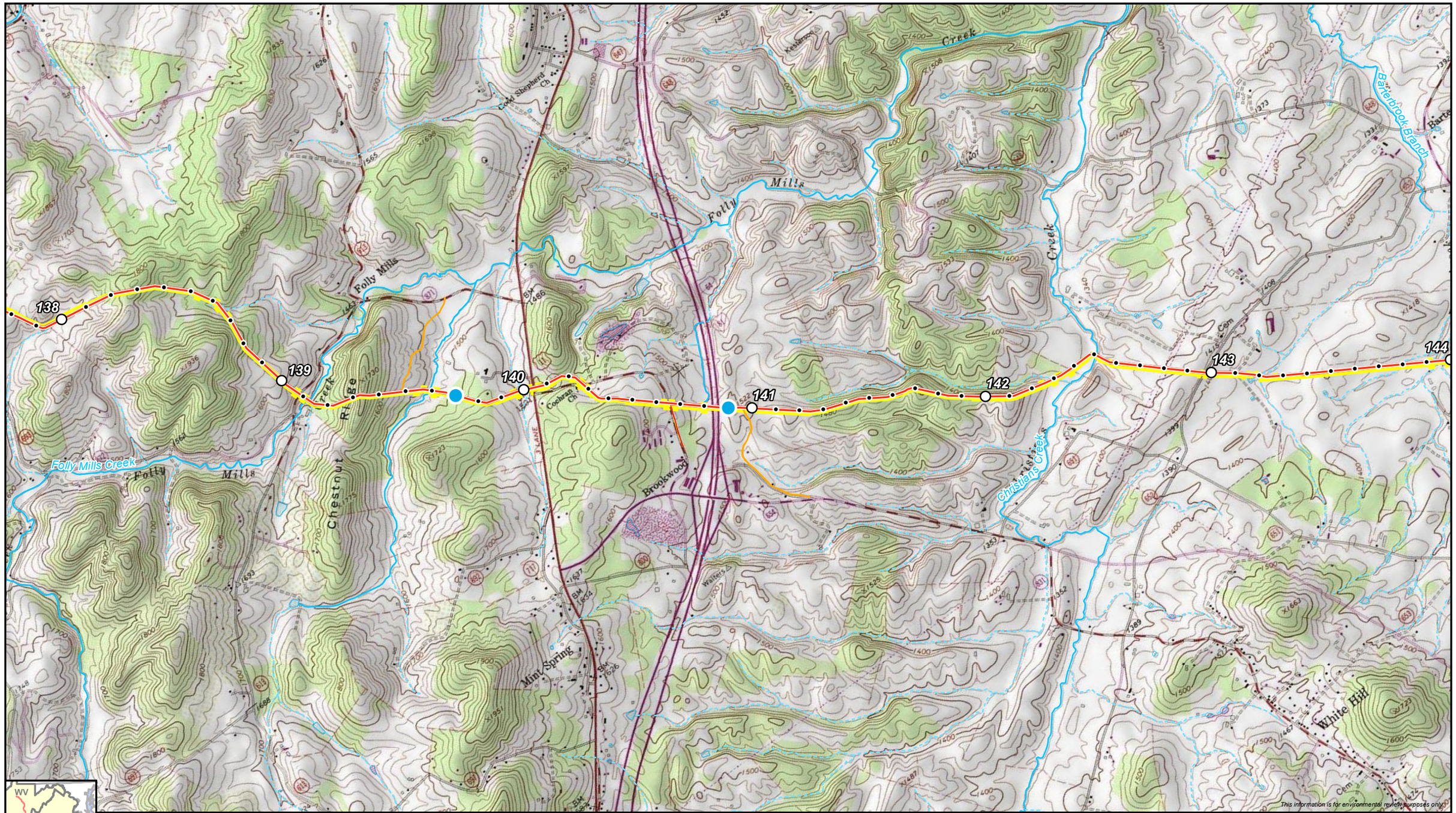

Atlantic Coast Pipeline

Atlantic Coast Pipeline
Hydrostatic Discharge Sites
Augusta County, Virginia

ERM

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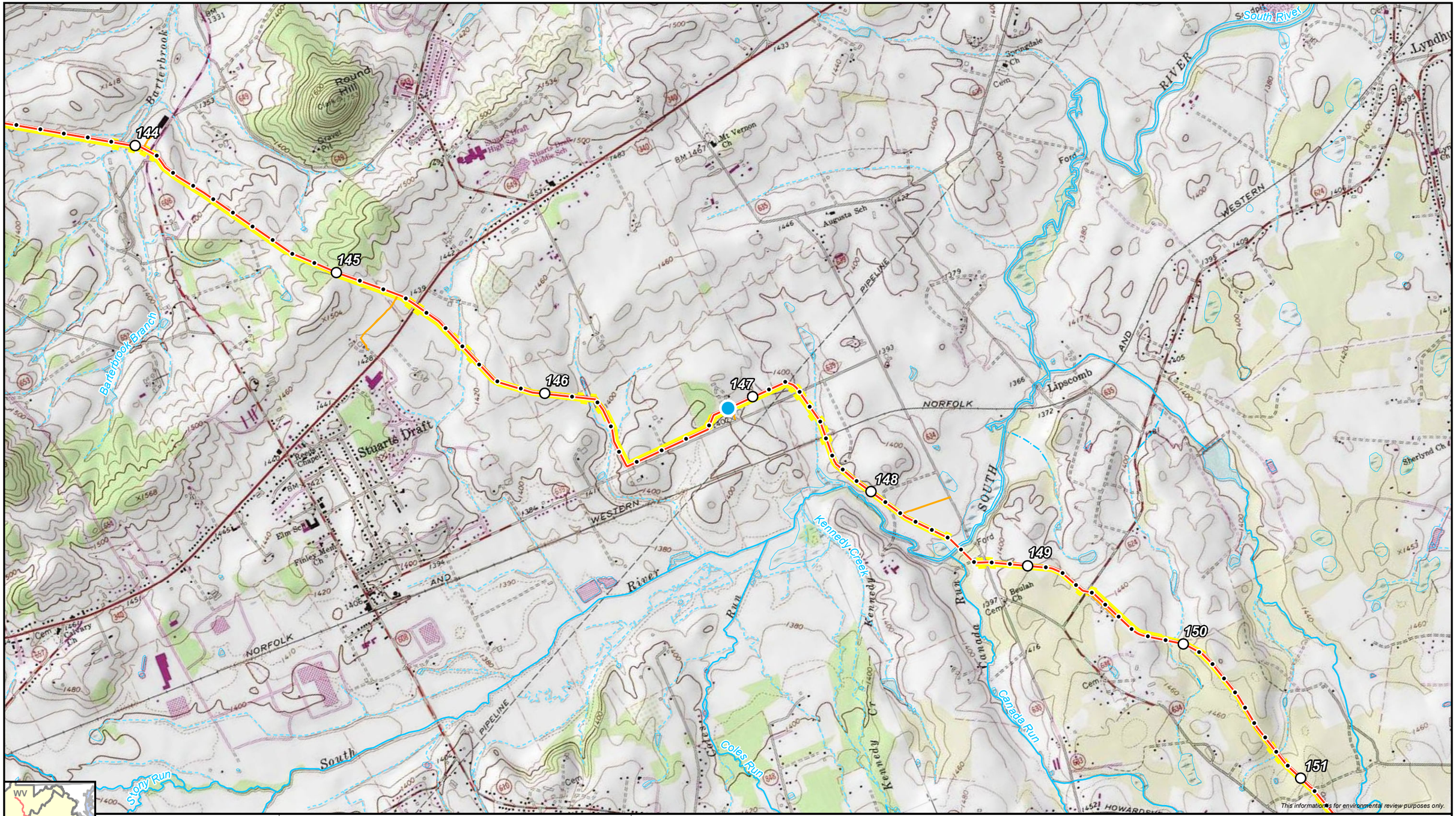

Atlantic Coast Pipeline

Atlantic Coast Pipeline
Hydrostatic Discharge Sites
Augusta County, Virginia

ERM

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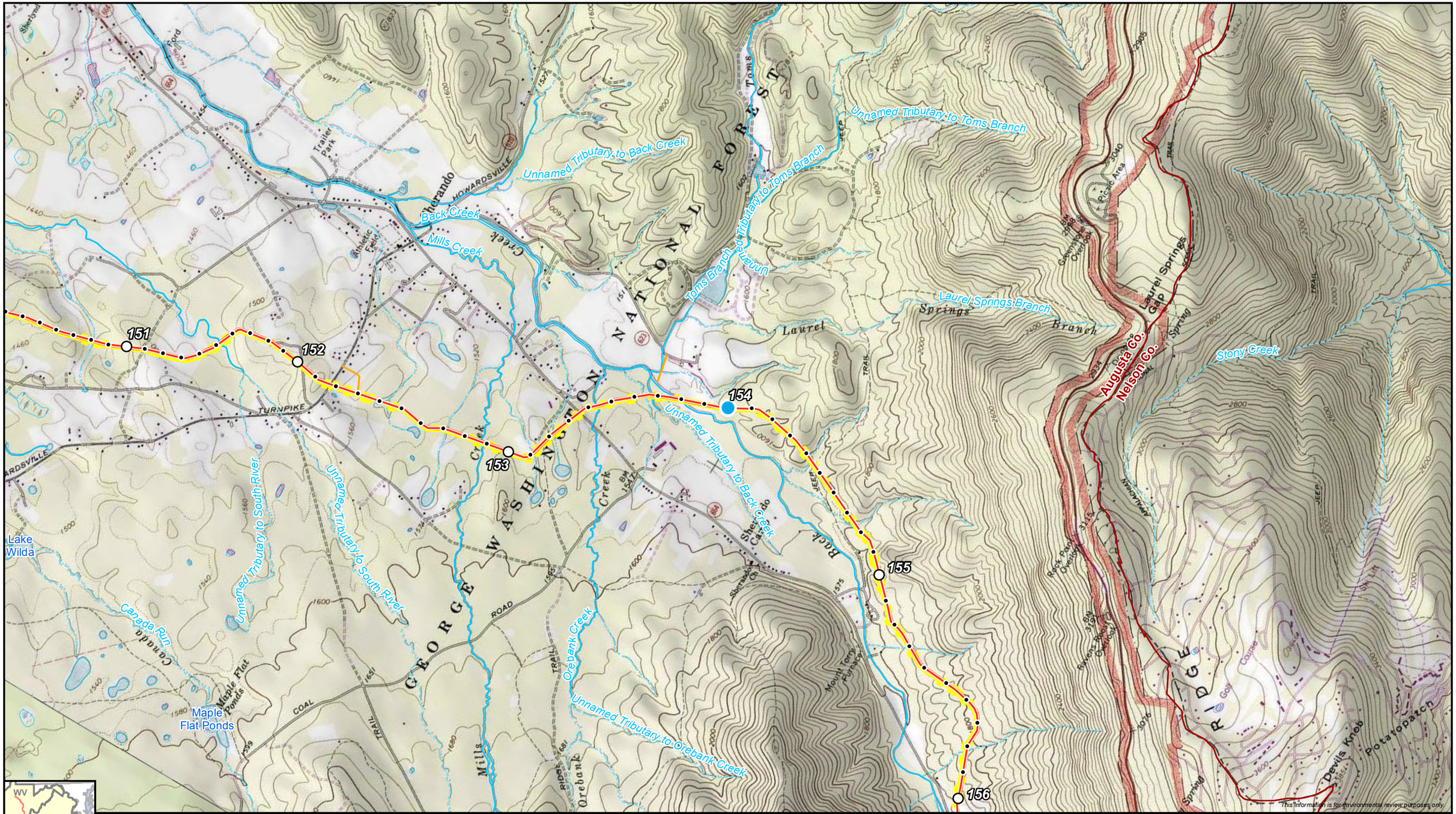

Atlantic Coast Pipeline
Hydrostatic Discharge Sites
Augusta County, Virginia

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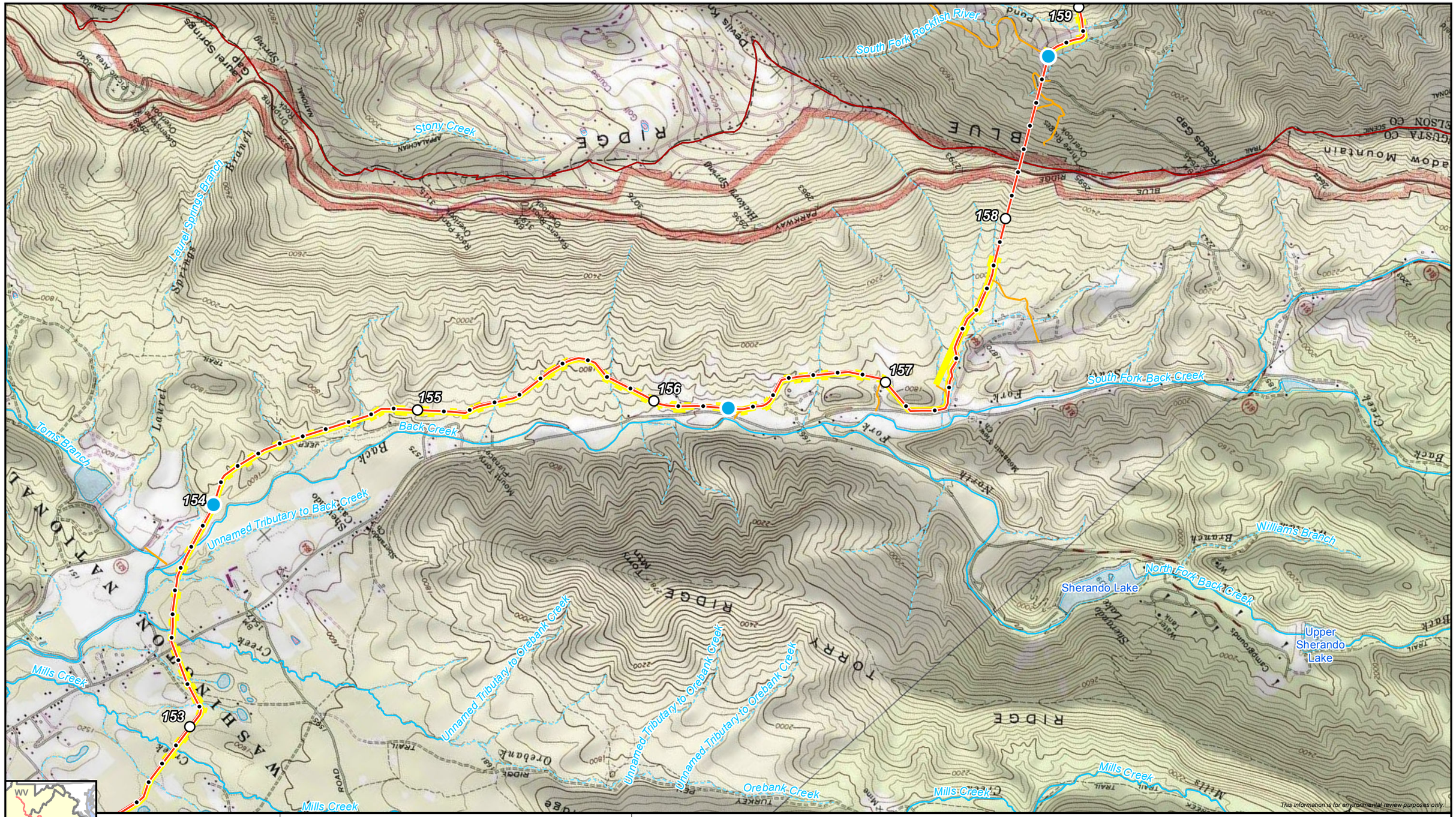

Atlantic Coast Pipeline

Hydrostatic Discharge Sites

Augusta County, Virginia

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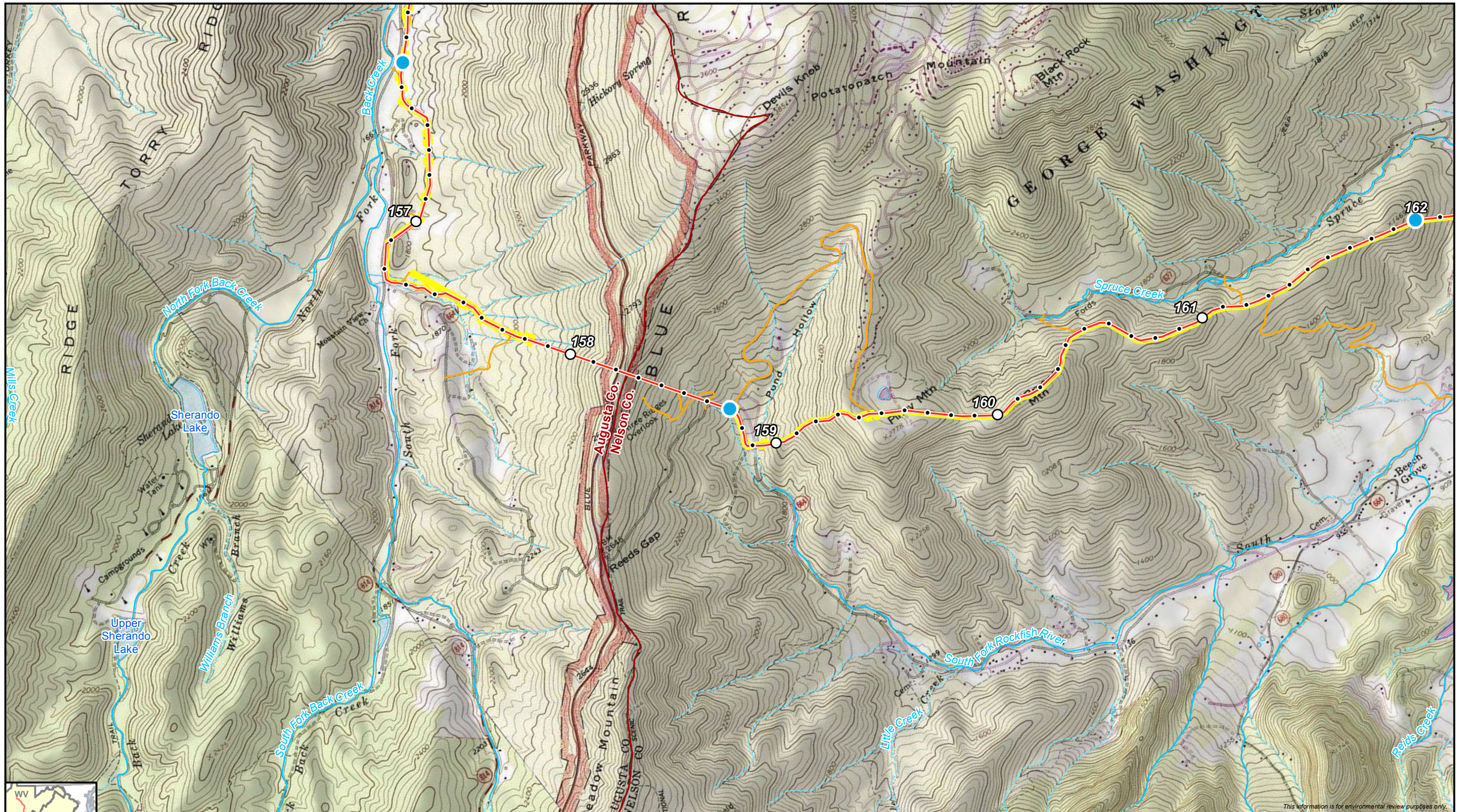
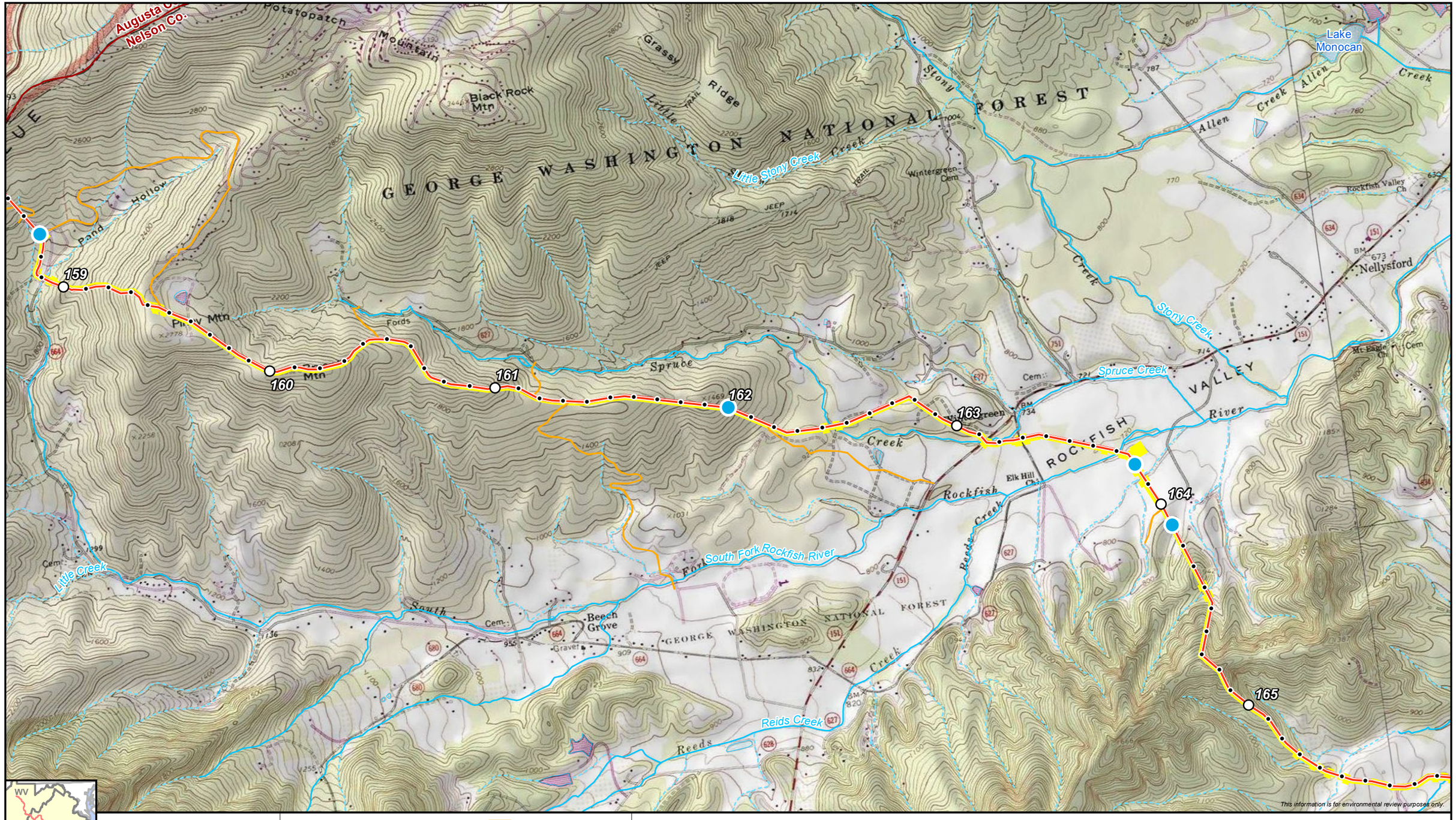


Atlantic Coast Pipeline

Atlantic Coast Pipeline
Hydrostatic Discharge Sites
Nelson County, Virginia

ERM



Atlantic Coast Pipeline

Atlantic Coast Pipeline
Hydrostatic Discharge Sites
Nelson County, Virginia

ERM

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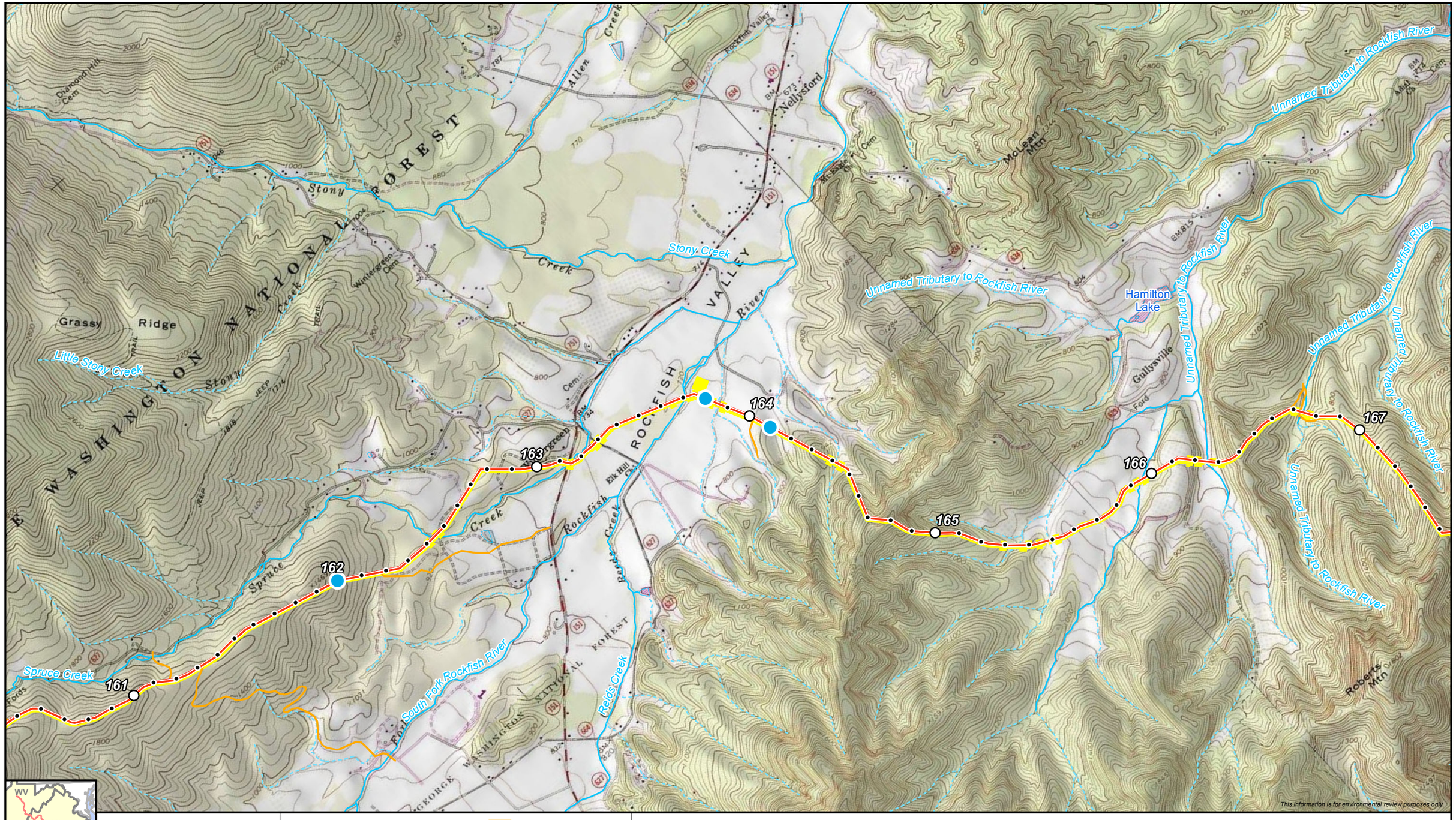

Atlantic Coast Pipeline

Hydrostatic Discharge Sites

Nelson County, Virginia

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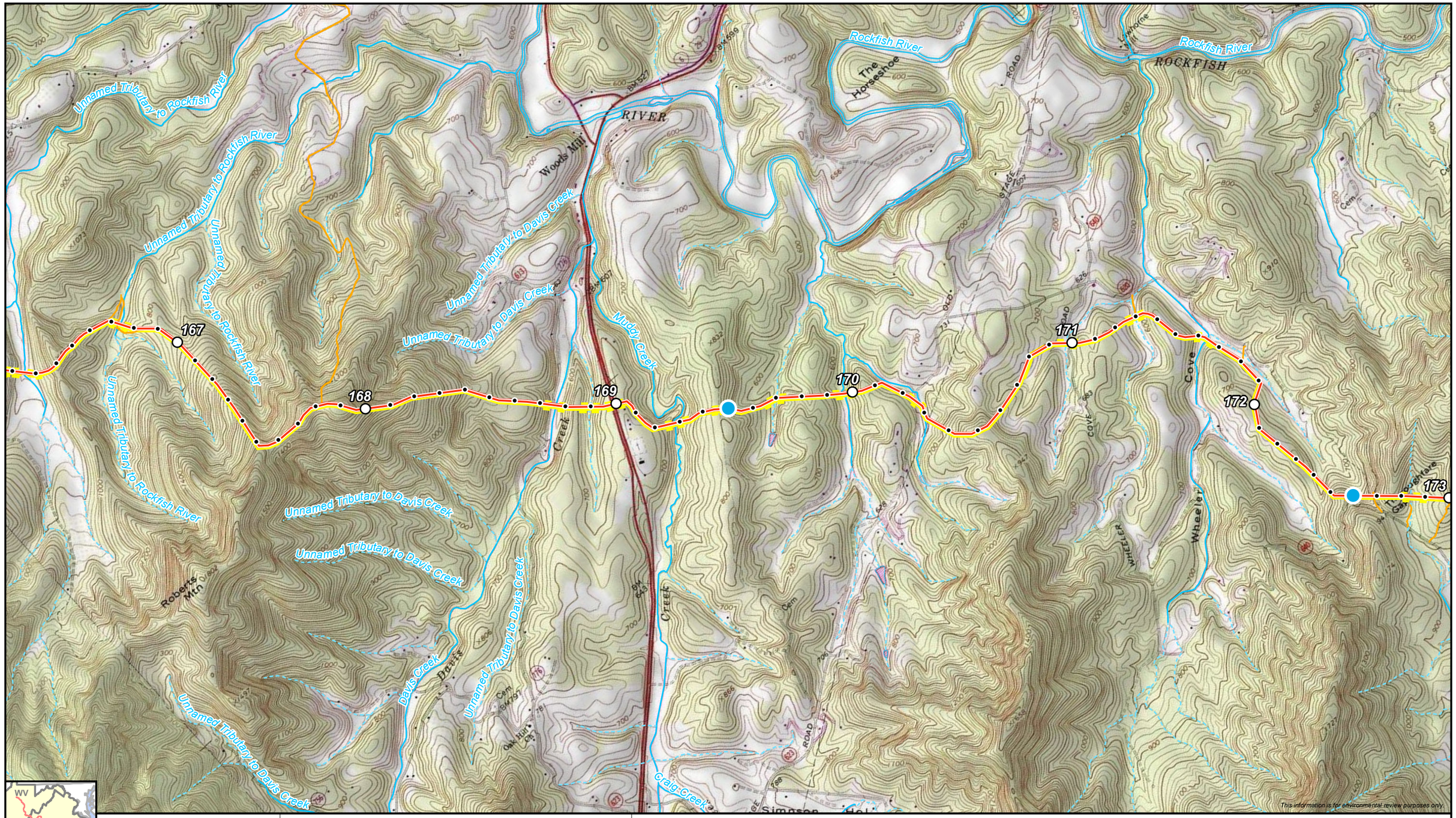

Atlantic Coast Pipeline

Atlantic Coast Pipeline

Hydrostatic Discharge Sites

Nelson County, Virginia

ERM

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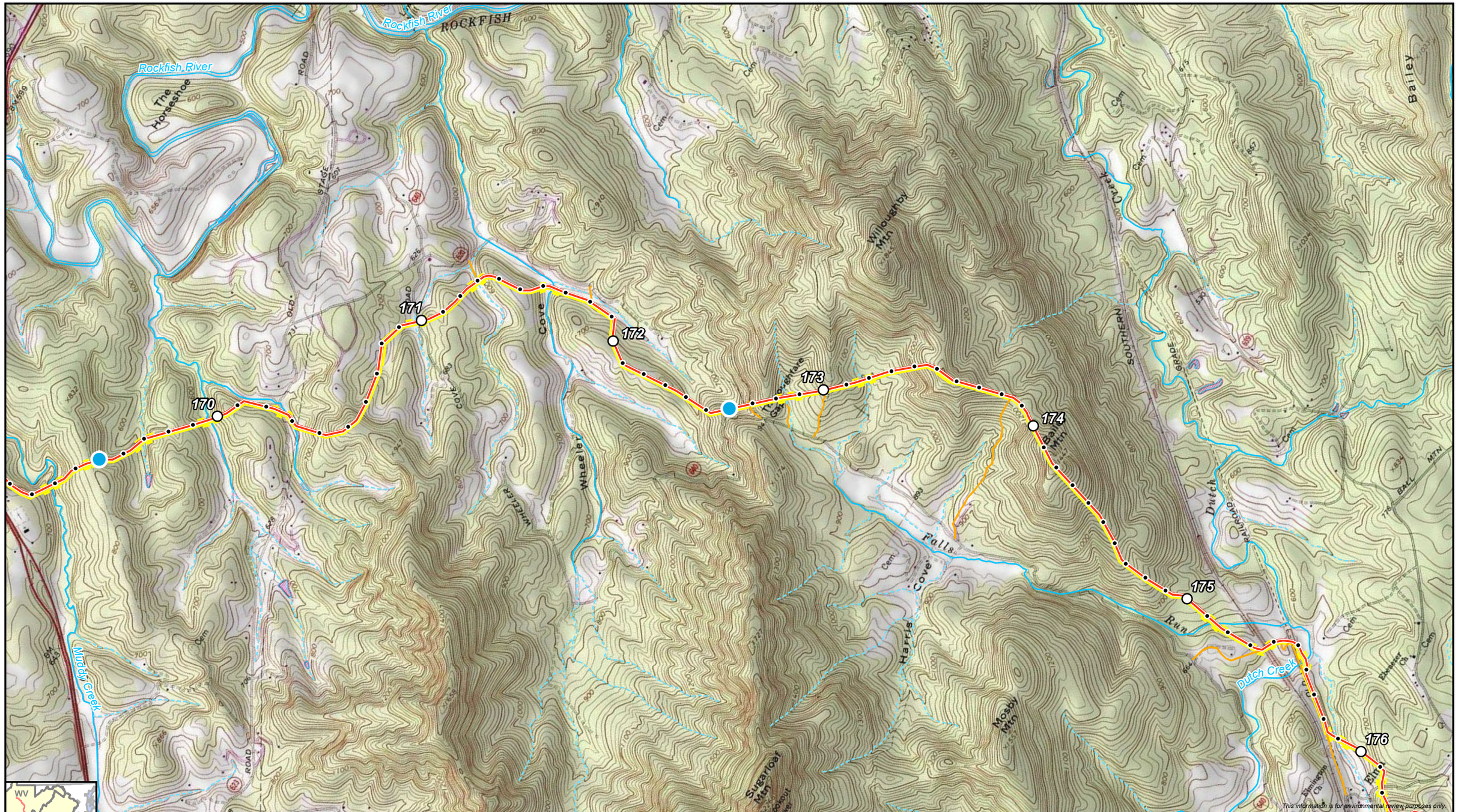

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Feet

1:24,000 | 1 inch = 2,000 feet

Proposed Centerline
Milepost
Hydrostatic Discharge Sites
Temporary Workspace
Permanent Workspace
Access Road

This information is for environmental review purposes only.

Atlantic Coast Pipeline

Atlantic Coast Pipeline
Hydrostatic Discharge Sites
Nelson County, Virginia

ERM

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Atlantic Coast Pipeline
Hydrostatic Discharge Sites
Nelson County, Virginia

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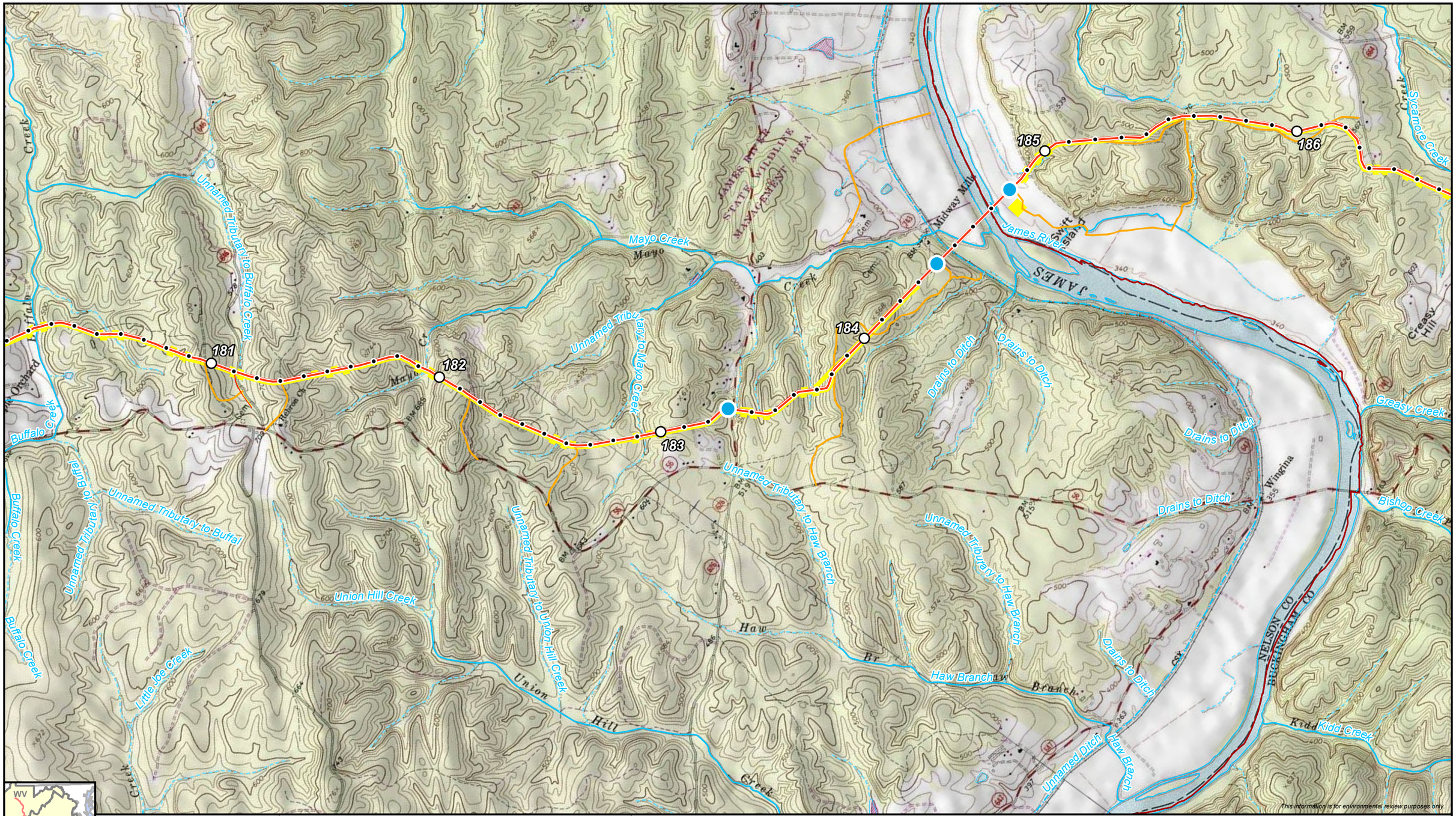

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Feet

1:24,000 | 1 inch = 2,000 feet

- Proposed Centerline
- Milepost
- Hydrostatic Discharge Sites
- Temporary Workspace
- Permanent Workspace
- Access Road

Atlantic Coast Pipeline

Atlantic Coast Pipeline
Hydrostatic Discharge Sites
Nelson County, Virginia

ERM

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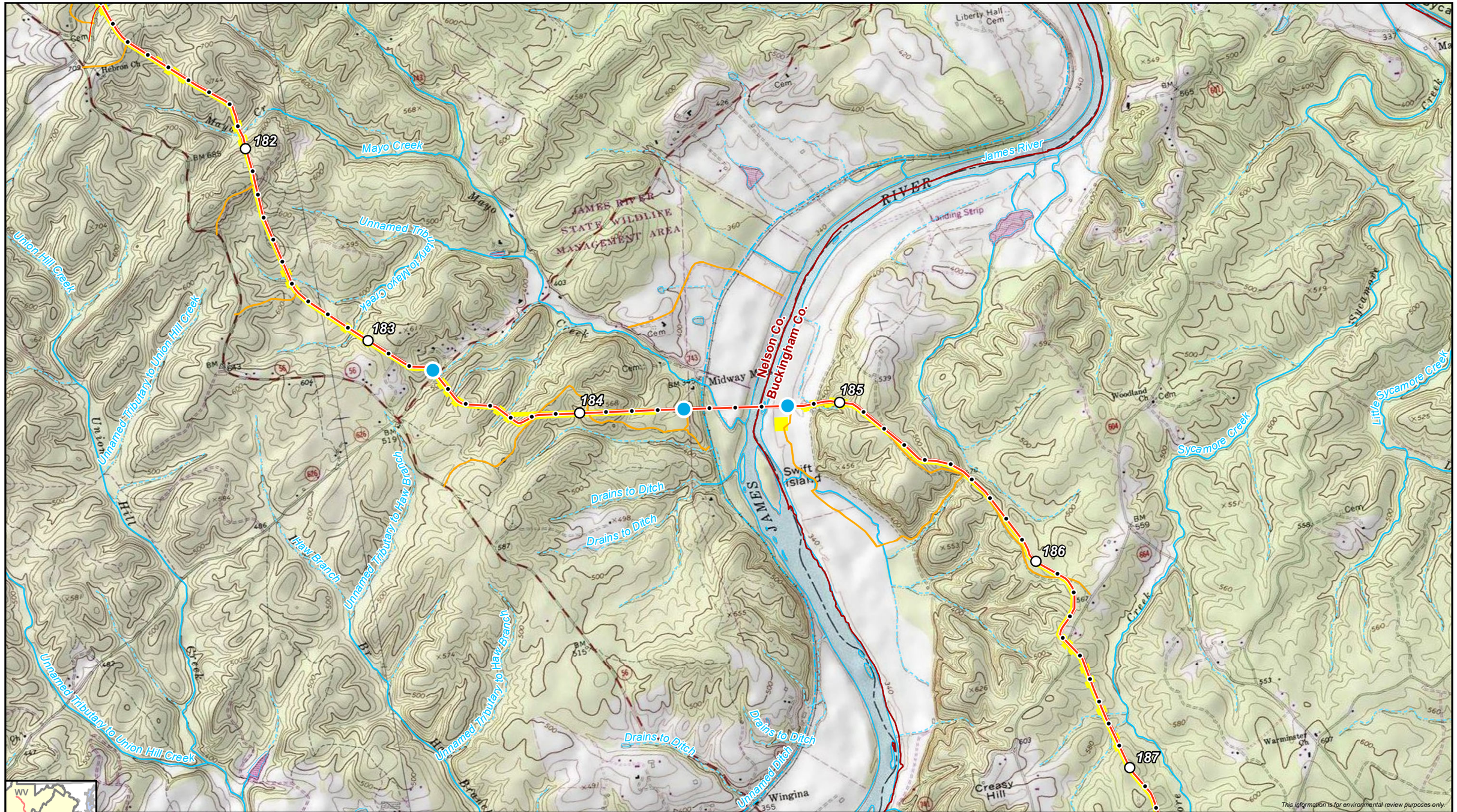

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Feet

1:24,000 | 1 inch = 2,000 feet

Proposed Centerline
Milepost
Hydrostatic Discharge Sites
Temporary Workspace
Permanent Workspace
Access Road

Atlantic Coast Pipeline

Atlantic Coast Pipeline
Hydrostatic Discharge Sites
Nelson County, Virginia

ERM

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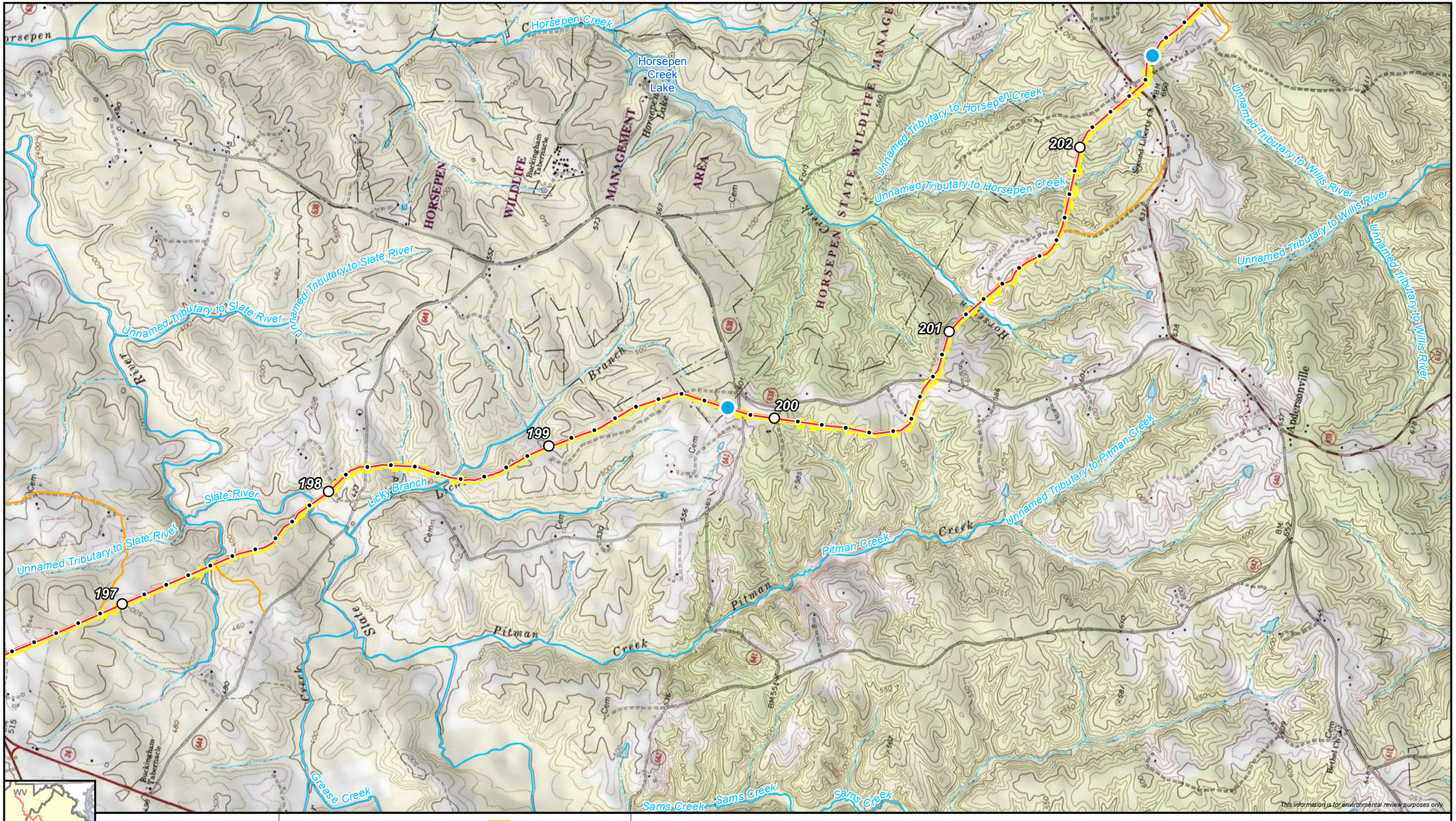

Atlantic Coast Pipeline

Atlantic Coast Pipeline

Hydrostatic Discharge Sites

Buckingham County, Virginia

ERM

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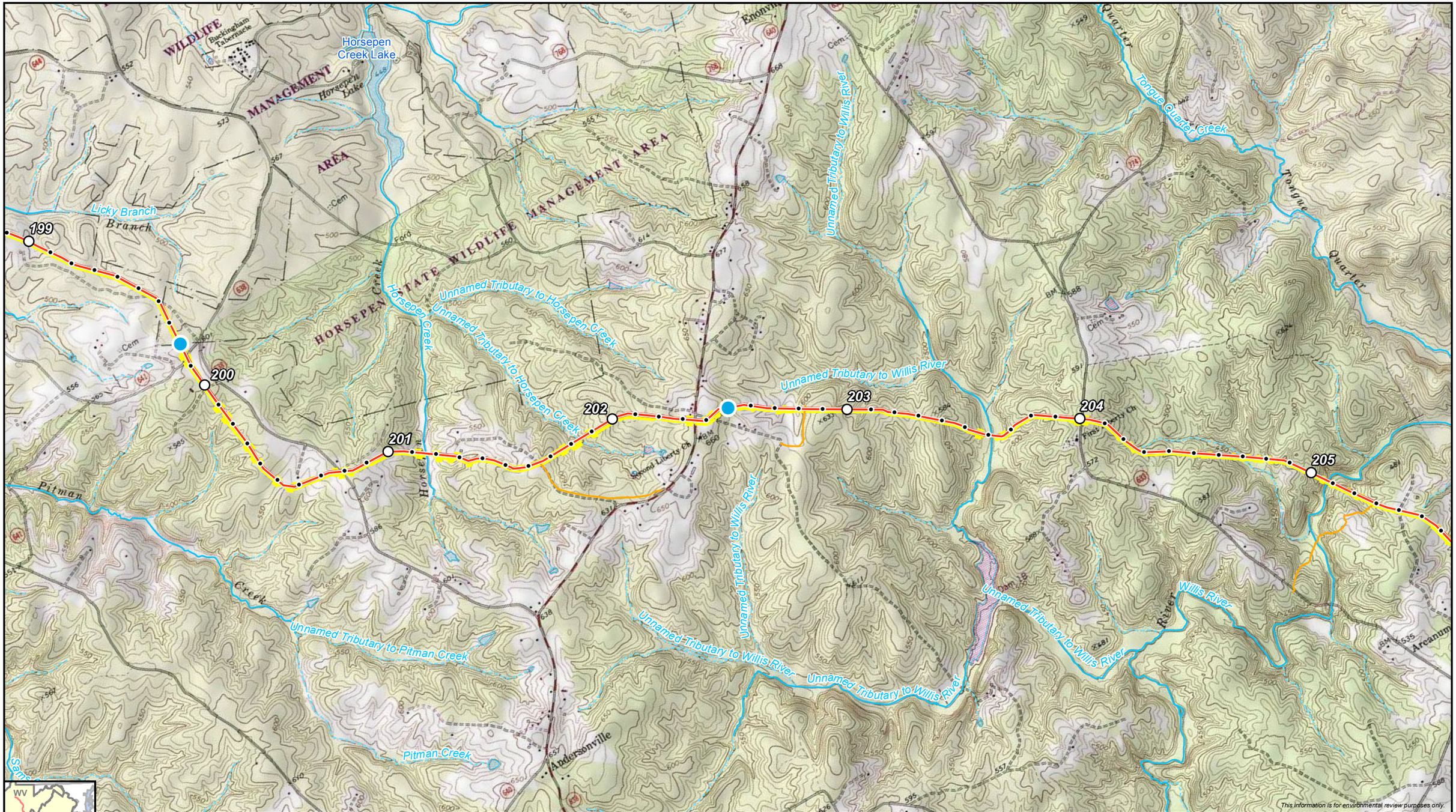

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Feet

1:24,000 | 1 inch = 2,000 feet

Proposed Centerline
Milepost
Hydrostatic Discharge Sites
Temporary Workspace
Permanent Workspace
Access Road

Atlantic Coast Pipeline

Atlantic Coast Pipeline
Hydrostatic Discharge Sites
Buckingham County, Virginia

ERM

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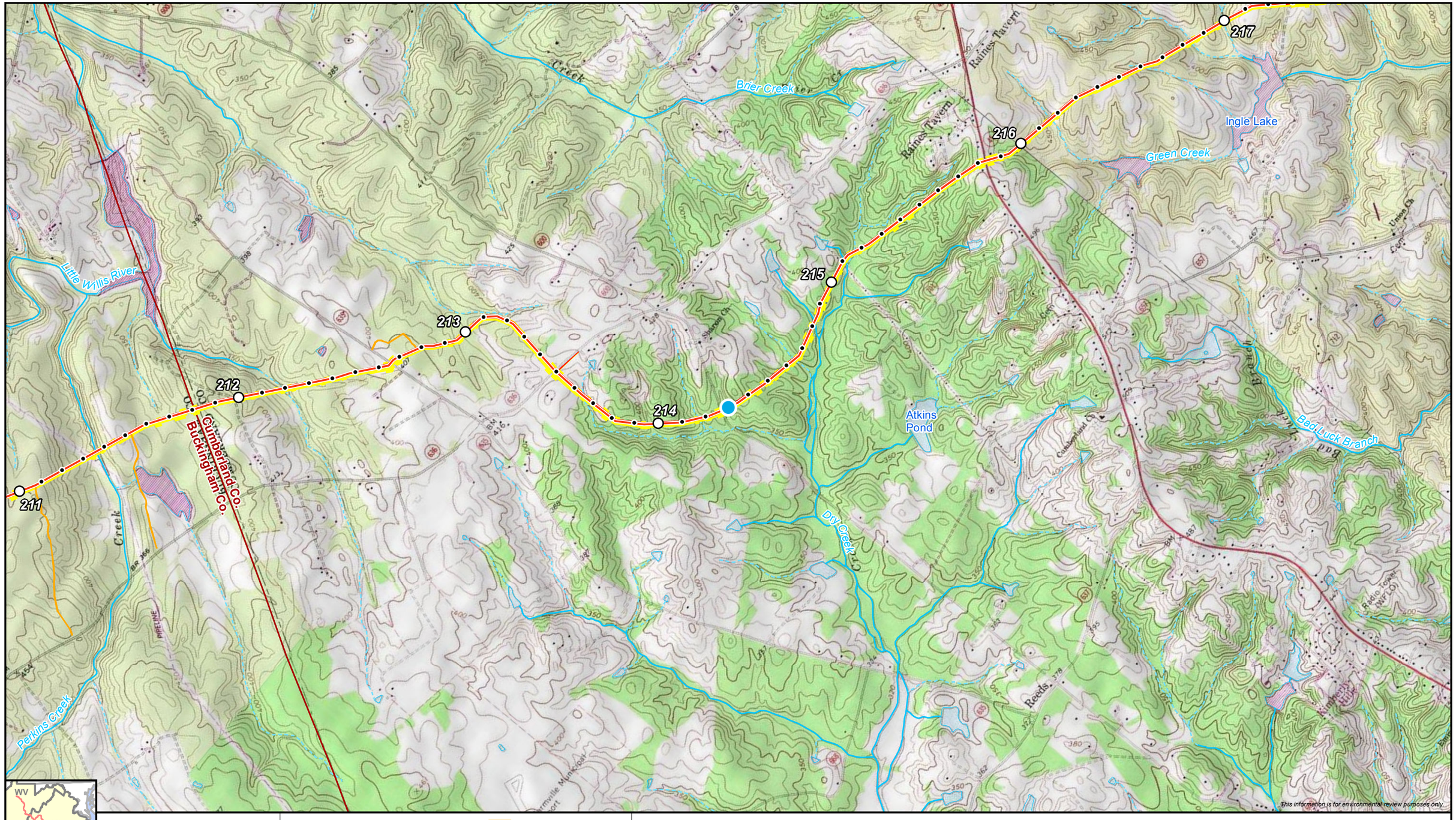

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1:24,000 | 1 inch = 2,000 feet

Proposed Centerline
Milepost
Hydrostatic Discharge Sites
Temporary Workspace
Permanent Workspace
Access Road

Atlantic Coast Pipeline

Atlantic Coast Pipeline
Hydrostatic Discharge Sites
Cumberland County, Virginia

ERM

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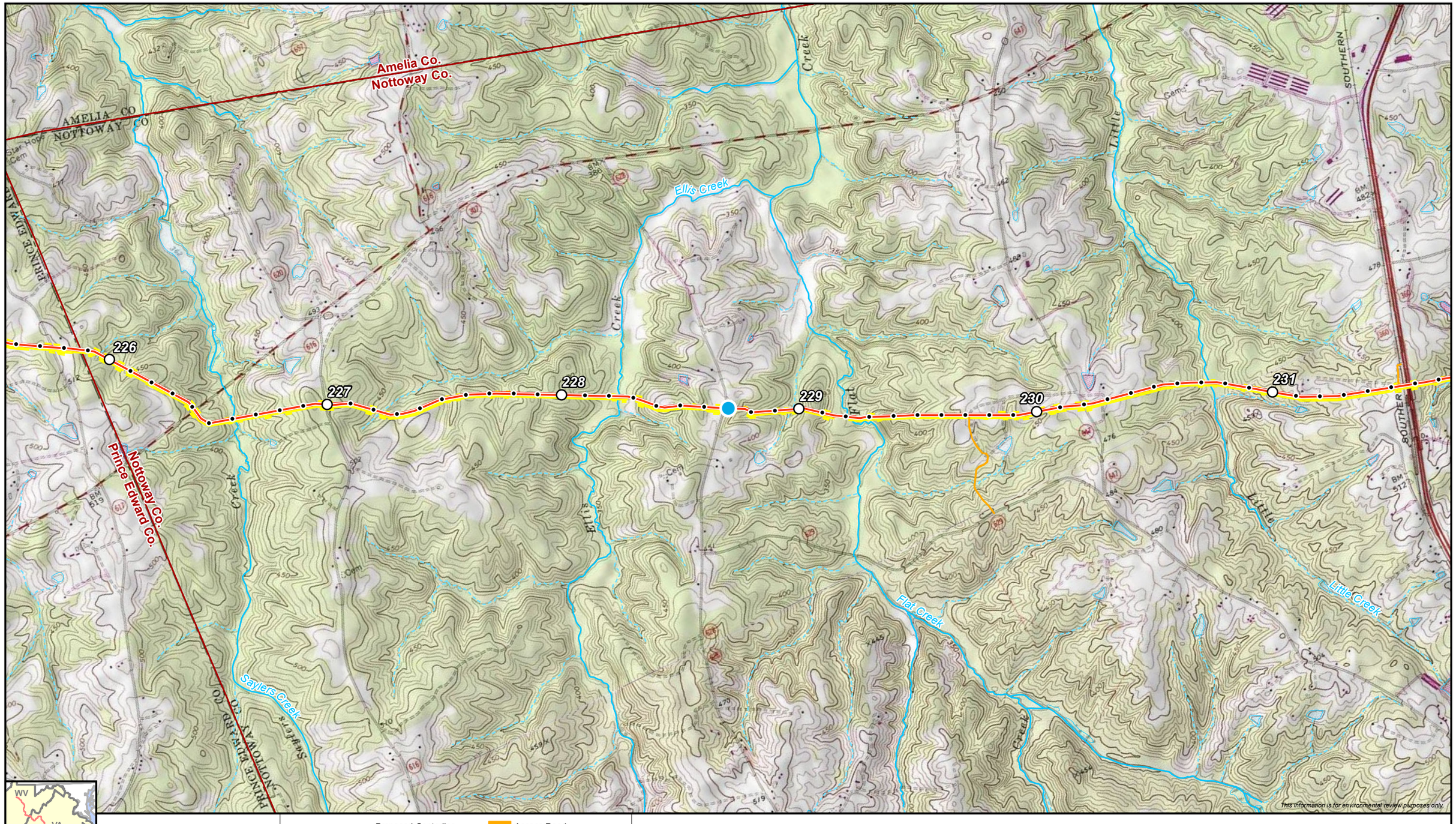

Atlantic Coast Pipeline
Hydrostatic Discharge Sites
Nottoway County, Virginia

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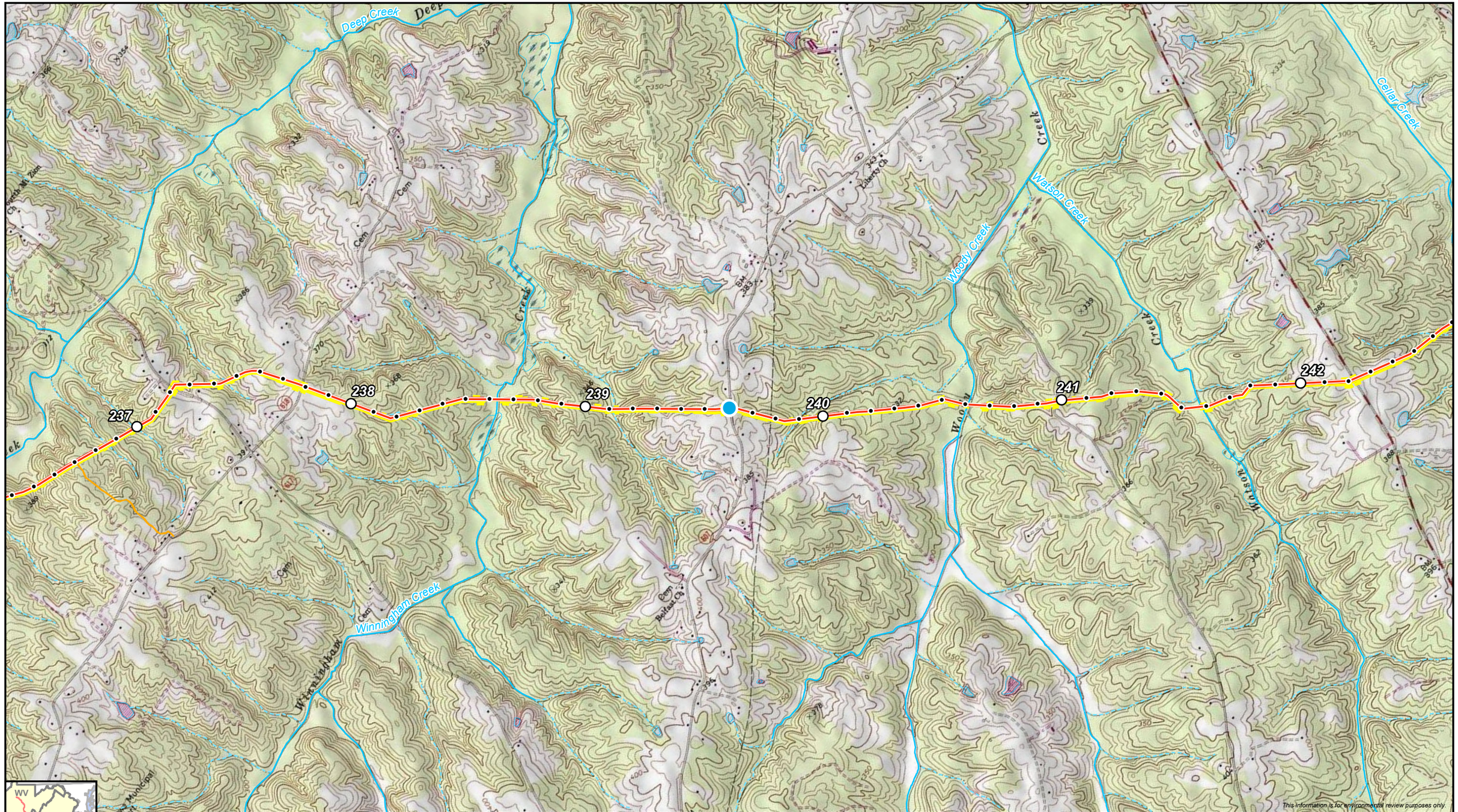

Atlantic Coast Pipeline

Atlantic Coast Pipeline
Hydrostatic Discharge Sites
Nottoway County, Virginia

ERM

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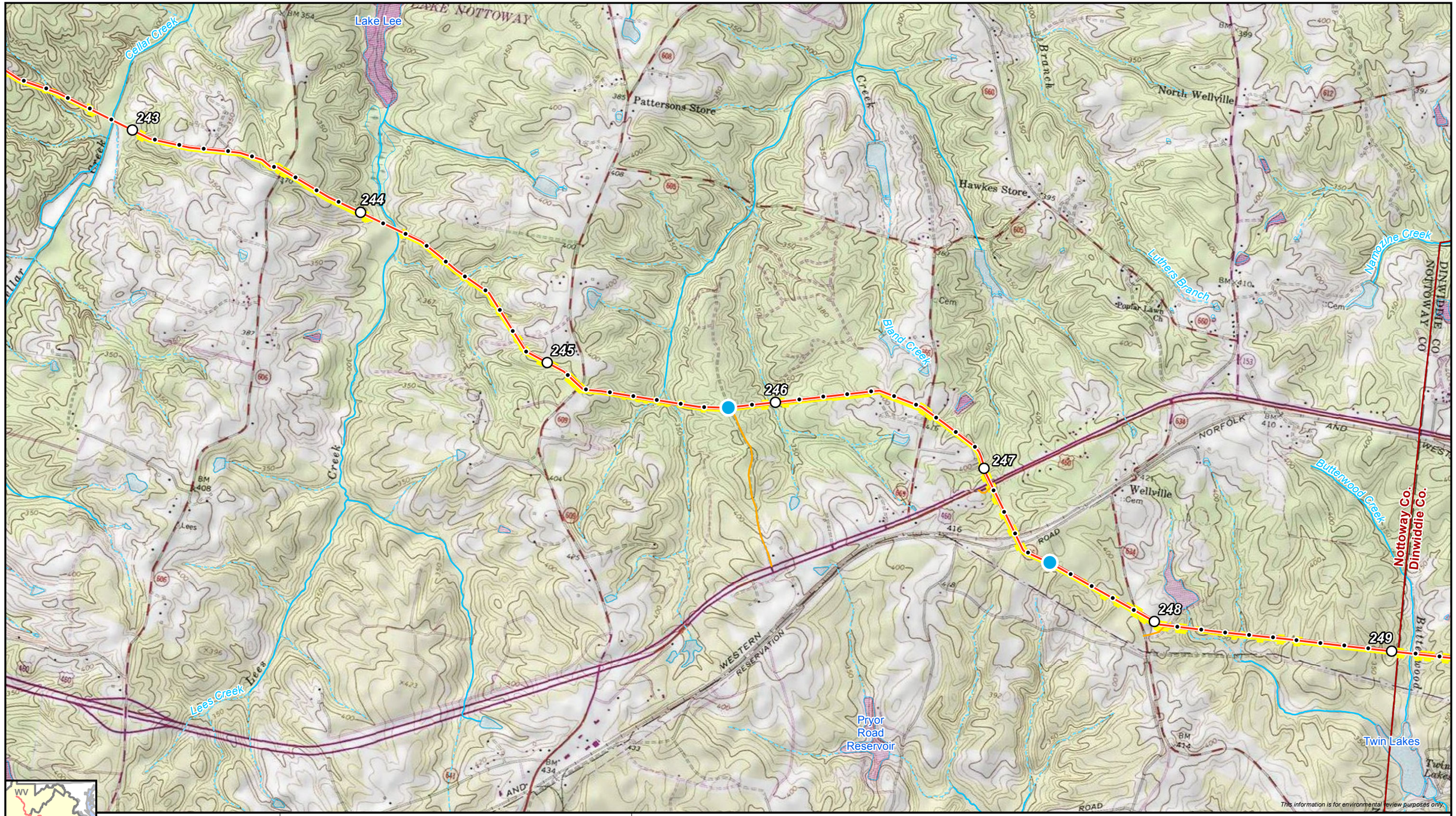

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Feet

1:24,000 | 1 inch = 2,000 feet

Proposed Centerline
Milepost
Hydrostatic Discharge Sites
Temporary Workspace
Permanent Workspace
Access Road

This information is for environmental review purposes only.

Atlantic Coast Pipeline
Hydrostatic Discharge Sites
Nottoway County, Virginia

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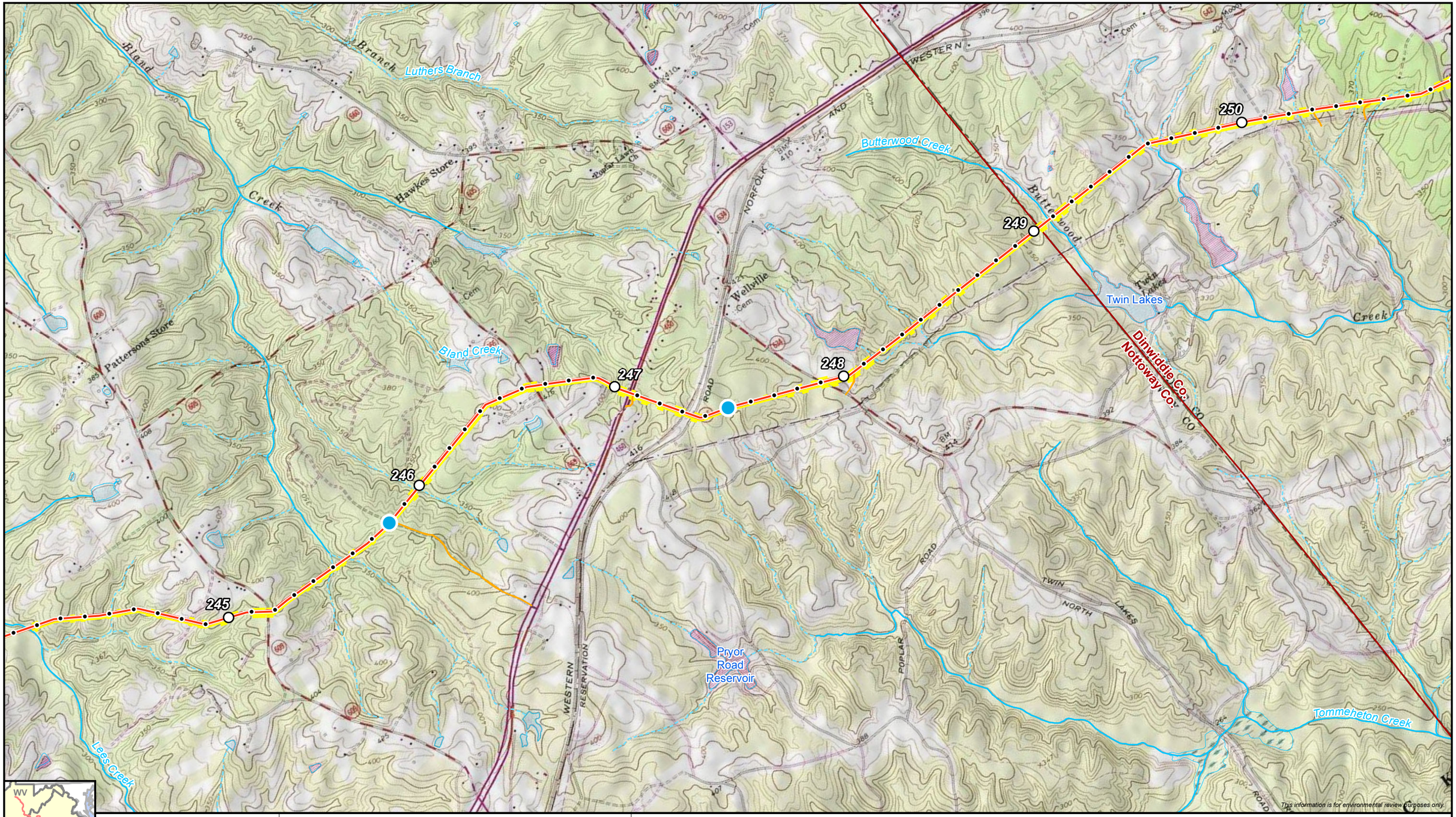

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Feet

1:24,000 | 1 inch = 2,000 feet

- Proposed Centerline
- Milepost
- Hydrostatic Discharge Sites
- Temporary Workspace
- Permanent Workspace
- Access Road

This information is for environmental review purposes only.

Atlantic Coast Pipeline

Hydrostatic Discharge Sites

Nottoway County, Virginia

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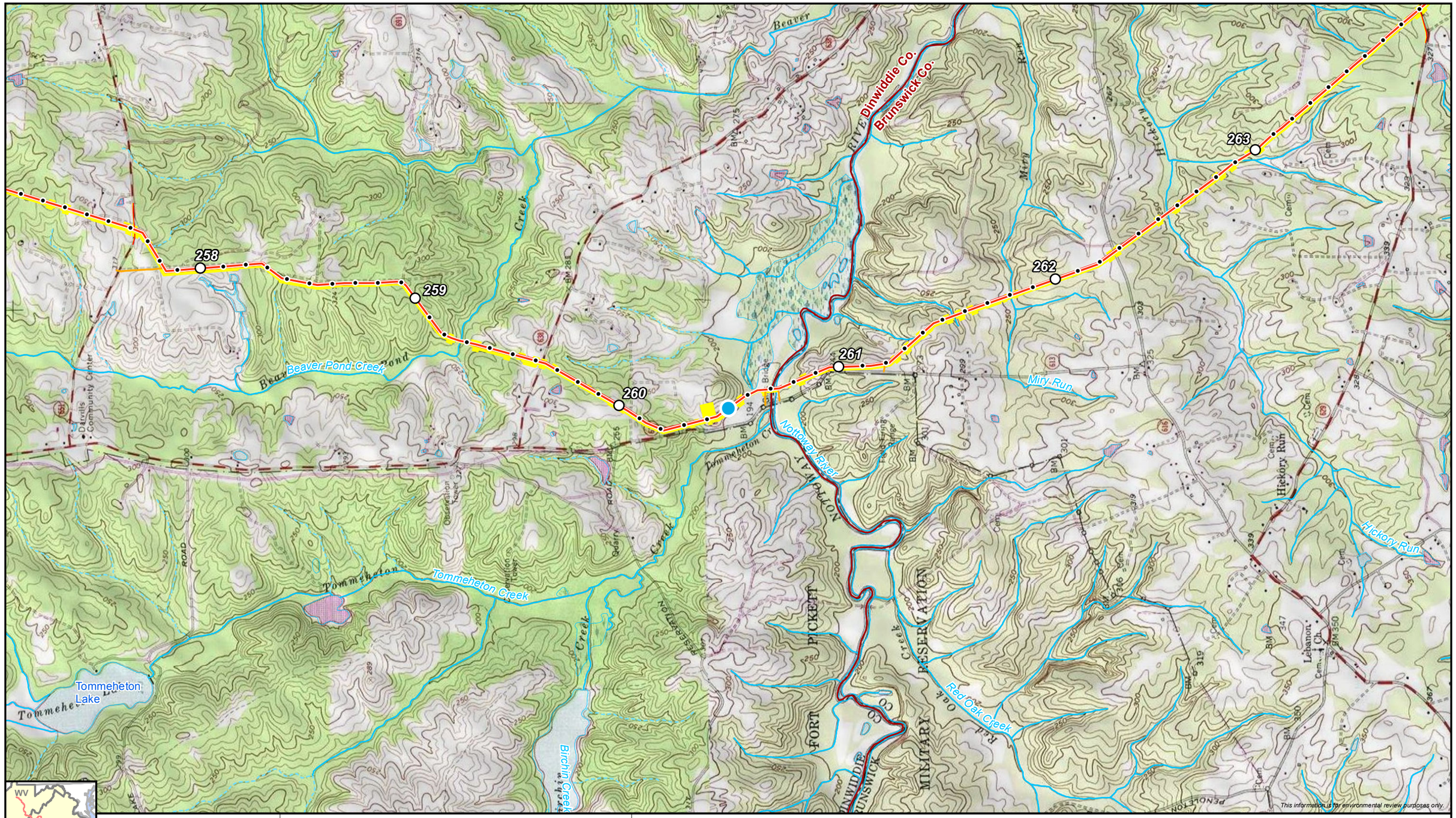

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Feet

1:24,000 | 1 inch = 2,000 feet

- Proposed Centerline
- Milepost
- Hydrostatic Discharge Sites
- Temporary Workspace
- Permanent Workspace
- Access Road

Atlantic Coast Pipeline

Hydrostatic Discharge Sites

Dinwiddie County, Virginia

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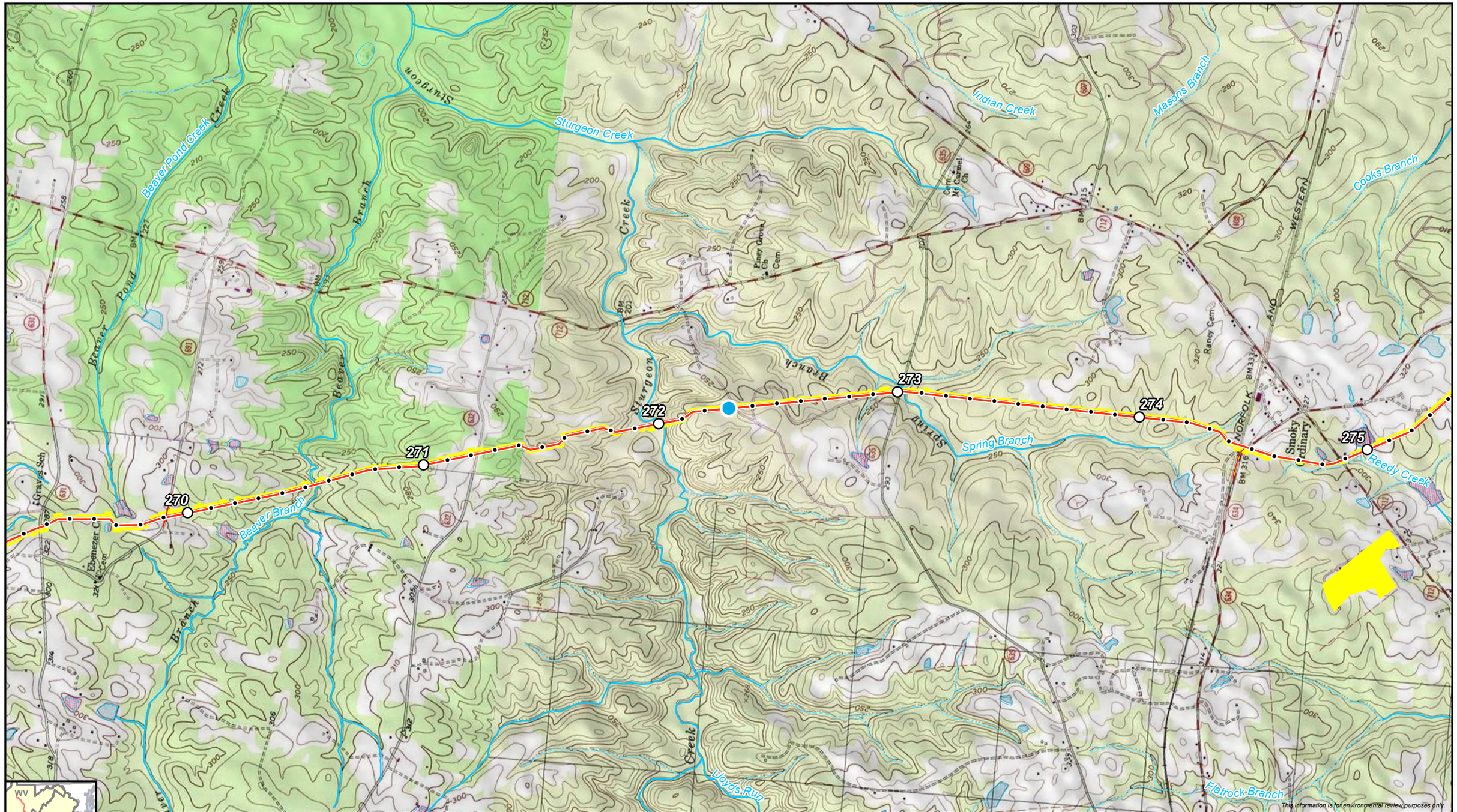

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Feet

1:24,000 | 1 inch = 2,000 feet

- Proposed Centerline
- Milepost
- Hydrostatic Discharge Sites
- Temporary Workspace
- Permanent Workspace

Atlantic Coast Pipeline

Atlantic Coast Pipeline
Hydrostatic Discharge Sites
Brunswick County, Virginia

ERM

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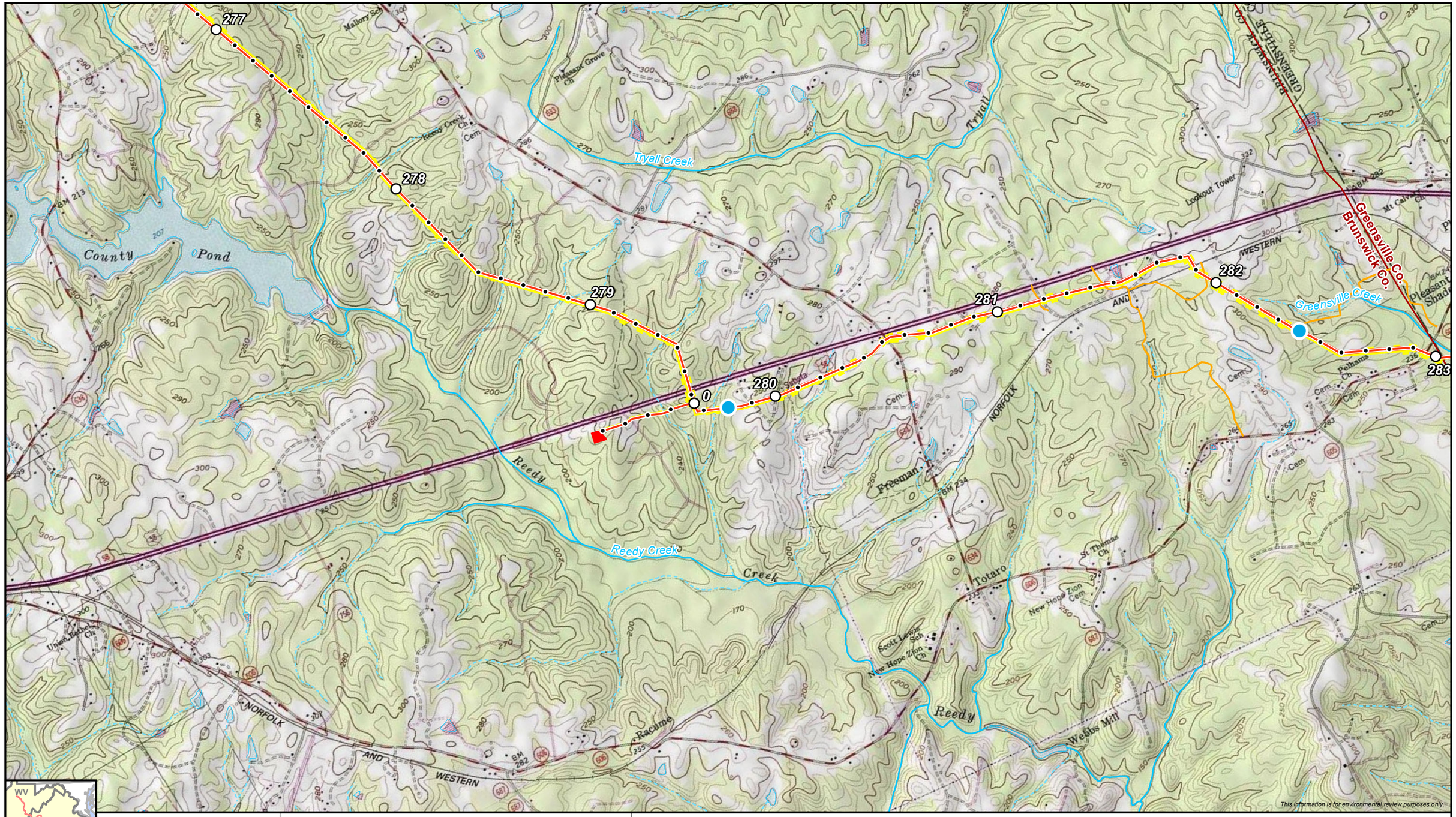

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Feet

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Proposed Centerline
Milepost
Hydrostatic Discharge Sites
Temporary Workspace
Permanent Workspace
Access Road

Atlantic Coast Pipeline
Hydrostatic Discharge Sites
Brunswick County, Virginia

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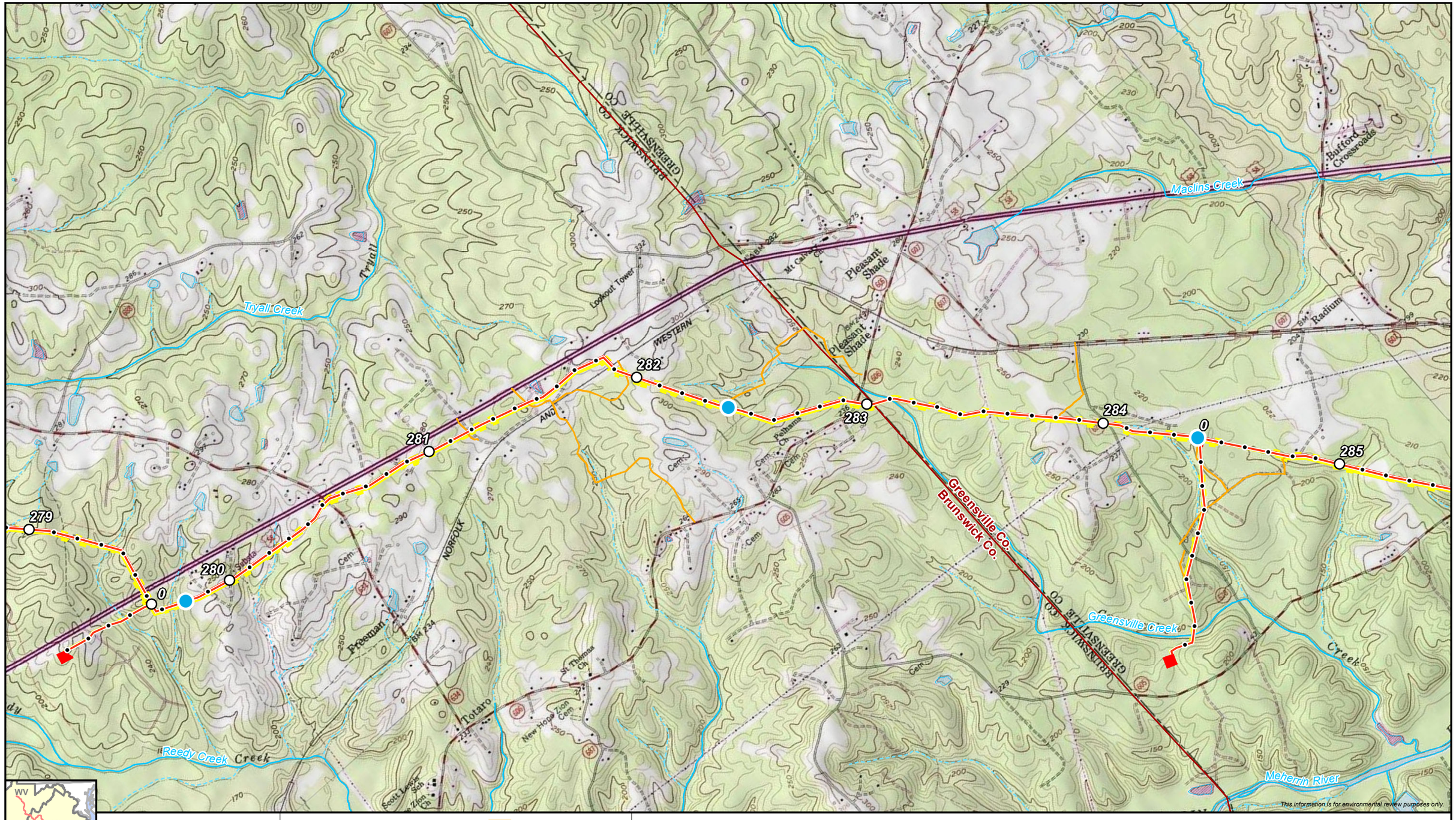

Atlantic Coast Pipeline
Hydrostatic Discharge Sites
Brunswick County, Virginia

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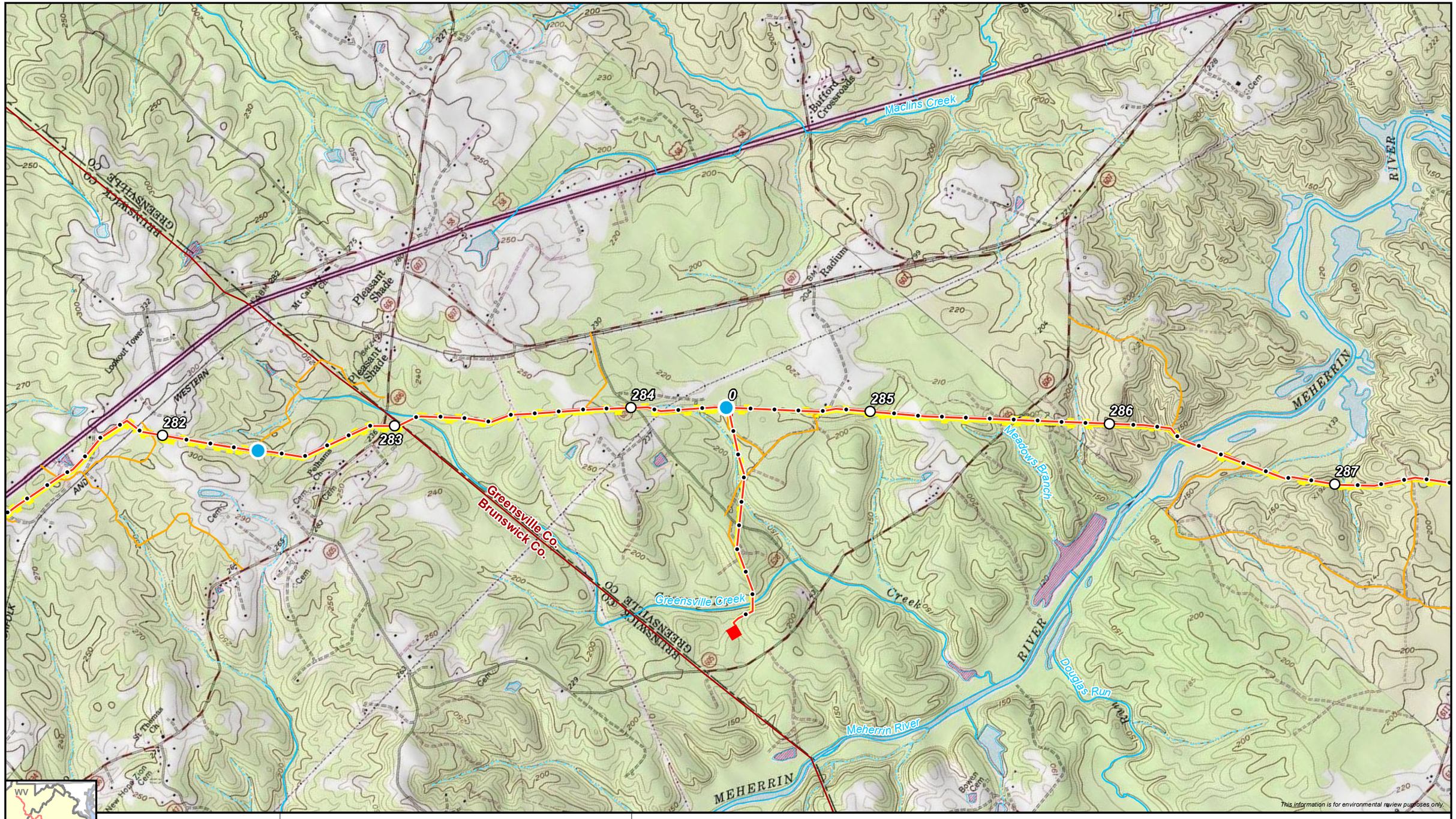

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Proposed Centerline
Milepost
Hydrostatic Discharge Sites
Temporary Workspace
Permanent Workspace
Access Road

Atlantic Coast Pipeline

Atlantic Coast Pipeline
Hydrostatic Discharge Sites
Greensville County, Virginia

ERM

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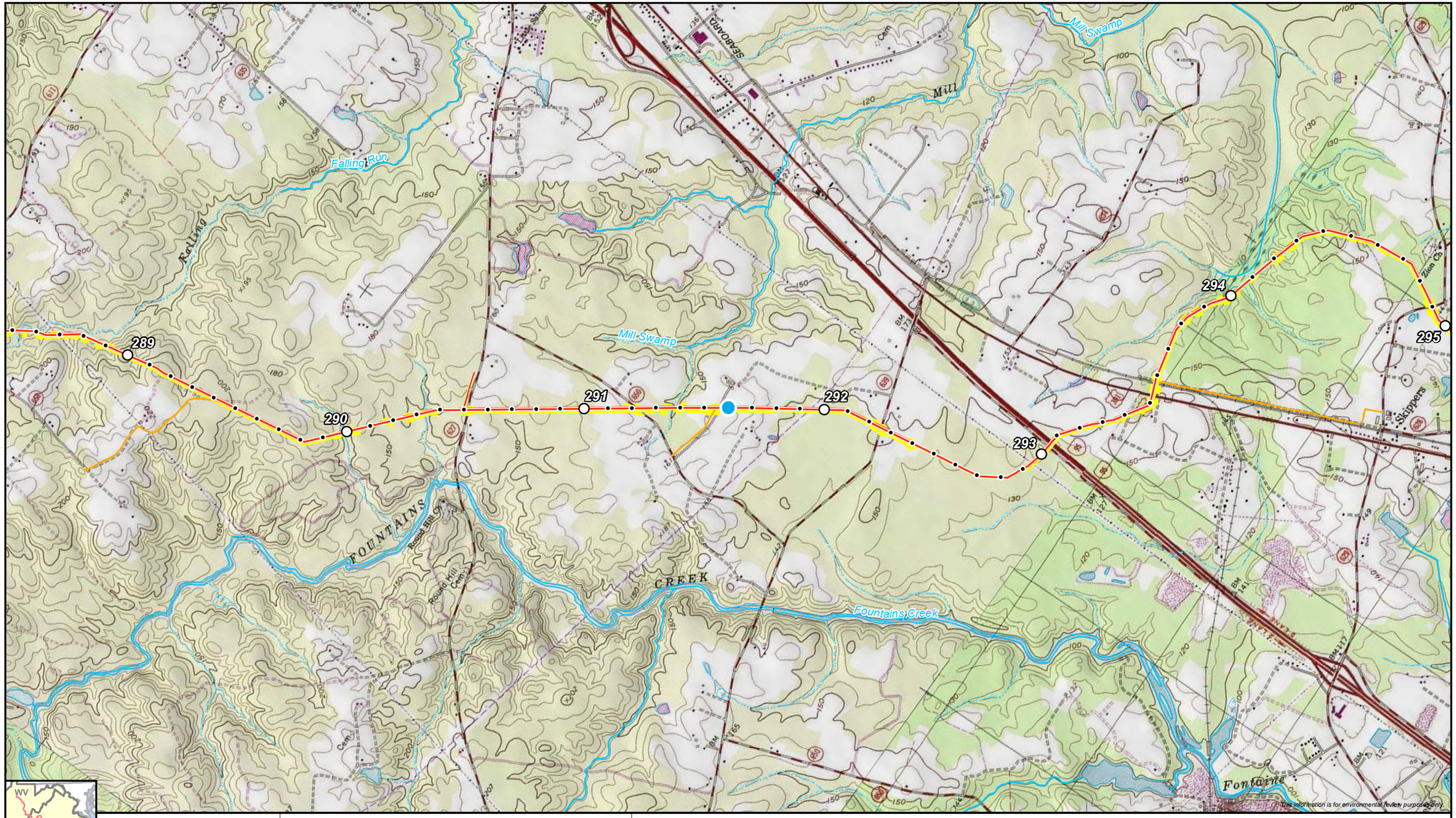

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Feet

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- Proposed Centerline
- Milepost
- Hydrostatic Discharge Sites
- Temporary Workspace
- Permanent Workspace
- Access Road

Atlantic Coast Pipeline

Atlantic Coast Pipeline
Hydrostatic Discharge Sites
Greensville County, Virginia

ERM

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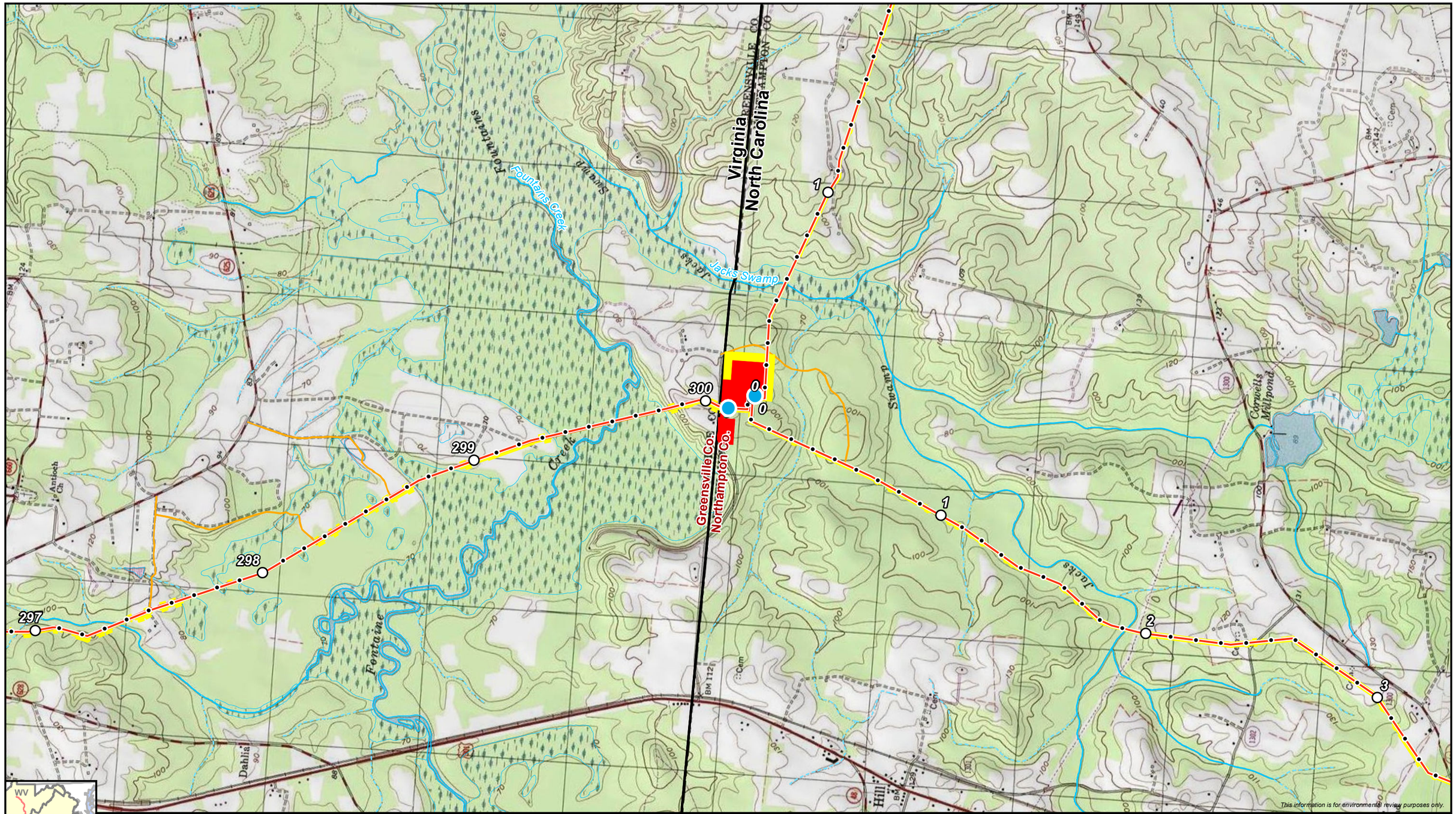

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Feet

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Proposed Centerline
Milepost
Hydrostatic Discharge Sites
Temporary Workspace
Permanent Workspace
Access Road

Atlantic Coast Pipeline

Atlantic Coast Pipeline
Hydrostatic Discharge Sites
Greensville County, Virginia
Page 40 of 55

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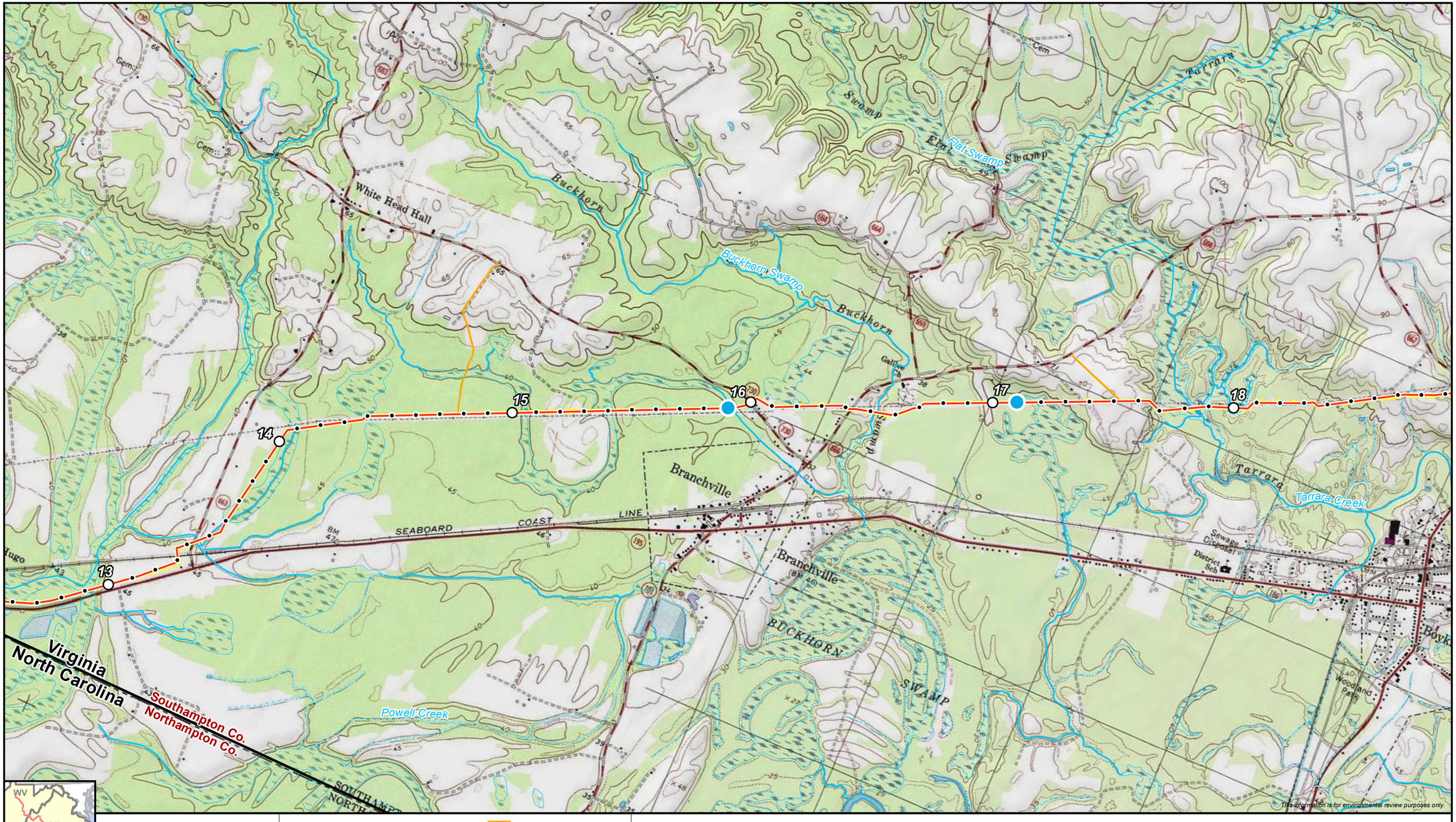

Atlantic Coast Pipeline

Atlantic Coast Pipeline

Hydrostatic Discharge Sites

Southampton County, Virginia

ERM

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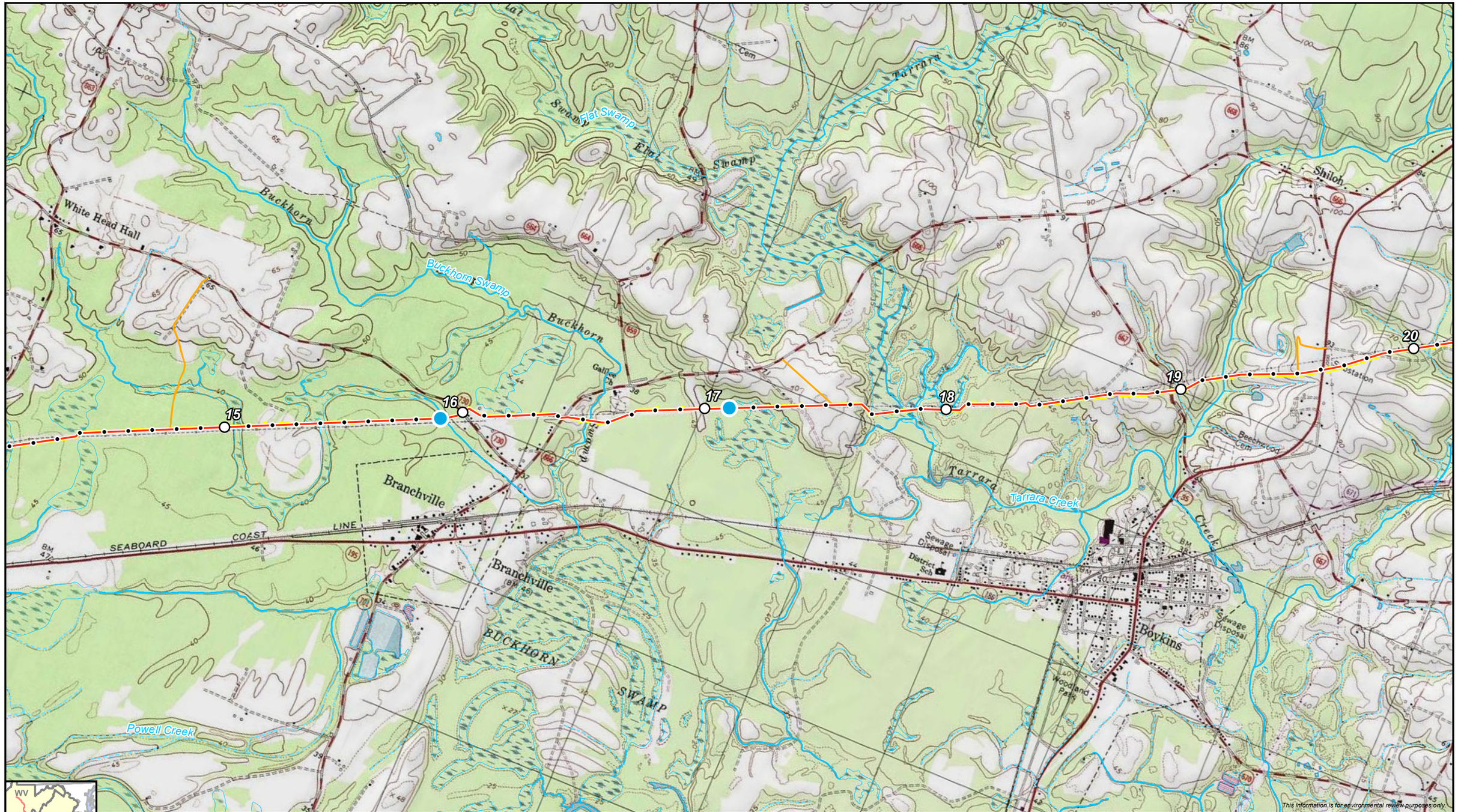

Atlantic Coast Pipeline

Atlantic Coast Pipeline
Hydrostatic Discharge Sites
Southampton County, Virginia

ERM

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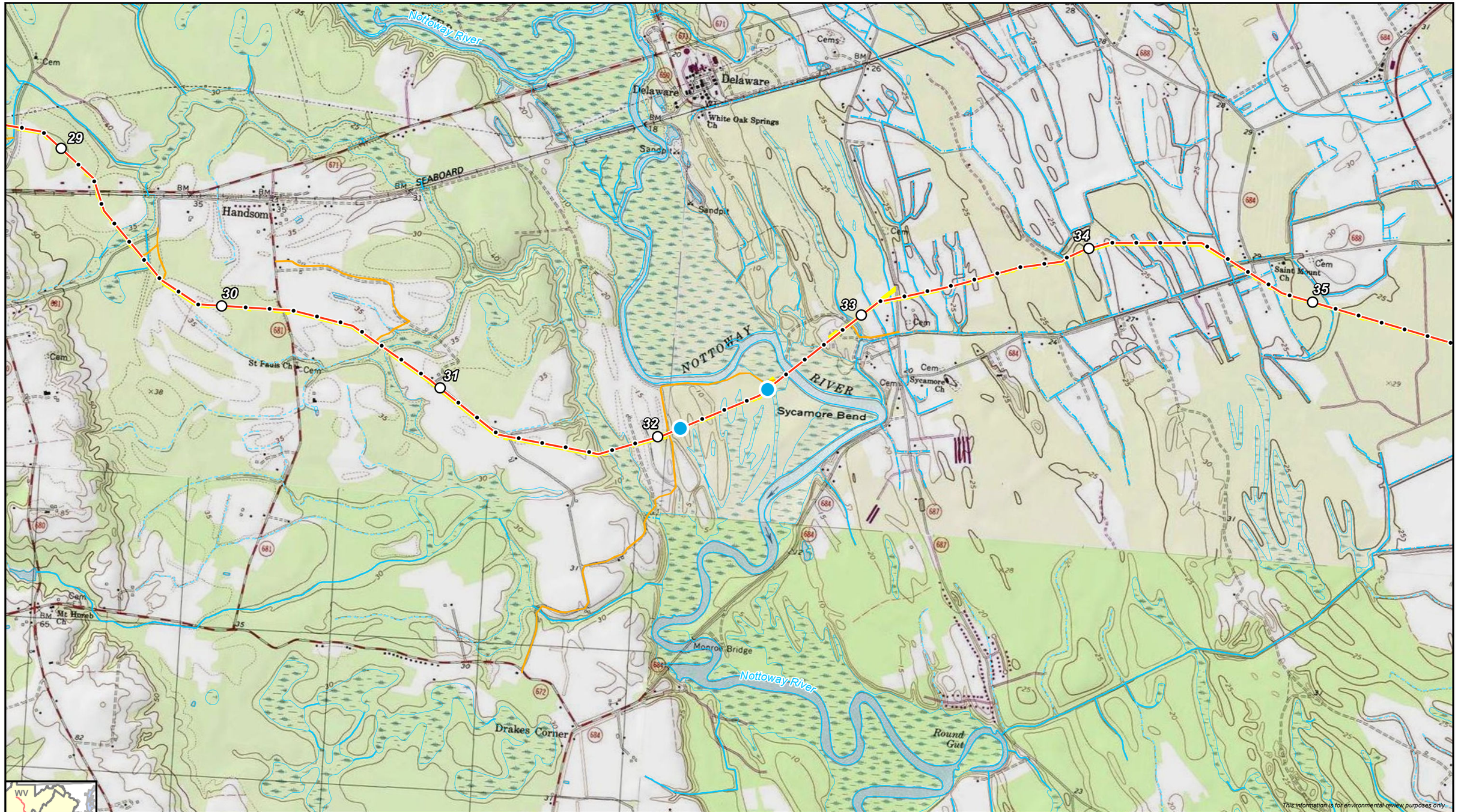

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1:24,000 | 1 inch = 2,000 feet

Proposed Centerline
Milepost
Hydrostatic Discharge Sites
Temporary Workspace
Permanent Workspace
Access Road

Atlantic Coast Pipeline

Atlantic Coast Pipeline
Hydrostatic Discharge Sites
Southampton County, Virginia

ERM

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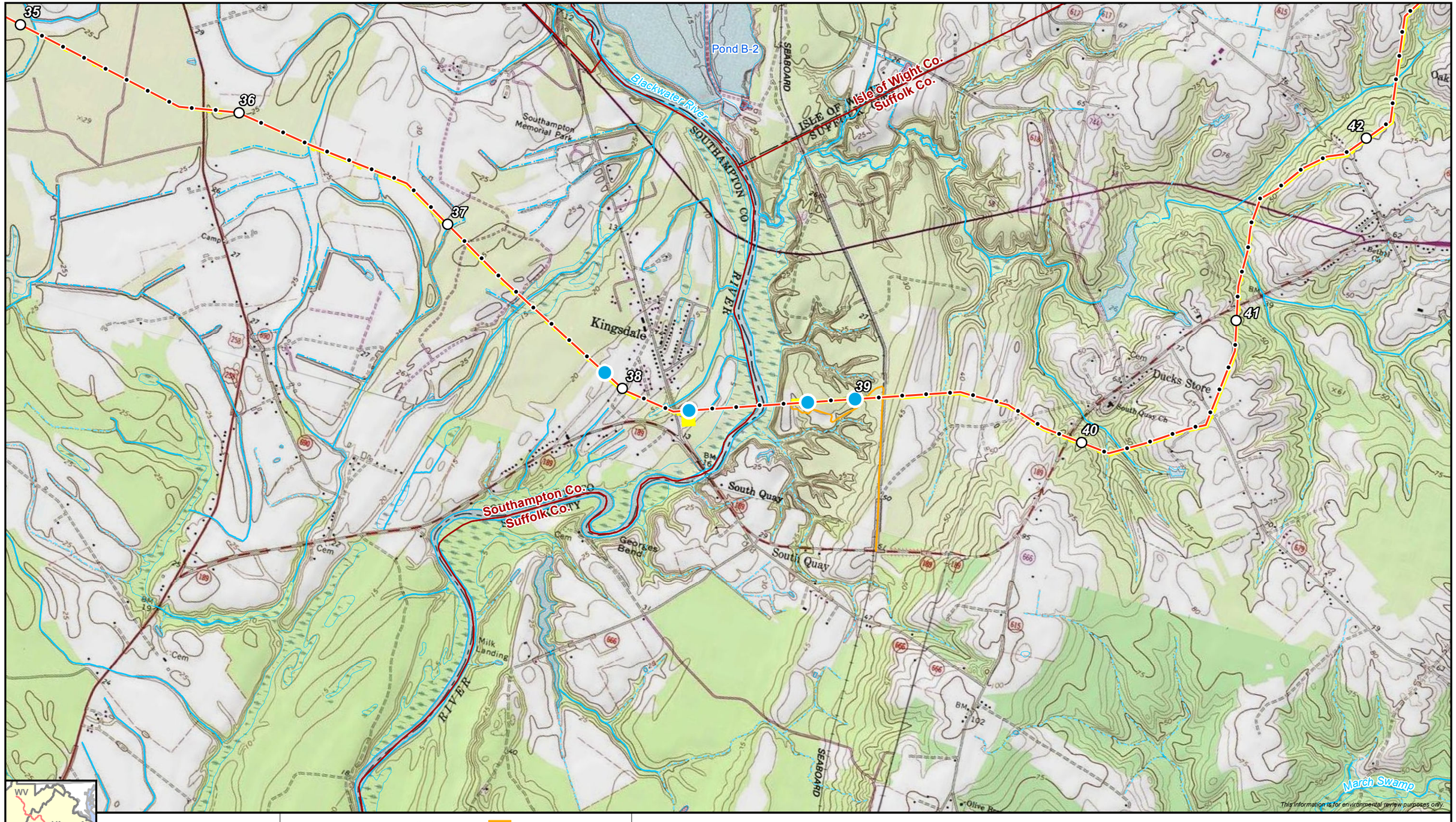

Atlantic Coast Pipeline
Hydrostatic Discharge Sites
Suffolk County, Virginia

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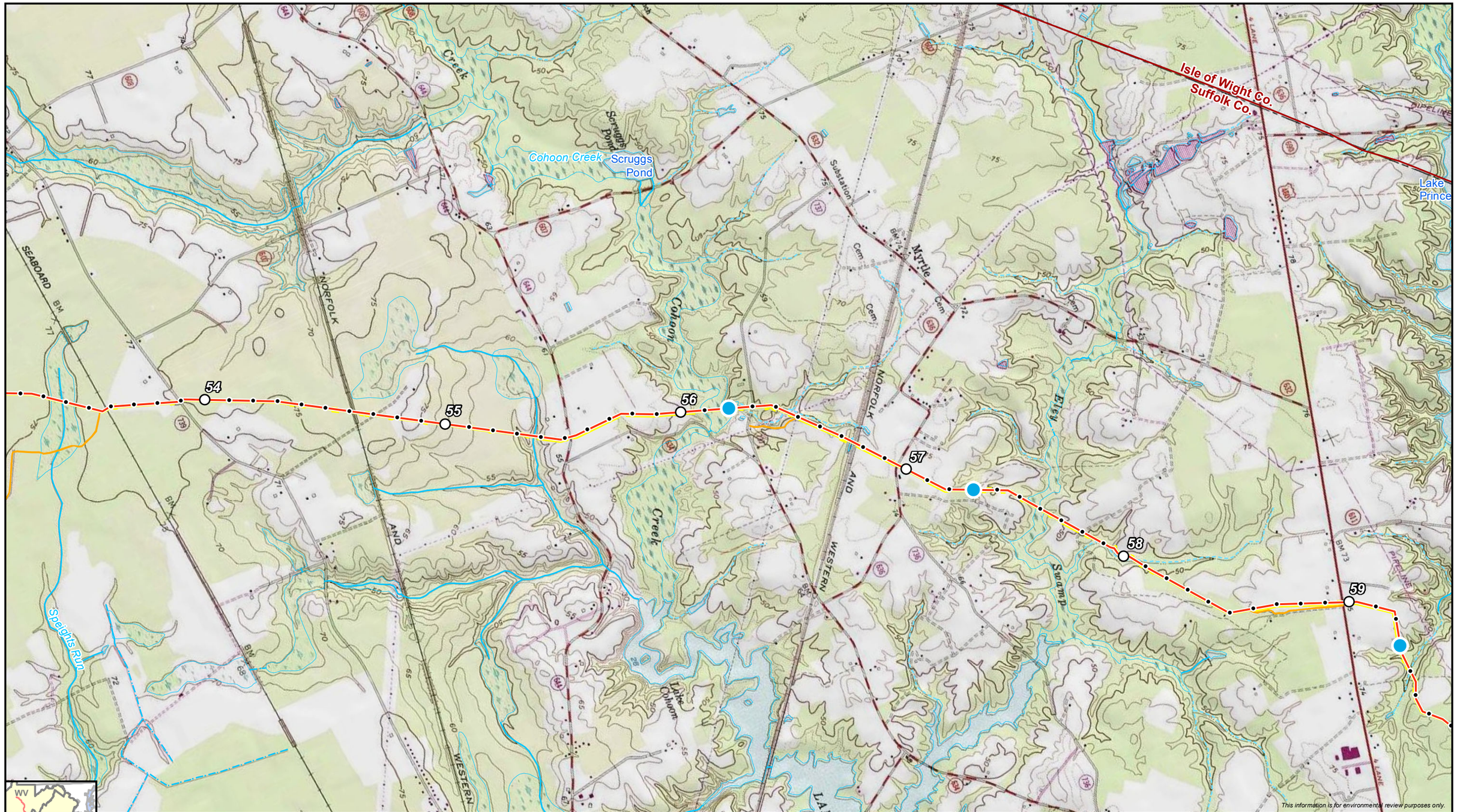

Atlantic Coast Pipeline
Hydrostatic Discharge Sites
Suffolk County, Virginia

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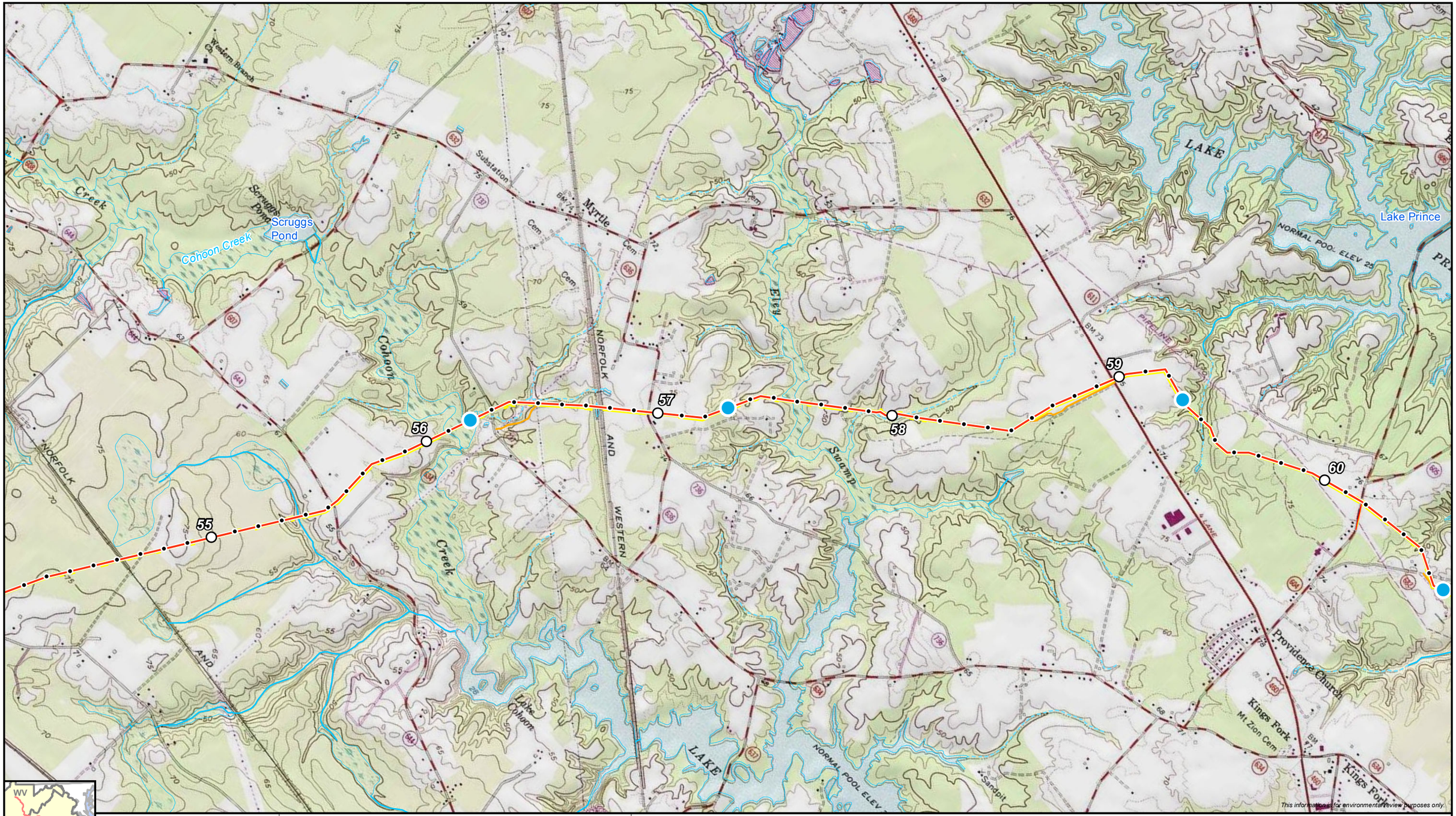

Atlantic Coast Pipeline
Hydrostatic Discharge Sites
Suffolk County, Virginia

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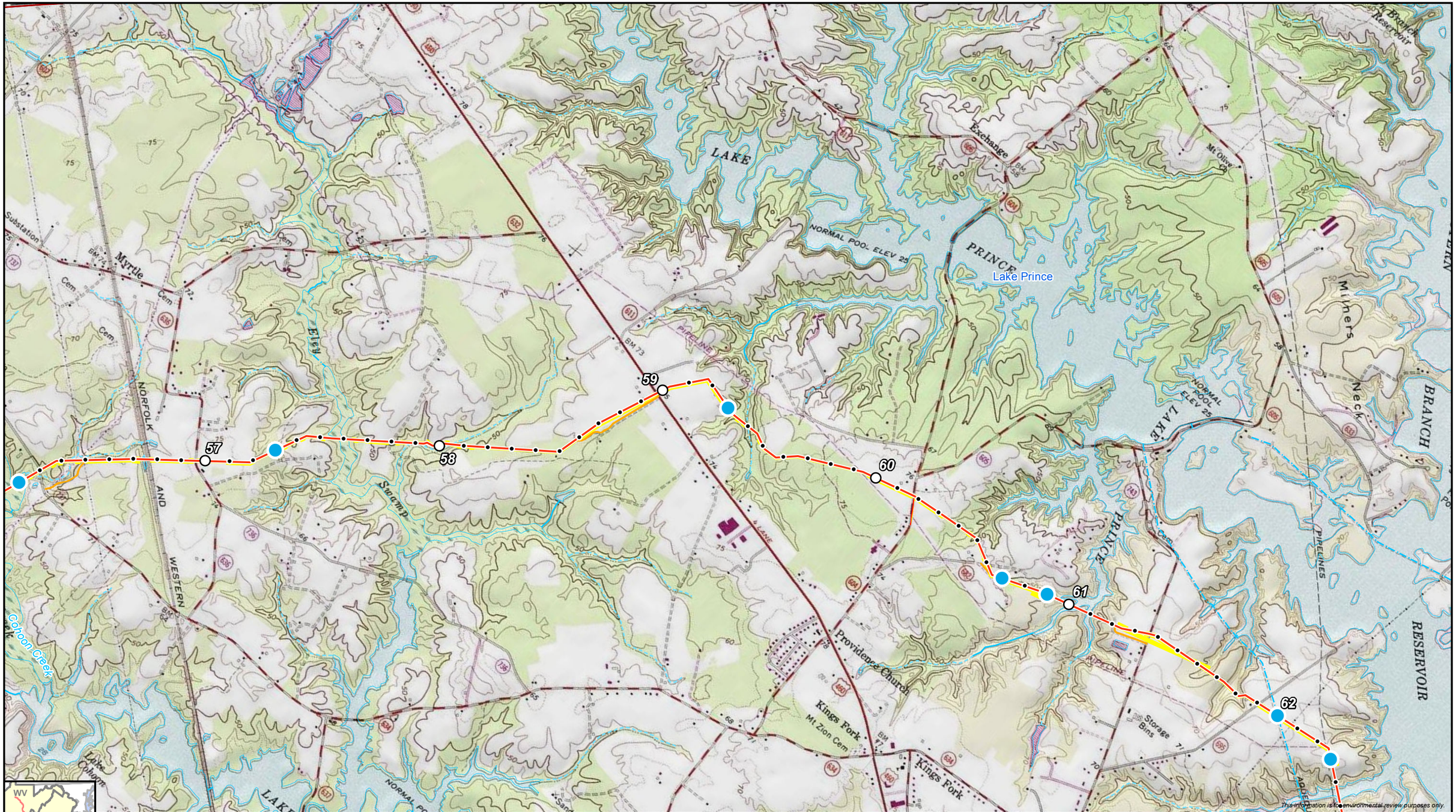

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1:24,000 | 1 inch = 2,000 feet

Proposed Centerline
Milepost
Hydrostatic Discharge Sites
Temporary Workspace
Permanent Workspace
Access Road

Atlantic Coast Pipeline

Atlantic Coast Pipeline
Hydrostatic Discharge Sites
Suffolk County, Virginia

ERM

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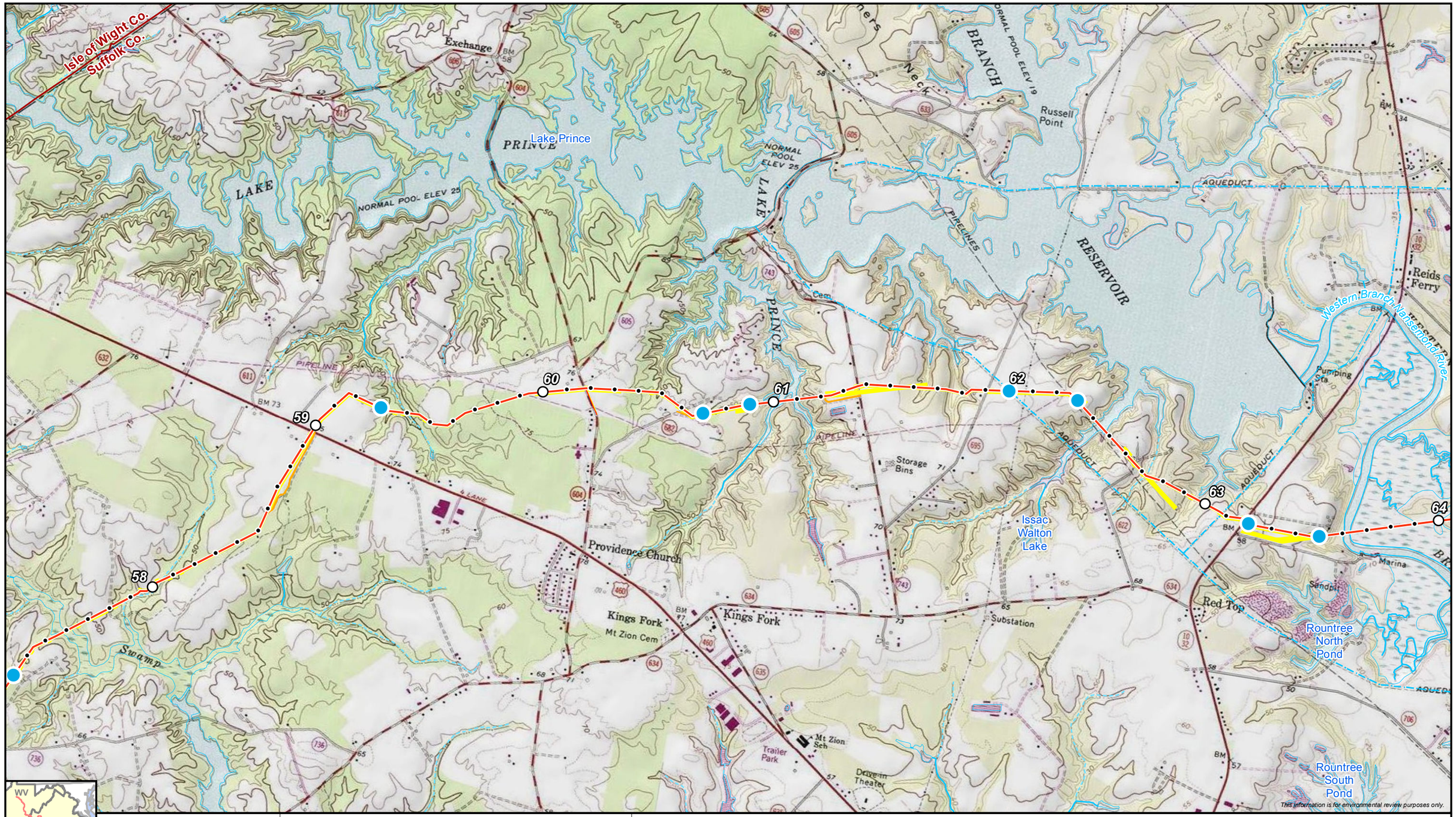

Atlantic Coast Pipeline
Hydrostatic Discharge Sites
Suffolk County, Virginia

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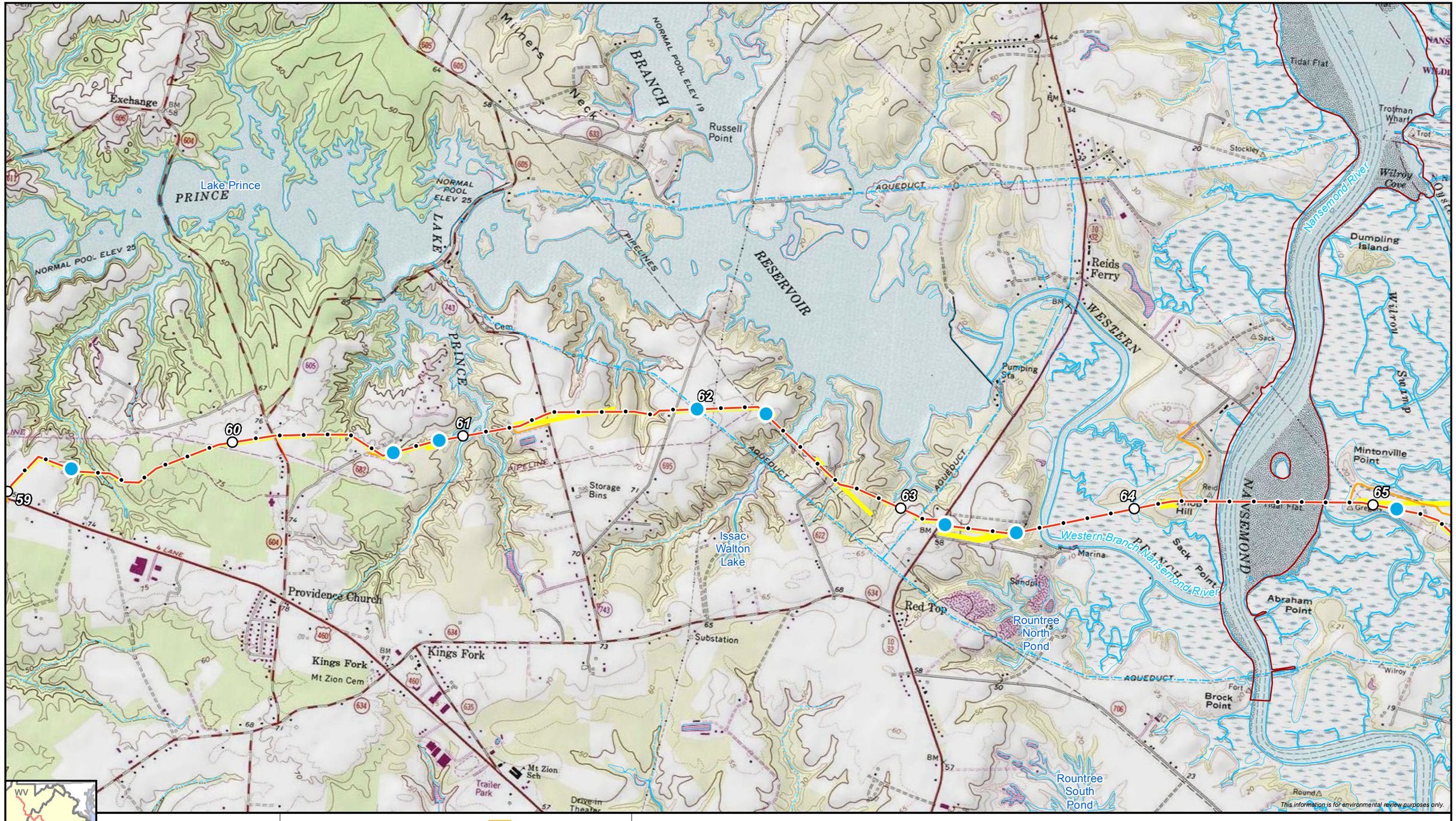

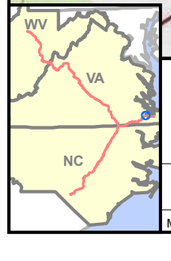

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Feet

1:24,000 | 1 inch = 2,000 feet

Proposed Centerline
Milepost
Hydrostatic Discharge Sites
Temporary Workspace
Permanent Workspace
Access Road

This information is for environmental review purposes only.

Atlantic Coast Pipeline
Hydrostatic Discharge Sites
Suffolk County, Virginia

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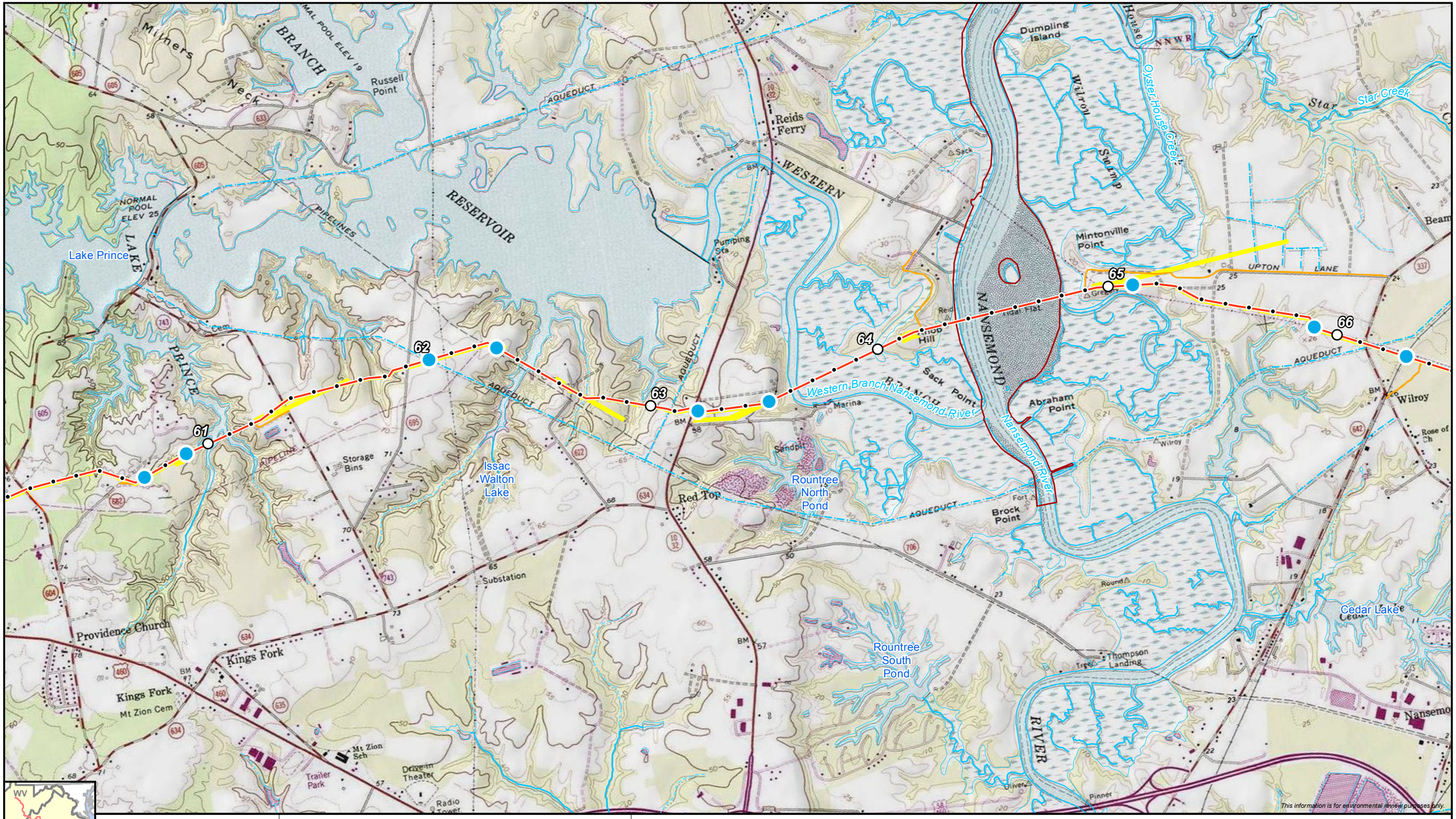
61
62
63
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Lake Prince
Issac Walton Lake
Rountree North Pond
Rountree South Pond
Cedar Lake
Western Branch Nansemond River
Nansemond River
Reids Ferry
Mintonville Point
Dumpling Island
Abraham Point
Brock Point
Sack Point
Red Top
Providence Church
Kings Fork
Wilroy
Star
Star Creek
Oyster House Creek
Wilroy Swamp
Thompson Landing
Pumping Sta
Substation
Storage Bins
Trailer Park
Drive-In Theater
Mt Zion Sch
Mt Zion Cem
Marina
Sandpit
Round
Pinner
Russell Point
Mithers Neck
RESERVOIR
WESTERN BRANCH
AQUEDUCT
PIPELINES
PIPELINE
NORMAL POOL ELEV 25
UPTON LANE
NNWR
RIVER
This information is for environmental review purposes only.
WV
VA
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1 inch = 2,000 feet
Proposed Centerline
Milepost
Hydrostatic Discharge Sites
Temporary Workspace
Permanent Workspace
Access Road
Atlantic Coast Pipeline
Atlantic Coast Pipeline
Hydrostatic Discharge Sites
Suffolk County, Virginia
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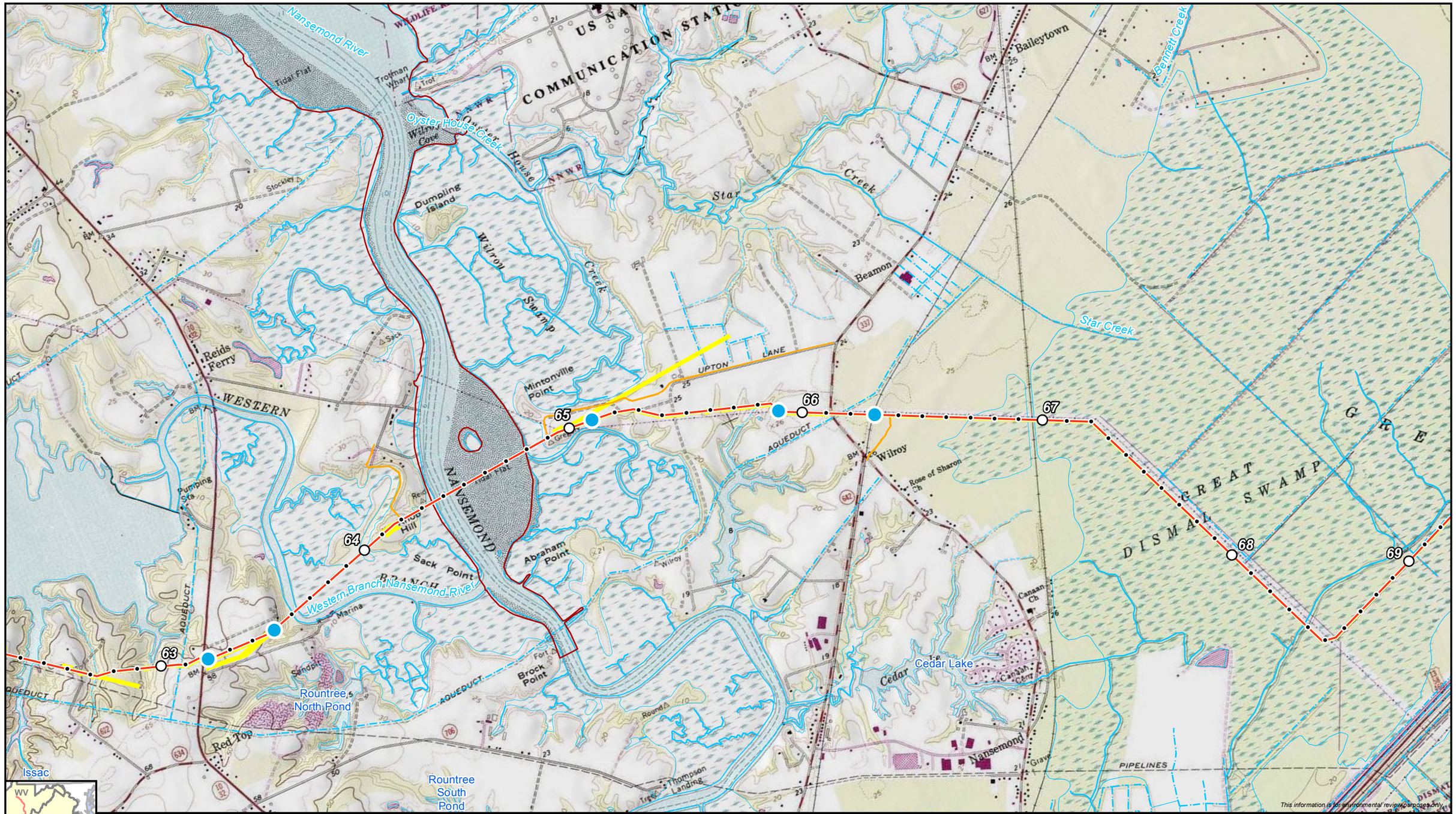

Atlantic Coast Pipeline
Hydrostatic Discharge Sites
Suffolk County, Virginia

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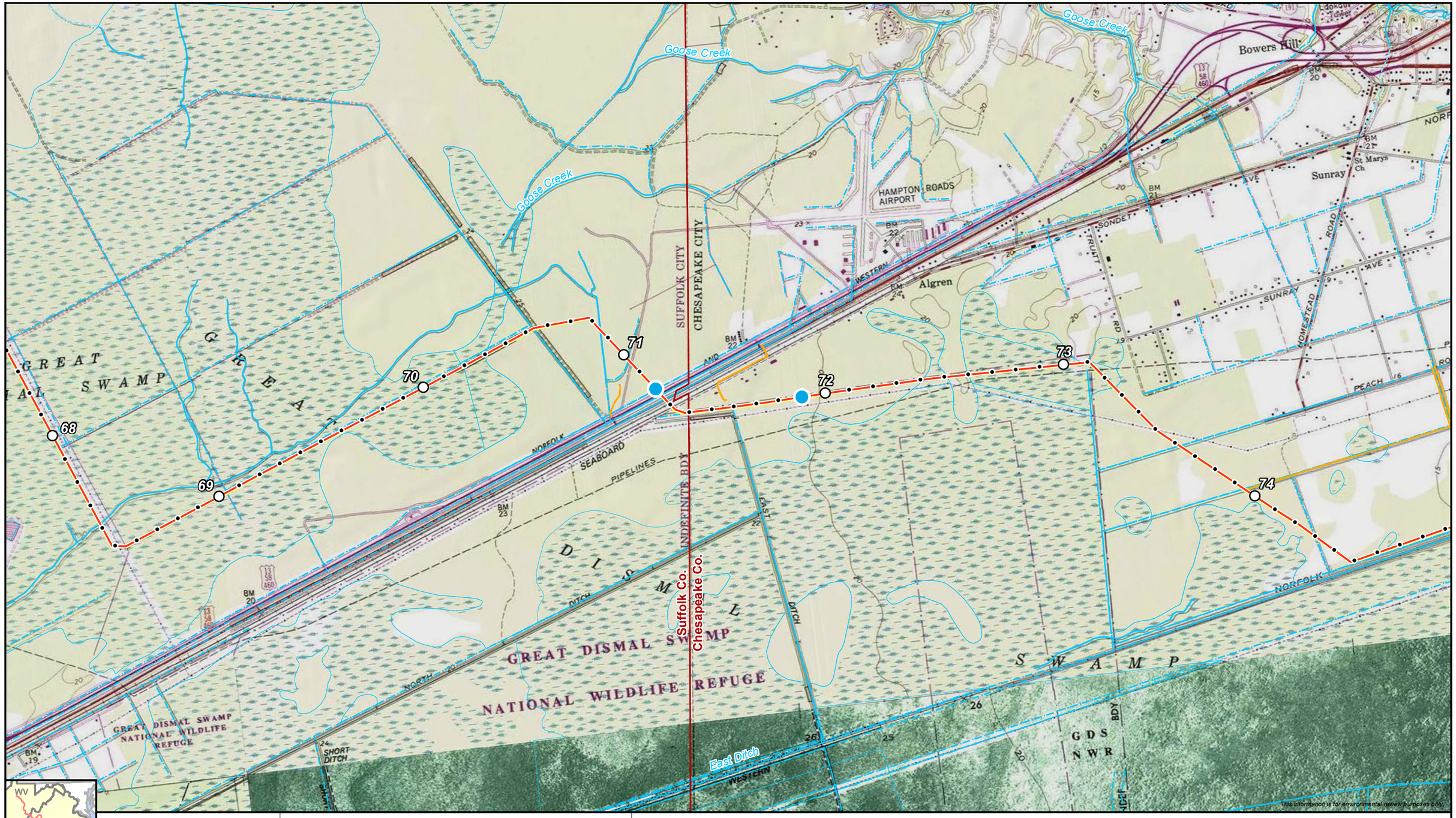

Atlantic Coast Pipeline

Hydrostatic Discharge Sites

Chesapeake County, Virginia

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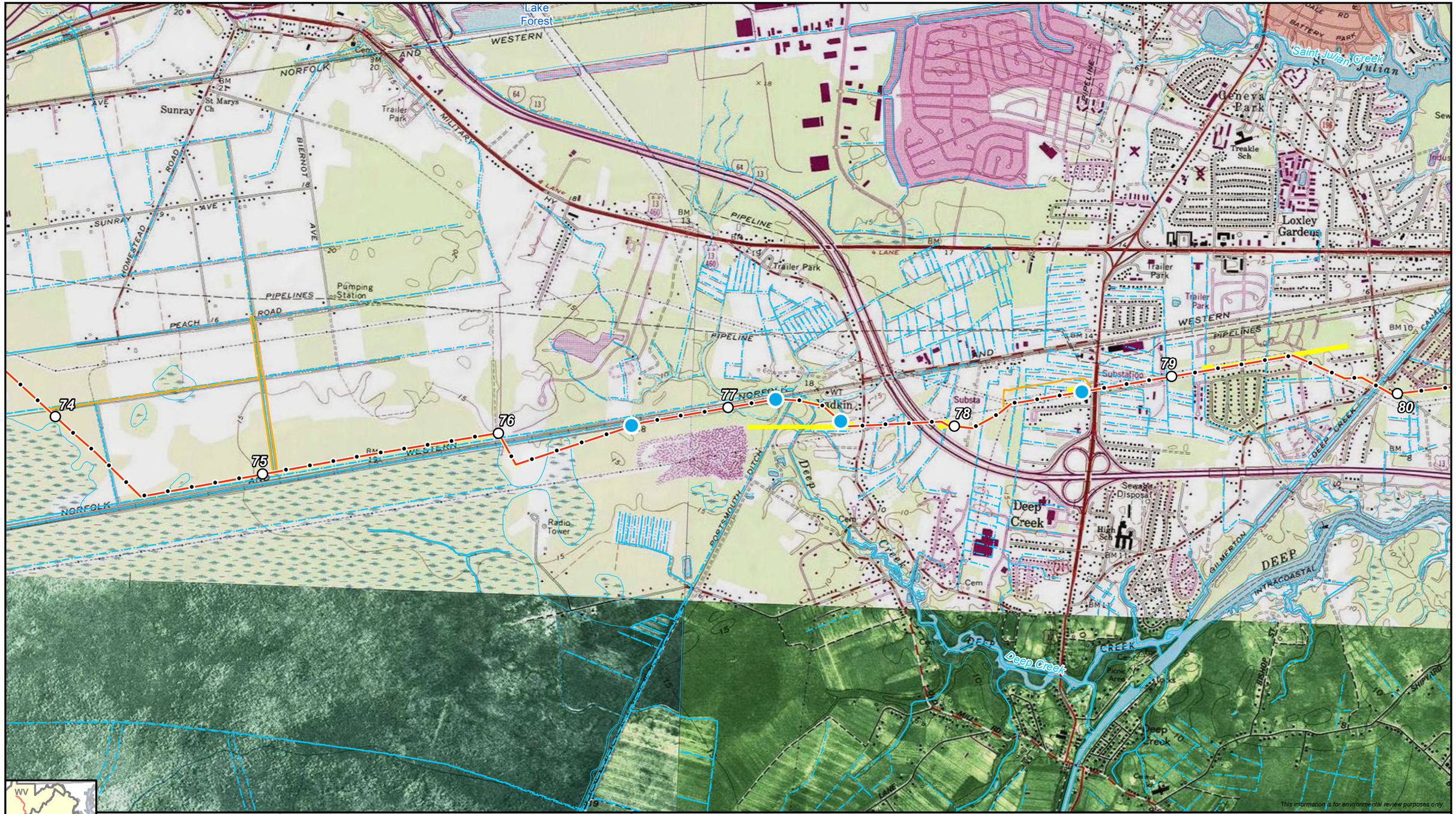

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Feet

1:24,000 | 1 inch = 2,000 feet

Proposed Centerline
Milepost
Hydrostatic Discharge Sites
Temporary Workspace
Permanent Workspace
Access Road

Atlantic Coast Pipeline

Atlantic Coast Pipeline
Hydrostatic Discharge Sites
Chesapeake County, Virginia

ERM

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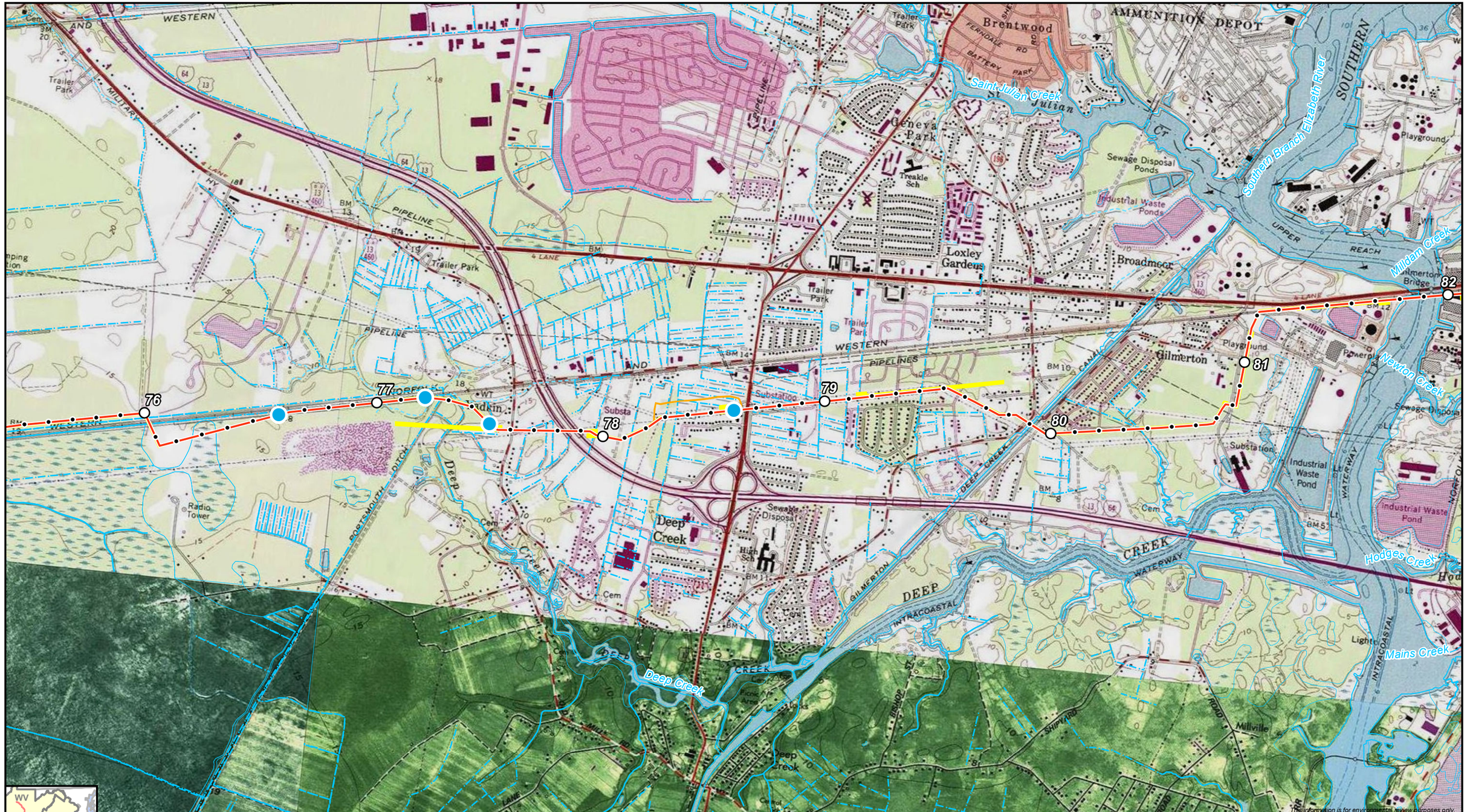

Atlantic Coast Pipeline
Hydrostatic Discharge Sites
Chesapeake County, Virginia

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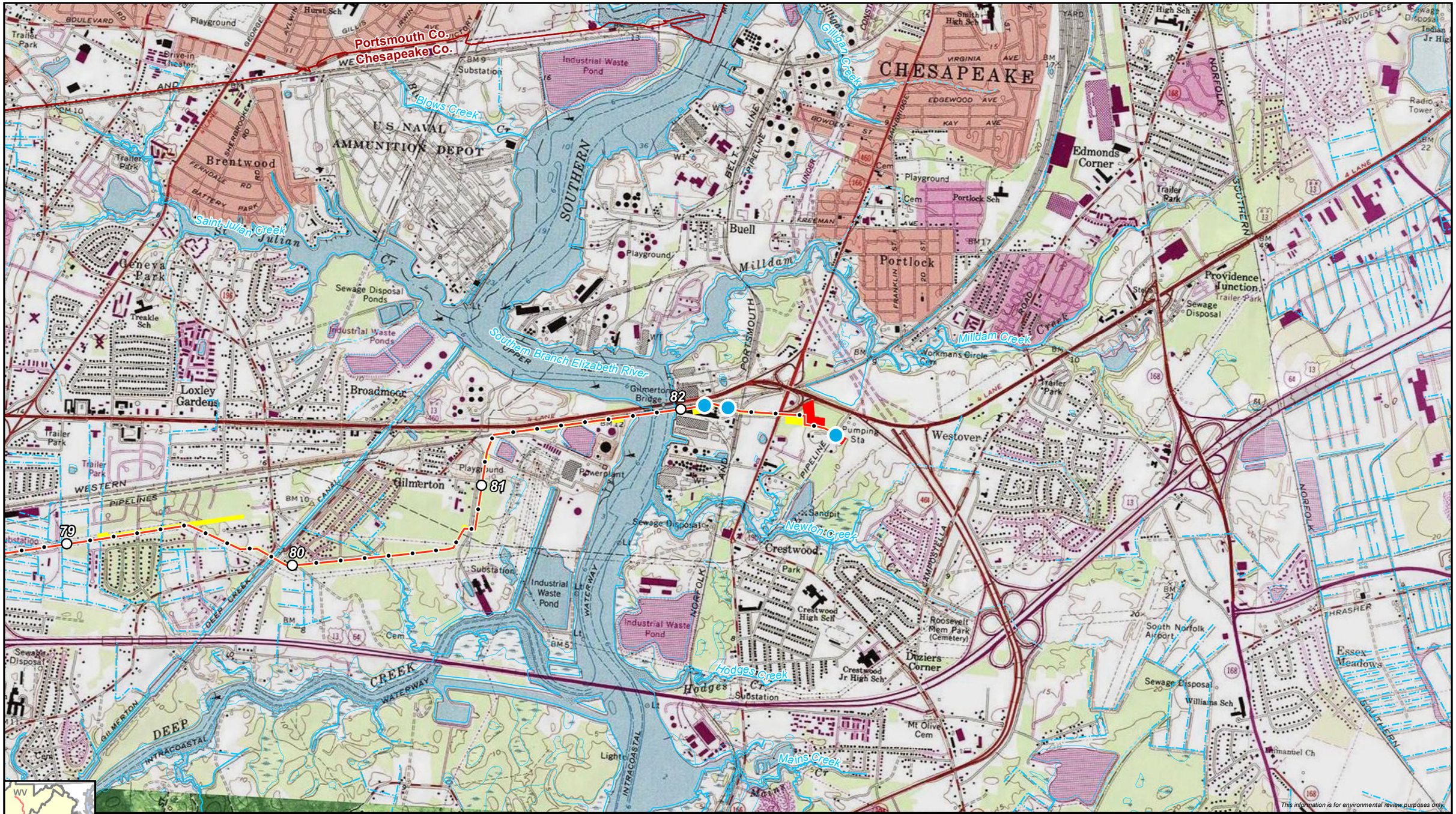

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Feet

1:24,000 | 1 inch = 2,000 feet

Proposed Centerline
Milepost
Hydrostatic Discharge Sites
Temporary Workspace
Permanent Workspace

Atlantic Coast Pipeline

Atlantic Coast Pipeline
Hydrostatic Discharge Sites
Chesapeake County, Virginia

ERM

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ATLANTIC COAST PIPELINE, LLC
ATLANTIC COAST PIPELINE

Response to Virginia Department of Environmental Quality Request for Information for the Section 401 Water Quality Certification

APPENDIX E

Spill Prevention, Control, and Countermeasures Plan

ATLANTIC COAST PIPELINE, LLC
ATLANTIC COAST PIPELINE
Docket Nos. CP15-554-000
CP15-554-001

and

DOMINION ENERGY TRANSMISSION, INC.
SUPPLY HEADER PROJECT
Docket No. CP15-555-000

Spill Prevention, Control, and Countermeasure Plan

Updated, Rev. 2

Prepared by

ERM

June 21, 2017

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3.0 TRAINING....1
4.0 ROLES AND RESPONSIBILITIES....2
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9.0 CERTIFICATION BY A PROFESSIONAL ENGINEER....13
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LIST OF ATTACHMENTS

Attachment A Spill Report Form
Attachment B Site-Specific Descriptions and Maps Depicting Locations of Fixed and Mobile Oil Containers and Type of Material Located within Containers *(to be provided by the Contractors prior to construction)*

LIST OF ACRONYMS AND ABBREVIATIONS

ACP	Atlantic Coast Pipeline
Atlantic	Atlantic Coast Pipeline, LLC
DTI	Dominion Transmission, Inc.
EI	Environmental Inspector
Projects	Atlantic Coast Pipeline and Supply Header Projects
RQ	Reportable Quantity
SHP	Supply Header Projects
SPCC Plan	Spill Prevention, Control, and Countermeasure Plan

1.0 INTRODUCTION

Atlantic Coast Pipeline, LLC (Atlantic) – a company formed by four major energy companies – Dominion Energy.; Duke Energy Corporation; Piedmont Natural Gas Co., Inc.; and Southern Company Gas – proposes to construct and operate approximately 600 miles of natural gas transmission pipelines and associated aboveground facilities in West Virginia, Virginia, and North Carolina. This Project, referred to as the Atlantic Coast Pipeline (ACP), will deliver up to 1.5 million dekatherms per day of natural gas from supply areas in the Appalachian region to demand areas in Virginia and North Carolina. Atlantic has contracted with Dominion Transmission, Inc. (DTI), a subsidiary of Dominion Resources, Inc., to construct and operate the ACP on behalf of Atlantic.

In conjunction with the ACP, DTI proposes to construct and operate approximately 37.5 miles of pipeline loop and modify existing compression facilities in Pennsylvania and West Virginia. This Project, referred to as the Supply Header Project (SHP), will enable DTI to provide firm transportation service to various customers, including Atlantic.

2.0 PURPOSE

The purpose of this *Spill Prevention, Control, and Countermeasure Plan* (SPCC Plan) is to identify preventive measures, such as training, equipment inspection, and refueling procedures, to reduce the likelihood of spills; and mitigation measures, such as containment and cleanup, to minimize potential impacts should a spill occur. Atlantic's and DTI's construction Contractors, [1] whose activities could result in a spill of fuel or other hazardous materials, will be required to adopt the following protocols for spill prevention, cleanup, and reporting during construction of the ACP and SHP.

3.0 TRAINING

Prior to the start of construction, Atlantic and DTI will conduct environmental and safety training for Company and Contractor personnel. The training program will focus on the Federal Energy Regulatory Commission's *Upland Erosion Control, Revegetation, and Maintenance Plan* and *Wetland and Waterbody Construction and Mitigation Procedures*; other construction, restoration, and mitigation plans, including this SPCC Plan; and applicable permit conditions. In addition, Atlantic and DTI will provide large-group training sessions before each work crew commences construction with periodic follow-up training for groups of newly assigned personnel.

Experienced, well-trained personnel are essential for the successful implementation of the SPCC Plan. Contractors will provide spill prevention and response training to their work crews. The training program will be designed to improve awareness of safety requirements, pollution control laws, and proper operation and maintenance of equipment. Contractors will train all employees who handle fuels and other regulated substances to prevent spills and to quickly and

[1] Contractor or Contractors refer to the company or companies retained by Atlantic/DTI or another contractor to construct the proposed facilities.

effectively contain and cleanup spills that may occur in accordance with applicable regulations and the provisions of this plan.

4.0 ROLES AND RESPONSIBILITIES

A. Spill Coordinator – Each Contractor will appoint a Spill Coordinator who will be responsible for coordinating Contractor Work Crews for spill cleanup, conducting site investigations, and completing spill reports. Upon learning of a spill, the Spill Coordinator will immediately report the spill to an Environmental Inspector (EI) [2], who will immediately initiate the spill reporting process to the appropriate state agency (see Section 7.0). The Spill Coordinator will be responsible for completing a Spill Report Form (Attachment A) within 24 hours of the occurrence of a spill, regardless of the size of the spill.

B. Contractor Work Crews – Contractor Work Crews will comply with this SPCC Plan and will notify the crew foreman or Spill Coordinator immediately of a spill of fuel or other hazardous material, regardless of the volume of the spill.

C. Environmental Inspectors – The EIs will monitor the Contractors' compliance with the provisions of the SPCC Plan to ensure that spill resources are allocated and cleanup is accomplished in accordance with this plan and applicable regulatory requirements. The EIs will work in conjunction with Atlantic's and DTI's environmental team to promptly report spills to appropriate Federal, State/Commonwealth, and local agencies, as required, and to coordinate with these agencies regarding contacting additional parties or agencies as may be required.

5.0 PREVENTIVE MEASURES

Contractors will minimize the potential for a spill during construction activities by implementing appropriate measures to prevent and contain spills. Equipment and materials will be located onsite to meet the provisions of this plan. The Contractors will comply with applicable environmental and safety laws and regulations and will ensure that a copy of this plan is available onsite to all Construction Work Crew members. All cleanup and other construction-related spill activities will be completed by the appropriate Contractors.

Spill prevention measures are described below.

A. Petroleum and Hazardous Liquid Storage, Refueling, and Equipment Maintenance

1. Staging Areas and Facility Sites:

[2] The role and responsibilities of an EI are defined in the Federal Energy Regulatory Commission's *Upland Erosion Control, Revegetation, and Maintenance Plan*.

a. Prior to construction, the Contractors will provide site-specific descriptions and maps depicting locations of fixed and mobile hazardous material containers and the types of materials located within containers. The site-specific descriptions and maps will identify the direction, rate of flow, and total quantity of petroleum or hazardous liquid which could be discharged from containers or from major equipment failures.

b. Contractors will visually inspect aboveground storage containers for leaks and spills on a regular basis and whenever containers are refilled. Contractors will maintain inspection records for every container.

c. Contractors will construct secondary containment structures (e.g., temporary liners and seamless impermeable berms) around aboveground, single wall, storage containers so that liquids will be contained and collected in specified areas isolated from waterbodies in the event of a leak or spill. Double wall containers will not require secondary containment. Storage containers will not be placed in areas subject to periodic flooding and washout.

d. Secondary containment structures must provide a containment volume equal to a minimum of 110 percent of the maximum storage volume of the storage container for single wall containers.

e. Secondary containment structures must be constructed so that no outlet is provided and a spill will be contained within the containment structure. Accumulated rainwater may be removed if authorized by the EI. Accumulated water with a visible sheen will be collected for proper storage, transport, and disposal.

f. Contractors will remove all secondary containment structures at the conclusion of the Projects. Contractors also will be responsible for returning the storage impoundment area to its original contours and appearance upon completion of the Projects.

g. Hazardous materials, including chemicals, fuels, and lubricating oils, will be stored only at designated staging areas and in appropriate service vehicles. The storage areas will be located at least 100 feet away from wetlands, waterbodies, and springs; at least 200 feet away from private water supply wells; at least 300 feet away from karst features; and at least 400 feet away from municipal water supply wells unless a larger buffer is required by regulatory agencies.

h. Storage containers will display labels that identify the contents of the container and whether the contents are hazardous. Contractors

will maintain and provide to Atlantic and DTI, when requested, copies of all Safety Data Sheets (formally known as Material Safety Data Sheets). All containers used for the storage of hazardous materials, including chemicals, fuels, and lubricating oils, will be of material and construction compatible with the material stored and the conditions of storage such as pressure and temperature. All containers will be in good condition.

i. Contractors will conduct routine equipment maintenance, such as oil changes, in staging areas and will dispose of waste oil in an appropriate manner (e.g., the Contractors will collect the waste oil in labeled, sealed containers and transport the waste oil to a recycling facility).

j. Contractors will correct visible leaks in storage containers as soon as possible. Leaks outside of secondary containment, regardless of volume, will immediately be reported to the Spill Coordinator and an EI, who will immediately initiate the spill reporting process to the appropriate state agency.

k. Drain valves on temporary storage containers will be locked to prevent accidental or unauthorized discharges from the containers.

l. All fuel nozzles will be equipped with functional automatic shut-off valves.

m. The drivers of tank trucks will be responsible for spill prevention and the provision of secondary containment during tank truck unloading. Procedures for loading and unloading tank trucks will meet the minimum requirements established by applicable law and associated regulations. Drivers will observe and control the fueling operations at all times to prevent overfilling. Contractors will be responsible for training drivers of tank trucks to comply with these provisions.

n. Prior to departure of a tank truck, all outlets of the vehicle will be closely examined by the driver for leakage and tightened, adjusted, or replaced, as necessary, to prevent liquid leakage while in transit. Contractors will be responsible for training drivers of tank trucks to comply with these provisions.

2. Right-of-Way:

a. All machinery will arrive on the right-of-way in a clean, washed condition, maintained free of fluid leaks.

b. Overnight parking of equipment, as well as refueling and servicing of construction equipment, will be restricted to upland areas at

least 100 feet away from waterbodies, wetlands, and springs; at least 200 feet from private water-supply wells; at least 300 feet from karst features; and at least 400 feet from municipal water-supply wells. Where this is not practicable, and where the EI finds in advance no reasonable alternative, the equipment will be fueled by designated personnel with specific training in refueling, spill containment, and cleanup, under the supervision of an EI. Prior to refueling, appropriate steps will be taken (including deployment of secondary containment structures) to prevent spills and provide for prompt cleanup in the event of a spill.

c. Fuel trucks transporting fuels to construction areas will only travel on approved access roads.

d. Contractors will keep a spill kit onsite and on all equipment in case of machinery leaks or spills. If a spill kit is used, it will be replaced within 24 hours.

3. Restricted Refueling Areas will be identified in the field with flagging or signs. A site-specific plan and written approval from an EI will be required to refuel in restricted areas.

a. Approval must be received from an Atlantic or DTI representative and, where necessary, appropriate regulatory permits must be obtained, prior to refueling in Restricted Refueling Areas.

b. In large wetlands where no upland site is available for refueling, auxiliary fuel tanks may be mounted to equipment to minimize the need for refueling.

c. Trained Contractor personnel must be available for refueling, and an EI or another trained Atlantic/DTI representative must be present.

d. Equipment such as large, stationary pumps will be fitted with auxiliary tanks as appropriate. The auxiliary tanks will be placed within secondary containment which provides for a containment volume equal to a minimum of 110 percent of the volume of the auxiliary tanks.

e. Refueling within Restricted Refueling Areas will take place in areas designated by an EI. Fuel trucks with a capacity in excess of 300 gallons will not be allowed within a Restricted Refueling Area unless adequate secondary containment is provided.

f. Refueling of dewatering pumps, generators, and other small, portable equipment will be performed using approved containers with a maximum volume of 5 gallons.

B. Spill Response Equipment

1. Staging Areas and Facility Sites:

    a. Contractors will stock a sufficient supply of sorbent and barrier materials at construction staging areas to allow the rapid containment and recovery of a spill. Sorbent and barrier materials will also be used to contain runoff from spill areas.

    b. Shovels and 55 gallon drums will be kept at each individual staging area. If small quantities of soil become contaminated within the staging area, they will be collected and placed in the drums. The drums will be labelled to indicate the contents of the drum, including the spilled/recovered material.

    c. Large quantities of contaminated soil will be collected using heavy equipment and will be stored in drums or other suitable containers prior to disposal. The drums will be labelled to indicate the contents of the drum, including the spilled/recovered material.

    d. The Contractors will dispose of all contaminated soil in accordance with applicable State/Commonwealth and Federal regulations.

2. Right-of-Way

    a. Each construction crew will have adequate absorbent materials and containment booms on hand to enable the rapid and complete cleanup of spills, as well as sufficient tools and materials to stop leaks.

    b. Contractors must maintain spill kits containing a sufficient quantity of absorbent and barrier materials to adequately contain and recover foreseeable spills. These kits may include, but are not limited to: absorbent pads, straw bales, absorbent clay, sawdust, floor drying agents, spill containment barriers, plastic sheeting, skimmer pumps, and 55 gallon drums. The equipment will be located near fuel storage areas and other locations, as necessary, to be readily available in the event of a spill.

    c. All fuel equipment, and where practicable, service trucks, will carry adequate spill response materials. Spill response materials present on trucks will consist of absorbent pads, absorbent material, plastic bags, and a shovel.

    d. The Spill Coordinator will inform the EIs and all Contractor personnel of the location of spill control equipment and materials, and have them readily accessible while construction activities are occurring.

e. If a spill kit is used, it will be replaced within 24 hours.

C. Concrete Coating

1. Concrete coating activities and washout activities will not be performed within 100 feet of wetlands, waterbodies, or springs, or with 300 feet of karst features unless the location is an existing industrial site designated for such use.

6.0 SPILL RESPONSE

A. The first priorities after discovering a spill are to protect the safety of personnel and the public and to minimize damage to the environment. Actions to be taken immediately following a spill will include the following:

1. The safety of the situation (including the surrounding public) will be assessed.

2. Sources of ignition will be removed from the area by trained personnel **if safe to do so**.

3. The source of the spill will be shut off by trained personnel **if safe to do so**.

4. Efforts to contain the spill immediately will be initiated by trained personnel **if safe to do so**.

5. Cleanup activities will be initiated as soon as possible after the spill is contained using properly trained and protected personnel with adequate spill cleanup materials and equipment (see Section 8.0).

6. If necessary, an Emergency Response Contractor will be secured for large spills to further contain and clean up the spill.

7.0 SPILL REPORTING

A. All spills will be reported immediately to Atlantic or DTI. Reports will include the following information (found on the Spill Report Form):

1. Date, time, and location of the spill.
2. Type of material spilled.
3. Amount of material spilled.
4. Extent of spill area.
5. Whether the material has reached or has the potential to reach a wetland, waterbody, or karst feature.
6. Status of spill containment and cleanup.

7. Circumstances leading up to the spill.

B. Atlantic's and DTI's environmental team will report the spill to the applicable regulatory agencies if the spill meets or exceeds a reportable threshold. Table 1 lists the Federal and State/Commonwealth agencies that would be contacted, as appropriate, if a spill meets or exceeds a reportable threshold.

C. Federal standards for reportable quantities (RQs) of hazardous materials are listed at 40 CFR 302.4, which is incorporated into this SPCC Plan by reference. Additional requirements by State/Commonwealth are as follows:

1. **Pennsylvania:**

   a. Liquid hazardous waste spills must be reported when equal to or exceeding the Federal RQs at 40 CFR 302.4, or 10 gallons, whichever is more stringent (25 Pa. Code § 262a.43(2)(i)).

   b. Solid hazardous waste spills must be reported when equal to or exceeding the Federal RQs at 40 CFR 302.4, or 500 pounds, whichever is more stringent (25 Pa. Code § 262a.43(2)(ii).

   c. A spill of oil, petroleum or other hazardous substance that discharges or has potential to discharge into Commonwealth waters must be reported, regardless of amount, (see 25 Pa. Code §§ 91.33, 78.66, 299.217, 299.218, § 262a.43(3)).

2. **West Virginia:**

   a. Hazardous waste spills must be reported when equal to or exceeding the Federal RQs at 40 CFR 302.4 (see e.g., W. Va. CSR § 60-3-5).

   b. Oil spills must be reported when "causing a film or sheen upon or discoloration of the surface of the water or adjoining shorelines or cause a sludge or emulsion to be deposited beneath the surface of the water or upon adjoining shorelines" (see CWA 111; 40 CFR 110.3(b); and, by analogy, W. Va. Legislative Rules § 31-1).

   c. Toxic air pollutant spills must be reported when exceeding (i) 1 pound for ethylene oxide and vinyl chloride, (ii) 10 pounds for acrylonitrile and butadiene, or (iii) 50 pounds for all others (W. Va. CSR § 45-27-10.4).

3. **Virginia:**

   a. Oil discharges to land must be reported, immediately upon learning of the discharge, in amounts equal to or greater than 25 gallons (or less if certain recordkeeping and clean-up requirements are not met) (Va. Code § 62.1-44.34:19).

TABLE 1

Agency Notification List

Agency	Program	Contact Information	Hours of Operation	Applicable Areas Served
Federal				
Environmental Protection Agency	National Response Center	800-424-8802	24-hour hotline	All Areas
Pennsylvania				
Department of Environmental Protection	Southwest Regional Office	412-442-4000	24-hour hotline	Greene and Westmoreland Counties
Commonwealth of Pennsylvania	Pennsylvania Emergency Response Management	717-651-2001	24-hour hotline	Entire Commonwealth
West Virginia				
Department of Environmental Protection (WVDEP)	Emergency 24-hour Hotline for Hazardous Waste Release	800-642-3074	24-hour hotline	Entire State
WVDEP	Elkview Emergency Response Unit	304-558-5938	Monday – Friday 8:00 am – 4:00 pm	Entire State
Virginia				
Department of Environmental Quality (VDEQ)	Pollution Response Program-Valley Regional Office	540-574-7800	Monday – Friday 8:30 am – 4:30 pm	Augusta, Highland, and Nelson Counties
VDEQ	Pollution Response Program-Blue Ridge Regional Office	540-562-6700	Monday – Friday 8:30 am – 4:30 pm	Buckingham, Cumberland, Prince Edward, and Nottoway Counties
VDEQ	Pollution Response Program-Piedmont Regional Office	804-527-5020	Monday – Friday 8:30 am – 4:30 pm	Dinwiddie, Brunswick, and Greensville Counties
VDEQ	Pollution Response Program-Tidewater Regional Office	757-518-2000	Monday – Friday 8:30 am – 4:30 pm	Southampton County and Cities of Suffolk and Chesapeake
VDEQ	Pollution Response Program – Online Reporting System	Online form at: http://www.deq.virginia.gov/Programs/PollutionResponsePreparedness/PollutionReportingForm.aspx	24-hour online reporting option	Entire Commonwealth
Department of Emergency Management	Virginia Emergency Response Team	800-468-8892 or 804-674-2400	24-hour hotline	Entire Commonwealth
North Carolina				
Department of Environment and Natural Resources	Division of Water Resources – Raleigh Regional Office Emergency Response	919-791-4200 800-858-0368	Monday – Friday 8:00 am – 5:00 pm After hours and weekends	Halifax, Johnston, Nash, Northampton, and Wilson Counties
Department of Environment and Natural Resources	Division of Water Resources – Fayetteville Regional Office Emergency Response	910-433-3300 800-858-0368	Monday – Friday 8:00 am – 5:00 pm After hours and weekends	Cumberland, Robeson, and Sampson Counties

b. An oil spill that discharges or may reasonably be expected to discharge into Commonwealth waters must be reported, immediately upon learning of the discharge, regardless of amount (Va. Code § 62.1-44.34:19).

c. An oil spill that discharges into or may reasonably be expected to discharge into Commonwealth waters must be reported, immediately upon learning of the discharge, to the director or coordinator of emergency services for the political subdivision in which the discharge occurs and any other political subdivision reasonably expected to be the affected by the discharge and to the appropriate federal authorities (Va. Code § 62.1-44.34:19).

d. Hazardous waste spills must be reported when equal to or exceeding Federal RQs at 40 CFR 302.4 (see 9 VAC 25-880-70, generally describing applicable reporting quantities).

4. **North Carolina:**

a. Petroleum spills into the environment must be reported when (i) 25 gallons or more, or (ii) if the petroleum causes a sheen on nearby surface water, or (iii) if the petroleum is discharged at a distance of 100 feet or less from a surface water body, or (iv) if less than 25 gallons of petroleum cannot be cleaned up within 24 hours (N.C. Gen. Statutes 143-215.85(b).

b. Mineral oil (i.e., light nontoxic liquid petroleum distillate used as a coolant and insulator in electrical equipment owned by a public utility) spills must be reported when (i) exceeding 25 gallons, (ii) discharging directly to surface waters or causing a sheen on surface waters of the State, or (iii) at a distance of 100 feet or less from a surface water and containing 50 parts per million or more of polychlorinated biphenyls (N.C. Gen. Statutes 143-215.85(c)).

c. Hazardous waste spills must be reported when equal to or exceeding the Federal RQs at 40 CFR 302.4 (s*ee* http://portal.ncdenr.org/web/wq/home/er).

d. A spill of oil, petroleum, or other hazardous substance that discharges into State waters must be reported, regardless of amount (N.C. Gen. Statutes 143-215.85(a)).

D. Contractors are responsible for assisting Atlantic and DTI with preparing follow-up written incident reports to regulatory agencies upon request.

8.0 SPILL CONTAINMENT AND CLEANUP

A. Land Spill

1. Berms will be constructed with available equipment to physically contain the spill and sorbent materials will be applied to the spill area. Traffic on contaminated soils will be prevented to the extent practicable. Some traffic on contaminated soils may be necessary to avoid impacts on adjacent or sensitive resources (e.g., wetlands).
2. Contaminated soils and vegetation will be removed and disposed of at a properly licensed waste disposal facility.
3. Waste materials from the spill will be disposed of according to applicable regulatory requirements.
4. The following information will be provided to an EI and Atlantic and DTI as available following containment and cleanup (but no later than 24 hours after transport and disposal of the contaminated waste material):
    a. The amount of the spilled material that was recovered during cleanup.
    b. Proposed reclamation of remaining contaminated areas.
    c. Storage method for the contaminated waste material before transport and disposal.
    d. Transport and disposal documentation for the contaminated waste material.
5. If necessary, an Emergency Response Contractor will be secured for large spills to further contain and clean up the spill.

B. Wetland or Waterbody Spill: The following measures will be implemented immediately to control a spill into a wetland or waterbody:

1. For spills in standing water, floating booms, skimmer pumps, and holding tanks will be readily available and used, as appropriate, by the Contractors to recover and contain released materials on the surface of the water.
2. Berms and/or trenches will be constructed in upland areas to contain a spill before it enters a wetland or waterbody. Deployment of booms, skimmers, and sorbent materials will be utilized if the spill reaches a waterbody. The spilled product will be retrieved and the contaminated area cleaned-up in accordance with recommendations from the Spill Coordinator and applicable regulations and guidelines.
3. If necessary, an Emergency Response Contractor will be secured for large spills in wetlands or waterbodies to further contain and clean up the spill.

Approvals or permits from regulatory agencies may be required to place equipment into a wetland or waterbody. Therefore, Contractors must receive written permission from Atlantic or DTI before placing equipment into a wetland or waterbody for the purpose of spill cleanup.

C. **Karst**: In addition to the measures described above, the following procedures will be implemented in areas of karst terrain:

1. Buffers of 300 feet around karst features (e.g., sinkholes, caves, sinking or losing streams, ponors, pinnacled bedrock, and large springs) within or adjacent to the construction right-of-way will be marked with signs and/or highly visible flagging until construction related ground disturbing activities are completed.

2. Equipment refueling will not be permitted within flagged or marked buffer areas for karst features or areas draining into karst features, except by hand-carried cans (5 gallon maximum capacity), when necessary.

3. Equipment servicing and maintenance areas will be sited outside of flagged or marked buffer areas for karst features or areas draining into karst features.

4. Erosion and sediment controls will be implemented, as appropriate, to prevent runoff resulting from construction equipment washing operations (if applicable) to directly enter a karst feature by locating these operations outside of karst buffer areas.

5. Construction equipment, vehicles, materials, hazardous materials, chemicals, fuels, lubricating oils, and petroleum products will not be parked, stored, or serviced within 300 feet of a karst feature.

6. Equipment will be checked for leaks daily by the Contractors prior to beginning work in karst areas; and damaged or defective equipment will be removed or repaired prior to use in karst areas.

7. Atlantic or DTI will notify the National Response Center and either the West Virginia Department of Environmental Protection or Virginia Department of Environmental Quality if a reportable spill impacts a karst feature (see Table 1).

9.0 CERTIFICATION BY A PROFESSIONAL ENGINEER

This SPCC Plan has been certified by a professional engineer in accordance with 40 Code of Federal Regulations 112.7 – *General Requirements for Spill Prevention, Control, and Countermeasure Plans*.

_____ _____

Professional Engineer Date

10.0 CERTIFICATION BY THE CONTRACTOR

The Contractor listed below agrees to follow the requirements of Atlantic's and DTI's *Spill Prevention, Control, and Countermeasure Plan* during all work activities conducted for Atlantic or DTI.

_____ _____

Contractor Date

_____ _____

Responsible Official (Print Name) Title

_____

Responsible Official (Signature)

ATLANTIC COAST PIPELINE, LLC
ATLANTIC COAST PIPELINE

and

DOMINION TRANSMISSION, INC.
SUPPLY HEADER PROJECT

Spill Prevention, Control, and Countermeasure Plan

ATTACHMENT A
Spill Report Form

Atlantic Coast Pipeline and Supply Header Project
Spill Report Form

Date of Spill:_____ Date of Spill Discovery:_____

Time of Spill:_____ Time of Spill Discovery:_____

Name and Title of Discoverer:_____

Type of material spilled and manufacturer's name:_____

Legal Description of spill location to the quarter section:_____

Directions from nearest community:_____

Estimated volume of spill:_____

Weather conditions:_____

Topography and surface conditions of spill site:_____

Spill medium (pavement, sandy soil, water, etc.):_____

Proximity of spill to surface waters: _____

Did the spill reach a waterbody? _____Yes _____No

If so, was a sheen present? _____Yes _____No

Describe the causes and circumstances resulting in the spill:_____

_____

_____

Describe the extent of observed contamination, both horizontal and vertical (i.e., spill-stained soil in a 5-foot radius to a depth of 1 inch): _____

_____

_____

Describe immediate spill control and/or cleanup methods used and implementation schedule: _____

_____

Current status of cleanup actions:_____

Name and Company for the following:

Construction Superintendent:_____

_____

Spill Coordinator:_____

_____

Environmental Inspector:_____

Person Who Reported the Spill:_____

_____

Environmental Inspector:_____

Form completed by:_____Date:_____

Spill Coordinator must complete this for all spills, regardless of size, and submit the form to the Environmental Inspector within 24 hours of the occurrence.

ATLANTIC COAST PIPELINE, LLC
ATLANTIC COAST PIPELINE

and

DOMINION TRANSMISSION, INC.
SUPPLY HEADER PROJECT

Spill Prevention, Control, and Countermeasure Plan

ATTACHMENT B
Site-Specific Descriptions and Maps Depicting Locations of Fixed and Mobile Oil Containers and Type of Material Located within Containers

(to be provided by the Contractors prior to construction)

ATLANTIC COAST PIPELINE, LLC
ATLANTIC COAST PIPELINE

Response to Virginia Department of Environmental Quality Request for Information for the Section 401 Water Quality Certification

APPENDIX F

Water Quality Monitoring Plan

ATLANTIC COAST PIPELINE, LLC
ATLANTIC COAST PIPELINE
Docket Nos. CP15-554-000 & CP15-554-001

Virginia Water Quality Monitoring Plan

June 2017

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LIST OF ACRONYMS AND ABBREVIATIONS

ACP	Atlantic Coast Pipeline
Atlantic	Atlantic Coast Pipeline, LLC
LOD	Limits of Disturbance
Project	Atlantic Coast Pipeline
QA/QC	Quality Assurance and Quality Control
TMDL	Total Maximum Daily Load
VAC	Virginia Administrative Code
VDEQ	Virginia Department of Environmental Quality
VSCI	Virginia Stream Condition Index

1.0 INTRODUCTION AND PURPOSE

This water quality monitoring plan has been prepared by Atlantic Coast Pipeline, LLC (Atlantic) for the Atlantic Coast Pipeline Project (ACP or Project) as requested by the Virginia Department of Environmental Quality (VDEQ) in its "Request for Information for Developing and Evaluating Additional Conditions for Section 401 Water Quality Certification for Interstate Natural Gas Infrastructure Project," dated May 19, 2017.

The purpose of the ACP water quality monitoring plan is to evaluate water quality prior to construction to establish baseline conditions above, directly adjacent to (generally within 50 feet of construction workspace, but not directly impacted), and below the project area of effect along streams that are adjacent to the planned pipeline construction corridor, and after construction within the same stream reaches (above, directly adjacent to, and below), to evaluate whether changes to water quality occurred as a result of ground disturbance from construction. Consistent with to the Request for Information from VDEQ, Atlantic focused on identifying waterbodies to sample according to categories outlined by VDEQ, as further described below.

2.0 STREAM CRITERIA EVALUATED TO SELECT MONITORING LOCATIONS

This water quality monitoring plan relates to perennial surface waters adjacent to the ACP proposed limits of disturbance (LOD) that are not crossed by the Project, and requires sampling in waterbodies that are:

- designated as wild/stocked trout streams or connected perennial tributaries;
- identified as waterbodies with potential for endangered/threatened species, or connected perennial tributaries;
- designated for public water supply (defined as anything within five miles of a public water intake that occurs in the same local watershed as the Project);
- classified as Tier 3 streams;[1]
- within a watershed that is subject to an established total maximum daily load (TMDL), including sediment, nutrients, and related impairments;
- within areas with geologic formations with potential for forming acid producing soils; and
- located where site access has been granted by the landowner or can be gained through public points of access.

[1] There are no Tier 3 waters crossed or directly adjacent to the ACP LOD.

3.0 STREAMS TO BE MONITORED

Applying the criteria in Section 2.0 Atlantic has identified streams for monitoring, as listed in Table 3.0-1. Only streams where landowner access or public access is available have been proposed. After determining the streams that are directly adjacent to the Project, and evaluating these streams according to the categories outlined in Section 2.0, the following selection criteria were developed to determine the streams to be monitored:

- only perennial streams were considered to ensure that flow would be present to collect data for the necessary monitoring parameters;
- a minimum of one stream for each category of stream, where available, was selected;
- an attempt was made to select streams that met more than one of the criteria (e.g., were both within a watershed with an established TMDL for sediment and/or nutrients and potential for endangered, threatened and special concern species water);
- streams were reviewed to provide general coverage for distribution along the Project in Virginia; and
- streams which were listed only due to a TMDL for bacteria, or for impairments of elevated chemicals in fish tissue were not considered due to the fact that the Project is not expected to cause or contribute to such impairments.

TABLE 3.0-1

Perennial Waterbody Monitoring Locations

Stream ID	Route ID	Milepost	Waterbody Name	Waterbody Category [a]
shiy001	AP-1	86.9	Ewing Draft	TMDL, Trout
sbar007	AP-1	103.1	UNT to Mill Creek	TMDL, Connected Trib. to T&E
saur001	AP-1	109.1	UNT to Guy Hollow	TMDL, Acid
sauc114	AP-1	148.1	South River	TMDL, Public Intake Watershed (upstream), T&E
saua400	AP-1	157.2	UNT to South Fork Back Creek	TMDL, Trout
scuk003	AP-1	213.2	UNT to Little Willis River	TMDL
spek003	AP-1	220.8	UNT to Appomattox River	TMDL, Public Intake Watershed (upstream), Connected Trib. to T&E

[a] Waterbody categories include:

TMDL -	Occurs in a watershed with an established TMDL for sediment or nutrient related impairment.
T&E -	Potential for federally listed threatened or endangered species. Connected Trib, is a tributary that has direct surface water connection.
Acid -	Occurs within geologic unit containing potentially significant acid-producing sulfide minerals.
Public Intake -	Occurs within a local watershed with a public water surface intake within 5 miles of the Project.
Trout -	Naturally occurring or stocked trout waters.

Maps depicting the recommended seven streams and associated upstream, adjacent, and downstream monitoring locations are included in Appendix A. A table including latitude, longitude, and distance from the Project workspace is included as an inset with each map included in Appendix A. Atlantic will utilize these locations as baseline points from which to select more refined field determined sampling locations. Once adjustments are made during the

first visits, based on stream morphology, access, depth of water, and other site-specific parameters, the locations will be located via GPS for replication during subsequent site visits.

4.0 MONITORING PARAMETERS

Table 4.0-1 provides the recommended monitoring parameters for chemical, physical, and biological parameters.

TABLE 4.0-1

Monitoring Parameters

Chemical Parameters
Temperature
Dissolved Oxygen
Specific conductance
pH
Turbidity (NTU's)
Physical Parameters
Photo documentation , general observations
Biological Monitoring
Family-level macroinvertebrate monitoring

Monitoring of the chemical parameters will take place above, directly adjacent, and below the Project area of effect along the selected stream segments that are adjacent to the disturbed pipeline construction corridor. Chemical parameter monitoring will occur where project or public access is available (i.e., waterbodies on properties where land access has been denied will not be proposed for monitoring).

Photo documentation of physical parameters will occur at all three sample locations, where the chemical parameter sampling occurs. Photos will be taken to document the view across, upstream, and downstream from the sampling locations. VDEQ approved monitoring methods for biological monitoring (i.e., benthic macroinvertebrates) requires that a 300-foot reach should be sampled both above and below the adjacent project area of effect. Similar to chemical sampling locations, project access or public access will be required to conduct the biological sampling.

5.0 MONITORING SCHEDULE

Atlantic will conduct three monitoring events, separated by a minimum of a week for chemical and physical parameters as outlined in Section 4.0 at each site prior to construction, once during active construction, and once after stabilization (i.e., seeding and mulching of the construction right-of-way). For the biological monitoring (benthic parameter), sampling will occur at least one month before and after construction during either the fall or spring index period[2]. Atlantic will notify a point of contact, to be assigned by VDEQ, in advance of pre-

[2] The spring index period is defined as March 1 through May 31; the fall index period is defined as September 1 through November 30.

construction monitoring events, which will provide VDEQ an opportunity to coordinate requested site visits for quality assurance review, as agreed by both parties.

6.0 MONITORING METHODOLOGY

Sampling of chemical and physical parameters will be performed in-situ; as several of the chemical parameters being measured are physically or chemically unstable and collection of samples for laboratory analysis is not proposed. Examples of unstable paramenters include pH, temperature, and dissolved oxygen.

Biological sampling will be performed in the field with laboratory analysis (i.e., sample sorting and identification) as necessary to follow VDEQ sampling protocols. The sampling and laboratory analyses will be completed under the supervision of scientists with Scientific Collectors Permits and experienced in the performance the Virginia Stream Condition Index (VSCI) analytical methodology and the U.S. Environmental Protection Agency (EPA) Rapid Bioassessment Protocols (RBPs) for both field and laboratory analysis. Atlantic has identified Civil and Environmental Consultants, Inc (CEC) and REI Consultants as companies with labs and individuals with experience in macroinvertebrate sampling and identification, with appropriate qualifications in Virginia. One of these companies, or a similarily qualified lab, will be contracted to complete the laboratory identification of macroinvertebrates.

The sampling parameters will be recorded as shown in Table 6.0-1.

TABLE 6.0-1

Sampling Methodology

Chemical Parameters	Sampling Equipment
Temperature	YSI 556 PRO PLUS Multi Probe System, or similar
Dissolved Oxygen	YSI 556 PRO PLUS Multi Probe System, or similar
Specific conductance	YSI 556 PRO PLUS Multi Probe System, or similar
pH	YSI 556 PRO PLUS Multi Probe System, or similar
Turbidity (NTU's)	LaMotte 2020we/wi Turbidimeter, Hanna Instruments HI 98703Turbidimeter, or similar
Physical Parameters	
Photo documentation, general observations	Camera and GPS location. Photos will have unique ID, date, and GPS coordinates. Photo stations will be located with GPS coordinates. General observations will also be recorded (i.e., weather, stream conditions)
Biological Parameters	
Family-level macroinvertebrate monitoring	*EPA's Rapid Bioassessment Protocol* [1] *and A Stream Condition Index for Virginia Non-Coastal Stream* [2]

[1] Barbour, M.T., J. Gerritsen, and B.D. Snyder and J.B. Stribling. 1999. Rapid bioassessment protocols for use in streams and rivers; periphyton, benthic macroinvertebrates, and fish 2nd edition. U.S. https://cfpub.epa.gov/watertrain/pdf/modules/rapbioassess.pdf

[2] Tetra Tech, Inc. 2003. A Stream Condition Index for Virginia Non-Coastal Streams. Tetra Tech, Inc. Owings Mills, Maryland. Prepared for Virginia Department of Environmental Quality, Richmond, Virginia. http://www.deq.virginia.gov/Portals/0/DEQ/Water/WaterQualityMonitoring/BiologicalMonitoring/vsci.pdf

Biologists will collect the following information at each sampling location:

- Field water chemistry measuresments as outlined in Table 6.0-1;

- Duplicate chemical sampling will be collected by two staff collecting samples at the same time and location using separate equipment to validate each measurement;
- Photographs of the benthic sampling locations (views upstream, downstream, and across the stream channel); and
- Latitude/longitude coordinates recorded using a Trimble GeoXH GPS unit of the sampling locations.

7.0 HANDLING AND ANALYTICAL QA/QC PROCEDURES

The field equipment used to collect chemical parameter measurements will be operated and calibrated in accordance with manufacturer specifications, or according to the best professional judgment of the staff collecting the field sample measurements. A multi-parameter water quality meter, similar to the YSI Professional Plus and YSI 556 Multi-Probe System, will be used and programed to measure for pH, temperature, dissolved oxygen, and specific conductivity. A portable turbidimeter, similar to the LaMotte 2020we/wi or Hanna Instruments HI 98703 turbidimeter, will be used to measure for turbidity. The manufacturer specifications that will be used to operate and calibrate the proposed field equipment are included in Appendix B. Appendix B also includes a Calibration Work Sheet and Directions that summarizes how the proposed field equipment will be calibrated.

At a minimum, field equipment will be calibrated daily prior to commencement of field measurement activities according to the manufacturer specifications and Calibration Work Sheet and Directions included in Appendix B. The standards that will be used for calibrating the equipment are also detailed in the manufacturer specifications included in Appendix B. Equipment calibration data will be maintained in a log similar to the log included in Appendix C.

In addition, to address quality assurance/quality control (QA/QC) concerns, all chemical parameter measurements will be taken via independent simultaneous sampling. Two staff members with the same make and model of equipment will perform the field sample measurements simultaneously to validate that the results are accurate between calibrated equipment. This protocol will also guard against unexpected equipment failures.

Biological sampling, sorting, identification, and reporting will be conducted by qualified biologists, as outlined in Table 6.0-1. Handling of samples, macroinvertebrate identification in the laboratory and reporting will be completed under the direction of the qualified biologist and according to standards following the methods that meet the requirements of the VDEQ Quality Assurance Project Plan and Standard Operating Procedures document dated August 13, 2008[3], and entitled "Biological Monitoring Program Quality Assurance Project Plan for Wadeable Streams and Rivers.

In order to address QA/QC concerns, the contracted laboratory completing the identification of macroinvertebrates, will provide the VDEQ a randomly selected set of

[3] Virginia DEQ Quality Assurance Project Plan and Standard Operating Procedures August 13, 2008, accessed June 2017 at:
http://www.deq.virginia.gov/Portals/0/DEQ/Water/WaterQualityMonitoring/BiologicalMonitoring/BioMonQAPP_13Aug2008.pdf

preserved species from the collected benthic samples to process and document the performance of the biologist sampling team. In addition, field notes will be taken by the biologist sampling team to document sampling observations, procedures, and any unique events that that occur.

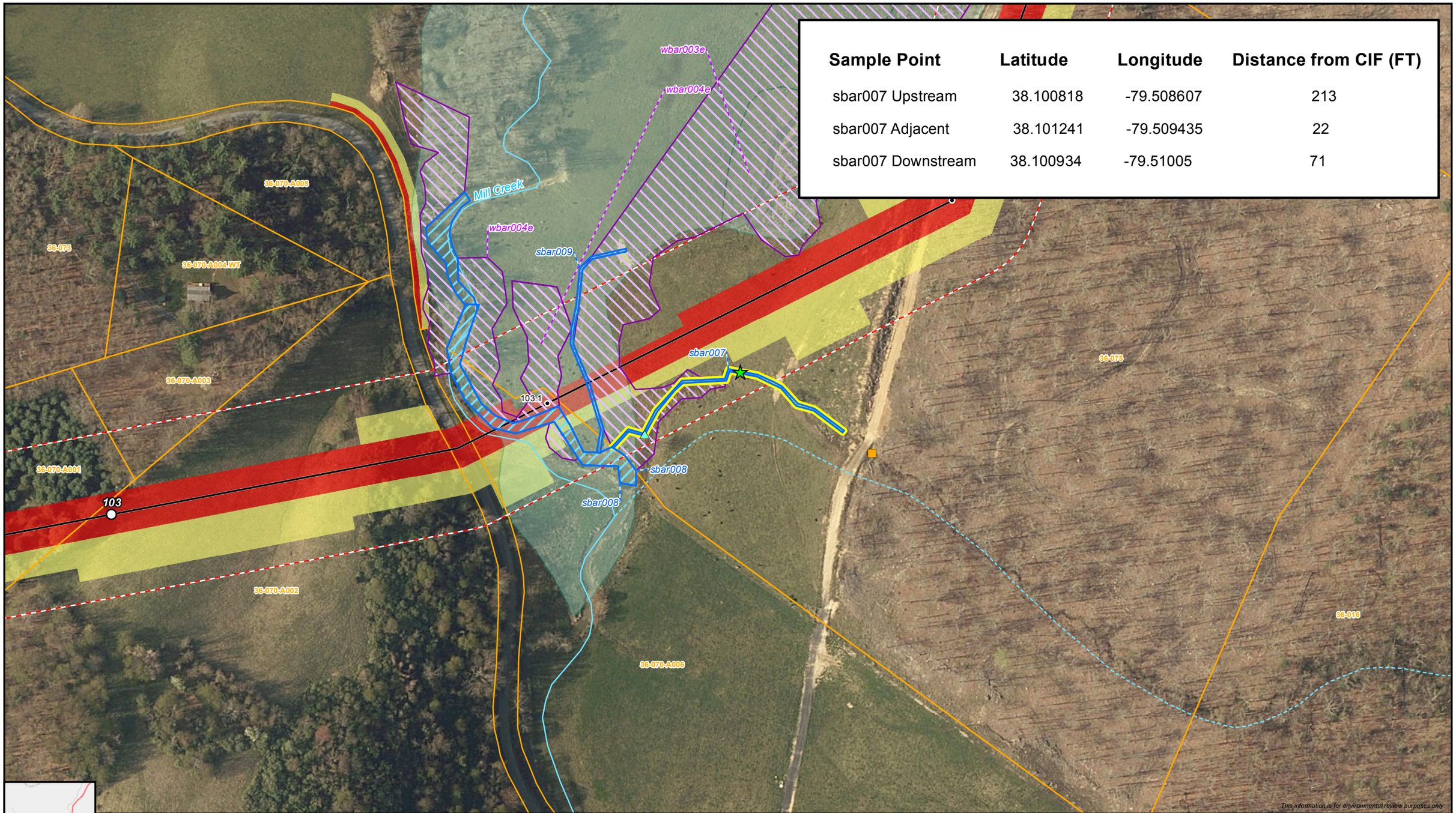
8.0 REPORTING PROCEDURES

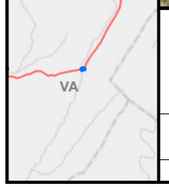
Within four weeks of completing each sampling event the data (chemical parameter sampling results, bench sheets, metrics, and Virginia Stream Condition Index (VSCI) scores) will be provided to VDEQ in electronic format via email. All data will be provided in PDF and Microsoft Excel file formats. Photographic information will be provided in a PDF and Microsoft Word file formats. VDEQ is requested to specify the recipients of the email information. Emails will be sent with a "read receipt" to confirm delivery.

Appendix A

Map Set of Monitoring Locations

Sample Point	Latitude	Longitude	Distance from CIF (FT)
sbar007 Upstream	38.100818	-79.508607	213
sbar007 Adjacent	38.101241	-79.509435	22
sbar007 Downstream	38.100934	-79.51005	71





0 80 160
Feet

1:2,000 | 1 inch = 167 feet

- Proposed Centerline
- Survey Corridor
- Milepost
- Tenth Milepost
- Parcel Boundary
- NHD Stream/River - Perennial
- NHD Stream/River - Intermittent
- NWI Wetland
- Subject Waterbodies
- Surveyed Waterbody
- Surveyed Wetland
- Permanent Workspace
- Temporary Workspace

Sampling Location

- Upstream from Construction
- Adjacent to Construction
- Downstream from Construction

Atlantic Coast Pipeline℠

Atlantic Coast Pipeline
Water Quality Monitoring Plans
UNT to Mill Creek Monitoring Site
Bath County, Virginia

ERM

M:\Clients\D-F\DOM\SRPP_ArcGIS\2017\05\26_Water_Monitoring_Loc_Maps\Water_Monitoring_Locations.mxd, **REVISED:** 6/9/2017

DRAWN BY: GIS

Sample Point	Latitude	Longitude	Distance from CIF (FT)
saur001 Upstream	38.201069	-79.421311	142
saur001 Adjacent	38.200728	-79.420424	74
saur001 Downstream	38.200351	-79.417622	130

07-001.AR1
07-001-F051
07-001-F029
saur001
saur003
109.1
109
saur006
109.2
saur002
waua408e
saua415
108.9
waua407e
This information is for environmental review purposes only.

VA
110

0 130 260
Feet

1:3,000
1 inch = 250 feet

- Proposed Centerline
- Survey Corridor
- Milepost
- Tenth Milepost
- Parcel Boundary
- NHD Stream/River - Intermittent
- NWI Wetland
- Subject Waterbodies
- Surveyed Waterbody
- Surveyed Wetland
- Permanent Workspace
- Temporary Workspace
- Access Roads

Sampling Location
- Upstream from Construction
- Adjacent to Construction
- Downstream from Construction

Atlantic Coast Pipeline℠

Atlantic Coast Pipeline
Water Quality Monitoring Plans
UNT to Guy Hollow Monitoring Site
Augusta County, Virginia

ERM

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Sample Point	Latitude	Longitude	Distance from CIF (FT)
sauc114 Upstream	38.019605	-78.99682	238
sauc114 Adjacent	38.018369	-78.995335	96
sauc114 Downstream	38.013265	-78.990797	110

0 180 360
Feet

1:4,000 | 1 inch = 333 feet

- Proposed Centerline
- Survey Corridor
- Milepost
- Tenth Milepost
- Parcel Boundary
- NHD Stream/River - Perennial
- NHD Stream/River - Intermittent
- NWI Wetland
- Subject Waterbodies
- Surveyed Waterbody
- Surveyed Wetland
- Permanent Workspace
- Temporary Workspace
- Access Roads

Sampling Location

- Upstream from Construction
- Adjacent to Construction
- Downstream from Construction

Atlantic Coast Pipeline

Atlantic Coast Pipeline
Water Quality Monitoring Plans
South River Monitoring Site
Augusta County, Virginia

ERM

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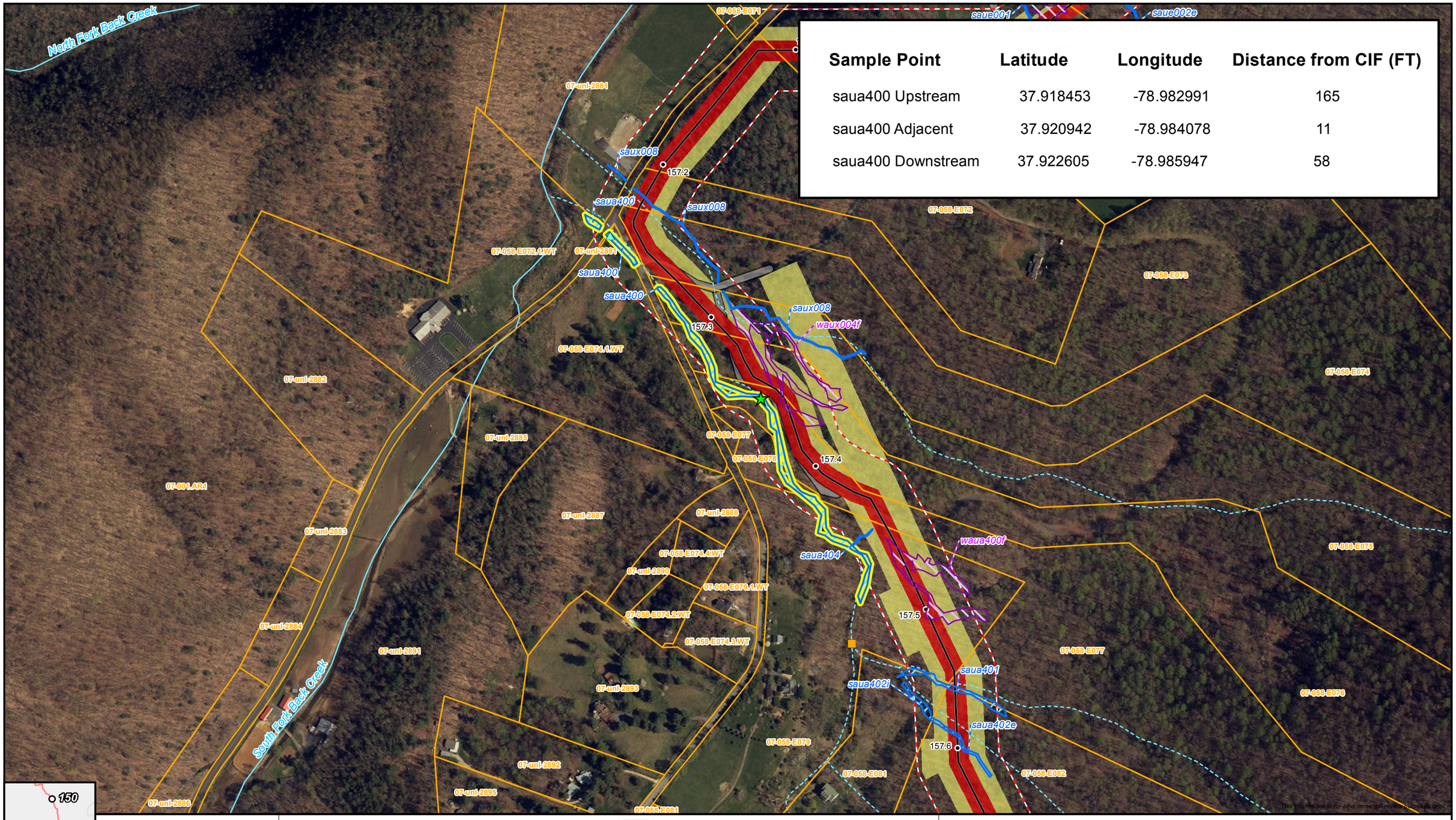
This information is for environmental review purposes only.

Sample Point	Latitude	Longitude	Distance from CIF (FT)
saua400 Upstream	37.918453	-78.982991	165
saua400 Adjacent	37.920942	-78.984078	11
saua400 Downstream	37.922605	-78.985947	58



Atlantic Coast Pipeline
Water Quality Monitoring Plans
UNT to South Fork Back Creek Monitoring Site
Augusta County, Virginia

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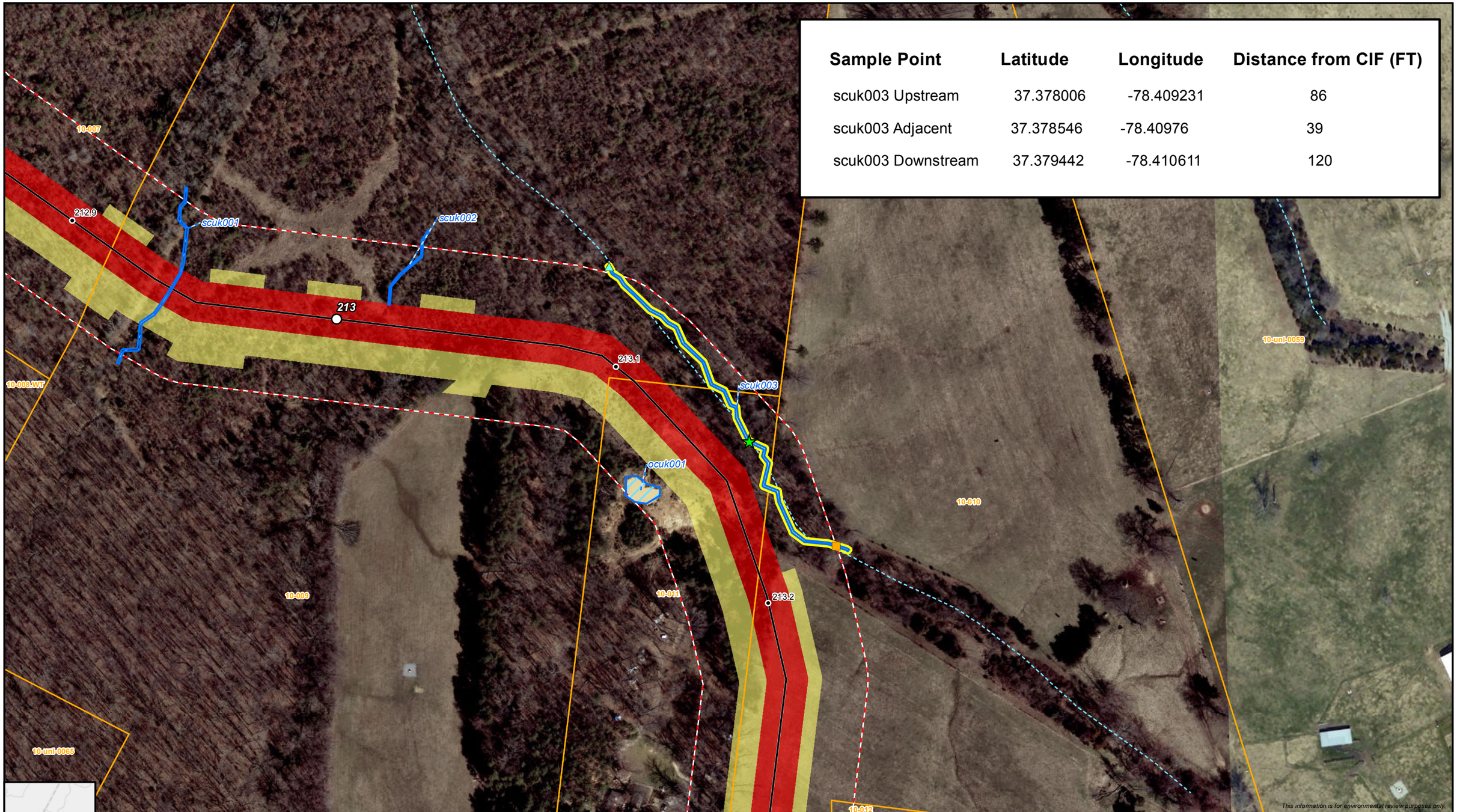
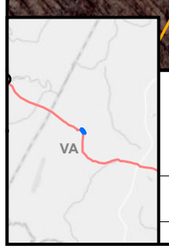
Sample Point	Latitude	Longitude	Distance from CIF (FT)
scuk003 Upstream	37.378006	-78.409231	86
scuk003 Adjacent	37.378546	-78.40976	39
scuk003 Downstream	37.379442	-78.410611	120





0 80 160
Feet

1:2,000 | 1 inch = 167 feet

- Proposed Centerline
- Survey Corridor
- Milepost
- Tenth Milepost
- Parcel Boundary
- NHD Stream/River - Intermittent
- Subject Waterbodies
- Surveyed Waterbody
- Permanent Workspace
- Temporary Workspace

Sampling Location

- Upstream from Construction
- Adjacent to Construction
- Downstream from Construction

Atlantic Coast Pipeline℠

Atlantic Coast Pipeline
Water Quality Monitoring Plans
UNT to Little Willis River Monitoring Site
Cumberland County, Virginia

ERM

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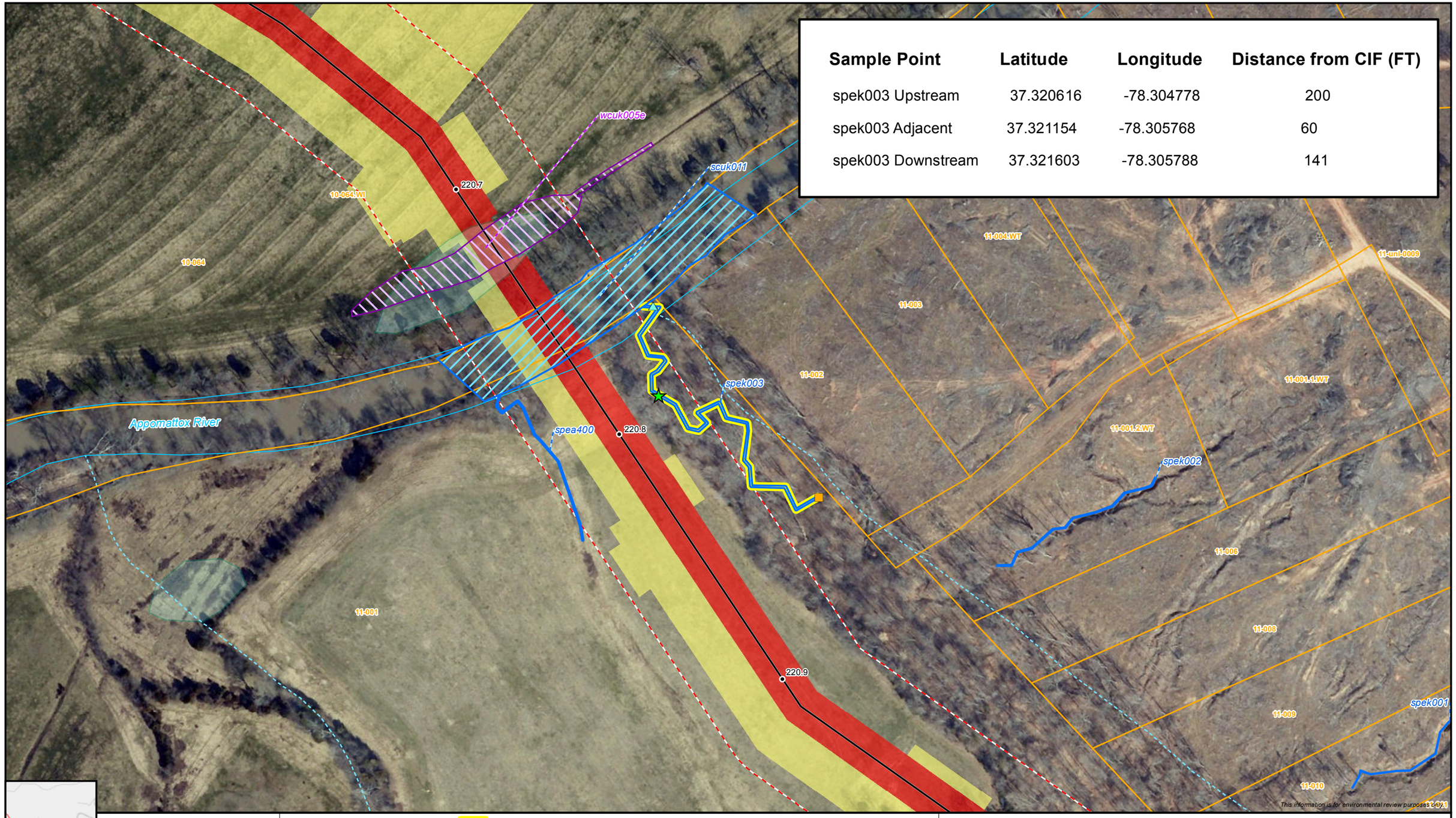
Sample Point	Latitude	Longitude	Distance from CIF (FT)
spek003 Upstream	37.320616	-78.304778	200
spek003 Adjacent	37.321154	-78.305768	60
spek003 Downstream	37.321603	-78.305788	141



0 80 160
Feet

1:2,000 | 1 inch = 167 feet

- Proposed Centerline
- Survey Corridor
- Tenth Milepost
- Parcel Boundary
- NHD Stream/River - Intermittent
- NWI Wetland
- Subject Waterbodies
- Surveyed Waterbody
- Surveyed Wetland
- Permanent Workspace
- Temporary Workspace

Sampling Location
- Upstream from Construction
- Adjacent to Construction
- Downstream from Construction

Atlantic Coast Pipeline
Water Quality Monitoring Plans
UNT to Appomattox River Monitoring Site
Prince Edward County, Virginia

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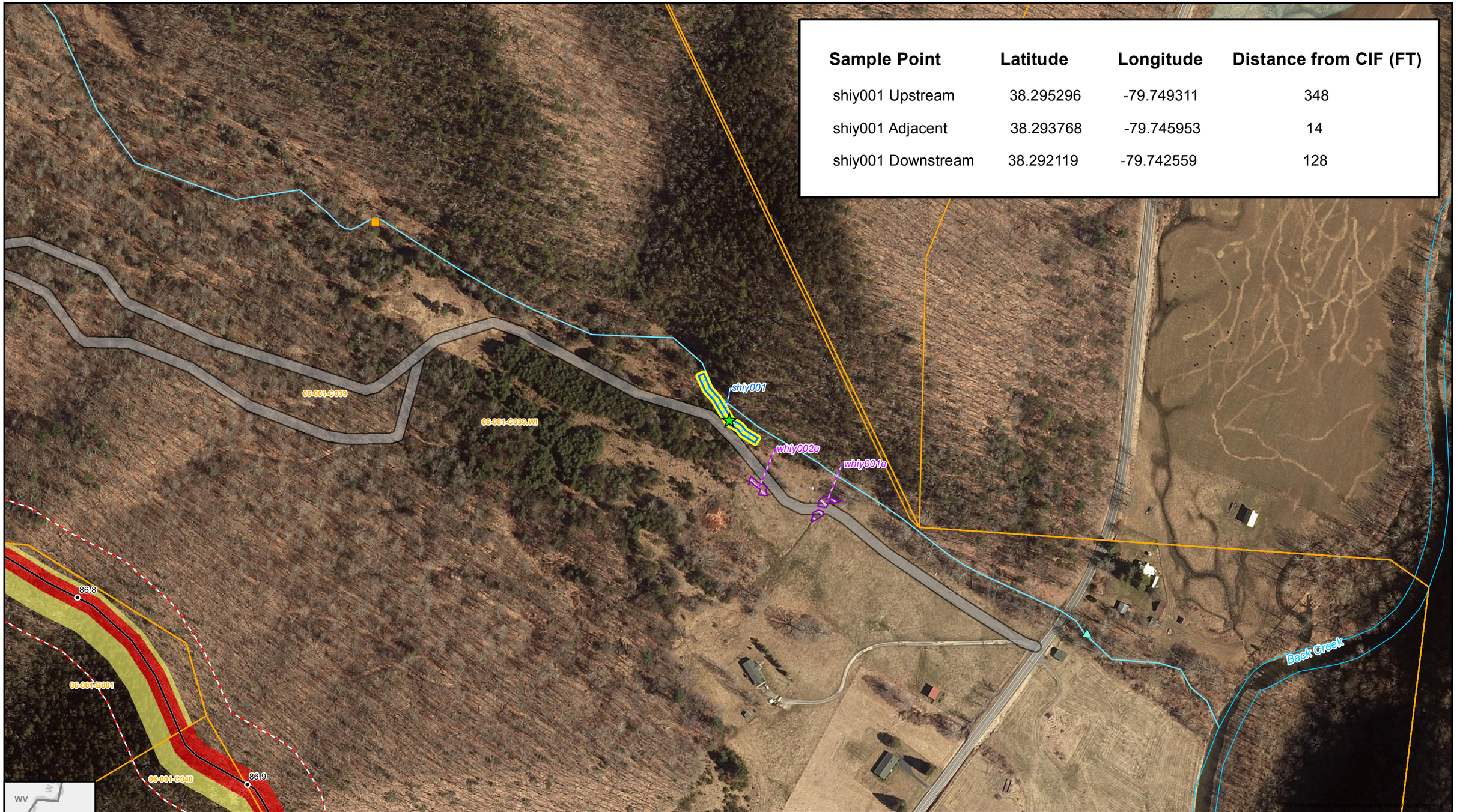
Sample Point	Latitude	Longitude	Distance from CIF (FT)
shiy001 Upstream	38.295296	-79.749311	348
shiy001 Adjacent	38.293768	-79.745953	14
shiy001 Downstream	38.292119	-79.742559	128



0 130 260
Feet

1:3,000 | 1 inch = 250 feet

- Proposed Centerline
- Survey Corridor
- Tenth Milepost
- Parcel Boundary
- NHD Stream/River - Perennial
- NWI Wetland
- Subject Waterbodies
- Surveyed Waterbody
- Surveyed Wetland
- Permanent Workspace
- Temporary Workspace
- Access Roads

Sampling Location
- Upstream from Construction
- Adjacent to Construction
- Downstream from Construction

Atlantic Coast Pipeline
Water Quality Monitoring Plans
Ewing Draft Monitoring Site
Highland County, Virginia

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Appendix B

Field Equipment Manufacturer Specifications & Calibration Work Sheet and Directions

YSI®

Professional *Plus*

USER MANUAL

Item # 605596
Rev D
Drawing # A605596
March 2009

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WARRANTY

The YSI Professional Plus Instrument (Pro Plus) is warranted for three (3) years from date of purchase by the end user against defects in materials and workmanship, exclusive of batteries and any damage caused by defective batteries. Pro Plus field cables are warranted for two (2) years from date of purchase by the end user against defects in material and workmanship (6 months for non-field rugged cables*). Pro Plus sensors (pH, ORP, pH/ORP combo, Polarographic DO) are warranted for one (1) year from date of purchase by the end user against defects in material and workmanship (6 months for ammonium**, nitrate**, chloride**, and Galvanic DO). Pro Plus systems (instrument, cables & sensors) are warranted for 90 days from date of purchase by the end user against defects in material and workmanship when purchased by rental agencies for rental purposes. Within the warranty period, YSI will repair or replace, at its sole discretion, free of charge, any product that YSI determines to be covered by this warranty.

To exercise this warranty, call your local YSI representative, or contact YSI Customer Service in Yellow Springs, Ohio at +1 937 767-7241, 800-897-4151 or visit www.YSI.com (Support tab) for a Product Return Form. Send the product and proof of purchase, transportation prepaid, to the Authorized Service Center selected by YSI. Repair or replacement will be made and the product returned, transportation prepaid. Repaired or replaced products are warranted for the balance of the original warranty period, or at least 90 days from date of repair or replacement.

LIMITATION OF WARRANTY

This Warranty does not apply to any YSI product damage or failure caused by:

1. failure to install, operate or use the product in accordance with YSI's written instructions;
2. abuse or misuse of the product;
3. failure to maintain the product in accordance with YSI's written instructions or standard industry procedure;
4. any improper repairs to the product;
5. use by you of defective or improper components or parts in servicing or repairing the product;
6. modification of the product in any way not expressly authorized by YSI.

THIS WARRANTY IS IN LIEU OF ALL OTHER WARRANTIES, EXPRESSED OR IMPLIED, INCLUDING ANY WARRANTY OF MERCHANTABILITY OR FITNESS FOR A PARTICULAR PURPOSE. YSI's LIABILITY UNDER THIS WARRANTY IS LIMITED TO REPAIR OR REPLACEMENT OF THE PRODUCT, AND THIS SHALL BE YOUR SOLE AND EXCLUSIVE REMEDY FOR ANY DEFECTIVE PRODUCT COVERED BY THIS WARRANTY. IN NO EVENT SHALL YSI BE LIABLE FOR ANY SPECIAL, INDIRECT, INCIDENTAL OR CONSEQUENTIAL DAMAGES RESULTING FROM ANY DEFECTIVE PRODUCT COVERED BY THIS WARRANTY.

* The warranty period for the non-field rugged cables (605107, 605177, 605108, 605178, 605109, 605179) is listed as 6 months. However, the true "working life" of these sensors may be 3-9 months depending on storage and usage in solutions other than clean aqueous samples.

** The warranty for the ammonium, nitrate, and chloride sensors (605104, 605105, 605106) is listed as 6 months. However, the true "working life" of these sensors may be 3-9 months depending on storage and usage in solutions other than clean aqueous samples.

INTRODUCTION

Thank you for purchasing the YSI Professional Plus (Pro Plus). The Pro Plus features a waterproof (IP-67) case, backlit display and keypad, user-selectable cable options, USB connectivity, large memory with extensive site list capabilities, and a rugged, rubber over-molded case.

Reading the entire manual before use is recommended for an overall understanding of the instrument's features.

GETTING STARTED

INITIAL INSPECTION

Carefully unpack the instrument and accessories and inspect for damage. Compare received parts with items on the packing list. If any parts or materials are damaged, contact YSI Customer Service at 800-897-4151 (+1 937 767-7241) or the authorized YSI distributor from whom the instrument was purchased.

BATTERY INSTALLATION

The Pro Plus requires (2) alkaline C-cell batteries which are included with the purchase of a new instrument. Battery life depends on parameters and usage. Under normal conditions, battery life is approximately 80 hours for continuous use at room temperature. To install or replace the batteries:

1. Turn the instrument over to view the battery cover on the back.
2. Unscrew the four captive battery cover screws.
3. Remove the battery cover and install the new batteries, ensuring correct polarity alignment on the instrument or the removed cover. (Figure 1)
4. Replace the battery cover on the back of the instrument and tighten the four screws. Do NOT over-tighten.

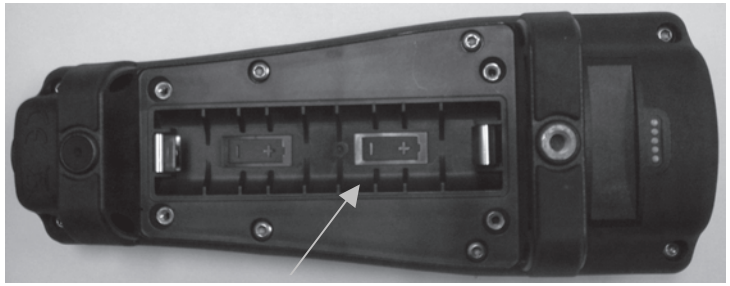


Figure 1. Pro Plus with battery cover removed. Notice battery symbols indicating polarities.

Batteries must be installed in the instrument even if powering the unit via the USB connection. This will retain the correct date and time if the PC is turned off. If the USB power is disconnected and there are no batteries in the instrument, the date and time will need to be reset upon subsequent power on.

NOTE - On subsequent battery changes you will have approximately 2 minutes to change the batteries before the clock resets. If the clock resets, the instrument will automatically bring up the Date/Time menu the next time it is powered on in order to update this information. This is important, especially if you intend to log data!

SETUP

The Pro Plus instrument has several compatible field-rugged cable/sensor options, each with temperature:

Cable:	*Available Sensors:*
Cable number 60520-x	DO/temp (605780 for lab BOD)
Cable number 60530-x	Conductivity/temp
Cable number 60510-x	ISE*/temp
Cable number 6051010-x	ISE*/ISE*/temp
Cable number 6051020-x	ISE*/DO/temp
Cable number 6051030-x	ISE*/conductivity/temp
Cable number 6052030-x	DO/conductivity/temp
Cable number 605790-x	DO/conductivity/ISE*/ISE*/temp (Quatro**)

*ISE (Ion Selective Electrode) notates a port that can accept pH, ORP, Ammonium, Nitrate, Chloride, and, in some cases, a pH/ORP combination sensor.

**Cable 605790 will be referred to as a Quatro cable throughout this manual.

All cables come in standard lengths of 1, 4, 10, 20, and 30-meters (3.28, 13, 32.8, 65.6, and 98.4-feet) with options for special order lengths up to 100-meters (328-feet) on the 60520-x cables. Contact YSI or your local representative for additional information.

In addition there are several cable options with built in sensors for the measurement of pH and ORP that are not considered field-rugged (non-replaceable sensors, less rugged single-junction sensors). These cables are recommended for lab use or controlled conditions where a more rugged, field cable is not necessary. These cables include:

Cable number 605107	1-meter cable; single-junction pH sensor
Cable number 605177	4-meter cable; single-junction pH sensor
Cable number 605108	1-meter cable; single-junction ORP sensor
Cable number 605178	4-meter cable; single-junction ORP sensor
Cable number 605109	1-meter cable; single-junction pH/ORP sensors
Cable number 605179	4-meter cable; single-junction pH/ORP sensors

STANDARD PRO SERIES SENSOR INSTALLATION

Throughout the manual, the term "sensor" refers to the removable portion or electrode sensing portion of the cable assembly. For example, the DO sensor or pH sensor is the part that can be removed from a field cable and replaced with a new sensor. The conductivity sensor is not removable from a non-Quatro cable but still refers to the "sensing" portion and will be referred to as a sensor. This section covers most of the sensor installations on a Professional Series cable bulkhead including the following sensors:

2003 - Polarographic DO (black)	1001 - pH	1003 - pH/ORP	1005 - Chloride
2002 - Galvanic DO (gray)	1002 - ORP	1004 - Ammonium	1006 - Nitrate

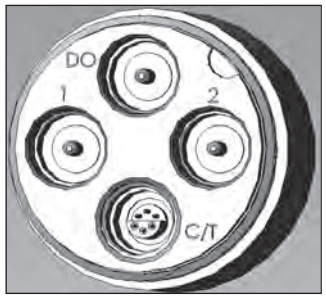
See the next section of this manual for installation instructions for the Quatro cable's Conductivity/Temperature sensor.

Dual sensor bulkhead ports are numbered 1 and 2, see figure to the left. Please refer to the following tables to determine correct sensor installation into each port of a two port cable.

	Port 1 Options	*Port 2 Options*
1010 dual cable	pH	pH
	ORP	ORP
	pH or pH/ORP*	pH or pH/ORP*
	ammonium	ammonium
	chloride	chloride
	nitrate	nitrate
		none (port plug)
* If using a 6051010 cable, a sensor must be installed in port 1 for correct operation. If you install a pH/ORP combo sensor into a 6051010 cable, ORP will not be measured. It is not recommended to use a pH/ORP combo sensor on a 6051010 cable.		

	Port 1 Options	*Port 2 Options*
1020 dual cable	pH	Polarographic DO
	ORP	Galvanic DO
	pH or pH/ORP	none (port plug)
	ammonium	
	chloride	
	nitrate	
	none (port plug)	
If using a 1020 cable, install a pH, ORP, pH/ORP, Ammonium, Nitrate or Chloride sensor in port 1 and a DO sensor in port 2.		

If using a 605103 pH/ORP combination probe on a 6051020 or 6051030 cable you can report both pH and ORP. However, it is recommended to set ISE1 as pH and ISE2 as ORP in the Sensor Setup menu.



The Quatro cable bulkheads are labeled 1, 2, DO, and CT, see figure to the left. All sensors except the Conductivity/Temperature sensor can be installed following the Standard Pro Series Sensor Installation instructions. Conductivity/Temperature sensor installation is described in the next section. For ease of installation, YSI recommends that you install a sensor into port 1 first; followed by DO installation, then port 2, and lastly C/T.

	Port 1 Options	*Port 2 Options*	*DO Port Options*	*CT Port Options*
Quatro Cable (pn: 605790)	pH	pH	Polarographic DO	5560 Conductivity/ Temperature sensor only
	ORP	ORP	Galvanic DO	
	pH or pH/ ORP*	pH or pH/ ORP*	none (port plug)	
	ammonium	ammonium		
	chloride	chloride		
	nitrate	nitrate		
		none (port plug)		
* If using a Quatro cable, a sensor must be installed in port 1 for correct operation of port 2. If you install a pH/ORP combo sensor into a Quatro cable, ORP will not be measured. It is not recommended to use a pH/ORP combo sensor on a Quatro cable.				

Before installing either dissolved oxygen sensor, the instrument must be configured for the sensor being installed. See the Setup - Dissolved Oxygen section of this manual for instrument configuration instructions. Failure to do this may result in damage not covered under warranty.

First, ensure both the sensor connector and sensor port on the cable are clean and dry. To connect the sensor, grasp the sensor with one hand and the sensor connection end of the cable (bulkhead) in the other. Push the sensor into the connector on the cable until it is properly seated and only one o-ring is visible. Failure to properly seat the probe may result in damage. Twist the sensor clockwise to engage threads and finger tighten (Figure 2). Do not use a tool. This connection is waterproof. Please refer to the sensor installation sheet that is included with each sensor for detailed instructions.

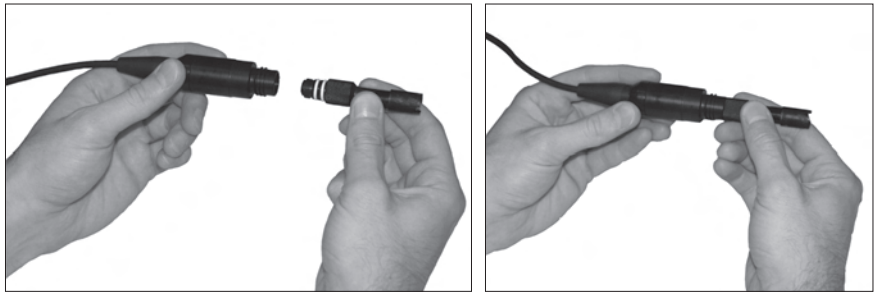


Figure 2. The image on the left shows a clean, dry sensor being aligned with the bulkhead. On the right, the sensor has been pushed into the bulkhead and is being screwed into place.

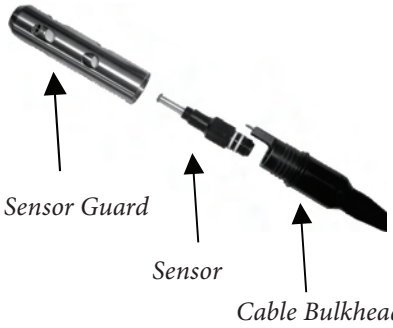


Figure 3. The sensor(s) will install directly in the cable bulkhead. Once installed, the sensor guard will protect the sensor during sampling (DO cap membrane not shown).

CONDUCTIVITY/TEMPERATURE SENSOR INSTALLATION IN A QUATRO CABLE

As mentioned, the installation of the Conductivity/Temperature sensor (model 5560) in a Quatro cable is different from all other Pro Series sensor installations. Follow these instructions when installing a conductivity/temperature sensor in a Quatro cable:

1. Locate the C/T port and, if replacing, remove the old sensor using the installation tool to loosen the stainless steel retaining nut. Once the stainless steel retaining nut has been completely unscrewed from the bulkhead, remove the old sensor from the bulkhead by pulling the sensor straight out of the bulkhead.
2. Apply a thin coat of o-ring lubricant (supplied with the sensor) to the o-rings on the connector side of the new sensor.

> ⓘ *Visually inspect the port for moisture. If moisture is found, it must be completely dried prior to sensor installation.*

3. Align the connectors of the new sensor and the port. With connectors aligned, push the sensor in towards the bulkhead until you feel the sensor seat in its port. You will experience some resistance as you push the sensor inward, this is normal
4. Once you feel the sensor seat into the port, gently rotate the stainless steel sensor nut clockwise with your fingers, Do not use the tool.
5. The nut must be screwed in by hand. If the nut is difficult to turn, STOP, as this may indicate cross threading. If you feel resistance or cross threading at any point, unscrew the nut and try again until you are able to screw the nut down completely without feeling any resistance. Damage to your cable/sensor may occur if you force the parts together.
6. Once completely installed, the nut will seat flat against the bulkhead. At this point, use the tool that was included with the sensor to turn the nut an additional ¼ to ½ turn so it cannot come loose (figure 4). DO NOT over tighten.

> ⓘ *Do not cross thread the sensor nut. Seat nut on face of bulkhead. Do not over tighten.*

Please refer to the sensor installation sheet that is included with the conductivity/temperature sensor for detailed instructions.

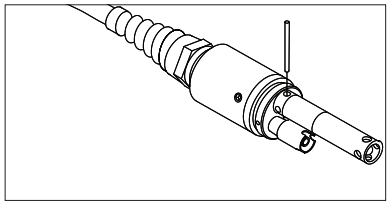


Figure 4. Installation tool used to tighten stainless steel retaining nut of 5560 conductivity/temperature sensor.

INSTALLING PORT PLUGS IN UNUSED PORTS

As necessary, install a port plug into any port that does not have an installed sensor. This will protect the bulkhead from water damage. Port plugs and a tube of o-ring lubricant are included with all Quatro cables. These items can be ordered separately if needed. To install a port plug, apply a thin coat of o-ring lubricant to the two o-rings on the port plug. After application, there should be a thin coat of o-ring lubricant on the o-rings. Remove any excess o-ring lubricant from the o-ring and/or port plug with a lens cleaning tissue. Next, insert the plug into an empty port on the bulkhead and press firmly until seated. Then, turn the plug clockwise to engage the threads and finger-tighten until the plug is installed completely. Do ***not*** use a tool to tighten the plug.

CONNECTING THE CABLE TO AN INSTRUMENT

To connect a cable, align the keys on the cable connector to the slots on the instrument connector. Push together firmly, then twist the outer ring until it locks into place (figure 5). This connection is water-proof.

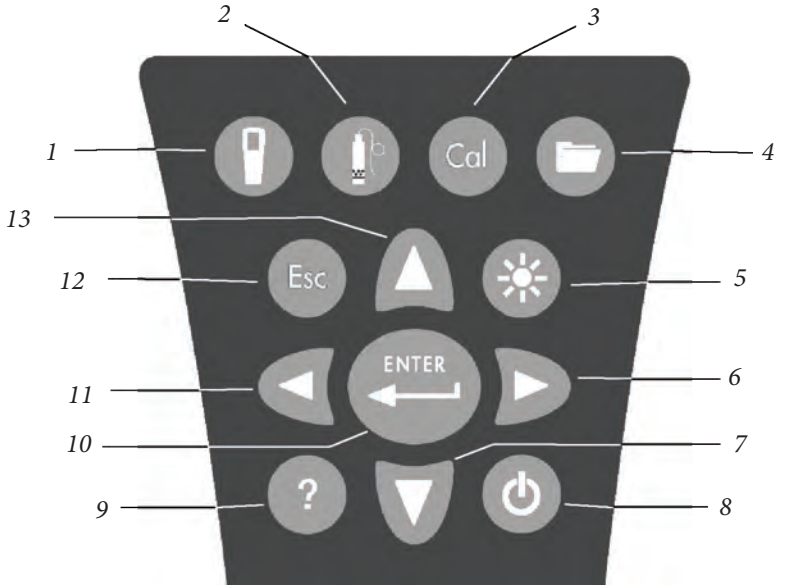
Figure 5. Note the keyed connector. The cable and instrument connectors can only be mated once the keys are properly aligned.

> *When a sensor is not installed, the sensor and cable sensor connectors are NOT water-proof. Do not submerge the cable without a sensor or port plug installed in all available ports.*
>
> *When the cable is disconnected, the cable's instrument connector and the connector on the instrument maintain an IP-67 rating.*

SENSOR STORAGE

The cable assembly is supplied with a storage container, or sleeve, that installs on to the cable. The container is used for short-term storage (less than 30 days). Be sure to keep a small amount of moisture (tap water) in the container during storage. This is done to maintain a 100% saturated air environment which is ideal for short-term sensor storage (see Care, Maintenance, and Storage for more detailed information). Do not submerge the sensors in an aqueous solution. The intent is to create a humid air storage environment.

KEYPAD

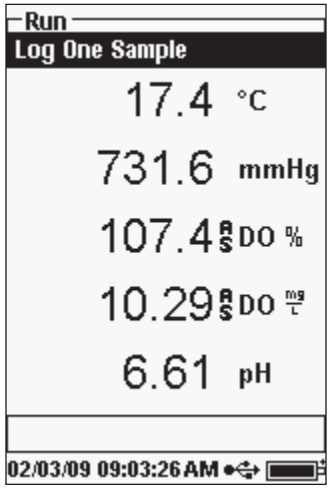


Number	*Key*	*Description*
1		**System** Opens System Menu from any screen. Use to adjust system settings.
2		**Sensor** Opens Sensor Menu from any screen. Use to enable sensors and display units.
3	Cal	**Calibrate** Opens Calibrate Menu from any screen. Use to calibrate all parameters except temperature.
4		**File** Opens File Menu from any screen. Use to view data and GLP files, set up site and folder lists, and delete data.
5		**Backlight** Press to turn the instrument backlight on and off and to adjust the display contrast when pressed with the left or right arrow key.

Number	Key	Description
6		**Right Arrow** Use to navigate right in alpha/numeric entry screens. Can be pressed simultaneously with Backlight key to increase display contrast.
7		**Down Arrow** Use to navigate through menus and to navigate down in alpha/numeric entry screens.
8		**Power** Press to turn the instrument on. Press and hold for 3 seconds to turn off.
9		**Help** Press to receive hints & tips during operation.
10	ENTER	**Enter** Press to confirm selections, including alpha/numeric key selections.
11		**Left Arrow** Use to navigate left in alpha/numeric entry screens. Press to return to previous menu in all screens except alpha/numeric entry. Can be pressed simultaneously with Backlight key to decrease display contrast.
12	Esc	**Exit/Escape** Exits back to Run Screen. When in alpha/numeric entry screen, escapes to previous menu.
13		**Up Arrow** Use to navigate through menus and to navigate up in alpha/numeric entry screens.

MAIN DISPLAY

Press the Power key to turn the instrument on. The instrument will briefly display the splash screen with the YSI logo then go directly to the main run screen. The first time the instrument is powered up or if the instrument has had a battery change (with batteries removed for more than 2 minutes), you will need to set the date and time. Follow the instructions under **System Menu | Date/Time**.



The display at the left shows the run mode (main display) with temperature in °C, barometer in mmHg, DO in % and mg/L, and pH as the reported parameters. The date, time and battery level are indicated at the bottom of the screen. The logging preference of Log One Sample at a time is indicated at the top of the screen.

This screen also shows the message line towards the bottom of the display above the date and time. In this case, it doesn't show a message but messages will appear frequently to indicate calibration steps, set date and time, etc.

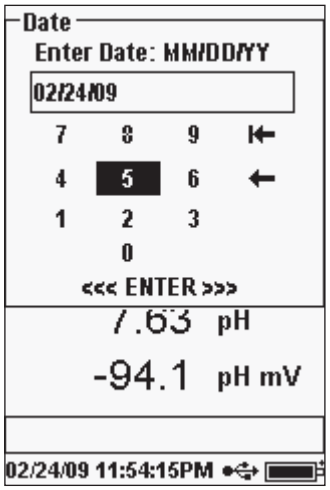
A USB symbol will show up on the bottom of the display when connected to a PC through USB with the communications saddle. The instrument will display full battery power when it is receiving power through the USB connection.

> ***Contrast*** *– the contrast adjustment can be accomplished by pressing the backlight key and the left or right arrow key at the same time.*

MENU LAYOUT

Press Esc at anytime in the menus to escape back to the Run screen. The left arrow can be used to go back to the previous menu in all screens except alpha/numeric entry screens. You must use Esc to get out of the alpha/numeric screens if you want to exit before finishing or without saving changes. Functions that are enabled appear as a circle with a dot ⊙ or a box with a check mark ☑. Disabled functions appear as a circle only ○ or an empty ☐.

ALPHA/NUMERIC ENTRY



The numeric screens will display numbers only (shown on the left). Alpha/numeric screens will display numbers across the top and letters along the bottom rows (shown on the right). Letters appear as a common keyboard arrangement.

When an alpha or numeric character is required, the screen will show the alpha/numeric entry screen. To select a character, highlight it by using the arrow keys to move the highlight box over the desired selection. Then, press **Enter** on the keypad to confirm the selection. After confirming the selection, it will appear in the line at the top of the display.

For capital letters or lower case entry, highlight "SHIFT" and press **Enter** on the keypad to change the characters from upper to lower case.

To delete the entire line of the current entry, highlight ⇤ and press **Enter** on the keypad. The ← symbol functions as a backspace key in the alpha/numeric entry screens by deleting one character at a time. Use the "SPACE" function to add a space between characters.

When you have finished entering the correct information (16 character max), highlight <<<ENTER>>> at the bottom of the screen and press **Enter** on the keypad to confirm.

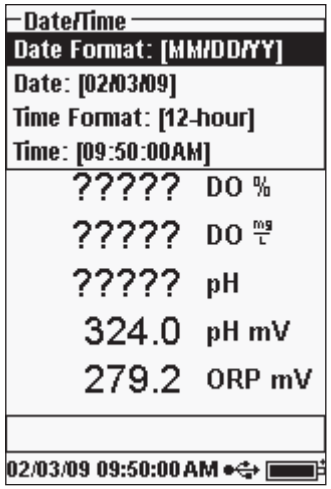
> *The ◀ key cannot be used to escape to the previous menu from an alpha/numeric entry screen. Instead, use the Esc key to go back to the previous menu when in alpha/numeric entry screens.*

SYSTEM MENU

Press System to access any of the following menu items.

The System menu will allow you to access the setup options of the instrument including; **Date/Time**, **GLP**, **Language**, **Radix Point**, **Logging**, **Auto-Shutoff**, **Backlight**, **SW** (Software) **Version**, **Serial #**, and **Unit ID**. Any item with [brackets] shows the current setting inside the brackets. For instance, in the example at the left, Radix Point is currently set to [Decimal]. The brackets will also give a quick visual clue as to what items can be changed.

DATE/TIME



Highlight **Date/Time** from the **System** menu. Press enter to select.

Date Format – Highlight and press enter to open a sub menu for selecting the preferred date format: YY/MM/DD, MM/DD/YY, DD/MM/YY, or YY/DD/MM.

Date – Highlight and press enter to use the numeric entry screen to set the correct date.

Time Format – Highlight and press enter to open a submenu to select the preferred time format from 12-hour or 24-hour.

Time – Highlight and press enter to use the numeric entry screen to set the correct time.

> *The date and time will need to be reset if a battery change takes longer than 2 minutes. When this occurs, the Date/Time menu will automatically appear upon power up and require you to set the date and time.*

GLP

The GLP or 'Good Laboratory Practice' file saves detailed information about calibrations. It also includes diagnostic information about the sensors. Calibrations are logged into a file, the GLP, for later review as needed. A single GLP file is utilized to store all calibration records and is capable of storing 500 records. Once the GLP file is full, the instrument will begin to overwrite the oldest record with each new calibration record.

> ⓘ *In order to keep all of your GLP records, periodically download the GLP to Data Manager and export it to another program. Otherwise, the unit will overwrite the oldest record once the memory is full. Also, since Data Manager saves GLP files under the Unit ID, you must periodically export and rename the GLP file on your PC or it will be overwritten each time you upload the GLP file from the instrument.*

Several calibration parameters are saved for each calibration record including optional ones that can be enabled by the user. Standard parameters include date/time stamp, calibration method, and sensor information. Optional, user selectable parameters include User ID, Probe ID, and User Fields 1 and 2.

The sensor specific information that is saved with each calibration point is different for each sensor. The sensor specific values saved are:

Conductivity
Method (Spec Cond, Cond, Salinity)
Cal Value (value of calibration solution)
Sensor Value (Cell Constant)
Temperature Reference (User selected in Sensor Setup menu)
Temperature Compensation Coefficient %/°C (User selected in Sensor Setup menu)
TDS Constant (User selected in Sensor Setup menu)
Temperature
Cal Cell Constant
Calibrate Status

DO
Method (%, mg/L)
Cal Value
Sensor Value (Sensor Current)
Sensor Type (Polarographic/Galvanic)
Membrane Type (Teflon Black, PE Yellow, PE Blue)
Salinity Mode (user entered value if in Manual Salinity Mode)
Temperature
Barometer
Calibrate Status

pH (up to 6 calibration points)
Buffer Value
Sensor Value (mV)
Temperature
Slope (mV/pH)
Slope (% of ideal)
Calibrate Status

ORP
Cal Solution Value
Sensor Value
Temperature
Calibrate Status

Ammonium
Buffer Value
Sensor Value (mV)
Temperature
Calibrate Status

Chloride
Buffer Value
Sensor Value (mV)
Temperature
Calibrate Status

Nitrate
Buffer Value
Sensor Value (mV)
Temperature
Calibrate Status

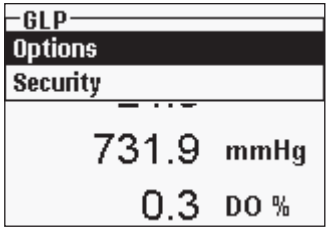
An example of a GLP record

(Operation performed is single point % DO Calibration)

*** Calibrate – DO% ***

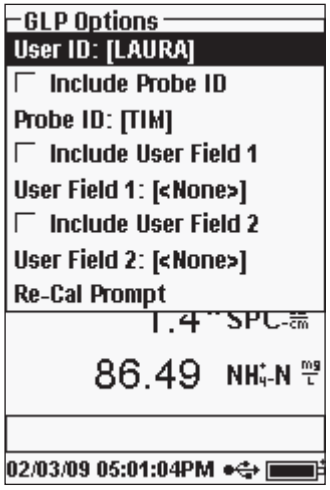
Date	02/03/09 MM/DD/YY
Time	12:14:57PM 12-hour
User ID:	Tech 1
Probe ID	08D
Method	DO Air Calibrate
Cal Value:	100.00%
Sensor Value:	5.175155uA
Sensor Type	Polarographic
Membrane Type	1.25 PE Yellow
Salinity Mode	5.175165 Auto
Temperature	23.9 °C
Barometer	731.4 mmHg
Calibrate Status	Calibrated

GLP SETTINGS



In the System menu, highlight **GLP** and press enter to view and modify the GLP settings.

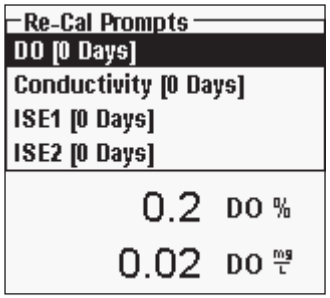
Highlight Options and press enter to access **User ID**, **Probe ID**, **User Defined Fields**, and **Re-Cal Prompt**.



User ID may be used to identify the person calibrating the instrument. Highlight **User ID** and press enter to select, edit, or delete a User ID from a list of previously entered IDs. Or, highlight **Add New** and press enter to create a new User ID using the alpha/numeric entry screen. The User ID may also be changed in the **Calibration** menu during the calibration process. The selected User ID will be stored in the GLP file with each calibration record. A User ID could be a person's initials or badge number. The character limit is 16 characters.

Probe ID is stored with the calibration record and may be used to distinguish one cable/probe assembly from another, typically by serial number. Highlight **Include Probe ID** and press enter to turn this function on (☑) and off (☐). Highlight **Probe ID** and press enter to add, view, edit, delete, or select a Probe ID. The Probe ID may also be changed in the **Calibration** menu during the calibration process. The character limit is 16 characters.

User Fields 1 and 2 are stored with the calibration record and may be used to enter other parameters pertinent to the user, such as weather conditions, elevation, etc. Highlight **Include User Field 1** or **Include User Field 2** and press enter to turn this function on and off. Highlight **User Field 1** or **User Field 2** and press enter to add, delete, view, edit, or select a User Field. The character limit is 16 characters. When enabled, a prompt for selecting a User Defined Field will appear during the calibration process.



Re-Cal Prompt may be used to remind the user to perform a calibration. To set a time interval, highlight the parameter you wish to be reminded about and press enter to access the numeric entry screen. Enter a value in days and press enter to confirm the reminder time. To turn off the Re-cal prompt, set the reminder to zero (0) days (this is the default).

The **Security** section of the GLP menu is a password protected area. This area includes options to set a new password and to lock access to the calibration menu. When first viewing the security menu, you will be required to enter a password. Use the "shift" on the alpha/numeric screen to switch to lower case if necessary and enter "**ysi123**". This is the default password.

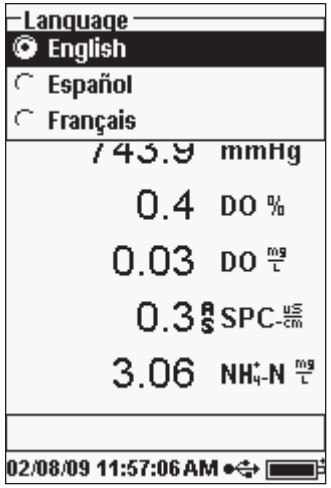
Protect Cal can be enabled (☑) or disabled (☐). When enabled, the user must know and enter the instrument's password to enter the calibration menu option. Highlight **Protect Cal** and press enter to enable or disable this feature.

Set Password allows a user to set the security password. Highlight **Set Password,** press enter, and use the alpha/numeric entry screen to set the new password. The password can have up to 16 characters.

Contact YSI Technical Support at environmental@ysi.com or +1 937 767-7241 if you forget or misplace your password.

> ⓘ *Once a password is set, and the GLP security screen exited, a password must be entered to make changes under GLP security. Keep passwords in a safe place.*

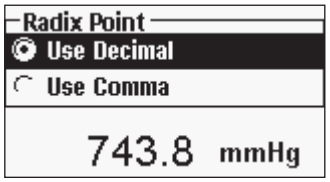
LANGUAGE



The Pro Plus can be configured to display all text in English, Spanish, French, German, Portuguese, Italian, Norwegian, Simplified Chinese, Traditional Chinese, or Japanese. From the factory, the instrument includes English, Spanish, and French language options. The other language options can be downloaded from www.ysi.com/support.

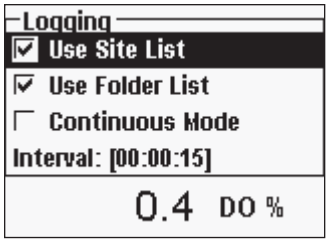
Once the appropriate language file is in the instrument, press System, highlight **Language,** and press enter. Highlight the desired language and press enter to confirm.

RADIX POINT



Radix Point allows the user the option to choose between a comma or a decimal in numeric displays. For example, 1.00 becomes 1,00 when **Use Comma** is selected. Highlight **Use Decimal** or **Use Comma** and press enter to make your selection.

LOGGING



From the System menu, highlight **Logging** and press enter to view or change the logging options. Logging options include **Use Site List**, **Use Folder List**, **Continuous Mode**, and **Interval**.

Use Site List and **Use Folder List** are optional ways of filing or 'tagging' your logged data points. If these settings are enabled, you will be prompted to select a Site and/or Folder to 'tag' to the logged data point. See the **File and Site Lists** section of this manual for information on creating Site and Folder Lists.

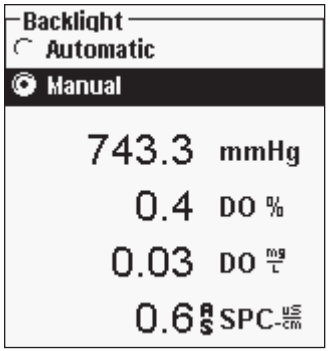
Check the box for **Continuous Mode** if you want to log samples continuously at a specific time interval. To set the length of time between logged samples, highlight **Interval** and press enter. Enter the interval as HH:MM:SS. This interval will display at the top of the screen when you select the **Start Logging** option in run mode.

To log one sample at a time, uncheck **Continuous Mode**. When Continuous Mode is unchecked, **Log One Sample** will appear at the top of the run screen.

AUTO SHUTOFF

Auto Shutoff powers the instrument off after a user specified time period. Highlight **Auto Shutoff** and press enter. Using the alpha/numeric entry screen, enter a value between 0 and 360 minutes. To disable auto shutoff, set the value to 0 (zero).

BACKLIGHT



Backlight can be set to **Automatic** or **Manual**. Automatic turns the backlight on when you turn the instrument on and when you press any key. Manual allows you to turn the backlight on or off with the backlight key. When in Automatic mode, the instrument will turn the backlight off 60 seconds after the last key press. The instrument will "reset" the 60 second time period every time a key is pressed. The lighted keypad will turn off after approximately 20 seconds.

SW VERSION (SOFTWARE VERSION)

SW Version shows the instrument's software version. The instrument's software can be updated via www.ysi.com/support. There you will find the new software files and instructions on how to update the instrument. There is no need to send the instrument back to the factory for upgrades.

SERIAL

Serial # shows the instrument's serial number and allows you to match it with the number engraved on the back of the instrument's case.

UNIT ID

Unit ID is used to identify instruments in the Data Manager software program that was included with your instrument. It is also used to identify GLP files, Site Lists, Configuration files, and Data files transferred from the instrument to the PC. The default Unit ID is the instrument's serial number. To modify the Unit ID, highlight **Unit ID**, press enter and then use the alpha/numeric entry screen. The character limit is 16 characters.

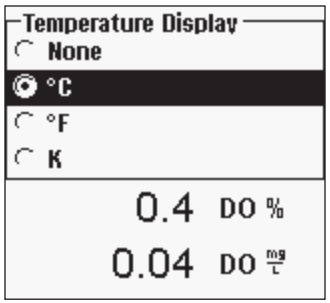
PARAMETERS: SETUP, DISPLAY, AUTO STABLE, AND CALIBRATION

The following section is separated by parameter and will discuss sensor setup, display options, auto stable features, and calibration procedures for each parameter. The sections are separated by parameter due to the versatility of the Pro Plus. You may focus solely on the parameters of your choice.

For the highest accuracy, calibrate or verify each sensor regularly. For your convenience, YSI offers 5580 Confidence Solution® which allows you to check the accuracy of pH, conductivity, and ORP readings to help determine if a sensor calibration is necessary.

If you receive an error message during a calibration that indicates questionable results, you have the option to either accept or decline the calibration. YSI recommends that you decline a questionable calibration since accepting it may result in erroneous data. After declining a questionable calibration, ensure the sensor is clean, the calibration solution is good, the calibration vessel is clean, and that you are entering the correct calibration value if entering manually. Then, try to recalibrate the sensor. If you continue to have problems, see the Troubleshooting section of this manual.

TEMPERATURE



All probe/cable assemblies, except the Quatro, have a built-in temperature sensor. The Quatro cable ships with a Conductivity/Temperature sensor that must be installed on the cable. Temperature calibration is not required nor is it available.

To set the units, press Sensor , highlight **Display** and press enter. Highlight **Temperature** and press enter. Highlight the desired temperature units of **°F**, **°C**, or **K** and press enter to confirm the selection. Only one temperature unit may be displayed at a time. You may also choose not to display temperature. If you choose not to display temperature, other parameters that require a temperature reading will still be temperature compensated.

DISSOLVED OXYGEN (DO)

DO sensors can be used on 60520-X, 6051020-X, 6052030-X, and Quatro cables.

PREPARING THE DO SENSOR FOR THE FIRST TIME

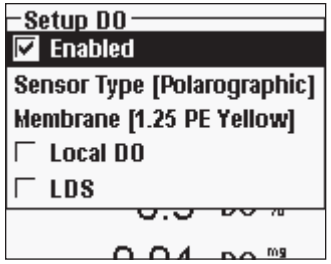
The dissolved oxygen sensor is shipped with a dry, protective red cap that will need to be removed before using. It is very important to put a new membrane with electrolyte solution on the sensor after removing the red cap.

Prepare the membrane solution according to the instructions on the bottle. After mixing, allow the solution to sit for 1 hour. This will help prevent air bubbles from later developing under the membrane. Ensure you are using the correct electrolyte solution for the correct sensor. Galvanic sensors utilize electrolyte with a light blue label and Polarographic sensors utilize electrolyte with a white label. The dissolved oxygen sensor is supplied with cap membranes specific to the sensor type ordered (Polarographic or Galvanic). 5912, 5913, and 5914 membrane kits are for Galvanic sensors and the 5906, 5908, and 5909 membrane kits are for Polarographic sensors. See the **Setup - Dissolved Oxygen** section of this manual for more information on the different types of membranes available from YSI.

Remove the red cap by pulling it straight off the sensor tip. Discard or save for later use during long term storage. Thoroughly rinse the sensor tip with distilled or deionized water. Fill the cap membrane 3⁄4 full of electrolyte solution, then tap the cap with a finger to release any trapped air. Be careful not to touch the membrane portion of the cap. Thread the membrane cap onto the sensor, moderately tight. Do not use a tool. It's typical for some of the electrolyte solution to spill over. For detailed instructions on changing a membrane cap, see the **Care, Maintenance, and Storage** section of this manual.

SETUP - DISSOLVED OXYGEN

Press Sensor, highlight **Setup** and press enter. Next, highlight **DO** and press enter.



Enabled allows you to enable or disable the Dissolved Oxygen function. Highlight **Enabled** and press enter to activate(☑) or deactivate(☐) dissolved oxygen. Disable dissolved oxygen if you do not have a dissolved oxygen sensor connected to the instrument.

> *If a sensor is Enabled that isn't connected to the instrument, the display will show an unstable, false reading, ?????, or ----- next to the units.*

Sensor Type sets the type of oxygen sensor being used: either Polarographic (black) or Galvanic (grey). Highlight **Sensor Type** and press enter. Highlight the correct sensor type installed on the cable and press enter to confirm.

If using a ProBOD sensor/cable assembly, the sensor type should be set to polarographic.

The Pro Plus has two compatible sensors for use with a field cable:

Polarographic – This sensor has a black sensor body and is engraved with the model number 2003.

Galvanic – This sensor has a grey sensor body and is engraved with the model number 2002.

In terms of physical configuration, membrane material, and general performance, YSI Professional Series Galvanic dissolved oxygen sensors are exactly like the Professional Series Polarographic sensors. The advantage of using Galvanic sensors is convenience. Galvanic sensors provide for an instant-on sensor without the need for warm-up time but this affects the life of the sensor. Polarographic sensors last longer and have a longer warranty but require a 5-15 minute warm-up time before use or calibration.

> **IMPORTANT** – *The instrument default setting is Galvanic. Please change the **Sensor Type** to match the correct sensor. If you observe readings very close to 0 or extremely high readings (i.e. 600%), your **Sensor Type** setting (Polarographic or Galvanic) may be set incorrectly and you should immediately ensure it matches the sensor installed on your cable.*

Membrane sets the type of membrane used on the dissolved oxygen sensor. Highlight **Membrane** and press enter. Highlight the correct membrane type installed on the sensor and press enter to confirm. The DO sensor is supplied with membranes specific to the sensor type ordered and are color coded as described in the following tables.

Galvanic membrane kits:

Item	*Color*	*Material*	*Description*
5912	Black	1 mil Teflon®	Traditional membrane material
5913	Yellow	1.25 mil polyethylene	Improved response time and less flow dependence than Teflon® Ships standard with the sensor.
5914	Blue	2 mil polyethylene	Less flow dependence than 1.25 mil but somewhat slower response

Polarographic membrane kits:

Item	*Color*	*Material*	*Description*
5906	Black	1 mil Teflon®	Traditional membrane material
5908	Yellow	1.25 mil polyethylene	Improved response time and less flow dependence than Teflon® Ships standard with the sensor.
5909	Blue	2 mil polyethylene	Less flow dependence than 1.25 mil but somewhat slower response

Selecting a Dissolved Oxygen Membrane:

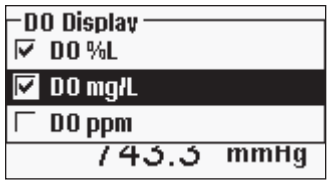
Membrane Type	*Flow Dependence After 4 Minutes*	*Typical Response Time - 95%*
5912, 5906 - Black	60%	18 seconds
5913, 5908 - Yellow	25%	8 seconds
5914, 5909 - Blue	18%	17 seconds

Local DO allows for localized DO% measurements. This sets the calibration value to 100% regardless of the altitude or barometric pressure. Highlight **Local DO** and press enter to enable (☑) or disable (☐) this function. Local DO is a method for the Pro Plus to factor in the barometric pressure on each DO measurement. In essence, if the barometric pressure changes you wouldn't notice the difference in the DO% readings in air-saturated water or water-saturated air. Local DO is ideal for EU compliance. When Local DO is enabled, an L will appear next to DO% on the run screen. DO mg/L readings are unaffected by the selection of DO Local.

LDS (Last Digit Suppression) rounds the DO value to the nearest tenth; i.e. 8.27 mg/L becomes 8.3 mg/L. Highlight **LDS** and press enter to enable (☑) or disable (☐) this function.

DISPLAY - DISSOLVED OXYGEN

Press Sensor , highlight **Display** and press enter. Highlight **DO** and press enter. All DO units can be displayed simultaneously. Highlight the unit(s) and press enter to activate (☑) or deactivate (☐) units from the run screen. Note - You will not be able to display dissolved oxygen unless it is **Enabled** in the Sensor Setup menu first, see previous section.



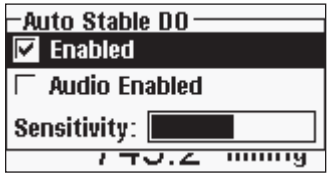
DO % will show DO readings in a percent scale from 0 to 500%.

DO mg/L will show DO readings in milligrams per liter (equivalent to ppm) on a scale from 0 to 50 mg/L.

DO ppm will show DO readings in parts per million (equivalent to mg/L) on a scale from 0 to 50 ppm.

AUTO STABLE - DISSOLVED OXYGEN

Auto Stable indicates when a reading is stable.When Auto Stable is enabled, **AS** will blink next to the parameter until it is stable. Once the parameter is stable, **AS** will stop blinking.



To enable Auto Stable, press Sensor , highlight **Auto Stable** and press enter. Highlight **DO** and press enter.

Highlight **Enabled** and/or **Audio Enabled** (instrument will beep when the stability is achieved) and press enter to confirm. The Auto Stable **Sensitivity** can be decreased or increased. Highlight **Sensitivity** and use the left and right arrow keys to slide the bar. The more sensitive you make it (larger black bar) the harder it is to achieve stability in a changing environment.

The **Auto Stable** system works by examining the previous 5 readings, computing the percent change in the data and comparing that change against a % threshold value. The % threshold value is determined by the **Sensitivity** bar setting. The following chart can be used as a guide when setting the Sensitivity bar.

Sensitivity selected by User	*% Data Variance Threshold*
100 - Most Sensitive, Sensitivity bar is set to the far right	0.05%
75	0.62525%
50	1.275%
25	1.8875%
0 - Least Sensitive, Sensitivity bar is set to the far left	2.5%

Example:

The instrument obtained the following data:

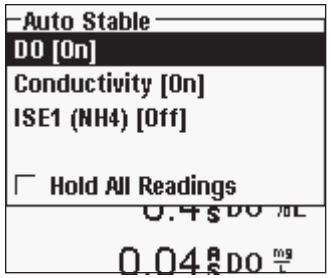
Reading #1 95.5 DO%
Reading #2 95.7 DO%
Reading #3 95.8 DO%
Reading #4 96.1 DO%
Reading #5 95.3 DO%

The instrument is programmed to determine the minimum and maximum data value over the previous 5 samples, and to compute the percent difference between those values. In this example, that gives a percent change of:

% Change = 100 * ((96.1 – 95.3) / 95.3)
% Change = 0.83%

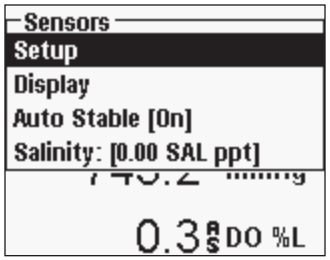
In this example, if the Sensitivity bar is set to the far right, the Auto Stable requirement would not be met and AS would continue to blink. However, if the sensitivity bar is set to the median threshold (1.275%), the Auto Stable requirement would be met and AS would display steadily on the display.

Within the Auto Stable menu, you can also choose to **Hold All Readings** for as many parameters as you set for Auto Stable. For instance, if DO and pH have



Auto Stable and Hold All Readings enabled, then the display will hold the readings once DO and pH have both reached their Auto Stable settings. You must press the **Esc** key to "release" the held display in order to take subsequent readings **Hold All Readings** must be reactivated after each use!

SALINITY CORRECTION



The last feature in the **Sensor** menu is the **Salinity** correction value which is used to calculate the dissolved oxygen mg/L and ammonia readings when a conductivity sensor is not in use. Press Sensor, highlight **Salinity**, and press enter. Then, use the numeric entry screen to enter the Salinity value of the water you will be testing from 0 to 70 ppt.

If using a cable with a conductivity sensor, the salinity measured by the conductivity sensor will be used in the DO and ammonia mg/L calculations and 'As Measured' will be displayed next to **Salinity** in the Sensor menu.

As the salinity of water increases, its ability to dissolve oxygen decreases. For example, fully oxygenated 20 °C water at sea level with zero salinity will hold 9.092 mg/L of dissolved oxygen. If that same sample had a salinity value of 9 ppt, then it would hold 8.621 mg/L of dissolved oxygen. Therefore, to obtain accurate mg/L readings, it is important to know the salinity of the water you will be testing and to input that value into the instrument. The salinity of fresh water is typically 0-0.5 ppt and seawater is typically 35 ppt. You will also have the opportunity to enter or modify the Salinity correction value during DO calibration.

CALIBRATION - DISSOLVED OXYGEN

The Pro Plus offers several options for calibrating dissolved oxygen: DO% in water saturated air, DO mg/L and DO ppm in a solution of known dissolved oxygen determined by a Winkler Titration, and a Zero point. If performing a zero point calibration, you must also perform a %, mg/L, or ppm calibration following the zero calibration. For both ease of use and accuracy, YSI recommends performing the following 1-point DO % water saturated air calibration:

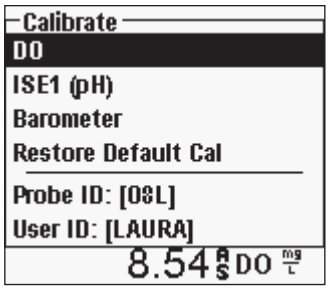
> *It is not necessary to calibrate in both % and mg/L or ppm. Calibrating in % will simultaneously calibrate mg/L and ppm and vice versa.*

Calibrating DO % in Water Saturated Air: **1-Point Calibration**

The supplied sensor storage container (a grey sleeve for a single port cable or a screw on plastic cup for the dual-port and Quatro cables) can be used for DO calibration purposes.

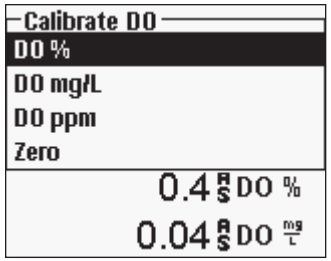
Moisten the sponge in the storage sleeve or plastic cup with a small amount of clean water. The sponge should be clean since bacterial growth may consume oxygen and interfere with the calibration. If using the cup and you no longer have the sponge, place a small amount of clean water (1/8 inch) in the plastic storage cup instead.

Make sure there are no water droplets on the DO membrane or temperature sensor. Then install the storage sleeve or cup over the sensors. The storage sleeve ensures venting to the atmosphere. If using the cup, screw it on the cable and then disengage one or two threads to ensure atmospheric venting. Make sure the DO and temperature sensors are not immersed in water. Turn the instrument on and wait approximately 5 to 15 minutes for the storage container to become completely saturated and to allow the sensors to stabilize.



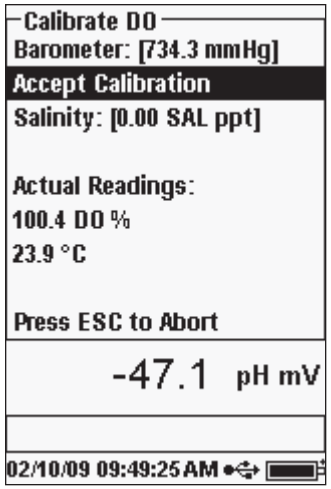
Press Cal . Highlight Probe ID or User ID if you wish to add, select, edit, or delete an ID. Probe ID must be enabled in the System GLP menu to appear in the Calibrate menu. User ID will appear automatically. Select 'None' if you do not want a User ID stored with the calibration. When enabled, these IDs are stored with each calibration record in the GLP file.

After selecting your User ID and/or Probe ID if appropriate, highlight DO and press enter.



Highlight **DO %** and press enter to confirm.

The instrument will use the internal barometer during calibration and will display this value in brackets at the top of the display. Highlight **Barometer** and press enter to adjust it if needed. If the barometer reading is incorrect, it is recommended that you calibrate the barometer. Note - the barometer should be reading "true" barometric pressure (see Barometer section for more information on "true" barometric pressure). If the value is acceptable, there is no need to change it or perform a barometer calibration.



The Salinity value displayed near the top of the screen is either the salinity correction value entered in the Sensor menu or the Salinity value as measured by the conductivity sensor in use and enabled. If you are not using a conductivity sensor, the Salinity correction value should be the salinity of the water you will be testing. Highlight **Salinity** and press enter to modify this setting if necessary. See the **Salinity Correction** section of this manual for more information.

Wait for the temperature and DO% values under "Actual Readings" to stabilize, then highlight **Accept Calibration** and press enter to calibrate. Or, press Esc to cancel the calibration. If User Field 1 or 2 are enabled in the GLP menu, you will be prompted to select these inputs and then press Cal to complete the calibration. The message line at the bottom of the screen will display "Calibrating Channel..." and then "Saving Configuration...".

Calibrating DO% in Water Saturated Air: **2-Point Calibration with Zero Solution**

Place the sensor in a solution of zero DO.

A zero DO solution can be made by dissolving approximately 8 - 10 grams of sodium sulfite (Na_2SO_3) into 500 mL tap water or DI water. Mix the solution thoroughly. It may take the solution 60 minutes to be oxygen-free.

Press Cal. Highlight Probe ID or User ID if you wish to add, select, edit, or delete an ID. Probe ID must be enabled in the System GLP menu to appear in the Calibrate menu. When enabled, these IDs are stored with each calibration record in the GLP file.

After selecting the Probe ID and/or User ID if appropriate, highlight DO and press enter. Highlight **Zero** and press enter. Wait for the temperature and DO% values under "Actual Readings" to stabilize, then press enter to **Accept Calibration**. If User Field 1 or 2 are enabled, you will be prompted to select the fields and then press Cal to complete the calibration. The screen will then prompt for a follow-up second point calibration.

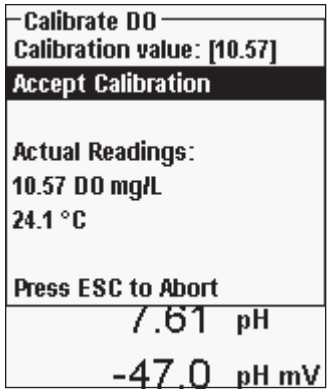
Highlight **DO%** and press enter to continue with the next calibration point. Rinse the sensor of any zero oxygen solution using clean water. Then follow the steps under Calibrating DO % in Water Saturated Air to complete the second point.

Calibrating in mg/L or ppm as a Titration: **1-Point Calibration**

Place the sensor into an adequately stirred sample that has been titrated to determine the dissolved oxygen concentration. Allow the sensor to stabilize.

Press Cal. Highlight Probe ID or User ID if you wish to add, select, edit, or delete an ID. Probe ID must be enabled in the System GLP menu to appear in the Calibrate menu. When enabled, these IDs are stored with each calibration record in the GLP file.

After selecting the Probe ID and/or User ID if appropriate, highlight DO and press enter. Highlight **DO mg/L or ppm** and press enter.



Highlight **Calibration value** and press enter to manually input the sample's dissolved oxygen value. Highlight **Accept Calibration** and press enter once the temperature and Dissolved Oxygen readings stabilize. Or, press Esc to cancel the calibration. If User Field 1 or 2 are enabled in the GLP menu, you will be prompted to select the fields after selecting **Accept Calibration**. After making your selection, press Cal to complete the calibration. After completing the calibration, the message line will display "Calibrating Channel..." and then "Saving Configuration...".

Calibrating in mg/L or ppm as a Titration: **2-Point Calibration with Zero Solution**

Place the sensor in a solution of zero DO.

A zero DO solution can be made by dissolving approximately 8 - 10 grams of sodium sulfite (Na_2SO_3) into 500 mL tap water. Mix the solution thoroughly. It may take the solution 60 minutes to be oxygen-free.

Press Cal. Highlight Probe ID or User ID if you wish to add, select, edit, or delete an ID. Probe ID must be enabled in the System GLP menu to appear in the Calibrate menu. When enabled, these IDs are stored with each calibration record in the GLP file.

After selecting the Probe ID and/or User ID if appropriate, highlight DO and press enter. Highlight **Zero** and press enter. Wait for the temperature and DO% values under "Actual Readings" to stabilize, then press enter to **Accept Calibration**. If User Field 1 or 2 are enabled, you will be prompted to select the fields and then Press Cal to complete the calibration. The screen will then prompt for a follow-up second point calibration.

Highlight the desired calibration units (mg/L or ppm) and press enter to continue with the next point. Rinse the sensor of any zero oxygen solution using clean water. To complete the second calibration point, follow the steps under Calibrating in mg/L or ppm as a Titration: **1-Point Calibration**.

BAROMETER

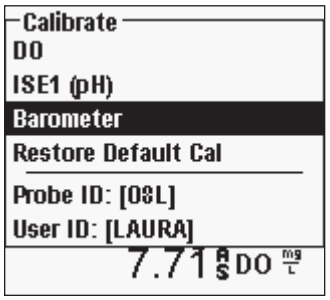
All Professional Plus instruments contain an internal barometer.

DISPLAY - BAROMETER

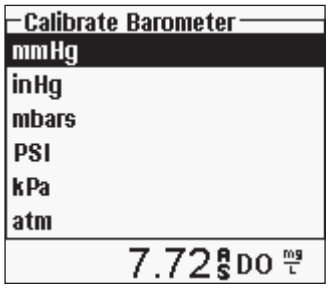
Press Sensor, highlight **Display** and press enter. Highlight **Barometer** and press enter. The measurement unit options are: mmHg, inHg, mBar, PSI, kPa, or Atm. Only one unit can be displayed at a time. Select **None** if you do not want to display a barometric pressure reading.

Whether or not you choose to display the barometer reading, the barometric pressure will still be used for calibrating DO% and for compensating for pressure changes if **Local DO** is enabled.

CALIBRATION - BAROMETER

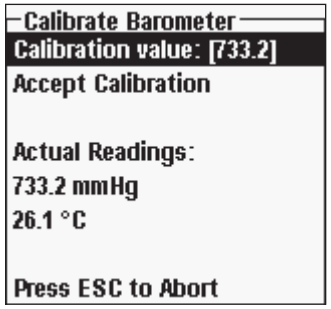


The barometer in the instrument is calibrated at the factory. If the barometer requires calibration, press **Cal**. Highlight Probe ID or User ID if you wish to add, select, edit, or delete an ID. Probe ID must be enabled in the System GLP menu to appear in the Calibrate menu. When enabled, these IDs are stored with each calibration record in the GLP file.



After selecting the Probe ID and/or User ID if appropriate, highlight **Barometer** and press enter.

Highlight the desired unit and press enter.



Highlight **Calibration Value** and press enter to manually enter the correct "true" barometric pressure. Next, highlight **Accept Calibration**, and press enter. If User Field 1 or 2 are enabled, you will be prompted to select the fields and then press Cal to complete the calibration or press Esc to cancel the calibration.

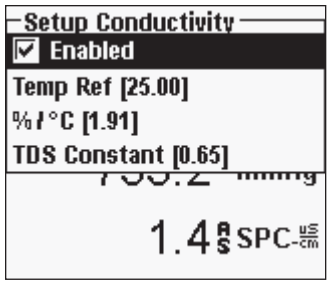
> *Laboratory barometer readings are usually "true" (uncorrected) values of air pressure and can be used "as is" for barometer calibration. Weather service readings are usually not "true", i.e., they are corrected to sea level, and therefore cannot be used until they are "uncorrected". An approximate formula for this "uncorrection" is below:*

True BP = [Corrected BP] – [2.5 * (Local Altitude in ft. above sea level/100)]

CONDUCTIVITY

Conductivity sensors are supplied with 60530-X, 6051030-X, 6052030-X , and Quatro cables. Conductivity sensors are built into the 60530-X, 6051030-X, and 6052030-X cables and are not replaceable. Conductivity/Temperature sensors are shipped with the Quatro cable, must be installed, and are replaceable.

SETUP - CONDUCTIVITY



Press Sensor , highlight **Setup,** and press enter. Highlight **Conductivity**, press enter.

Enabled allows you to enable or disable the conductivity measurement. Highlight **Enabled** and press enter to activate (☑) or deactivate (☐) conductivity. Disable conductivity if you do not have a conductivity sensor connected to the instrument.

> *If a sensor is Enabled that isn't connected to the instrument, the display will show an unstable, false reading next to the units.*

Temp Ref (Temperature Reference) is the reference temperature used for calculating temperature compensated Specific Conductance. This will be the temperature all Specific Conductance values are compensated to. The default is 25 °C. To change the Reference Temperature, highlight **Temp Ref** and press enter. Use the numeric entry screen to enter a new value between 15.00 and 25.00 °C. Next, highlight <<<ENTER>>> at the bottom of the screen and press enter on the keypad to confirm.

%/°C (Percent per Degree Celsius) is the temperature coefficient used to calculate temperature compensated Specific Conductance. The default is 1.91% which is based on KCl standards. To change the temperature coefficient, highlight %/°C and press enter. Use the numeric entry screen to enter a new value between 0 and 4%. Next, highlight <<<ENTER>>> at the bottom of the screen and press **Enter** on the keypad to confirm.

TDS Constant is a multiplier used to calculate an estimated TDS (Total Dissolved Solids) value from conductivity. The multiplier is used to convert Specific Conductance in mS/cm to TDS in g/L. The default value is 0.65. This multiplier is highly dependent on the nature of the ionic species present in the water sample. To be assured of moderate accuracy for the conversion, you must determine a multiplier for the water at your sampling site. Use the following procedure to determine the multiplier for a specific sample:

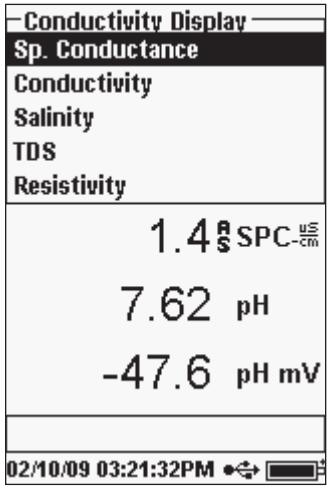
1. Determine the specific conductance of a water sample from the site;
2. Filter a portion of water from the site;
3. Completely evaporate the water from a carefully measured volume of the filtered sample to yield a dry solid;
4. Accurately weigh the remaining solid;
5. Divide the weight of the solid (in grams) by the volume of water used (in liters) to yield the TDS value in g/L for this site; Divide the TDS value in g/L by the specific conductance of the water in mS/cm to yield the conversion multiplier. Be certain to use the correct units.

> *If the nature of the ionic species at the site changes between sampling studies, the TDS values will be in error. TDS cannot be calculated accurately from specific conductance unless the make-up of the chemical species in the water remains constant.*

To change the multiplier, highlight **TDS Constant** and press enter. Use the numeric entry screen to enter a new value between 0 and 0.99. Highlight <<<ENTER>>> at the bottom of the screen and press **Enter** on the keypad to confirm.

DISPLAY - CONDUCTIVITY

Press Sensor, highlight **Display** and press enter. Highlight **Conductivity** and press enter. Highlight **Sp. Conductance** (Specific Conductance), **Conductivity**, **Salinity**, **TDS**, or **Resistivity**, and press enter to select the reporting units for each parameter. One reporting unit per parameter may be enabled. To disable a parameter, select **None**. You will not be able to display any of these parameters unless the Conductivity sensor is **Enabled** in the Sensor Setup menu first.



Sp. Conductance can be displayed in us/cm or ms/cm. Specific conductance is temperature compensated conductivity.

Conductivity can be displayed in uS/cm or mS/cm. Conductivity is the measure of a solution's ability to conduct an electrical current. Unlike specific conductance, conductivity is a direct reading without any temperature compensation.

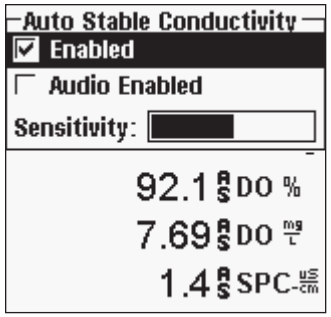
Salinity can be displayed in ppt (parts per thousand) or PSU (practical salinity units). The units are equivalent as both use the Practical Salinity Scale for calculation.

TDS can be displayed in mg/L (milligrams per liter), g/L (grams per liter), or kg/L (kilograms per liter).

Resistivity can be displayed in ohm-cm (ohms per centimeter), kohm-cm (kilo ohms per centimeter), or Mohm-cm (mega ohms per centimeter).

AUTO STABLE - CONDUCTIVITY

Press Sensor, highlight **Auto Stable** and press enter. Highlight **Conductivity** and press enter.

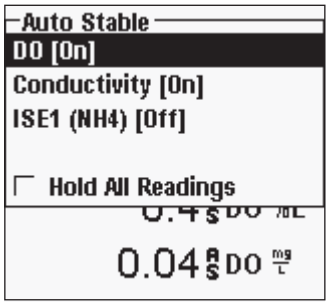


Auto Stable indicates when a reading is stable. Highlight **Enabled** and/or **Audio Enabled** (instrument will beep when the stability is achieved) and press enter enable (☑) or disable (☐). When Auto Stable is enabled, **AS** will blink next to the parameter until it is stable. Once the parameter is stable, **AS** will stop blinking.

The Auto Stable **Sensitivity** can be decreased or increased. Highlight **Sensitivity** and use the left and right arrow keys to slide the bar. The more sensitive you make it (larger black bar) the harder it is to achieve stability in a changing environment.

The **Auto Stable** system works by examining the previous 5 readings, computing the percent change in the data and comparing that change against a % threshold value. The % threshold value is determined by the **Sensitivity** bar setting. The following chart can be used as a guide when setting the Sensitivity bar.

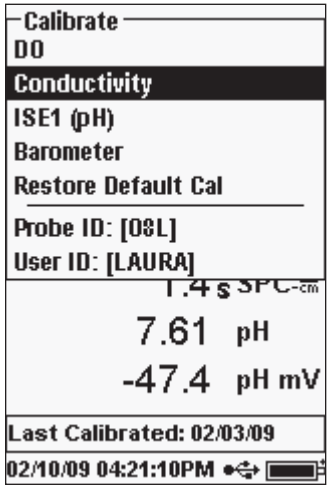
Sensitivity selected by User	*% Data Variance Threshold*
100 - Most Sensitive, Sensitivity bar is set to the far right	0.025%
75	0.39375%
50	0.7625%
25	1.13125%
0 - Least Sensitive, Sensitivity bar is set to the far left	1.5%



Within the Auto Stable menu, you can also choose to **Hold All Readings** for as many parameters as you set for Auto Stable. For instance, if conductivity and DO have Auto Stable and Hold All Readings enabled, then the display will hold the readings once conductivity and DO have both reached their Auto Stable settings. You must press the **Esc** key to "release" the held display in order to take subsequent readings. **Hold All Readings** must be reactivated after each use!

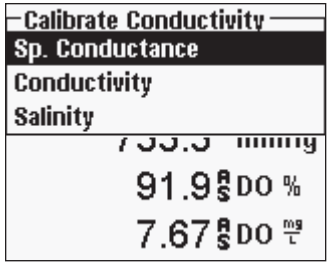
CALIBRATION - CONDUCTIVITY

> *The 6051030 ISE/conductivity cable has a specialized calibration container that resembles a large test tube. This calibration chamber can be used to calibrate the conductivity sensor with an ISE sensor installed. A ring-stand should be used to support this chamber.*



Press Cal . Highlight Probe ID or User ID if you wish to add, select, edit, or delete an ID. Probe ID must be enabled in the System GLP menu to appear in the Calibrate menu. User ID will appear automatically. Select 'None' if you do not want a User ID stored with the calibration. When enabled, these IDs are stored with each calibration record in the GLP file.

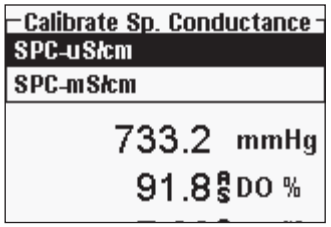
After selecting the User ID and/or Probe ID if appropriate, highlight **Conductivity** and press enter.



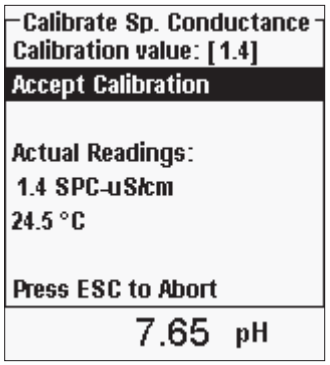
Highlight the desired calibration method; **Sp. Conductance**, **Conductivity**, or **Salinity** and press enter. YSI recommends calibrating in specific conductance for greatest ease.

Calibrating in Specific (Sp.) Conductance or Conductivity

Place the sensor into a fresh, traceable conductivity calibration solution. The solution must cover the holes of the conductivity sensor that are closest to the cable. Ensure the entire conductivity sensor is submerged in the solution or the instrument will read approximately of half the expected value!



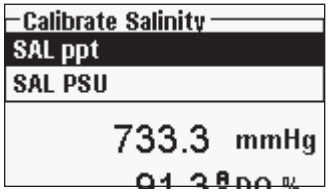
Choose the units in either **SPC-us/cm**, **C-us/cm** or **SPC-ms/cm**, **C-ms/cm** and press enter.



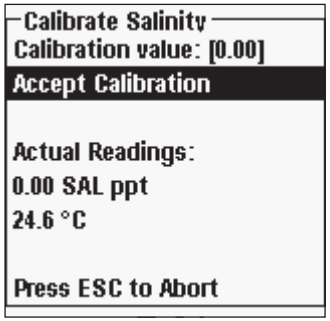
Highlight **Calibration value** and press enter to input the value of the calibration standard. Then, once the temperature and conductivity readings stabilize, highlight **Accept Calibration** and press enter. Or, press Esc to cancel the calibration. If User Field 1 or 2 are enabled in the GLP menu, you will be prompted to select the fields and then press Cal to complete the calibration. After completing the calibration, the message line at the bottom of the screen will display "Calibrating Channel..." and then "Saving Configuration...".

Calibrating in Salinity

Place the sensor into a salinity calibration solution. The solution must cover the holes of the conductivity sensor that are closest to the cable. Ensure the entire conductivity sensor is submerged in the solution or the instrument will read approximately of half the expected value!



Select **SAL ppt** or **SAL PSU** and press enter.



Highlight **Calibration value** and press enter to input the value of the calibration standard. Then, once the temperature and conductivity readings stabilize, highlight **Accept Calibration** and press enter. Or, press Esc to cancel the calibration. If User Field 1 or 2 are enabled, you will be prompted to select the fields and then press Cal to complete the calibration.

pH

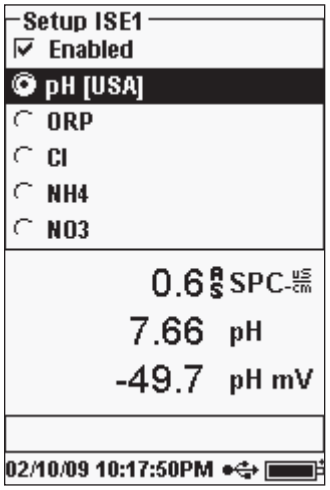
pH sensors can be used on 60510-X, 6051020-X, 6051030-X, 6051010-X, and Quatro cables.

If using a 605103 pH/ORP combination sensor on a 6051020 or 6051030 cable you can report both pH and ORP by configuring ISE1 as pH and ISE2 as ORP in the Sensor Setup menu.

The 605103 pH/ORP combination sensor is not recommended for use on a 6051010 or Quatro cable. If used on one of these cable, only pH will be reported and ORP will not be measured.

SETUP - pH

Press Sensor, highlight **Setup**, press enter. Highlight **ISE1** if using a 60510, 6051020, or 6051030 cable. If using a 6051010 or Quatro cable, highlight **ISE1** if the pH sensor is installed in port 1 or highlight **ISE2** if the pH sensor is installed in port 2(a sensor must be installed in port 1 for port 2 to operate). Press enter.



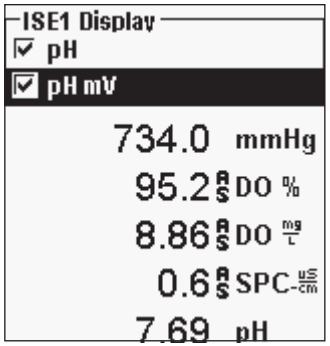
Enabled allows you to enable or disable the ISE function and select which ISE sensor is installed on the cable. Highlight **Enabled** and press enter to enable (☑) or disable (☐) the ISE you selected previously (either ISE1 or ISE2). Disable the ISE function(s) if you do not have a ISE sensor connected to the instrument.

After enabling the ISE function, ensure that it is set to pH as shown in the left screen shot. If necessary, highlight pH and press enter to set the ISE to pH.

Highlighting **pH[USA]** and pressing enter will also allow you to select the values for auto buffer recognition which are used during calibration. The buffer options are **USA** (4, 7, 10), **NIST** (4.01, 6.86, 9.18), and **User-Defined**. The selected option will be displayed in [brackets].

> ⓘ *If a sensor is Enabled that isn't connected to the instrument, the display will show an unstable false reading, ?????, or ----- next to the units.*

DISPLAY - pH



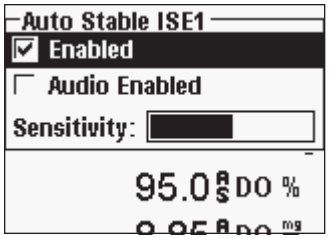
Press Sensor, highlight **Display** and press enter.

Highlight **ISE (pH)** and press enter. You will not be able to **Display** the sensor unless it is **Enabled** in the Sensor Setup menu.

Highlight **pH** and/or **pH mV**, press enter to enable (☑) or disable (☐). Both can be reported at the same time.

AUTO STABLE - pH

Press Sensor, highlight **Auto Stable** and press enter. Highlight **ISE (pH)** and press enter.

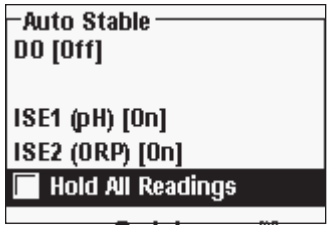


Auto Stable indicates when a reading is stable. Highlight **Enabled** and/or **Audio Enabled** (instrument will beep when the stability is achieved) and press enter enable (☑) or disable (☐). When Auto Stable is enabled, **AS** will blink next to the parameter until it is stable. Once the parameter is stable, **AS** will stop blinking.

The Auto Stable **Sensitivity** can be decreased or increased. Highlight **Sensitivity** and use the left and right arrow keys to slide the bar. The more sensitive you make it (larger black bar) the harder it is to achieve stability in a changing environment.

The **Auto Stable** system works by examining the previous 5 readings, computing the percent change in the data and comparing that change against a % threshold value. The % threshold value is determined by the **Sensitivity** bar setting. The following chart can be used as a guide when setting the Sensitivity bar.

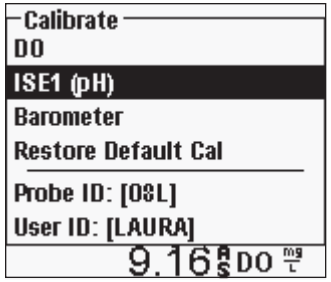
Sensitivity selected by User	*% Data Variance Threshold*
100 - Most Sensitive, Sensitivity bar is set to the far right	0.025%
75	0.39375%
50	1.5%
25	1.13125%
0 - Least Sensitive, Sensitivity bar is set to the far left	0.15%



Within the Auto Stable menu, you can also choose to **Hold All Readings** for as many parameters as you set for Auto Stable. For instance, if ORP and pH have Auto Stable enabled and Hold All Readings is enabled, then the display will hold the readings once ORP and pH have both reached their Auto Stable settings. You must press the **Esc** key to "release" the held display in order to take subsequent readings. **Hold All Readings** must be reactivated after each use!

CALIBRATION - pH

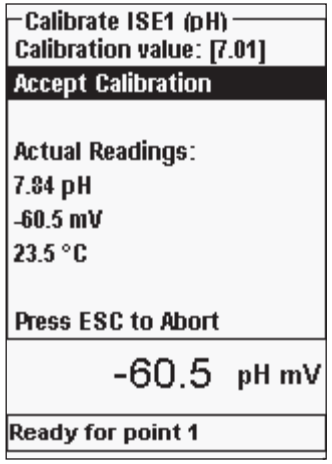
> *Calibration can be accomplished in any buffer order. pH 7 buffer should be used regardless of how many calibration points you use but it does not have to be used first.*

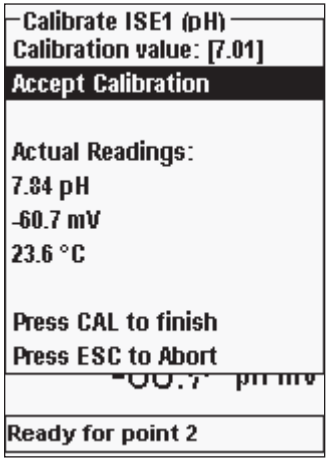


Press Cal . Highlight Probe ID or User ID if you wish to add, select, edit, or delete an ID. Probe ID must be enabled in the System GLP menu to appear in the Calibrate menu. User ID will appear automatically. Select 'None' if you do not want a User ID stored with the calibration. When enabled, these IDs are stored with each calibration record in the GLP file.

After selecting your User ID and/or Probe ID if appropriate, highlight **ISE (pH)** and press enter. The message line will show the instrument is "Ready for point 1". The pH calibration allows up to six calibration points.

Place the sensor in a traceable pH buffer solution. The instrument should automatically recognize the buffer value and display it at the top of the calibration screen. If the calibration value is incorrect, the auto buffer recognition setting





in the Sensor Setup menu may be incorrect. If necessary, highlight the **Calibration Value** and press enter to input the correct buffer value.

Once the pH and temperature readings stabilize, highlight **Accept Calibration** and press enter to accept the first calibration point. The message line will then display "Ready for point 2".

If you do not wish to perform a second point, press Cal to finalize the calibration. Or, press Esc to cancel the calibration. If User Field 1 or 2 are enabled, you will be prompted to select these fields and then press Cal to finalize the calibration.

To continue with the 2nd point, place the sensor in the second buffer solution. The instrument should automatically recognize the second buffer value and display it at the top of the screen. If necessary, highlight the **Calibration Value** and press enter to input the correct buffer value. Once the pH and temperature readings stabilize, highlight **Accept Calibration** and press enter to confirm the second calibration point. The message line will then display 'Ready for point 3" and you can continue with the 3rd calibration point if desired.

If you do not wish to perform a 3rd calibration point, press Cal to complete the calibration. If User Field 1 or 2 are enabled, you will be prompted to select these fields and then press Cal to finalize the calibration.

Continue in this fashion until the desired number of calibration points is achieved (up to six).

> *Once you've achieved the desired number of cal points you must press* Cal *to finalize the calibration and to allow the instrument to update the pH offset and slope. The instrument will not take these cal values into account until Cal has been pressed.*

The actual readings displayed during the calibration will NOT reflect the updated calibration information. These values will not change until Cal is pressed to finalize the calibration and to update the instrument.

ORP

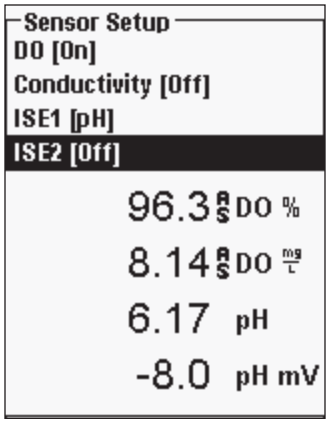
ORP sensors can be used on 60510-X, 6051020-X, 6051030-X, 6051010-X, and Quatro cables.

If using a 605103 pH/ORP combination sensor on a 6051020 or 6051030 cable you can report both pH and ORP by configuring ISE1 as pH and ISE2 as ORP in the Sensor Setup menu.

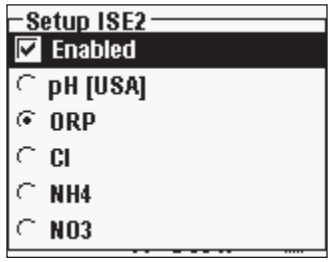
The 605103 pH/ORP combination sensor is not recommended for use on a 6051010 or Quatro cable. If used on one of these cable, only pH will be reported and ORP will not be measured.

SETUP - ORP

Press Sensor, highlight **Setup**, press enter.



Highlight **ISE1** if using a 605102 (ORP sensor) on a 60510, 6051020, or 6051030 cable. Highlight **ISE2** is using a 605103 (pH/ORP sensor) on a 60510, 6051020, or 6051030 cable. If using a 6051010 or Quatro cable, highlight **ISE1** if the ORP sensor is installed in port 1 or highlight **ISE2** if the ORP sensor is installed in port 2 (a sensor must be installed in port 1 for port 2 to operate). Press enter.

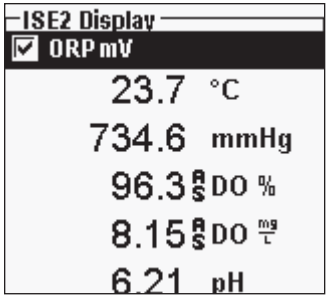


Enabled allows you to enable or disable the ISE function and select which ISE sensor is installed on the cable. Highlight **Enabled** and press enter to enable (☑) or disable (☐) the ISE you selected previously (either ISE1 or ISE2).

After enabling the ISE function, ensure ORP is selected as the ISE sensor as shown in screen shot to the left. If necessary, highlight ORP and press enter to set the selected ISE to ORP.

If a sensor is Enabled that isn't connected to the instrument, the display will show an unstable false reading, ?????, or ----- next to the units.

DISPLAY - ORP

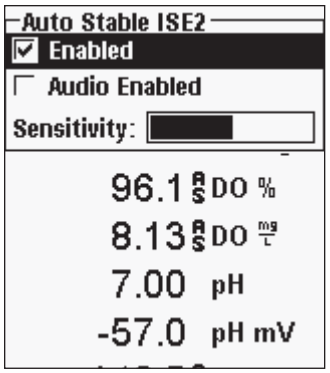


Press Sensor, highlight **Display** and press enter.

Highlight **ISE (ORP)** and press enter. You will not be able to **Display** the sensor unless it is **Enabled** in the Sensor Setup menu.

Press enter to enable (☑) or disable (☐) **ORP mV.**

AUTO STABLE - ORP



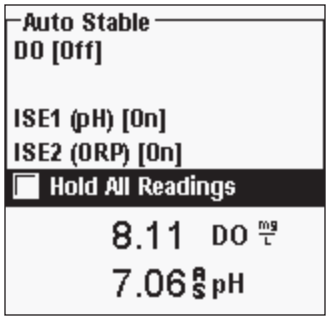
Press Sensor, highlight **Auto Stable** and press enter. Highlight **ISE (ORP)** and press enter.

Auto Stable indicates when a reading is stable. Highlight **Enabled** and/or **Audio Enabled** (instrument will beep when the stability is achieved) and press enter enable (☑) or disable (☐). When Auto Stable is enabled, **AS** will blink next to the parameter until it is stable. Once the parameter is stable, **AS** will stop blinking.

The Auto Stable **Sensitivity** can be decreased or increased. Highlight **Sensitivity** and use the left and right arrow keys to slide the bar. The more sensitive you make it (larger black bar) the harder it is to achieve stability in a changing environment.

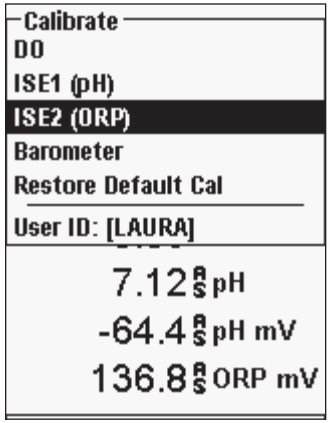
The **Auto Stable** system works by examining the previous 5 readings, computing the percent change in the data and comparing that change against a % threshold value. The % threshold value is determined by the **Sensitivity** bar setting. The following chart can be used as a guide when setting the Sensitivity bar.

Sensitivity selected by User	*% Data Variance Threshold*
100 - Most Sensitive, Sensitivity bar is set to the far right	0.05%
75	0.62525%
50	1.275%
25	1.8875%
0 - Least Sensitive, Sensitivity bar is set to the far left	2.5%



Within the Auto Stable menu, you can also choose to **Hold All Readings** for as many parameters as you set for Auto Stable. For instance, if ORP and pH have Auto Stable enabled and Hold All Readings is enabled, then the display will hold the readings once ORP and pH have both reached their Auto Stable settings. You must press the **Esc** key to "release" the held display in order to take subsequent readings. **Hold All Readings** must be reactivated after each use!

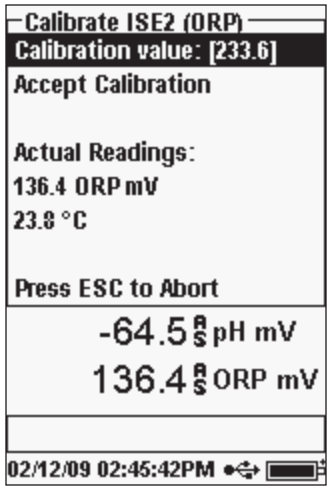
CALIBRATION - ORP



Press Cal . Highlight Probe ID or User ID if you wish to add, select, edit, or delete an ID. Probe ID must be enabled in the System GLP menu to appear in the Calibrate menu. User ID will appear automatically. Select 'None' if you do not want a User ID stored with the calibration. When enabled, these IDs are stored with each calibration record in the GLP file.

After selecting your User ID and/or Probe ID if appropriate, highlight **ISE (ORP)** and press enter. The message line will show the instrument is "Ready for point".

Place the sensor in a solution of known ORP and wait for the readings to stabilize.



Highlight **Calibration value** and press enter to input the value of the ORP calibration standard. If using the YSI Zobell calibration solution, the Pro Plus will automatically determine the calibration value. However, the calibration value should be verified against the chart on the side of the Zobell bottle. Next, once the temperature and ORP readings stabilize, highlight **Accept Calibration** and press enter to calibrate. Or, press Esc to cancel the calibration. If User Field 1 or 2 are enabled, you will be prompted to select the fields and then press Cal to complete the calibration.

AMMONIUM, NITRATE, CHLORIDE

Ammonium, Nitrate, and Chloride sensors can be used on 60510-X, 6051020-X, 6051030-X, 6051010-X, and Quatro cables. These cables also accommodate pH and ORP sensors so instrument setup is important.

WARNING: *Ammonium, Nitrate, and Chloride sensors should only be used at DEPTHS OF LESS THAN 55 FEET (17 METERS). Use of the sensors at greater depths is likely to permanently damage the sensor membrane.*

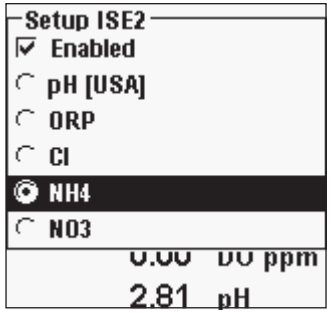
WARNING: *Ammonium, Nitrate, and Chloride sensors should only be used in FRESHWATER.*

SETUP - AMMONIUM, NITRATE, CHLORIDE

Install the Ammonium, Nitrate, or Chloride sensor in Port 2 if using in conjunction with pH or ORP sensor on a 6051010 or Quatro cable. See the **Getting Started Setup** section of this manual for a complete list of cable/sensor configurations.

Press Sensor , highlight **Setup**, press enter. Highlight **ISE1** if using an ammonium, nitrate, or chloride sensor on a 60510, 6051020, or 6051030 cable.

If using a 6051010 or Quatro cable highlight **ISE1** if the sensor is installed in Port 1 or highlight **ISE2** if the sensor is installed in Port 2. Press enter.



Enabled allows you to enable or disable the ISE function and select which ISE sensor is installed on the cable.

Highlight **Enabled** and press enter to enable (☑) or disable (☐) the ISE you selected previously (either ISE1 or ISE2).

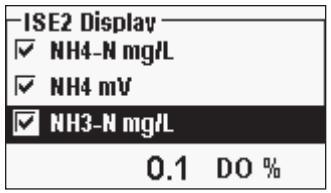
After enabling the ISE function, choose the parameter you want enabled for that ISE. In this example, NH4 is selected.

Cl - Chloride
NH4 - Ammonium
NO3 - Nitrate

> ⓘ *If a sensor is Enabled that isn't connected to the instrument, the display will show an unstable, false reading next to the units.*

DISPLAY - AMMONIUM, NITRATE, CHLORIDE

Press Sensor, highlight **Display**, press enter. Highlight **ISE2(NH4)**, press enter. You will not be able to **Display** the sensor unless it is **Enabled**.



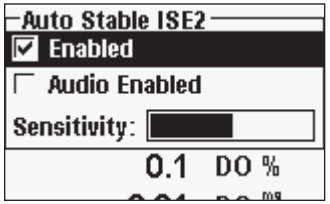
Highlight the value you wish to display and press enter to enable (☑) . Ammonium can be displayed as **NH4-N mg/L** (Ammonium), **NH3-N** (Ammonia) and/or **NH4 mV** (sensor signal).

The same steps would be followed to display nitrate or chloride.

Ammonia is calculated from the pH, salinity, and temperature readings. If a pH sensor is not in use, the instrument will assume the sample is neutral (pH 7) for the calculation. If a conductivity sensor (Salinity) is not in use, the instrument will use the salinity correction value entered in the Sensor Menu for the calculation (see Salinity Correction within the Dissolved Oxygen Setup section of this manual for more information).

AUTO STABLE - AMMONIUM, NITRATE, CHLORIDE

Auto Stable indicates when a reading is stable. When Auto Stable is enabled, **AS** will blink next to the parameter until it is stable. Once the parameter is stable, **AS** will stop blinking.

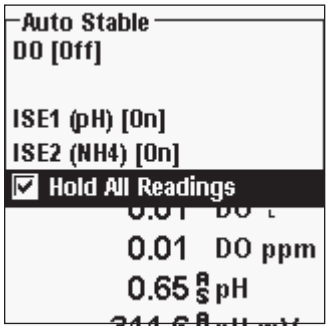


To enable Auto Stable, press Sensor, highlight **Auto Stable** and press enter. Highlight **ISE1** or **ISE2** and press enter.

Highlight **Enabled** and/or **Audio Enabled** (instrument will beep when the stability is achieved) and press enter to confirm. The Auto Stable **Sensitivity** can be decreased or increased. Highlight **Sensitivity** and use the left and right arrow keys to slide the bar. The more sensitive you make it (larger black bar) the harder it is to achieve stability in a changing environment.

The **Auto Stable** system works by examining the previous 5 readings, computing the percent change in the data and comparing that change against a % threshold value. The % threshold value is determined by the **Sensitivity** bar setting. The following chart can be used as a guide when setting the Sensitivity bar.

Sensitivity selected by User	*% Data Variance Threshold*
100 - Most Sensitive, Sensitivity bar is set to the far right	0.05%
75	0.62525%
50	1.275%
25	1.8875%
0 - Least Sensitive, Sensitivity bar is set to the far left	2.5%



Within the Auto Stable menu, you can also choose to **Hold All Readings** for as many parameters as you set for Auto Stable. For instance, if pH and Ammonium have Auto Stable enabled and Hold All Readings is also enabled, then the display will hold the readings once pH and Ammonium have both reached their Auto Stable settings. You must press the **Esc** key to "release" the held display in order to take subsequent readings. **Hold All Readings** must be reactivated after each use!

CALIBRATION - AMMONIUM, NITRATE, CHLORIDE

The 6051030 ISE/conductivity cable has a specialized calibration container that resembles a large test tube. This calibration chamber can be used to calibrate the ISE sensors with the conductivity sensor. A ring-stand should be used to support this chamber.

> *The ISE sensors can be calibrated at 1, 2, or 3-points.*
> **A 2-point calibration without chilling a third calibration solution is extremely accurate and is the preferred method.**
> *Greatest accuracy is achieved if the actual samples to be measured are within 10 ˚C of the calibration solutions.*

CALIBRATION TIP: Exposure to the high ionic content of pH buffers can cause a significant, but temporary, drift in the ammonium, nitrate, and chloride ISE sensors. Therefore, when calibrating the pH sensor, YSI recommends that you use one of the following methods to minimize errors in the subsequent readings:

- When calibrating pH, remove ISE sensors from the cable bulkhead and plug the ports. After pH calibration is complete, replace the ISE sensors and proceed with their calibration with no stabilization delay.

- Calibrate pH first, immersing all of the sensors in the pH buffers. After calibrating pH, place the sensors in 100 mg/L nitrate or ammonium standard or 1000 mg/L chloride standard depending on the sensor in use and monitor the reading. Usually, the reading starts low and may take awhile to reach a stable value. When it does, proceed with the calibration. This may take several hours.

Preparing Chloride Standards

The following recipes are provided for preparation of 10 and 1000 mg/L chloride reagents. Nitrate and Ammonium standards can be purchased from YSI or other laboratory supply companies.

It is important to note that some of the chemicals required for these solutions could be hazardous under some conditions. It is the responsibility of the user to obtain and study the MSDS for each chemical and to follow the required instructions with regard to handling and disposal of these chemicals.

You will need: Solid sodium chloride or a certified 1000 mg/L chloride solution from a supplier, magnesium sulfate, high purity water, a good quality analytical balance, 1000 mL volumetric flask, an accurate 10 mL measuring devices, and 1000 mL glass or plastic storage vessels.

1000 mg/L Standard: Accurately weigh 1.655 grams of anhydrous sodium chloride and transfer into a 1000 mL volumetric flask. Add 0.5 grams of anhydrous magnesium sulfate to the flask. Add 500 mL of water to the flask, swirl to dissolve all of the reagents , and then dilute to the volumetric mark with water. Mix well by repeated inversion and then transfer the 1000 mg/L standard to a storage bottle. Rinse the flask extensively with water prior to its use in the preparation of the 10 mg/L standard. Alternatively, simply add 0.5 grams of magnesium sulfate to a liter of a 1000 mg/L chloride standard from a certified supplier.

10 mg/L Standard: Accurately measure 10 mL of the above 1000 mg/L standard solution into a 1000 mL volumetric flask. Add 0.5 grams of anhydrous magnesium sulfate to the flask. Add 500 mL of water, swirl to dissolve the solid reagents, and then dilute to the volumetric mark with water. Mix well by repeated inversion and then transfer the 10 mg/L standard to a storage bottle.

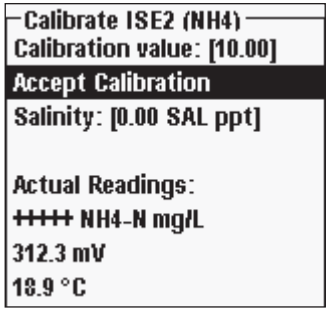
AMMONIUM (NH4+) , NITRATE (NO3-), AND CHLORIDE CL- 2-POINT

The calibration procedures for ammonium, nitrate, or chloride are similar to pH. The only differences are the calibration solutions. Recommended values for calibration solutions and the order of calibration are as follows:

Sensor	*1st Point*	*2nd Point*
Ammonium-nitrogen (NH4-N)	1 mg/L	100 mg/L
Nitrate-nitrogen (NO3-N)	1 mg/L	100 mg/L
Chloride (Cl-)	10 mg/L	1000 mg/L

Place the proper amount of 1 mg/L standard for Ammonium or Nitrate (10 mg/l for Chloride) into a clean, dry or pre-rinsed calibration cup. Carefully immerse the sensor into the solution. Allow at least 1 minute for temperature equilibration before proceeding.

Press Cal . Highlight Probe ID or User ID if you wish to add, select, edit, or delete an ID. Probe ID must be enabled in the System GLP menu to appear in the Calibrate menu. User ID will appear automatically. Select 'None' if you do not want a User ID stored with the calibration. When enabled, these IDs are stored with each calibration record in the GLP file.



After selecting your User ID and/or Probe ID if appropriate, highlight **Ammonium**, **Nitrate**, or **Chloride** to access the appropriate calibration, and press enter. The parameter you want to calibrate may appear under ISE1 or ISE2 depending on your cable type and setup. The message line will show the instrument is ready for the 1st calibration point.

The instrument will display the calibration value at the top of the screen. If necessary, highlight the **Calibration value** and press enter to input the correct value.

Once the readings stabilize, highlight **Accept Calibration** and press enter to accept the first calibration point. The message line will then display "Ready for point 2".

If you do not wish to perform a second point, press Cal (Cal) to finalize the calibration. If User Field 1 or 2 are enabled, you will be prompted to select these fields and then press Cal (Cal) to finalize the calibration. Alternatively, you may press Esc (Esc) to cancel the calibration.

To continue with the 2nd point, rinse the sensor with clean water, then dry it before placing it in the second calibration standard. Allow at least 1 minute for temperature equilibration before proceeding. The instrument will display the second calibration value at the top of the screen. If necessary, highlight the **Calibration value** and press enter to input the correct buffer value. Once the readings stabilize, highlight **Accept Calibration** and press enter to confirm the second calibration point. The message line will then display "Ready for point 3" and you can continue with the 3rd calibration point if desired.

If you do not wish to perform a 3rd calibration point, press Cal (Cal) to complete the calibration. If User Field 1 or 2 are enabled, you will be prompted to select these fields and then press Cal (Cal) to finalize the calibration. Alternatively, you may press Esc (Esc) to cancel the calibration.

AMMONIUM (NH4+) , NITRATE (NO3-), AND CHLORIDE CL- 3-POINT

A 2-point calibration without chilling a third calibration solution is extremely accurate and is the preferred method. If you must perform a 3-point calibration, the following procedure requires one portion of the high concentration calibration solution and two portions of the low concentration calibration solution. The

high concentration solution and one of the low concentration solutions should be at ambient temperature. The other low concentration solution should be chilled to less than 10 °C prior to calibration.

> ⚠ **WARNING**: *The chilled calibration solution MUST BE CHILLED TO AT LEAST 5 °C COOLER THAN THE 1ST CALIBRATION POINT, otherwise the 1st point will be OVERRIDDEN.*

Follow the procedure for a 2-point cal. After the second calibration point is complete, the message line with state 'Ready for point 3". Place the proper amount of chilled 1 mg/L standard (10 mg/L for the chloride) into a clean, dry or pre-rinsed calibration cup. Carefully immerse the sensor into the solution. Allow for temperature equilibration. If necessary, highlight **Calibration value** and press enter to manually enter the 3rd buffer value. Once the readings are stable, highlight **Accept Calibration** and press enter to confirm. Press Cal (Cal) to complete the calibration. If User Field 1 or 2 are enabled, you will be prompted to select these fields and then press Cal (Cal) to finalize the calibration. Alternatively, press Esc (Esc) to cancel the calibration.

TAKING MEASUREMENTS

To obtain the most accurate readings, be sure the instrument is calibrated before taking measurements.

DISSOLVED OXYGEN

Turn the instrument on and wait 5-15 minutes if using a polarographic sensor. If using a field cable/sensor, install the sensor guard to protect the sensor and membrane. Place the probe in the sample to be measured and give the probe a quick shake to release any air bubbles. Allow the temperature readings to stabilize. Next, stir the probe in the sample to overcome the stirring dependence of the dissolved oxygen sensor. You must provide at least 3 inches per second for 2.0 PE membranes, 6 inches per second for 1.25 PE membranes, and 12 inches per second for Teflon® membranes. Once the values plateau and stabilize, you may record the measurement and/or log the data set. The dissolved oxygen reading will drop over time if stirring is ceased.

If placing the DO sensor into a stream or fast flowing waters it is best to place it perpendicular to the flow and NOT facing into the flow.

If using the DO sensor in an aeration tank/basin, it is helpful to make sure bubbles do not burst on the membrane since this may cause unstable readings. You should be able to prevent this by pointing the sensor upwards so it's facing

the sky and then twist tying, zip tying, or rubber banding the bulkhead to the cable. Making a simple curve to the cable without bending or breaking the cable will allow you to lower the sensor into the aeration tank while the sensor points skyward so the bubbles are no longer bursting on the membrane surface.

CONDUCTIVITY

The conductivity sensor will provide quick readings as long as the entire sensor is submerged and no air bubbles are trapped in the sensor area. Immerse the probe into the sample so the sensors are completely submerged and then shake the probe to release any air bubbles. Occasional cleaning of the sensor may be necessary to maintain accuracy and increase the responsiveness. To clean the sensor, use the conductivity cleaning brush with a mild detergent.

pH/ORP

pH and ORP readings are typically quick and accurate. However, it may take the sensors a little longer to stabilize if they become coated or fouled. To improve the response time of a sensor, follow the cleaning steps in the Maintenance section of this manual.

AMMONIUM, NITRATE, AND CHLORIDE

These sensors may take a little longer to stabilize if the tips are dirty or fouled. If installed with a pH sensor, always maintain a clean pH sensor for a more rapid sensor stabilization.

These sensors can only be used in freshwater.

LOGGING DATA

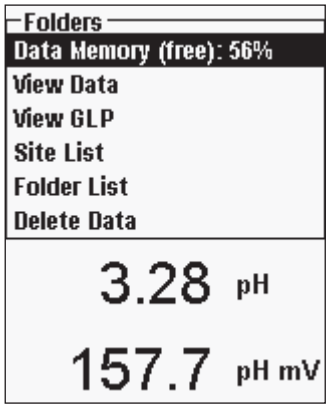
Log One Sample is already highlighted in Run mode. Press enter to open a submenu. If **Use Site List** and or **Use Folder List** are enabled in the Logging Setup menu, you will have to option to select these two items before the data point is logged. If necessary, use the keypad to create a new Site or Folder name. If Site List and Folder List are disabled in the **System** menu, you will not see these options when logging a sample. Once the Site and/or Folder name is selected, highlight **Log Now** and press Enter. The instrument will confirm that the data point was successfully logged.

If you would like to log at a specific interval vs. logging one sample at a time or vice versa, press **System**, then highlight **Logging** and press enter. Select **Continuous Mode** and adjust the time Interval if necessary. On the Run screen, the option to log will change from **Log One Sample** to **Start Logging** based on the time interval entered in the Logging Menu.

During a continuous log, the Start Logging dialog box on the Run screen will change to Stop Logging. Press Enter to stop continuous logging.

FILES AND SITE LISTS

FILE MEMORY

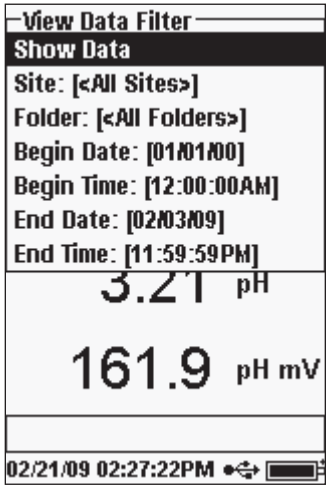


To view the file memory, press **File**.

The **Data Memory** shows a percentage indicating the amount of memory available. If the file memory is near 0%, files should be downloaded to a PC and/or deleted to free up memory.

VIEWING SAVED DATA

Press **File**, highlight **View Data** and press enter.

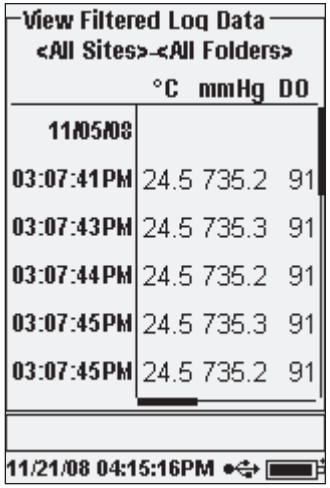


Configuring your data view:

Site: will allow you to view data from one particular site or all sites. Highlight **Site**, press enter, and select the site you wish to view data from or select **All Sites** to view data from all sites.

Folder: will allow you to view data from one particular folder or all folders. Highlight **Folder**, press enter, and select the file you wish to view data from or select **All Folders** to view data from all folders.

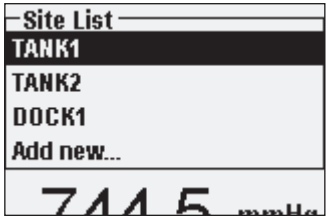
Begin Date, Begin Time, End Date, and **End Time:** will allow you to view data collected between a specific time period. Highlight the



time qualifier you would like to set, press enter, and use the numeric entry screen to select the date/time you wish to view.

After making your selections in the Data Filter, highlight **Show Data** and press enter. The data will have date and time stamps. You will likely have to scroll up and down and side to side using the arrow keys to completely view the data file. No more than 100 data records can be viewed at one time.

SITE LIST



To modify the **Site List**, press **File**, highlight **Site List**, and press enter. Enter new site names or edit existing sites with the alpha/numeric entry screen. Site lists can also be created and edited on your PC with Data Manager and then downloaded to the instrument.

FOLDER

To modify the **Folder List**, press **File**, highlight **Folder List**, and press enter. Enter new Folder names or edit existing folders with the alpha/numeric entry screen.

DELETE DATA

Press **File**, highlight **Delete Data**, and press enter. Enter the criteria for the data you wish to delete in the Delete Data Filter, then highlight **Delete Data** and press enter.

DATA MANAGER DESKTOP SOFTWARE

Data Manager is provided with the purchase of a Pro Plus Instrument. Data Manager is a powerful Windows® based software that will allow you to easily manage logged data, set up instruments, and conduct real time studies.

Minimum PC system requirements for Data Manager are Windows® 2000 with SP4 (minimum) or Windows® XP with SP2 (minimum) Operating System, 300 MHz or higher Pentium®-compatible CPU, 128 MB of RAM or higher, 80 MB or more of free hard-disk space, USB 2.0, and Microsoft® .NET.

Data Manager needs to be installed on a PC before use and before you try to connect a Pro Plus to your PC. First install Data Manger, then connect the communications saddle to the PC and, lastly, connect the saddle to your Pro Plus. Data Manager will identify the connected instruments by their Unit ID.Refer to the Data Manager Readme file for detailed installation instructions. Data Manager will then recognize the attached instruments.

From the 'home' screen of Data Manager, see below, you can select one of the following functions: Retrieve Instrument Data, Real Time Instrument Data, Instrument Configuration, or View Saved File/Data.

USING THE COMMUNICATIONS SADDLE

> ⚠ **WARNING**: *DO NOT connect the Communications Saddle to your PC before installing Data Manager. The Communication Saddle drivers MUST be installed prior to connecting it to your PC. The drivers will install automatically during the Data Manager installation. The first time the saddle is connected to the PC, you may have to walk through a couple of installation wizards. For detailed instruction, please refer to the Readme file located on the CD that was included with your instrument.*

A PC will recognize the Communications Saddle (saddle) as a YSI water quality instrument with or without the Pro Plus installed in the saddle.

To connect the saddle to a Pro Plus, simply align the saddle to the oval section on top of the instrument and push it down to snap it in place (Figure 6).

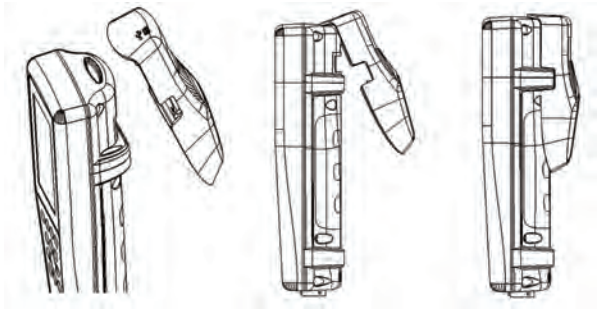


Figure 6. Locate the oval alignment groove at the top of the instrument and inside the saddle. Insert the saddle into this oval groove. Press the saddle towards the back of the instrument until it snaps into place.

Connect the USB cable to the top of the saddle and to a USB port on the PC. Once Data Manager is launched, the program will recognize all saddles with instruments connected to the PC.

The instrument will be powered through the saddle and USB connection when connected to the PC. However, the instrument must still have batteries installed in order to keep the date and time correct when powering the PC off at night. Make sure the instrument is turned off first, then turn off the PC to keep the instrument from running all night on the batteries. If you power it off and power off the PC the instrument will keep the correct date and time if it has batteries installed. If batteries are not installed, the instrument's date and time will not remain correct and will need to be reset each morning.

MANAGE LOGGED DATA

Data that has been logged to the Professional Plus can easily be uploaded to the PC via the provided USB saddle. You can upload sensor data, GLP files, site lists, and instrument configuration files individually or all at once. After connecting the instrument to the PC via the USB saddle and cable and launching Data Manager, click the **Retrieve Instrument Data** tab. Click on the Instrument's Unit ID you would like to retrieve data from, then select the files you would like to retrieve and click Start.

Once the sensor data is uploaded to the PC, you can graph and view tabular data by instrument Unit ID, date/time, site name, and/or folder name. This allows you to configure the report according to your needs. You can choose to view all data from all instruments, or select a certain date/time range for only a few specific instruments, there are multiple ways to view the data. Once the report has been defined, you will be able to print the graph and/or export the table.

Data Manager takes information management one step further and allows you to delete specific points instead of entire files. This allows you to clean up data that is no longer needed or that may have been collected erroneously, for example, when the sensor was out of the water. If you can not delete data due to regulation and compliance purposes, Data Manager has the solution. While viewing logged data or real time data, you have the ability to 'tag' individual data points with comments.

In addition to sensor data, you will be able to view GLP files, site lists, and configuration files that have been uploaded from the instrument. These can be printed and exported as well.

REAL TIME STUDIES

Data Manager allows you to view real time data on the PC.

After selecting your instrument, click the **Real Time Instrument Data** tab. Next, input your sample interval, site/folder name, select the parameters you wish to view and click **OK**. You must click **Start** on the next screen to begin your real time study. Choose to hide the table or graph by unchecking the box next to these options. Click **Stop**, then **Edit Setup** to change the Y-scale min/max of the graph, to select different colors, or to name your graph. Add a comment to a data point by clicking in the comment field of the table next to the data point. You may also **Print** the graph and **Export** the data for viewing in another program.

CONFIGURE INSTRUMENTS

Data Manager allows for easy and quick configuration of single or multiple instruments. Once you have uploaded a site list or configuration file, you can edit it as needed, save it, and download it to other instruments. You no longer need to configure each instrument individually. By using the same configuration file for all instruments, you can rest assured that all instruments will have identical settings.

New site lists and configuration files can be created in Data Manager as well. These lists and files can be downloaded to one or multiple instruments. Save time by creating these files on your PC and downloading them to the instrument as opposed to creating them on the instrument.

CARE, MAINTENANCE, AND STORAGE

This section describes the proper procedures for care, maintenance and storage of the sensors. The goal is to maximize their lifetime and minimize down-time associated with improper sensor usage.

UPDATING INSTRUMENT FIRMWARE

The instrument's firmware can be updated via www.ysi.com. There you will find the new firmware file and instructions on how to update the instrument. There is no need to send the instrument back to the factory for upgrades.

GENERAL MAINTENANCE

GENERAL MAINTENANCE - O-RINGS

The instrument utilizes o-rings as seals to prevent water from entering the battery compartment and sensor ports. Following the recommended procedures will help keep your instrument functioning properly.

If the o-rings and sealing surfaces are not maintained properly, it is possible that water can enter the battery compartment and/or sensor ports of the instrument. If water enters these areas, it can severely damage the battery terminals or sensor ports causing loss of battery power, false readings, and corrosion to the sensors or battery terminals. Therefore, when the battery compartment lid is removed, the o-ring that provides the seal should be carefully inspected for contamination (e.g. debris, grit, etc.) and cleaned if necessary.

The same inspection should be made of the o-rings associated with the sensor connectors when they are removed. If no dirt or damage to the o-rings is evident, then they should be lightly greased without removal from their groove. However, if there is any indication of damage, the o-ring should be replaced with an identical o-ring. At the time of o-ring replacement, the entire o-ring assembly should be cleaned.

To remove the o-rings:
Use a small, flat-bladed screwdriver or similar blunt-tipped tool to remove the o-ring from its groove. Check the o-ring and the groove for any excess grease or contamination. If contamination is evident, clean the o-ring and nearby plastic parts with lens cleaning tissue or equivalent lint-free cloth. Alcohol can be used to clean the plastic parts, but use only water and mild detergent on the o-ring itself. Also, inspect the o-rings for nicks and imperfections.

> ⚠ *Using alcohol on o-rings may cause a loss of elasticity and may promote cracking. Do not use a sharp object to remove the o-rings. Damage to the o-ring or the groove may result.*

Before re-installing the o-rings, make sure to use a clean workspace, clean hands, and avoid contact with anything that may leave fibers on the o-ring or grooves. Even a very small amount of contamination (hair, grit, etc.) may cause a leak.

To re-install the o-rings:
Place a small amount of o-ring grease between your thumb and index finger. (More grease is NOT BETTER!)

Draw the o-ring through the grease while pressing the fingers together to place a very light covering of grease to the o-ring. Place the o-ring into its groove making sure that it does not twist or roll.

Use your grease-coated finger to once again lightly go over the mating surface of the o-ring.

> ⚠ *Do not over-grease the o-rings. The excess grease may collect grit particles that can compromise the seal. Excess grease can also cause the waterproofing capabilities of the o-ring to diminish, potentially causing leaks. If excess grease is present, remove it using a lens cloth or lint-free cloth.*

GENERAL MAINTENANCE - SENSOR PORTS

It is important that the entire sensor connector end be dry when installing, removing or replacing. This will prevent water from entering the port. Once a sensor is removed, examine the connector inside the port. If any moisture is present, use compressed air to completely dry the connector or place directly in front of a steady flow of fresh air. If the connector is corroded, return the cable to your dealer or directly to an YSI Repair Center.

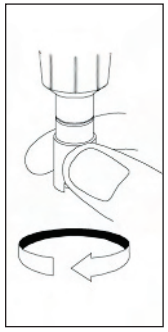
> ⓘ *Remove sensors upside down (facing the ground) to help prevent water from entering the port upon removal.*

SENSOR MAINTENANCE

SENSOR MAINTENANCE - DISSOLVED OXYGEN

Membrane Cap Installation

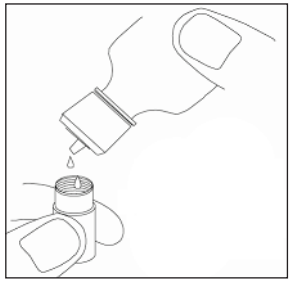
The DO sensor (Polarographic and Galvanic) is shipped with a dry, protective red cap that will need to be removed before using. Remove the protective cap or used membrane cap and replace it with a new membrane cap following these instructions:



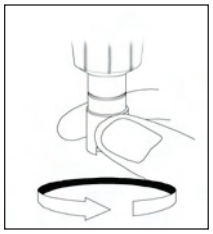
Remove the sensor guard to access the sensor tip.

Unscrew and remove any old membrane cap by holding the sensor when unscrewing the membrane cap and discard.

Thoroughly rinse the sensor tip with distilled or DI water.



Fill a new membrane cap with O2 sensor electrolyte solution that has been prepared according to the directions on the bottle. Be very careful not to touch the membrane surface. Lightly tap the side of the membrane cap to release bubbles that may be trapped.



Thread the membrane cap onto the sensor. It is normal for a small amount of electrolyte to overflow.

Polarographic Sensors - Model # 605203

The KCl (potassium chloride) solution and the membrane cap should be changed at least once every 30 days during regular use. In addition, the KCl solution and membrane should be changed if (a) bubbles are visible under the membrane; (b) significant deposits of dried electrolyte are visible on the membrane; and (c) if the sensor shows unstable readings or other sensor-related symptoms.

During membrane changes, examine the gold cathode at the tip of the sensor and the silver anode along the shaft of the sensor. If either the silver anode is black in color or the gold cathode is dull, the sensor may need resurfaced using the fine sanding disks included in the membrane kit. Do not sand the electrode every membrane change as this is not routine maintenance. In fact, visually, the anode may appear tarnished and operate just fine. YSI recommends using the 400 grit wet/dry sanding disks to resurface the electrodes if the sensor has difficulty stabilizing or calibrating after a membrane change.

To resurface the sensor using the fine sanding disk, follow the instructions below.

Gold Cathode:

For correct sensor operation, the gold cathode must be textured properly. It can become tarnished or plated with silver after extended use. Never use chemicals or abrasives not recommended or supplied by YSI.

First dry the sensor tip completely with lens cleaning tissue. Wet a sanding disk with a small amount of clean water and place it face up in the palm of your hand. Next, with your free hand, hold the sensor in a vertical position, tip down. Place the sensor tip directly down on the sanding disk and twist it in a circular motion to sand the gold cathode. The goal is to sand off any build-up and to lightly scratch the cathode to provide a larger surface area for the O2 solution under the membrane. Usually, 3 to 4 twists of the sanding disk are sufficient to remove deposits and for the gold to appear to have a matte finish. Rinse thoroughly and wipe the gold cathode with a wet paper towel before putting on a new membrane

cap. If the cathode remains tarnished, contact YSI Technical Support or the Authorized dealer where you purchased the instrument.

Silver Anode

After extended use, a thick layer of Silver Chloride (AgCl) builds up on the silver anode reducing the sensitivity of the sensor. The anode must be cleaned to remove this layer and restore proper performance. The cleaning can be chemical or mechanical:

Chemical cleaning: Remove the membrane cap and rinse the electrodes with deionized or distilled water. Soak the sensing anode section of the sensor in a 14% ammonium hydroxide solution for 2 to 3 minutes or in a 3% ammonia solution overnight for 8-12 hours (most household ammonia cleaners are typically around 3%). Rinse heavily in cool tap water followed by a thorough rinsing with distilled or deionized water. The anode should then be thoroughly wiped with a wet paper towel to remove the residual layer from the anode. You can smell the tip of the sensor to help ensure all the ammonia has been rinsed off. Trapping residual ammonia under the new membrane cap can quickly tarnish the electrode and/or give false readings.

Chemical cleaning should be performed as infrequently as possible. First attempt a membrane change and recalibrate. If a new membrane does not resolve the problem, then proceed with cleaning.

Mechanical cleaning: In order to sand the silver anode along the shaft of the sensor, simply hold the sensor in a vertical position. Wet the sanding disk with a small amount of clean water then gently wrap it around the sensor shaft and twist it a few times to lightly sand the anode (the goal is to simply sand off any build-up without scratching or removing layers of the anode itself). Usually, 3 to 4 twists of the sanding disk are sufficient to remove deposits. However, in extreme cases, more sanding may be required to regenerate the original silver surface.

After completing the sanding procedure, repeatedly rinse the electrode with clean water and wipe with lens cleaning tissue to remove any grit left by the sanding disk. Thoroughly rinse the entire tip of the sensor with distilled or deionized water and install a new membrane.

IMPORTANT: *Be sure to: (1) Use only the fine sanding disks provided and (2) Sand as mentioned in the above procedures. Not adhering to either of these instructions can damage the electrodes. If this procedure is unsuccessful, as indicated by improper electrode performance, contact YSI Technical Support or the Authorized dealer where you purchased the instrument.*

Galvanic Sensors – Model # 605202

We recommend that the Sodium Chloride (NaCl) solution and the membrane cap be changed at least once every 60 days during regular use. In addition, the NaCl solution and membrane should be changed if (a) bubbles are visible under the membrane; (b) significant deposits of dried electrolyte are visible around the membrane; and (c) if the sensor shows unstable readings or other sensor-related symptoms.

The Galvanic dissolved oxygen sensor is continuously reducing oxygen even when the display of the instrument is not active. This factor allows the sensor to be used with no warm-up period as soon as the instrument is powered on (instant on DO). However, because the sensor is "on" all the time, some solid from the oxidation of the zinc anode will form in the electrolyte within 1-2 weeks of activation. Small amounts of the solid will generally cause no performance problems, but excessive amounts may result in jumpy dissolved oxygen readings. The rate of solid formation is dependent on the type of membrane installed. The formation of solids based on membrane type typically form more rapidly with the 5912 (1 mil Teflon), less rapid with 5913 (1.25 mil PE), and least rapid with 5914 (2 mil PE).

The Galvanic DO sensor solution will appear milky white after use but will NOT affect the accuracy of the sensor unless there is excessive build up. The color change is acceptable and normal as long as DO readings remain stable.

At the time the membrane cap is changed, YSI recommends that you rinse the anode (silver shaft of the sensor) with purified water and wipe with a clean paper towel. If white deposits are evident on the anode after cleaning, YSI recommends that you remove this material by sanding the anode with the sandpaper disk enclosed in your membrane kit. Follow the "Mechanical Cleaning" instructions under the Polarographic Silver Anode section.

IMPORTANT: *Be sure to: (1) Use only the fine sanding disks provided and (2) Sand as mentioned in the above procedures. Not adhering to either of these instructions can damage the electrodes.*
WARNING: *DO NOT PERFORM THE POLAROGRAPHIC CHEMICAL CLEANING ON A GALVANIC SENSOR. If this procedure is unsuccessful, as indicated by improper electrode performance, contact YSI Technical Support or the Authorized dealer where you purchased the instrument.*

SENSOR MAINTENANCE - CONDUCTIVITY

The openings that allow sample access to the conductivity electrodes should be cleaned regularly. The small cleaning brush included in the Maintenance Kit is ideal for this purpose. Dip the brush in clean water and insert it into each hole 10 to 12 times. In the event that deposits have formed on the electrodes, it may be necessary to use a mild detergent (laboratory grade soap or bathroom foaming tile cleaner) with the brush. Rinse thoroughly with clean water, then check the response and accuracy of the conductivity cell with a calibration standard.

If this procedure is unsuccessful, as indicated by improper electrode performance, contact YSI Technical Support or the Authorized dealer where you purchased the instrument.

SENSOR MAINTENANCE - TEMPERATURE

You must keep the temperature portion of the sensor free of build up. Other than that, the sensor requires no maintenance. The conductivity cleaning brush can be used to scrub the temperature sensor if needed. Alternatively, you can use a toothbrush to clean the sensor.

SENSOR MAINTENANCE - pH, ORP AND COMBINATION pH/ORP

Typical working life for pH and ORP sensors is approximately 12-24 months depending on usage, storage, and maintenance. Proper storage and maintenance generally extends the sensor's working life.

Cleaning is required whenever deposits or contaminants appear on the glass and/or platinum surfaces or when the sensor's response slows. The cleaning can be chemical and/or mechanical.

Removing the sensor from the cable may make cleaning easier. Initially, use clean water and a soft clean cloth, lens cleaning tissue, or cotton swab to remove all foreign material from the glass bulb and/or platinum button. Then use a moistened cotton swab to carefully remove any material that may be blocking the reference electrode junction of the sensor.

CAUTION: *When using a cotton swab, be careful NOT to wedge the swab between the guard and the glass sensor. If necessary, remove cotton from the swab tip, so that the cotton can reach all parts of the sensor tip without stress. You can also use a pipe cleaner for this operation if more convenient.*

If good pH and/or ORP response is not restored, perform the following additional procedure:

1. Soak the sensor for 10-15 minutes in clean water containing a few drops of commercial dishwashing liquid.
2. GENTLY clean the glass bulb and platinum button by rubbing with a cotton swab soaked in the cleaning solution.
3. Rinse the sensor in clean water, wipe with a cotton swab saturated with clean water, and then rerinse with clean water.

If good pH and/or ORP response is still not restored, perform the following additional procedure:

1. Soak the sensor for 30-60 minutes in one molar (1 M) hydrochloric acid (HCl). This reagent can be purchased from most lab supply distributors. Be sure to follow the safety instructions included with the acid.
2. Rinse the sensor in clean water, wipe with a cotton swab saturated with clean water (not DI water), and then rerinse with clean water. To be certain that all traces of the acid are removed from the sensor crevices, soak the sensor in clean water for about an hour with occasional stirring.

If biological contamination of the reference junction is suspected or if good response is not restored by the above procedures, perform the following additional cleaning step:

1. Soak the sensor for approximately 1 hour in a 1:1 dilution of commercially-available chlorine bleach.
2. Rinse the sensor with clean water and then soak for at least 1 hour in clean water with occasional stirring to remove residual bleach from the junction. (If possible, soak the sensor for a period of time longer than 1 hour in order to be certain that all traces of chlorine bleach are removed.) Then rerinse the sensor with clean water and retest.

Dry the port and sensor connector with compressed air and apply a very thin coat of o-ring lubricant to all o-rings before reinstallation.

SENSOR MAINTENANCE - CHLORIDE

Typical working life for chloride sensors is approximately 3-6 months depending on usage, storage, and maintenance. Proper storage and maintenance generally extends the sensor's working life.

The chloride sensor is considered a pellet membrane ISE. As always, when handling sensors, care should be taken to avoid damaging the membrane. This

sensor can be regenerated by washing with alcohol and/or gently polishing with fine emery paper in a circular motion to remove any deposits or discoloration, then thoroughly washing with deionized water to remove any debris. The sensor may require soaking in the high standard chloride calibration solution to recover its performance.

SENSOR MAINTENANCE - AMMONIUM AND NITRATE

> ⓘ *Typical working life for ammonium and nitrate sensors is approximately 3-6 months depending on usage, storage and maintenance. Proper storage and maintenance generally extends the sensor's working life.*

The ammonium and nitrate sensors are PVC membranes. As always, when handling a sensor, care should be taken to avoid damaging the membrane. After extensive use the membranes may become coated with a deposit or scoured with fine scratches which may cause a slow or reduced response (low slope) or unstable readings. Deposits may be removed with a fine jet of deionized water or rinsing in alcohol followed by soaking in the high standard calibration solution. Gently dab dry with a lint-free tissue before taking measurements.

SENSOR STORAGE

SHORT-TERM STORAGE

The cable assembly is supplied with a sensor storage container, or sleeve, that attaches to the cable. The container is used for short-term storage (less than 30 days). Be sure to keep a small amount of moisture (tap water) in the container during storage. This is done to maintain a 100% saturated air environment which is ideal for short-term sensor storage. The sensors should not be submersed in water. The intent is to create a humid air storage environment.

LONG-TERM STORAGE

Long-term Storage - Temperature

No special storage is required. The temperature sensor can be stored dry or wet as long as solutions in contact with the thermistor are not corrosive (for example, chlorine bleach).

Long-term Storage Temperature: -5 to 70°C (23 to 158°F)

Long-term Storage - Conductivity

No special storage is required. Sensors can be stored dry or wet as long as solutions in contact with conductivity electrodes are not corrosive (for example, chlorine bleach). However, it is recommended that the sensor be cleaned with the provided brush prior to and after long term storage.

Long-term Storage Temperature: -5 to 70°C (23 to 158°F)

Long-term Storage - Dissolved Oxygen

Dissolved oxygen sensors (Polarographic and Galvanic) should be stored in a dry state for long term storage First, remove the membrane cap and thoroughly rinse the sensor with clean water. Next, either blow it dry with compressed air or allow to air dry completely. Install a clean, dry new membrane cap over the sensor to keep it dry and to protect the electrodes.

After storing the sensor for a long period of time, it is necessary to "condition" the sensor by putting a new membrane with electrolyte solution on the sensor and then turning the instrument on to allow the sensor sufficient time to stabilize.

Long-term Storage Temperature: -5 to 70°C (23 to 158°F)

Long-term Storage - pH

The key to pH sensor storage, short or long-term, is to make certain that the sensor does not dry out. Sensors which have been allowed to dry out due to improper storage procedures may be irreparably damaged by the dehydration and will require replacement. You can try to rehydrate the sensor by soaking it (preferably overnight) in a potassium chloride solution or a pH 4 buffer before attempting to calibrate.

To store the sensor, remove it from the cable and seal the vacant port with a port plug. Fill the original shipping/storage vessel (plastic boot or bottle) with buffer 4 solution and then submerge the sensor into the solution. The sensor should remain submerged in the solution during the storage period; therefore, make certain that the vessel is sealed to prevent evaporation and periodically check the vessel to ensure the sensor does not dry out.

Long-term Storage Temperature: 0 to 30°C (32 to 86°F)

> ⓘ *It is important not to store the pH sensor in distilled or deionized water as the glass sensor may be damaged by exposure to this medium.*

Long-term Storage - ORP

To store, remove the sensor from the cable and seal the vacant port with the provided plug. Fill the original shipping/storage vessel (plastic boot or bottle) with buffer 4 solution and then submerge the sensor into the solution. The sensor should remain submerged in the solution during the storage period; therefore, make certain that the vessel is sealed to prevent evaporation and periodically check the vessel to ensure the sensor does not dry out.

Long-term Storage Temperature: 0 to 30°C (32 to 86°F)

Long-term Storage - Ammonium, Nitrate, and Chloride

The key to ISE sensor storage, short or long-term, is to make certain that the sensor does not dry out. Sensor junctions that have been allowed to dry out due to improper storage procedures may be irreparably damaged by the dehydration and will require replacement. You can attempt to rehydrate the sensor by soaking it (preferably overnight) in the sensor's high calibration solution before attempting to calibrate.

The recommended storage of these sensors is in moist air. Remove the sensor from the cable and seal the vacant port with the provided plug. Place the sensor in its original shipping storage vessel (plastic boot or bottle) with a small amount of tap water or its high calibration standard. The vessel should remain a saturated air environment. The sensor only needs to be kept in moist air, not submerged. Make certain that the vessel is sealed to prevent evaporation.

Long-term Storage Temperature: 0 to 30°C (32 to 86°F)

TROUBLESHOOTING

Illegal Value may appear during alpha/numeric entry on the message line. This only appears if the values entered do not match the formatting. This will also appear in GLP security area if the password is incorrect.

If you forget the GLP Security Password please contact YSI Tech Support at environmental@ysi.com, 800-897-4151, or +1 937 767-7241.

HELP

During use of the Professional Plus instrument, press **Question** ? from any screen to view help messages directly on the display.

ERROR MESSAGES

If readings for a certain parameter are over range you will see a series of +++++ and if the readings are under range you will see a series of ----- plus the error message along the bottom of the screen. If you see a series of ????? that will indicate that a certain parameter can not be calculated. The following are potential error messages:

Probe Temp over range
Probe Temp under range
Case Temp over range
Case Temp under range
pH over range
pH under range
ORP over range
ORP under range
Cl over range
Cl under range
NH4 over range
NH4 under range
NO3 over range
NO3 under range
DO over range
DO under range
Conductivity over range
Conductivity under range
Barometer over range
Barometer under range

Error messages for the sensors typically indicate a need to properly clean the sensor. First verify the sensor is properly setup in the Sensor menu, then conduct the recommended cleaning and attempt to calibrate the sensor. If this does not work, it may indicate the useful life of the sensor has been reached and may need to be replaced. You may also contact Technical Support to help determine the next step.

DISSOLVED OXYGEN

The dissolved oxygen sensors will use Probe Current (DO uA) and Probe Slope (%/uA) as part of their GLP file records. The following information indicates the acceptable values for each of these readings:

Polarographic DO at 25 ˚C, 100% saturated air environment at 760 mmHg

Probe Current

1.25 mil PE membrane

Average 6.15 uA (min. 4.31 uA, max. 8.00 uA)

2.0 mil PE membrane

Average 3.38 uA (min. 2.37 uA, max. 4.40 uA)

1 mil Teflon® membrane

Average 16.29 uA (min. 11.40 uA, max. 21.18 uA)

Probe Slope

1.25 mil PE membrane

Average 16.26 % sat/uA (min. 12.51 uA, max. 23.23 uA)

2.0 mil PE membrane

Average 29.56 % sat/uA (min. 22.74 uA, max. 42.23 uA)

1 mil Teflon® membrane

Average 6.14 % sat/uA (min. 4.72 uA, max. 8.77 uA)

RESTORE DEFAULT CALIBRATION VALUES

Occasionally, the instrument may need to have the factory calibration default values restored. In order to accomplish this press Calibrate (Cal), highlight **Restore Default Cal** and press enter. Highlight the parameter you wish to restore to default and press enter. Next you will be asked to confirm the operation. Highlight **Yes** and press enter to confirm.

ACCESSORIES / PART NUMBERS

*Cable Part Number**	*Description*
6050000	Professional Plus Instrument
60510-1, -4, -10, -20, or -30	1, 4, 10, 20, or 30-meter cable for ISE/temp
60520-1, -4, -10, -20, or -30**	1, 4, 10, 20, or 30-meter cable for DO/temp
60530-1, 4, -10, -20, or -30	1, 4, 10, 20 or 30-meter cable for Cond/temp
6051010-1, 4, -10, -20, or -30	1, 4, 10, 20, or 30-meter cable for ISE/ISE/temp
6051020-1, -4, -10, -20, or -30	1, 4, 10, 20, or 30-meter cable for ISE/DO/temp
6051030-1, 4, -10, -20, or -30	1, 4, 10, 20, or 30-meter cable for ISE/Cond/temp
6052030-1, -4, -10, -20, or -30	1, 4, 10, 20 or 30-meter cable for DO/Cond/temp
605790-1, -4, -10, -20, or -30	1, 4, 10, 20 or 30-meter Quatro cable for DO/Cond/temp/ISE/ISE
605107	1-meter pH/temp single junction lab-grade combo electrode
605177	4-meter pH/temp single junction lab-grade combo electrode
605108	1-meter ORP/temp single junction lab-grade combo electrode
605178	4-meter ORP/temp single junction lab-grade combo electrode
605109	1-meter pH/ORP/temp single junction lab-grade combo electrode
605179	4-meter pH/ORP/temp single junction lab-grade combo electrode

Sensor Part Number	*Description*
605202	Galvanic DO sensor
605203	Polarographic DO sensor
605101	pH (ISE)
605102	ORP (ISE)
605103***	pH/ORP Combination (ISE)
605104****	Ammonium (ISE)

Sensor Part Number	*Description*
605105****	Chloride (ISE)
605106****	Nitrate (ISE)
605780	Self-Stirring BOD sensor
005560	Conductivity/Temperature sensor for Quatro cable

* All cables include temperature.
Cables with conductivity include sensor
(no need to order separate conductivity sensor).
** Special order cables up to 100-meters are available with 60520 cables.
*** Not compatible with 6051010-X or Quatro cables.
**** Freshwater only

Accessory Part Number	*Description*
603059	Flow cell, standard, 203 mL (for two-port sensors)
603077	Flow cell kit, 1 or 2 port sensor (includes 603059 flow cell for two-port sensors with the 603078 adapter for one-port sensors)
603078	Flow cell adapter, single port (use with 603059 flow cell to accommodate one-port sensors)

Accessory Part Number	*Description*
605990	Flow cell kit for Quatro cable assemblies.
603056	Flow cell mounting spike
605604	Communications saddle kit
605515	Data Manager desktop software
603075	Carrying case, soft-sided
603074	Carrying case, hard-sided
605745	Maintenance kit
038213	Brush, tube cleaner
601205	Grease, o-ring

Accessory Part Number	*Description*
603069	Belt clip
063517	Ultra clamp
063507	Tripod clamp
603062	Cable management kit
605978	Weight, sensor/cable, 4.9 oz.
063019	Weight, sensor/cable, 24 oz., 3”
063020	Weight, sensor/cable, 51 oz., 6”
603070	Shoulder strap

Solutions Part Number	*Description*
3161	1,000 us/cm conductivity solution (quart)
3163	10,000 us/cm conductivity solution (quart)
3169	50,000 us/cm conductivity solution (8 pints)
3682	Zobell ORP solution (125 mL)
3824	pH 4, 7, 10 buffers (2 pints of each)
3841	1 mg/L ammonium solution (500 mL)
3842	10 mg/L ammonium solution (500 mL)
3843	100 mg/L ammonium solution (500 mL)
3885	1 mg/L nitrate solution (500 mL)
3886	10 mg/L nitrate solution (500 mL)
3887	100 mg/L nitrate solution (500 mL)
5580	Confidence Solution (verifies pH, ORP, conductivity sensor performance)

DECLARATION OF CONFORMITY

The undersigned hereby declares on behalf of the named manufacturer under our sole responsibility that the listed product conforms to the requirements for the listed European Council Directive(s) and carries the CE mark accordingly.

Manufacturer:	YSI Incorporated 1725 Brannum Lane Yellow Springs, OH 45387 USA
Product Name:	Professional Plus Water Quality Instrument
Model Numbers	
Instrument/Accessory:	Professional Plus (6050000) / ProComm (605604)
Probe/Cable Assemblies:	605107, 605177, 605108, 605178, 605109, 605179, 605780, 60510, 60520, 60530, 6051010, 6051020, 6051030, 6052030, 605790
Sensors:	605202, 605203, 605780, 605101, 605102, 605103, 605104, 605105, 605106, 005560
Conforms to the following:	
Directives:	EMC 2004/108/EC RoHS 2002/95/EC WEEE 2002/96/EC

Harmonized Standards:	• EN61326-1:2006, Electrical equipment for measurement, control, and laboratory use – EMC requirements – Part 1: General Requirements • EN61326-2-3:2006, Electrical equipment for measurement, control and laboratory use – EMC requirements – Part 2-3: Particular Requirements – Test configuration, operational conditions, and performance criteria for transducers with integrated or remote signal conditioning. • EN61000-3-2:2006, Electromagnetic compatibility (EMC) – Part 3-2: Limits – Limits for harmonic current emissions (equipment input current < 16A per phase). • EN61000-3-3:1995 +A1:2001 +A2:2005, Electromagnetic compatibility (EMC) – Part 3: Limits – Section 3: Limitation of voltage fluctuations and flicker in low-voltage supply systems for equipment with rated current < 16A.
Supplementary Information:	All performance met the continuous unmonitored operation criteria as follows: 1. ESD, EN61000-4-2, Performance Criterion B 2. Radiated Immunity, EN61000-4-3, Performance Criterion A 3. EFT, EN61000-4-4, (EFT) Performance Criterion B 4. Surge, EN61000-4-5, Performance Criterion B 5. Conducted Immunity, EN61000-4-6, Performance Criterion A 6. Voltage Interrupts, EN61000-4-11, Performance Criterion B 7. RF Emissions, EN55011:1998, A1:1999 Class B equipment
Authorized EU Representative	YSI Hydrodata Ltd Unit 8, Business Centre West, Avenue 1 Letchworth, Hertfordshire, SG6 2HB UK

Signed: Lisa M. Abel Date: 22 February 2008
Title: Director of Quality

The undersigned hereby declares on behalf of the named manufacturer under our sole responsibility that the listed product conforms to the requirements for electrical equipment under US FCC Part 15 and ICES-003 for unintentional radiators.

Manufacturer:	YSI Incorporated 1725 Brannum Lane Yellow Springs, OH 45387 USA
Product Name:	
Model Numbers	
Instrument/Accessory:	Professional Plus (6050000) / ProComm (605604)
Probe/Cable Assemblies:	605107, 605177, 605108, 605178, 605109, 605179, 605780, 60510, 60520, 60530, 6051010, 6051020, 6051030, 6052030, 605790
Sensors:	605202, 605203, 605780, 605101, 605102, 605103, 605104, 605105, 605106, 005560
Conforms to the following:	
Standards:	• FCC 47 CFR Part 15-2008, Subpart B, Class B, Radio Frequency Devices • ICES-003:2004, Digital Apparatus
Supplementary Information:	Tested using ANSI C63.4-2003 (excluding sections 4.1, 5.2, 5.7, 9, and 14)

Signed: Lisa M. Abel Date: 22 February 2008
Title: Director of Quality

The undersigned hereby declares on behalf of the named manufacturer under our sole responsibility that the listed product conforms with the Australian and New Zealand Electromagnetic Compatibility (EMC) requirements for generic products to be used in residential, commercial, and light industrial environments.

Manufacturer:	YSI Incorporated 1725 Brannum Lane Yellow Springs, OH 45387 USA
Product Name:	Professional Plus Water Quality Instrument
Model Numbers	
Instrument/Accessory:	Professional Plus (6050000) / ProComm (605604)
Probe/Cable Assemblies:	605107, 605177, 605108, 605178, 605109, 605179, 605780, 60510, 60520, 60530, 6051010, 6051020, 6051030, 6052030, 605790
Sensors:	605202, 605203, 605780, 605101, 605102, 605103, 605104, 605105, 605106, 005560
Conforms to the following:	
Standards:	• AS/NZS 4251.1:1999, Electromagnetic Compatibility (EMC) – Generic emission standard – Part 1: Residential, commercial, and light industry.

Signed: Lisa M. Abel Date: 22 February 2008
Title: Director of Quality

RECYCLING

YSI is committed to reducing the environmental footprint in the course of doing business. Even though materials reduction is the ultimate goal, we know there must be a concerted effort to responsibly deal with materials after they've served a long, productive life-cycle. YSI's recycling program ensures that old equipment is processed in an environmentally friendly way, reducing the amount of materials going to landfills.

- Printed Circuit Boards are sent to facilities that process and reclaim as much material for recycling as possible.
- Plastics enter a material recycling process and are not incinerated or sent to landfills.

- Batteries are removed and sent to battery recyclers for dedicated metals.

When the time comes for you to recycle, follow the easy steps outlined at www.ysi.com.

CONTACT INFORMATION

ORDERING AND TECHNICAL SUPPORT

Telephone: 800 897 4151 (US)
+1 937 767 7241 (Globally)
Monday through Friday, 8:00 AM to 5:00 ET

Fax: +1 937 767 9353 (orders)
+1 937 767 1058 (technical support)

Email: environmental@ysi.com or proseries@ysi.com

Mail: YSI Incorporated
1725 Brannum Lane
Yellow Springs, OH 45387 USA

Internet: www.ysi.com

When placing an order please have the following available:
1.) YSI account number (if available)
2.) Name and phone number
3.) Purchase Order or Credit Card
4.) Model Number or brief description
5.) Billing and shipping addresses
6.) Quantity Telephone: 800 897 4151 (US)

SERVICE INFORMATION

YSI has authorized service centers throughout the United States and Internationally. For the nearest service center information, please visit www.ysi.com and click 'Support' or contact YSI Technical Support directly at 800-897-4151.

When returning a product for service, include the Product Return form with cleaning certification. The form must be completely filled out for a YSI Service Center to accept the instrument for service. The form may be downloaded from www.ysi.com by clicking on the 'Support" tab, then the Product Return Form button.

Item # 605596
Rev D
Drawing # A605596
March 2009

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YSI **Environmental**

YSI 556 MPS

Multi Probe System

Operations Manual

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1. Safety

1.1 General Information

Read all safety information in this manual carefully before using the YSI 556 Multi-Probe System (MPS). Reagents that are used to calibrate and check this instrument may be hazardous to your health. Take a moment to review Appendix D Health and Safety.

⚠ **WARNING**

Warnings are used in this manual when misuse of the instrument could result in death or serious injury to a person.

⚠ **CAUTION**

Cautions are used in this manual when misuse of the instrument could result in mild or serious injury to a person and/or damage to equipment.

⚠ **IMPORTANT SAFETY INSTRUCTIONS!**

⚠ **SAVE THESE INSTRUCTIONS!**

⚠ In essence, the most important safety rule for use of the YSI 556 MPS is to utilize the instrument ONLY for purposes documented in this manual. This is particularly true of the YSI 6117 rechargeable battery pack that contains nickel metal hydride (NiMH) batteries. The user should be certain to read all of the safety precautions outlined below before using the instrument.

⚠ Batteries

⚠ This instrument is powered by alkaline or optional nickel-metal hydride batteries, which the user must remove and dispose of when the batteries no longer power the instrument. Disposal requirements vary by country and region, and users are expected to understand and follow the battery disposal requirements for their specific locale.

The circuit board in this instrument contains a manganese dioxide lithium "coin cell" battery that must be in place for continuity of power to memory devices on the board. This battery is not user serviceable or replaceable.

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When appropriate, an authorized YSI service center will remove this battery and properly dispose of it, per service and repair policies.

⚠YSI Rechargeable Battery Pack Safety Information

⚠Restrictions on Usage

1. Never dispose of the battery pack in a fire.
2. Do not attempt to disassemble the YSI 6117 battery pack
3. Do not tamper with any of the electronic components or the batteries within the battery pack. Tampering with either the electronic circuitry or the batteries will result in the voiding of the warranty and the compromising of the system performance, but, more importantly, can cause safety hazards which result from overcharging such as overheating, venting of gas, and loss of corrosive electrolyte.
4. Do not charge the battery pack outside the 0–40°C temperature range.
5. Do not use or store the battery at high temperature, such as in strong direct sunlight, in cars during hot weather, or directly in front of heaters.
6. Do not expose the battery pack to water or allow the terminals to become damp.
7. Avoid striking or dropping the battery pack. If the pack appears to have sustained damage from these actions or malfunctions after an impact or drop, the user should not attempt to repair the unit. Instead, contact YSI Customer Service. Refer to *Appendix E Customer Service.*
8. If the battery pack is removed from the YSI 556 MPS, do not store it in pockets or packaging where metallic objects such as keys can short between the positive and negative terminals.

⚠Precautions for Users with Small Children.

Keep the battery pack out of reach of babies and small children.

⚠Danger Notifications – Misuse creates a STRONG possibility of death or serious injury.

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FAILURE TO CAREFULLY OBSERVE THE FOLLOWING PROCEDURES AND PRECAUTIONS CAN RESULT IN LEAKAGE OF BATTERY FLUID, HEAT GENERATION, BURSTING, AND SERIOUS PERSONAL INJURY.

1. Never dispose of the battery pack in a fire or in heat.
2. Never allow the positive and negative terminals of the battery pack to become shorted or connected with electrically conductive materials. When the battery pack has been removed from the YSI 556 MPS, store it in a heavy plastic bag to prevent accidental shorting of the terminals.
3. Never disassemble the battery pack and do not tamper with any of the electronic components or the batteries within the battery pack. The battery pack is equipped with a variety of safety features. Accidental deactivation of any of these safety features can cause a serious hazard to the user.
4. The NiMH batteries in the battery pack contain a strong alkaline solution (electrolyte). The alkaline solution is extremely corrosive and will cause damage to skin or other tissues. If any fluid from the battery pack comes in contact with a user's eyes, immediately flush with clean water and consult a physician immediately. The alkaline solution can damage eyes and lead to permanent loss of eyesight.

⚠ Warning Notifications – Misuse creates a possibility of death or serious injury

1. Do not allow the battery pack to contact freshwater, seawater, or other oxidizing reagents that might cause rust and result in heat generation. If a battery becomes rusted, the gas release vent may no longer operate and this failure can result in bursting.
2. If electrolyte from the battery pack contacts the skin or clothing, thoroughly wash the area immediately with clean water. The battery fluid can irritate the skin.

⚠ Caution Notifications – Misuse creates a possibility of mild or serious injury or damage to the equipment.

1. Do not strike or drop the battery pack. If any impact damage to the battery pack is suspected, contact YSI Customer Service. Refer to *Appendix E Customer Service*.

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2. Store the battery pack out of reach of babies and small children.
3. Store the battery pack between the temperatures of -20 and 30°C.
4. Before using the battery pack, be sure to read the operation manual and all precautions carefully. Then store this information carefully to use as a reference when the need arises.

⚠YSI 616 Cigarette Lighter Charger Safety Information

1. This section contains important safety and operating instructions for the YSI 556 MPS cigarette lighter battery charger (YSI 616; RadioShack Number 270-1533E). BE SURE TO SAVE THESE INSTRUCTIONS.
2. Before using the YSI 616 cigarette lighter charger, read all instructions and cautionary markings on battery charger, battery pack, and YSI 556 MPS.
3. Charge the YSI 6117 battery pack with the YSI 616 cigarette lighter charger ONLY when the YSI 6117 is installed in the YSI 556 MPS.
4. Do not expose charger to rain, moisture, or snow.
5. Use of an attachment not recommended or sold by the battery charger manufacturer may result in a risk of fire, electric shock, or injury to persons.
6. To reduce risk of damage to cigarette lighter and cord, pull by cigarette lighter rather than cord when disconnecting charger.
7. Make sure that the cord is located so that it will not be stepped on, tripped over, or otherwise subjected to damage or stress.
8. Do not operate charger with damaged cord or cigarette lighter connector – replace it immediately.
9. Do not operate charger if it has received a sharp blow, been dropped, or otherwise damaged in any way; contact YSI Customer Service. Refer to *Appendix E Customer Service*.
10. Do not disassemble charger other than to change the fuse as instructed. Replace the part or send it to YSI Product Service if repair is required (refer to *Appendix E Customer Service*). Incorrect reassembly may result in a risk of electric shock or fire.

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11. To reduce risk of electric shock, unplug charger before attempting any maintenance or cleaning. Turning off controls will not reduce this risk.

⚠ YSI 556 MPS Water Leakage Safety Information

The YSI 556 MPS has been tested and shown to comply with IP67 criterion, i.e. submersion in 1 meter of water for 30 minutes with no leakage into either the battery compartment or the main case. However, if the instrument is submersed for periods of time in excess of 30 minutes, leakage may occur with subsequent damage to the batteries, the rechargeable battery pack circuitry, and/or the electronics in the main case.

If leakage into the battery compartment is observed when using alkaline C cells, remove batteries, dispose of batteries properly, and dry the battery compartment completely, ideally using compressed air. If corrosion is present on the battery terminals, contact YSI Customer Service for instructions. Refer to *Appendix E Customer Service*.

If leakage into the battery compartment is observed when using the YSI rechargeable battery pack, remove the battery assembly and set aside to dry. Return the battery pack to YSI Product Service for evaluation of possible damage. Finally dry the battery compartment completely, ideally using compressed air. If corrosion is present on the battery terminals, contact YSI Customer Service for instructions. Refer to *Appendix E Customer Service*.

⚠ **CAUTION:** If water has contacted the rechargeable battery pack, do not attempt to reuse it until it has been evaluated by YSI Product Service (refer to Appendix E Customer Service). Failure to follow this precaution can result in serious injury to the user.

If it is suspected that leakage into the main cavity of the case has occurred, remove the batteries immediately and return the instrument to YSI Product Service for damage assessment. Refer to *Appendix E Customer Service*.

⚠**CAUTION:** Under no circumstances should the user attempt to open the main case.

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2. General Information

2.1 Description

The rugged and reliable YSI 556 MPS (Multi-Probe System) combines the versatility of an easy-to-use, easy-to-read handheld unit with all the functionality of a multi-parameter system. Featuring a waterproof, impact-resistant case, the YSI 556 MPS simultaneously measures dissolved oxygen, conductivity, temperature, and optional pH and ORP. A simple cellular phone style keypad and large display make the instrument easy to use. The YSI 556 MPS is compatible with YSI EcoWatch™ for Windows™ software.

The YSI 556 MPS assists the user in conforming to Good Laboratory Practice (GLP) standards which help ensure that quality control/quality assurance methods are followed. Battery life is displayed with a fuel gauge, and the user can choose standard alkaline batteries or an optional rechargeable battery pack.

The 1.5 MB memory can store more than 49,000 data sets. Other options include a flow cell and barometer. The internal barometer can be user-calibrated and displayed along with other data, used in dissolved oxygen calibrations, and logged to memory for tracking changes in barometric pressure.

Features

- Waterproof -meets IP67 specifications
- Field-replaceable DO electrode module; pH and pH/ORP sensors
- Compatible with EcoWatch™ for Windows™ data analysis software
- Assists with Good Laboratory Practice Standards (GLP)
- Choice of DO membrane material for different applications
- Easy-to-use, screw-on cap DO membranes
- User-upgradeable software from YSI website
- Three-year warranty on the instrument; one-year on the probe modules
- Available with 4,10, and 20 m cable lengths
- Stores over 49,000 data sets, time and date stamped

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- Auto temperature compensating display contrast
- Optional barometer
- Optional rechargeable battery pack or standard alkaline batteries

2.2 Unpacking the Instrument

1. Remove the instrument from the shipping box. Note that the probe module and sensors are shipped in a separate box and will be unpacked later in Section *3.2 Unpacking the Probe Module*

   NOTE: Do not discard any parts of supplies.

2. Use the packing list to ensure all items are present.

3. Visually inspect all components for damage.

   NOTE: If any parts are missing or damaged, contact your YSI Service Center immediately. Refer to Appendix E Customer Service or www.ysi.com.

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2.3 Features of the YSI 556 Multi-Probe System

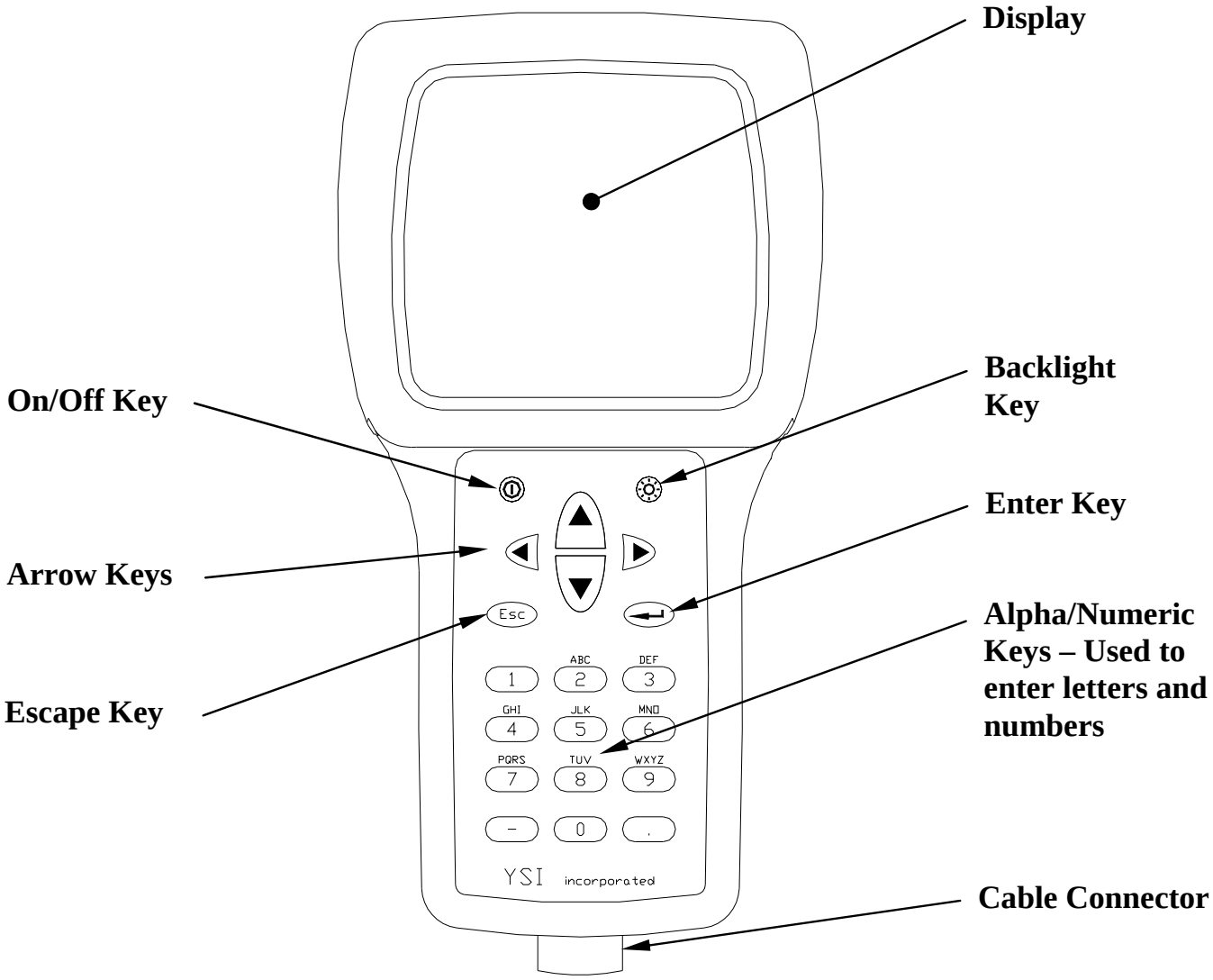

Figure 2.1 Front View of YSI 556 MPS

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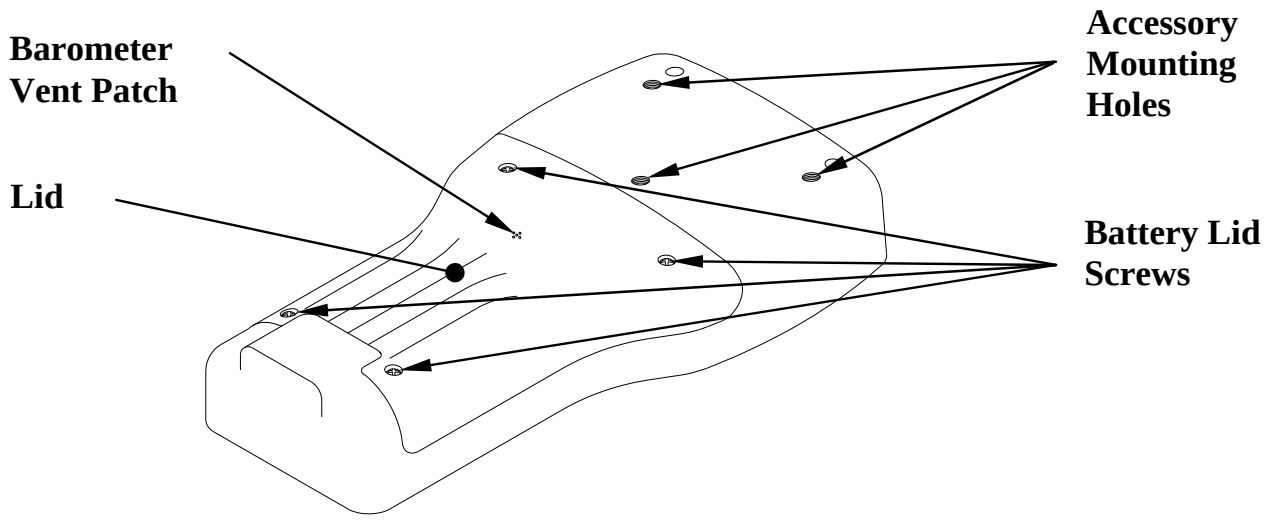

Figure 2.2 Back View of YSI 556 MPS

2.4 Batteries

2.4.1 Battery Life

Standard Alkaline Batteries

With the standard battery configuration of 4 alkaline C cells, the YSI 556 MPS will operate continuously for approximately 180 hours. Assuming a standard usage pattern when sampling of 3 hours of "on time" in a typical day, the alkaline cells will last approximately 60 days.

Optional Rechargeable Battery Pack

When fully charged, the optional rechargeable battery pack will provide approximately 50 hours of battery life.

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2.4.2 Inserting 4 C Batteries

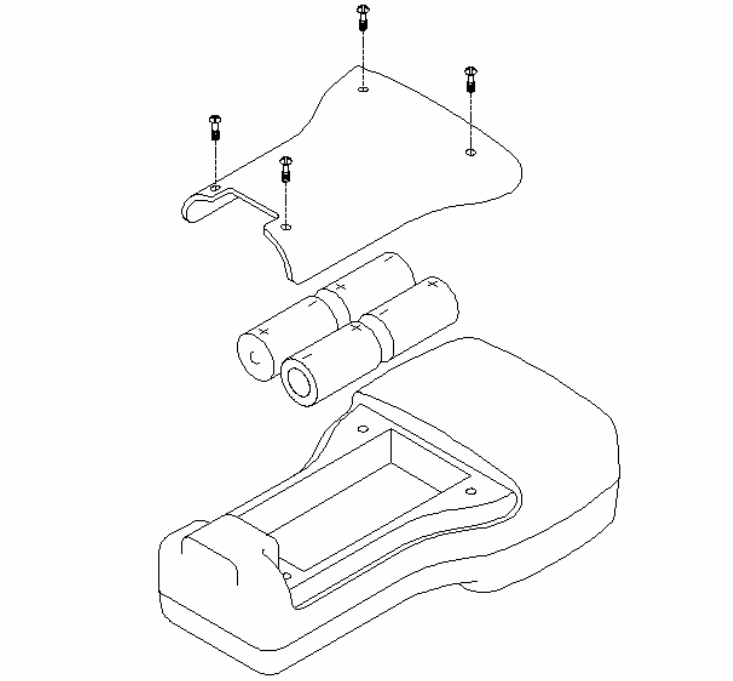

Figure 2.1 Inserting C Cells

⚠ **CAUTION: Install batteries properly to avoid damage to the instrument**.

1. Loosen the four screws in the battery lid on the back of the instrument using any screwdriver.
2. Remove the battery lid.
3. Insert four C batteries between the clips following the polarity (+ and -) labels on the bottom of the battery compartment.
4. Check gasket for proper placement on the battery lid.
5. Replace the battery lid and tighten the 4 screws securely and evenly.

NOTE: Do not over-tighten the screws.

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2.4.3 Inserting Optional Rechargeable Battery Pack

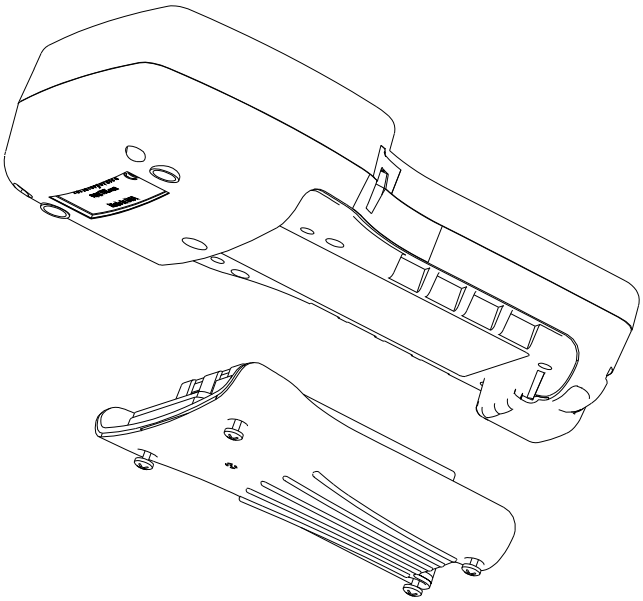

Figure 2.2 Inserting Battery Pack

⚠ **CAUTION: Read all cautions and warning that come with the battery pack before using the battery pack.**

1. Loosen the four screws in the battery lid on the back of the instrument using any screwdriver.

2. Remove the C battery lid and store for future use. Remove C batteries, if installed.

3. Install the rechargeable battery pack and lid and tighten the 4 screws securely and evenly.

NOTE: Do not over tighten the screws.

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2.4.4 Charging the Optional Rechargeable Battery Pack

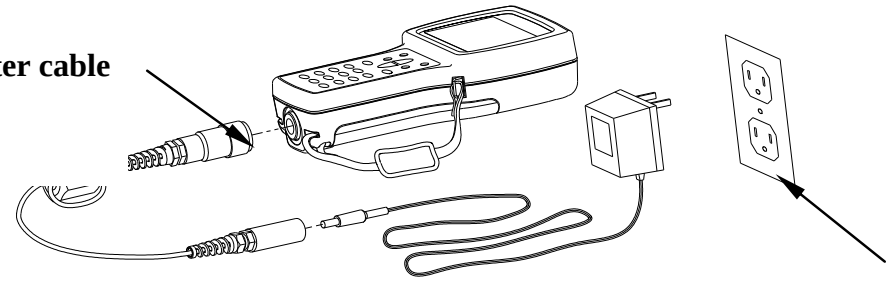

Figure 2.3 Charging the Battery Pack

⚠ **CAUTION: Do not use or store the battery pack at extreme temperatures such as in strong direct sunlight, in cars during hot weather or close to heaters.**

1. Install the rechargeable battery pack into the instrument as described in Section *2.4.3 Inserting Optional Rechargeable Battery Pack.*

2. Attach the charger adapter cable (YSI 6119) to the instrument.

NOTE: Wall power supplies for use in countries outside the US and Canada can be found in *Appendix B Instrument Accessories.*

3. Insert the barrel connector of the wall power supply into the barrel of the adapter cable.

⚠ **CAUTION: Do not charge the battery pack continuously for more than 48 hours.**

⚠ **CAUTION: Do not drop or expose to water.**

⚠ **CAUTION: Do no charge the battery pack at temperatures below 0°C or above 40°C.**

4. Plug the wall power supply into an AC power outlet for approximately 2 hours to obtain an 80% to 90% charge for 6 hours to get a full charge.

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NOTE: The battery pack can be recharged whether the instrument is on or off.

2.4.5 Storing the Battery Pack

Remove the battery pack from the instrument when the instrument will not be used for extended periods of time to prevent over discharge of the battery pack.

Store the battery pack in a heavy plastic bag to prevent accidental shorting of the terminals. Store between –20 and 30°C.

2.4.6 Optional Cigarette Lighter Charger

⚠ **CAUTION: Read all warnings and cautions that come with the charger before using the charger.**

⚠ **CAUTION: Only use cigarette lighter charger when rechargeable battery pack is inserted into instrument.**

⚠ **CAUTION: Do not mishandle cigarette lighter charger. Do not expose to moisture.**

1. Plug the barrel connector of the cigarette lighter charger into the mating end of the YSI 6119 Charger Adapter Cable.

2. Attach the MS-19 end of the YSI 6119 Charger Adapter Cable to the instrument.

3. Make one of the following modifications to the other end of the charger:

Slide the adapter ring off the plug to use the device with an American or Japanese vehicle.

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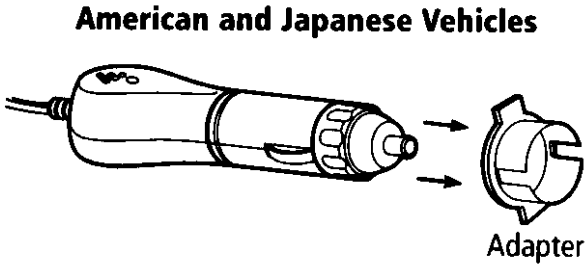

Figure 2.1 Charger Plug Adapter Use

Leave the adapter ring on the plug and position it so that the slots on the adapter ring line up with the plug's spring clips to use the device on a European vehicle.

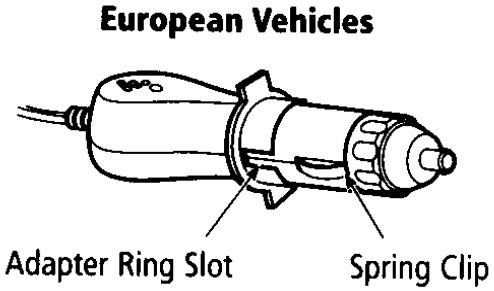

Figure 2.2 European Charger Plug Adapter Use

NOTE: If the charger stops working properly, refer to Section 13 *Troubleshooting.*

2.5 Power On

Press and release the on/off button in the upper left corner of the instrument keypad to turn the instrument on or off. See Figure2.1 Front View of YSI 556 MPS.

2.6 Setting Display Contrast

The display contrast automatically compensates for temperature changes. However, under extreme temperature conditions you may wish to optimize the display by manual adjustment as follows:

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1. Press and *hold down* the backlight key in the upper right corner of the keypad and press the “up” arrow to increase (darken) the contrast.

2. Press and *hold down* the backlight key in the upper right corner of the keypad and press the “down” arrow to decrease (lighten) the contrast.

2.7 Backlight

Press and *release* the backlight key in the upper right corner of the keypad to turn the backlight on or off. See Figure 2.1 Front View of YSI 556 MPS.

NOTE: The backlight turns off automatically after two minutes of non-use.

2.8 General Screen Features

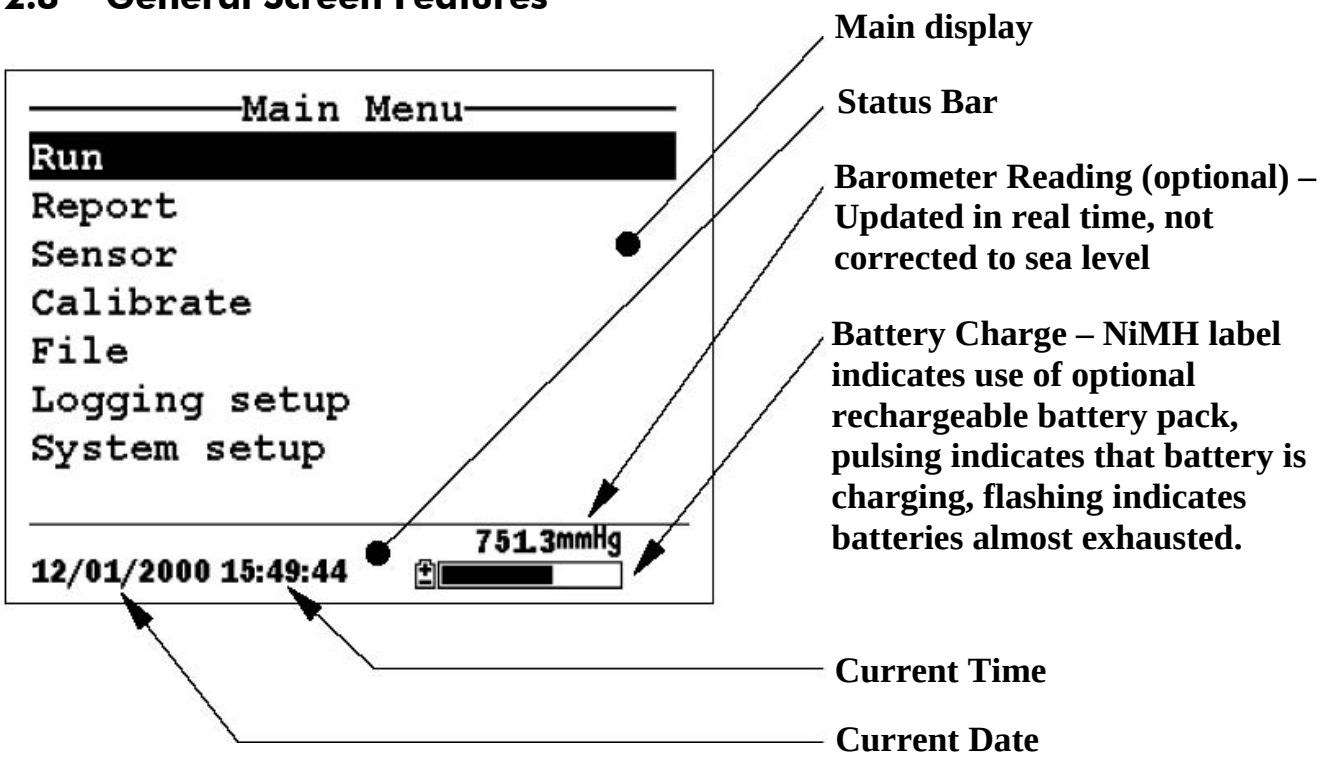

Figure 2.4 Main Screen Menu

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2.9 Keypad Use

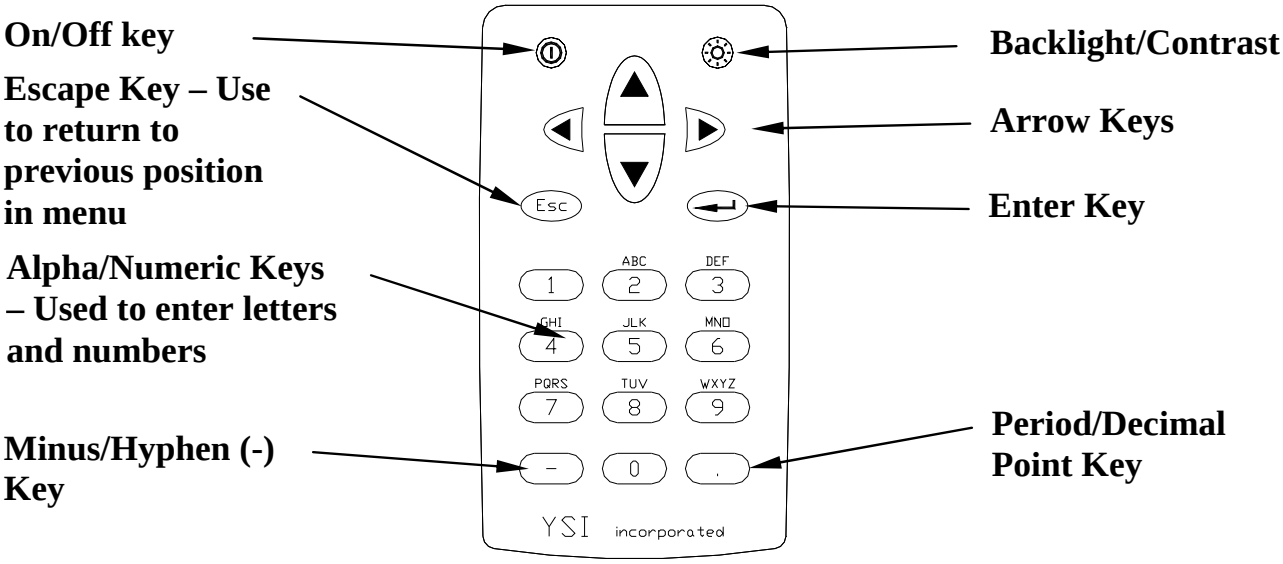

Figure 2.5 Keypad Features

KEY	LETTER/NUMBER
1	1
2	ABC2abc3
3	DEF3def3
4	GHI4ghi4
5	JKL5jkl5
6	MNO6mno6
7	PQRS7pqrs7
8	TUV8tuv8
9	WXYZ9wxyz9
0	0

Figure 2.6 Keypad Features

1. See Figure 2.10 Keypad Letters & Numbers and press the appropriate key repeatedly until letter or number desired appears in display.

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NOTE: Press the key repeatedly in rapid succession to get to the desired letter or number. If you pause for more than a second, the cursor automatically scrolls to the right to prepare for the next input.

EXAMPLE 1: Press the **6** key *once* and *release* to display an uppercase "M".

EXAMPLE 2: Press the **6** key *four times* and *release* to display the number "6".

EXAMPLE 3: Press the **6** key *five times* and *stop* to display a lowercase "m".

2. Press the left arrow key to go back and reenter a number or setter that needs to be changed.

Press the **Enter** key when your entry is complete.

NOTE: The instrument software permits only numeric entries in many instances, such as when setting the clock or entering calibration parameters.

2.10 Instrument Reset

The YSI 556 MPS is characterized by sophisticated software that should provide trouble-free operation. However, as with all high-capability software packages, it is always possible that the user will encounter circumstances in which the instrument does not respond to keypad entry. If this occurs, the instrument function can easily be restored by removing and then reapplying battery power. Simply remove either your C-cells or rechargeable battery pack from the battery compartment, wait 30 seconds and then replace the batteries. See Section *2.4 Batteries* for battery removal/reinstallation instructions.

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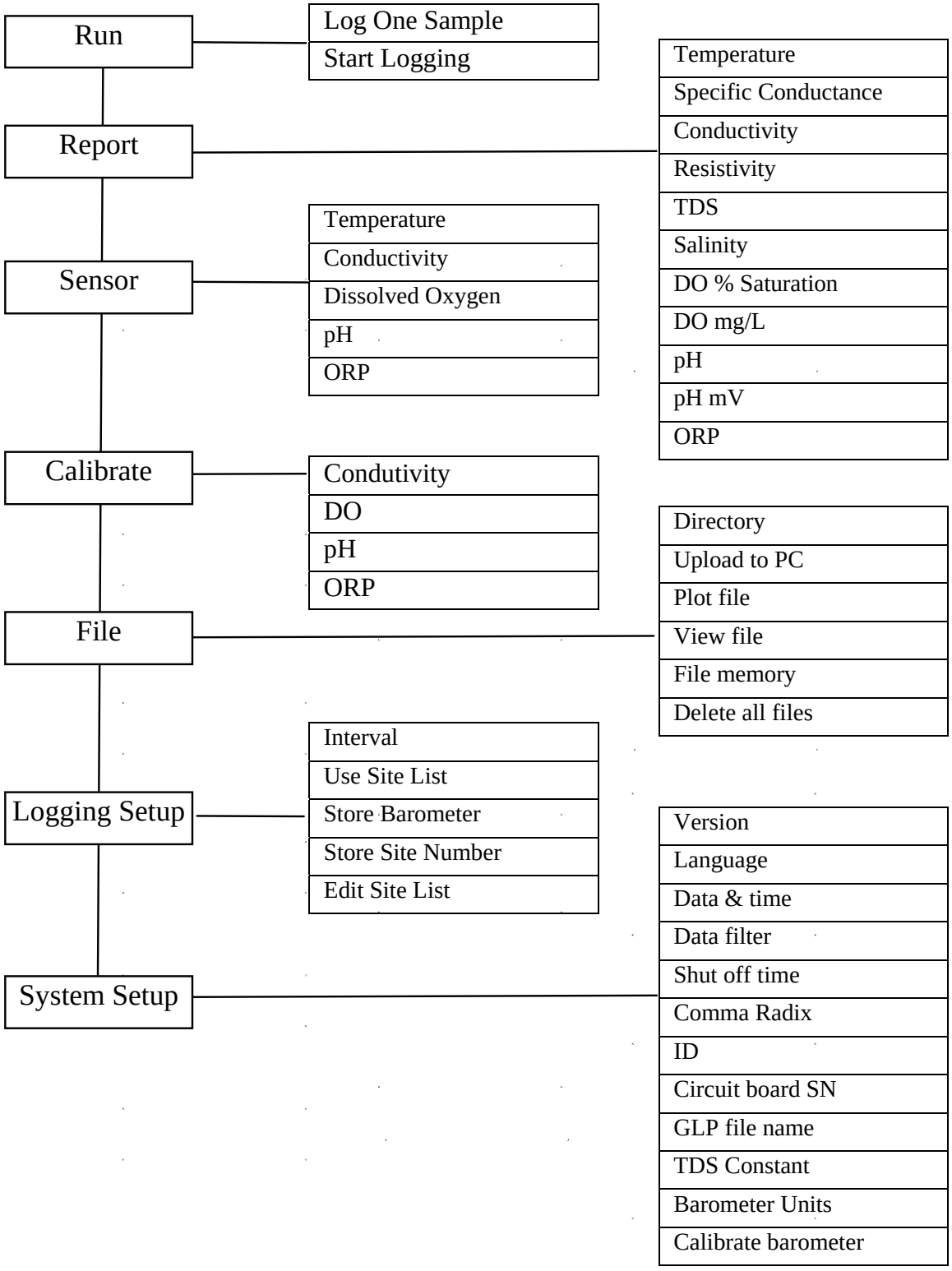
2.11 Menu Flowchart



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3. Probe Module

3.1 Introduction

The YSI 5563 Probe module is used for measuring dissolved oxygen, temperature, conductivity, and optional pH and ORP. The probe module is rugged, with the sensors enclosed in a heavy duty probe sensor guard with attached sinking weight. A 4, 10 or 20 meter cable is directly connected to the probe module body making it waterproof. An MS-19 connector at the end of the cable makes the YSI 5563 fully compatible with the YSI 556 Multi-Probe System.

3.2 Unpacking the Probe Module

1. Remove the YSI 5563 Probe Module from the shipping boxes.

   NOTE: Do not discard any parts or supplies.

2. Use the packing list to ensure all items are present.

3. Visually inspect all components for damage.

NOTE: If any parts are missing or damaged, contact a YSI representative immediately. Refer to: *Appendix E Customer Service* o visit www.ysi.com.

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3.3 Features of the YSI 5563 Probe Module

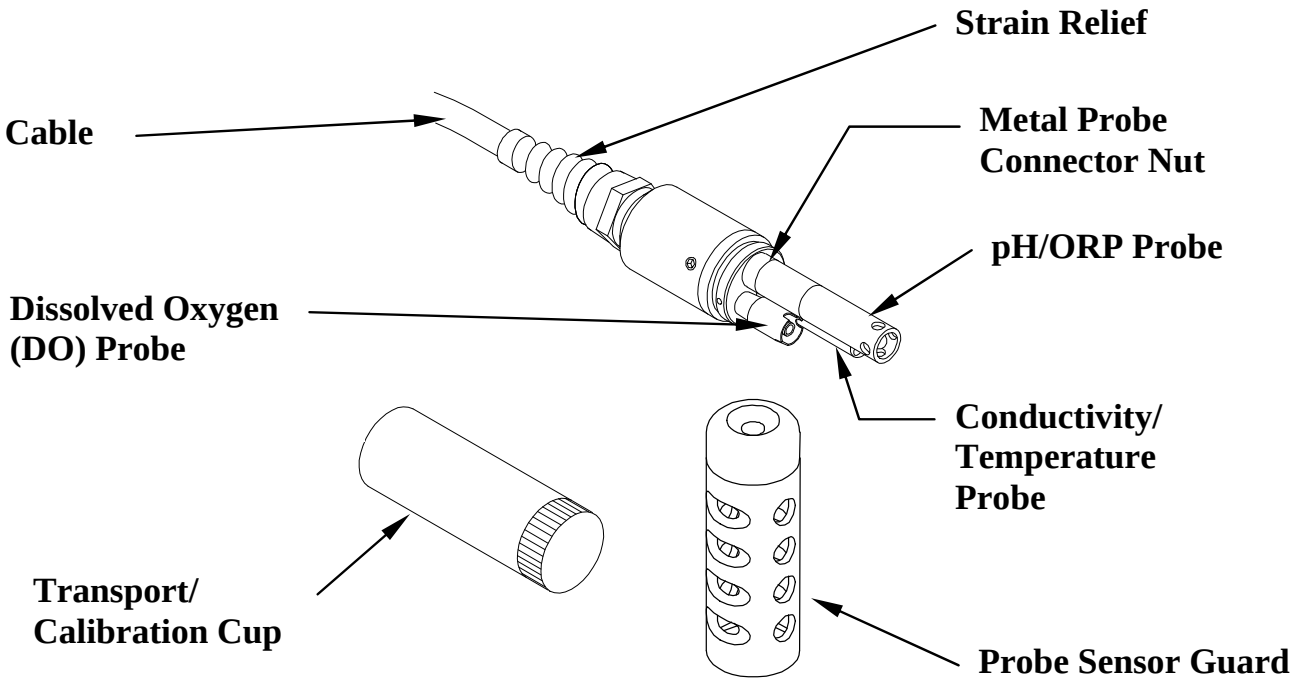

Figure 3.1 Probe Module

3.4 Preparing the Probe Module

To prepare the probe module for calibration and operation, you need to install the sensors into the connectors on the probe module bulkhead. In addition to sensor installation, you need to install a new DO membrane cap.

3.4.1 Sensor Installation

Whenever you install, remove or replace a sensor, it is extremely important that the entire probe module and all sensors be thoroughly dried prior to the removal of a sensor or a sensor port plug. This will prevent water from entering the port. Once you remove a sensor or plug, examine the connector inside the probe module sensor port. If any moisture is present, use compressed air to completely dry the connector. If the connector is corroded, return the probe module to your YSI Distributor or directly to YSI Customer Service. Refer to *Appendix E Customer Service*.

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Conductivity/Temperature and pH, pH/ORP Sensor Installation

1. Unscrew and remove the probe sensor guard.

2. Using the sensor installation tool supplied in the YSI 5511 maintenance kit, unscrew and remove the sensor port plugs.

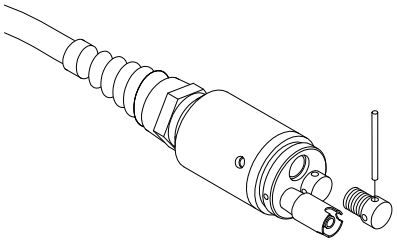

Figure 3.2 Port Plug Removal

3. Locate the port with the connector that corresponds to the sensor that is to be installed.

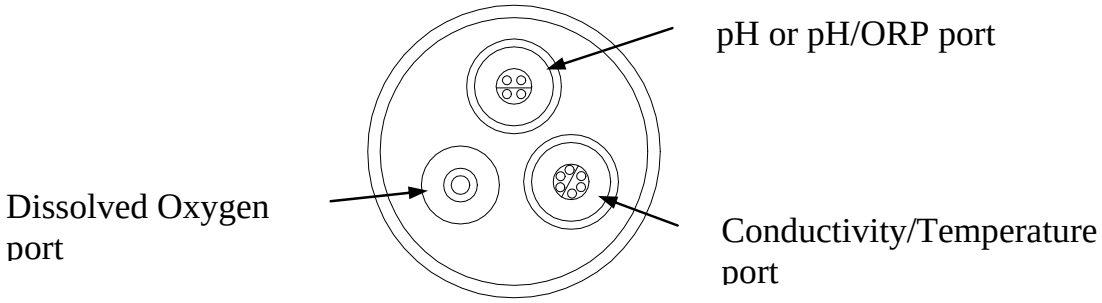

Figure 3.3 Sensor Port Identification

4. Apply a thin coat of o-ring lubricant (supplied in the YSI 5511 maintenance kit) to the o-rings on the connector side of the sensor (see Figure 3.4 O-ring Lubrication).

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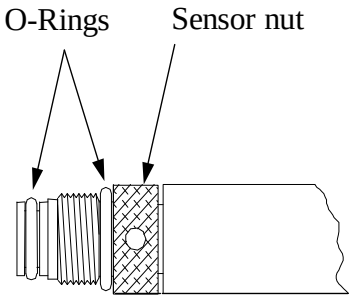

Figure 3.4 O-ring Lubrication

⚠ **CAUTION:** Make sure that there are NO contaminants between the o-ring and the sensor. Contaminants that are present under the o-ring may cause the o-ring to leak.

5. Be sure the probe module sensor port is free of moisture and then insert the sensor into the correct port. Gently rotate the sensor until the two connectors align.

6. With the connectors aligned, screw down the sensor nut using the sensor installation tool.

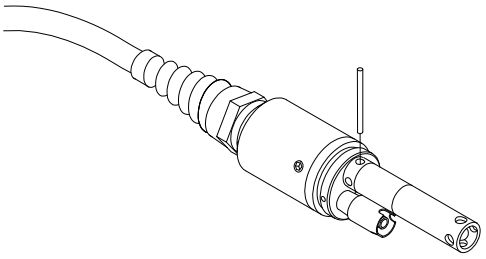

Figure 3.5 Sensor Installation

⚠ **CAUTION:** Do not cross thread the sensor nut. Tighten the nut until it is flush with the face of the probe module bulkhead. Do not over tighten.

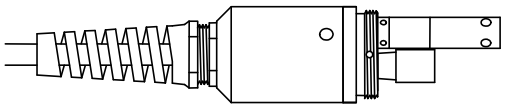

Figure 3.6 Bulkhead Seating

7. Repeat steps 3-6 for any other sensors.

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8. Replace the probe sensor guard.

Dissolved Oxygen Sensor Installation

The YSI 5563 comes with the DO sensor already installed. Refer to Section *11.1.2 DO Sensor Replacement* for instructions on installing the YSI 559 Replaceable DO Module Kit.

3.4.2 Membrane Cap Selection

The YSI 5563 is shipped with a YSI 5909 kit that contains membrane caps made with 2 mil polyethylene (PE), a material which should be ideal for most field applications of the 556. However, YSI also offers membrane caps made with two other materials (1 mil polyethylene and 1 mil Teflon) which some users may also prefer. All membranes available for the 556/5563 system provide comparable accuracy if used properly. The difference between the two thicknesses of PE is found in the trade-off of flow dependence and response time as described below. Teflon is offered because some users may prefer to continue using the traditional membrane material used by YSI. To avoid confusion, the membrane caps are color coded as described below and can be ordered in kits as noted:

1 mil Teflon – Black Caps (Kit = YSI 5906)
1 mil Polyethylene (PE) – Yellow Caps (Kit = YSI 5908)
2 mil Polyethylene (PE) – Blue Caps (Kit = YSI 5909)

The 1 mil Teflon caps will offer traditional, reliable performance for most dissolved oxygen applications. The 1 mil PE caps will provide a significantly faster dissolved oxygen response (as long as your 556 Data Filter is set correctly as described below in Sections 10.2 and 10.3.1) while also giving readings which are significantly less flow dependent than the 1 mil Teflon caps. Finally, 2 mil PE caps will show a large reduction in flow dependence over 1 mil Teflon while not significantly increasing the response time. Generally, one of the PE caps is likely to provide better performance for your application.

IMPORTANT: No matter which type of membrane cap you select, you will have to confirm your selection in the 556 software from the Sensor menu as described in Section *4 Sensors*.

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3.4.3 Membrane Cap Installation

NOTE: The YSI 5563 DO sensor (already installed in the probe module) was shipped dry. A shipping membrane was installed to protect the electrode. **A new membrane cap must be installed before the first use.**

1. Unscrew and remove the probe sensor guard.
2. Unscrew, remove, and discard the old membrane cap.
3. Thoroughly rinse the sensor tip with distilled water.
4. Prepare the electrolyte according to the directions on the electrolyte solution bottle.
5. Hold the new membrane cap and fill it at least ½ full with the electrolyte solution.
6. Screw the membrane cap onto the sensor moderately tight. A small amount of electrolyte should overflow.

⚠ **Caution:** Do not touch the membrane surface.

7. Screw the probe sensor guard on moderately tight.

3.5 Transport/Calibration Cup

The YSI 5563 Probe module has been supplied with a convenient transport/calibration cup. This cup is an ideal container for calibration of the different sensors, minimizing the amount of solution needed. Refer to Section *6 Calibrate*.

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3.5.1 Transport/Calibration Cup Installation

1. Remove probe sensor guard, if already installed.

2. Ensure that an o-ring is installed in the o-ring groove on the threaded end of the probe module body.

3. Screw the transport/calibration cup on the threaded end of the probe module and securely tighten.

   NOTE: Do not over tighten as this could cause damage to the threaded portions.

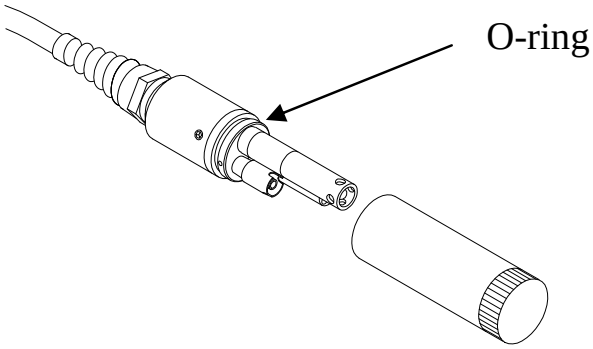

Figure 3.7 Transport/Calibration Cup Installation

3.6 Instrument/Cable Connection

Attach the cable to the instrument as follows:

1. Line up the pins and guides on the cable with the holes and indentations on the cable connector at the bottom of the YSI 556 instrument. See Figure 2.1 Front View of YSI 556 MPS.

2. Holding the cable firmly against the cable connector, turn the locking mechanism clockwise until it snaps into place.

Remove the cable from the instrument by turning the cable connector counterclockwise until the cable disengages from the instrument.

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4. Sensors

The Sensors screen allows the user to enable or disable each of the sensors and select which membrane material will be used for the dissolved oxygen sensor. Disabled sensors will not be displayed on the screen in real time or logged to files.

1. Press the **On/off** key to display the run screen.

2. Press the **Escape** key to display the main menu screen.

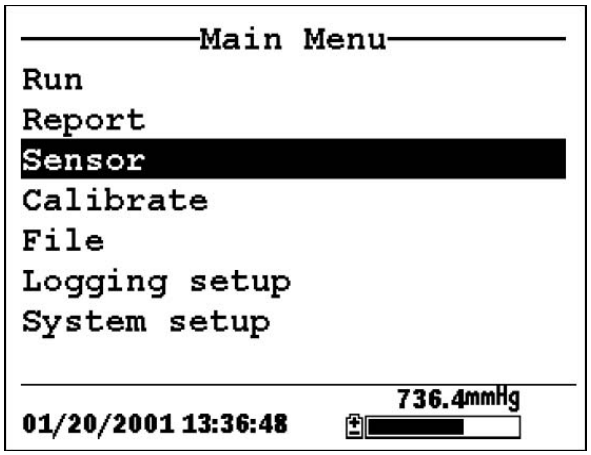

Figure 4.1 Main Menu Screen

3. Use the arrow keys to highlight the **Sensor** selection.

4. Press the **Enter** key to display the sensors enabled screen.

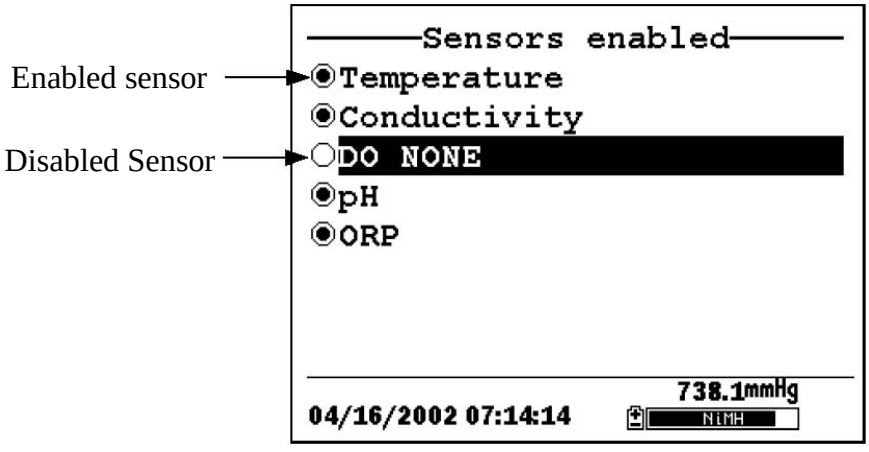

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Figure 4.2 Sensors Enabled Screen Before DO Membrane Selection

A black dot to the left of a sensor indicates that sensor is enabled. Sensors with an empty circle are disabled.

Highlight the "DO None" entry as shown above and press **Enter** to display the membrane choice screen. Consult Section *3.4.2 Membrane Cap Selection* for information on the advantages of each type of membrane material. Blue membrane caps using 2 mil polyethylene (PE) were shipped with your YSI 5563 and are likely to be the best choice for most 556 field applications.

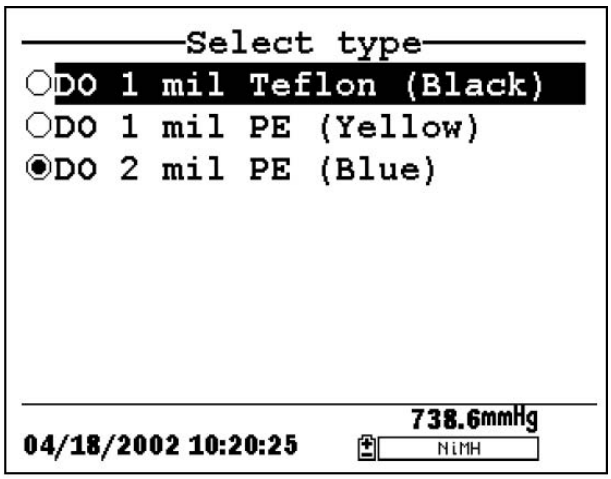

Figure 4.3 Membrane Selection Screen

Highlight the desired membrane choice – in this case, 2 mil PE - and press Enter to activate your selection with a dot to the left of the screen. Then press **Escape** to return to the Sensor menu that now shows your DO membrane selection.

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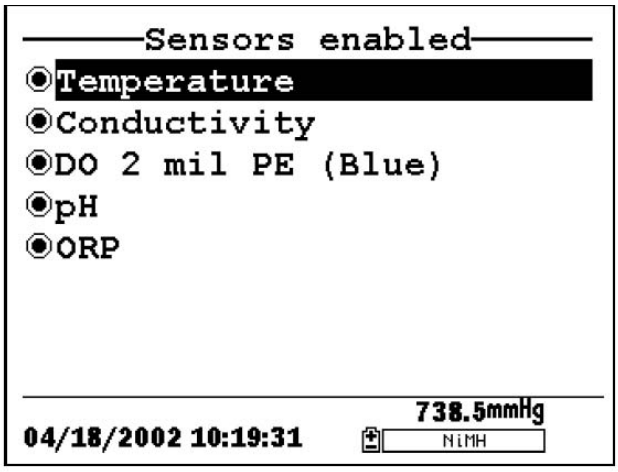

Figure 4.4 Sensors Enabled Screen After DO Membrane Selection

NOTE: The Temperature sensor cannot be disabled. Most other sensors require temperature compensation for accurate readings. In addition, the conductivity sensor must be activated in order to obtain accurate dissolved oxygen mg/L readings.

5. Use the arrow keys to highlight the sensor you want to change, then press the Enter key to enable or disable it.

6. Repeat step 5 for each sensor you want to change.

7. Press the Escape key to return to the main menu screen.

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5. Report

The Report Setup screen allows the user to select which sample parameters and units the YSI 556 MPS will display on the screen. It does NOT determine which parameters are logged to memory. Refer to Section *4 Sensors.*

1. Press the **On/off** key to display the run screen.

2. Press the **Escape** key to display the main menu screen.

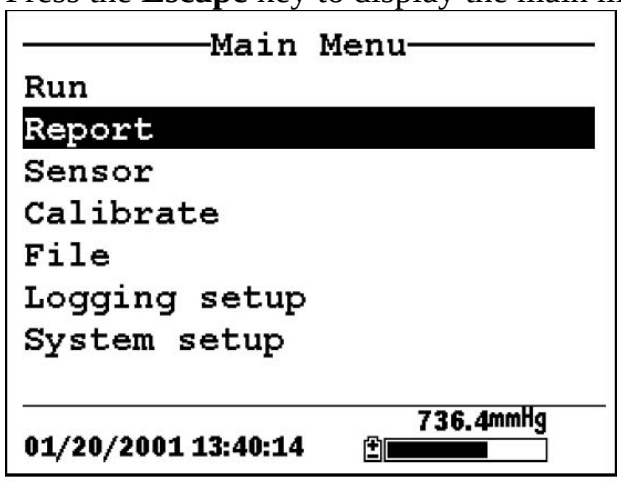

Figure 5.1 Main Menu

3. Use the arrow keys to highlight the **Report** selection.

4. Press the **Enter** key to display the report setup screen.

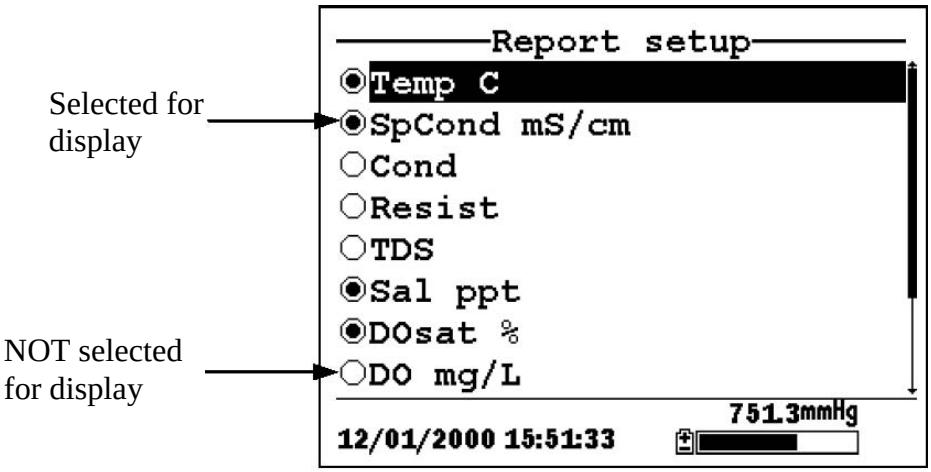

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Figure 5.2 Report Setup Screen

NOTE: A black dot to the left of a parameter indicates that parameter is selected for display. Parameters with an empty circle will not be displayed.

NOTE: You may have to scroll down past the bottom of the screen to see all the parameters.

5. Use the arrow keys to highlight the parameter you want to change, then press the **Enter** key. If you can't find the parameter you want, even after scrolling down past the bottom of the screen, the sensor used for that parameter is disabled. Refer to Section *4 Sensors*.

6. If you selected Temperature, Specific Conductivity, Conductivity, Resistance or Total Dissolved Solids, the Units screen will appear.

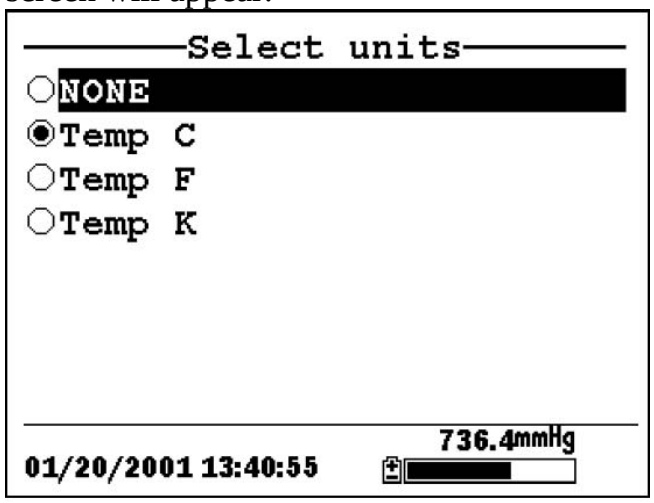

Figure 5.3 Units Screen

7. Use the arrow keys to select the units desired, then press the **Enter** key to return to the report setup screen.

8. Repeat steps 5 and 6 for each parameter you want to change.

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NOTE: Specific Conductance (temperature compensated conductivity) is notated on the Run screen with a small ‘c’ after the units of measure.

All parameters may be enabled at the same time.

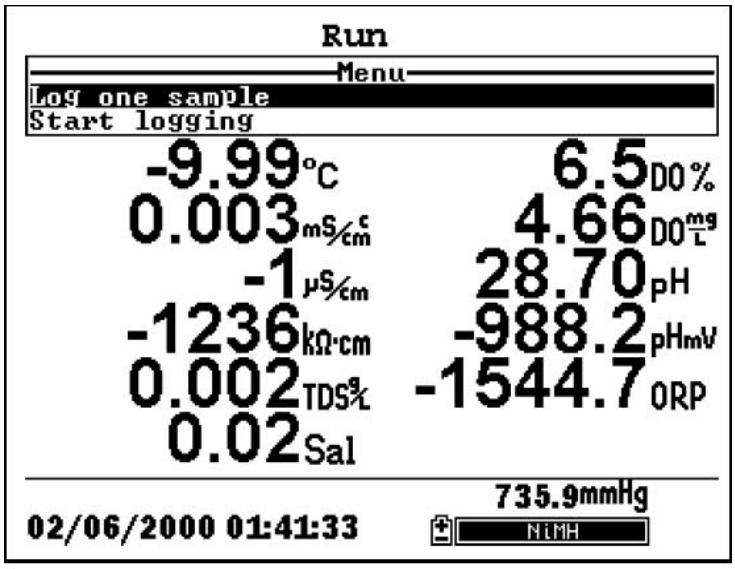

Figure 5.4 All Parameters Displayed

9. Press the **Escape** key to return to the Main menu screen.

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6. Calibrate

All of the sensors, except temperature, require periodic calibration to assure high performance. You will find specific calibration procedures for all sensors that require calibration in the following sections. If a sensor listed is not installed in your probe module, skip that section and proceed to the next sensor until the calibration is complete.

⚠ **CAUTION:** Reagents that are used to calibrate and check this instrument may be hazardous to your health. Take a moment to review *Appendix D Health and Safety*. Some calibration standard solutions may require special handling.

6.1 Getting Ready to Calibrate

6.1.1 Containers Needed to Calibrate the Probe Module

The transport/calibration cup that comes with your probe module serves as a calibration chamber for all calibrations and minimizes the volume of calibration reagents required.

Instead of the transport/calibration cup, you may use laboratory glassware to perform calibrations. If you do not use the transport/calibration cup that is designed for the probe module, you are cautioned to do the following:

- ✓ Perform all calibrations with the Probe Sensor Guard installed. This protects the sensors from possible physical damage.
- ✓ Use a ring stand and clamp to secure the probe module body to prevent the module from falling over. Most laboratory glassware has convex bottoms.
- ✓ Ensure that all sensors are immersed in calibration solutions. Many of the calibrations factor in readings from other sensors (e.g., temperature sensor). The top vent hole of the conductivity sensor must also be immersed during some calibrations.

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6.1.2 Calibration Tips

1. If you use the Transport/Calibration Cup for dissolved oxygen (DO) calibration, make certain to loosen the seal to allow pressure equilibration before calibration. The DO calibration is a water-saturated air calibration.

2. When calibrating pH, always calibrate with buffer 7 first, regardless if performing a 1, 2, or 3 point calibration

3. The key to successful calibration is to ensure that the sensors are completely submersed when calibration values are entered. Use recommended volumes when performing calibrations.

4. For maximum accuracy, use a small amount of previously used calibration solution to pre-rinse the probe module. You may wish to save old calibration standards for this purpose.

5. Fill a bucket with ambient temperature water to rinse the probe module between calibration solutions.

6. Have several clean, absorbent paper towels or cotton cloths available to dry the probe module between rinses and calibration solutions. Shake the excess rinse water off of the probe module, especially when the probe sensor guard is installed. Dry off the outside of the probe module and probe sensor guard. Making sure that the probe module is dry reduces carry-over contamination of calibrator solutions and increases the accuracy of the calibration.

7. If you are using laboratory glassware for calibration, you do not need to remove the probe sensor guard to rinse and dry the sensors between calibration solutions. The inaccuracy resulting from simply rinsing the sensor compartment and drying the outside of the guard is minimal.

8. If you are using laboratory glassware, remove the stainless steel weight from the bottom of the probe sensor guard by turning the weight counterclockwise. When the weight is removed, the calibration solutions have access to the sensors

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without displacing a lot of fluid. This also reduces the amount of liquid that is carried between calibrations.

9. Make certain that port plugs are installed in all ports where sensors are not installed. It is extremely important to keep these electrical connectors dry.

6.1.3 Recommended Volumes

Follow these instructions to use the transport/calibration cup for calibration procedures.

- ✓ Ensure that an o-ring is installed in the o-ring groove of the transport/calibration cup bottom cap, and that the bottom cap is securely tightened.

  NOTE: Do not over-tighten as this could cause damage to the threaded portions.

- ✓ Remove the probe sensor guard, if it is installed.
- ✓ Remove the o-ring, if installed, from the probe module and inspect the installed o-ring on the probe module for obvious defects and, if necessary, replace it with the extra o-ring supplied.
- ✓ Some calibrations can be accomplished with the probe module upright or upside down. A separate clamp and stand, such as a ring stand, is required to support the probe module in the upside down position.
- ✓ To calibrate, follow the procedures in the next section, Calibration Procedures. The approximate volumes of the reagents are specified below for both the upright and upside down orientations.
- ✓ When using the Transport/Calibration Cup for dissolved oxygen % saturation calibration, make certain that the vessel is vented to the atmosphere by loosening the bottom cap or cup assembly and that approximately 1/8 inch (3 cm) of water is present in the cup.

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Sensor to Calibrate	Upright	Upside Down
Conductivity	55ml	55ml
pH/ORP	30ml	60ml

Table 6.1 Calibration Volumes

6.2 Calibration Procedures

6.2.1 Accessing the Calibrate Screen

1. Press the **On/off** key to display the run screen.
2. Press the **Escape** key to display the main menu screen.
3. Use the arrow keys to highlight the **Calibrate** selection.

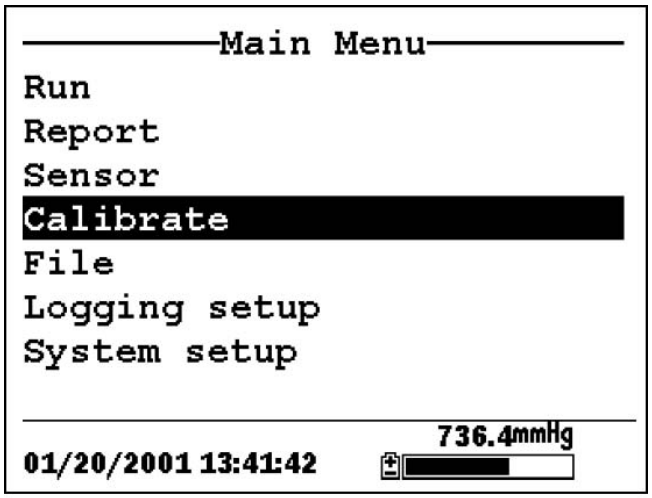

Figure 6.1 Main Menu

4. Press the **Enter** key. The Calibrate screen will be displayed.

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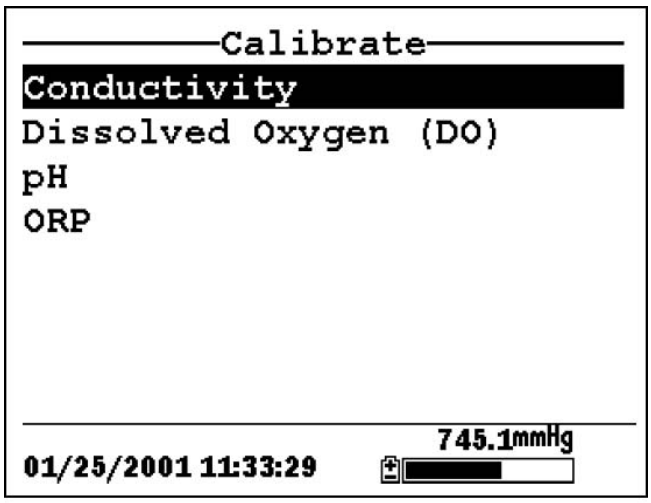

Figure 6.2 Calibrate Screen

6.2.2 Conductivity Calibration

This procedure calibrates specific conductance (recommended), conductivity and salinity. Calibrating any one option automatically calibrates the other two.

1. Go to the calibrate screen as described in Section *6.2.1Accessing the Calibrate Screen.*.

2. Use the arrow keys to highlight the **Conductivity** selection. See Figure 6.2 Calibrate Screen.

3. Press **Enter**. The Conductivity Calibration Screen is displayed.

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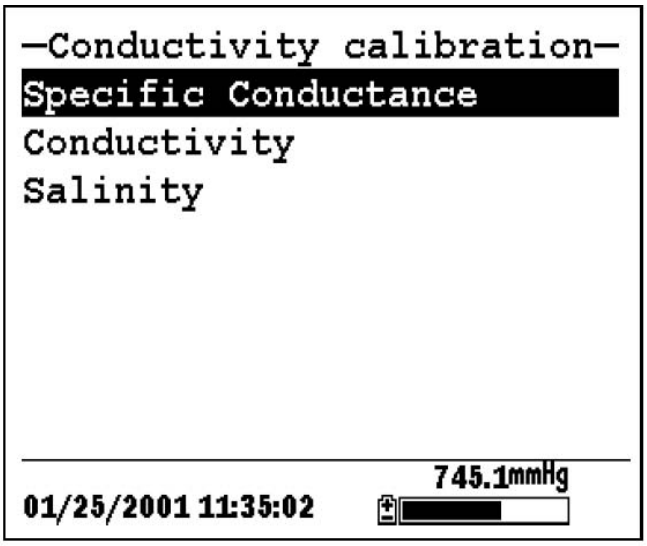

Figure 6.3 Conductivity Calibration Selection Screen

4. Use the arrow keys to highlight the Specific Conductance selection.

5. Press **Enter**. The Conductivity Calibration Entry Screen is displayed.

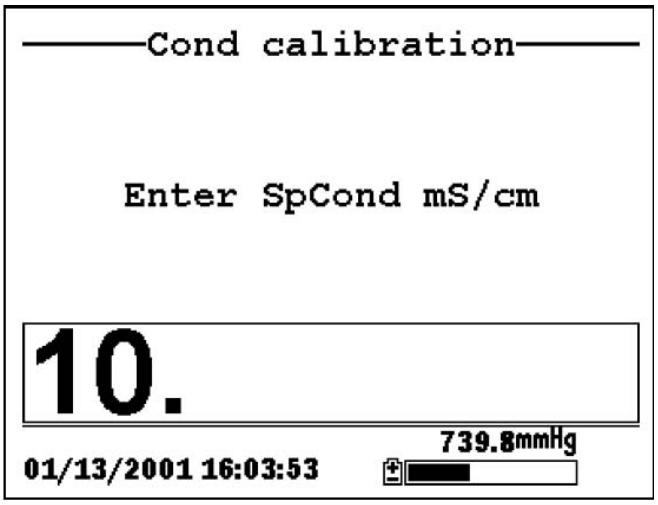

Figure 6.4 Conductivity Calibration Selection Screen

6. Place the correct amount of conductivity standard (see Table 6.1 Calibration Volumes) into a clean, dry or pre-rinsed transport/calibration cup.

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⚠ **WARNING**: Calibration reagents may be hazardous to your health. See *Appendix D Health and Safety* for more information.

NOTE: For maximum accuracy, the conductivity standard you choose should be within the same conductivity range as the samples you are preparing to measure. However, we do not recommend using standards less than 1 mS/cm. For example:

- ✓ For fresh water use a 1 mS/cm conductivity standard.
- ✓ For brackish water use a 10 mS/cm conductivity standard.
- ✓ For seawater use a 50 mS/cm conductivity standard.

NOTE: Before proceeding, ensure that the sensor is as dry as possible. Ideally, rinse the conductivity sensor with a small amount of standard that can be discarded. Be certain that you avoid cross-contamination of solutions. Make certain that there are no salt deposits around the oxygen and pH/ORP sensors, particularly if you are employing standards of low conductivity.

7. Carefully immerse the sensor end of the probe module into the solution.

8. Gently rotate and/or move the probe module up and down to remove any bubbles from the conductivity cell.

NOTE: The sensor must be completely immersed past its vent hole. Using the recommended volumes from Table 6.1 Calibration Volumes, should ensure that the vent hole is covered.

9. Screw the transport/calibration cup on the threaded end of the probe module and securely tighten.

NOTE: Do not over tighten as this could cause damage to the threaded portions.

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10. Use the keypad to enter the calibration value of the standard you are using.

NOTE: Be sure to enter the value in **mS/cm at 25°C**.

11. Press **Enter**. The Conductivity Calibration Screen is displayed.

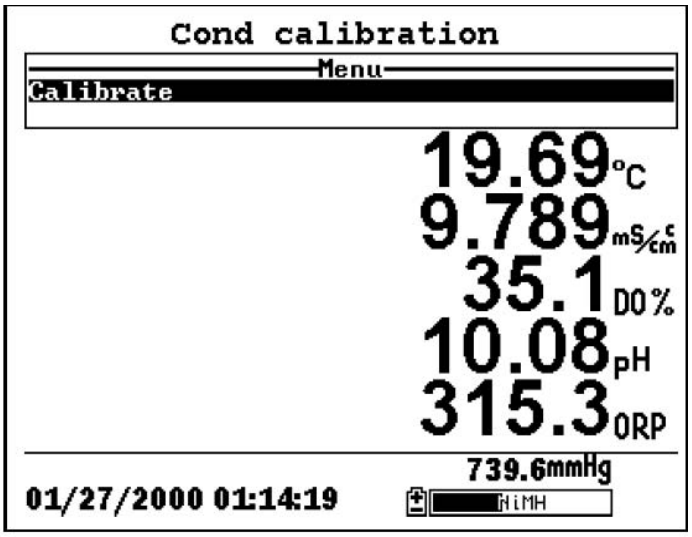

Figure 6.5 Conductivity Calibration Screen

12. Allow at least one minute for temperature equilibration before proceeding. The current values of all enabled sensors will appear on the screen and will change with time as they stabilize.

13. Observe the reading under Specific Conductance. When the reading shows no significant change for approximately 30 seconds, press **Enter**. The screen will indicate that the calibration has been accepted and prompt you to press **Enter** again to Continue.

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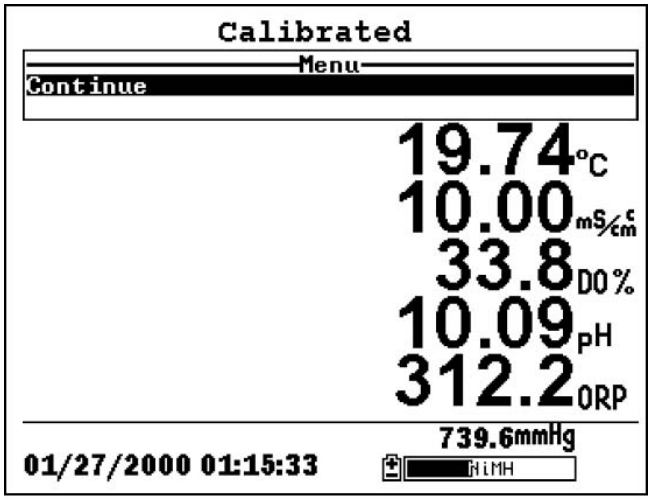

Figure 6.6 Calibrated

14. Press **Enter**. This returns you to the Conductivity Calibrate Selection Screen, See Figure 6.3 Conductivity Calibration Selection Screen..

15. Press **Escape** to return to the calibrate menu. See Figure 6.2 Calibrate Screen .

16. Rinse the probe module and sensors in tap or purified water and dry.

6.2.3 Dissolved Oxygen Calibration

This procedure calibrates dissolved oxygen. Calibrating any one option (% or mg/L) automatically calibrates the other.

1. Go to the calibrate screen as described in Section *6.2.1 Accessing the Calibrate Screen*.

NOTE: The instrument must be on for at least 10 - 15 minutes to polarize the DO sensor before calibrating.

2. Use the arrow keys to highlight the **Dissolved Oxygen** selection. See Figure 6.2 Calibrate Screen.

3. Press **Enter**. The dissolved oxygen calibration screen is displayed.

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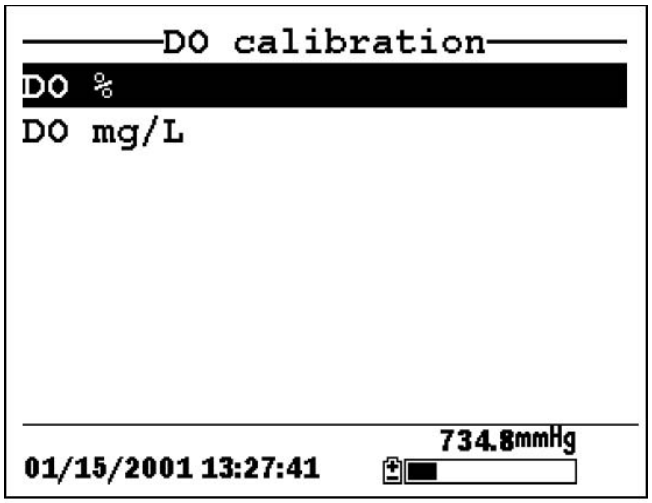

Figure 6.7 DO Calibration Screen

DO Calibration in % Saturation

1. Use the arrow keys to highlight the DO% selection.

2. Press **Enter**. The DO Barometric Pressure Entry Screen is displayed.

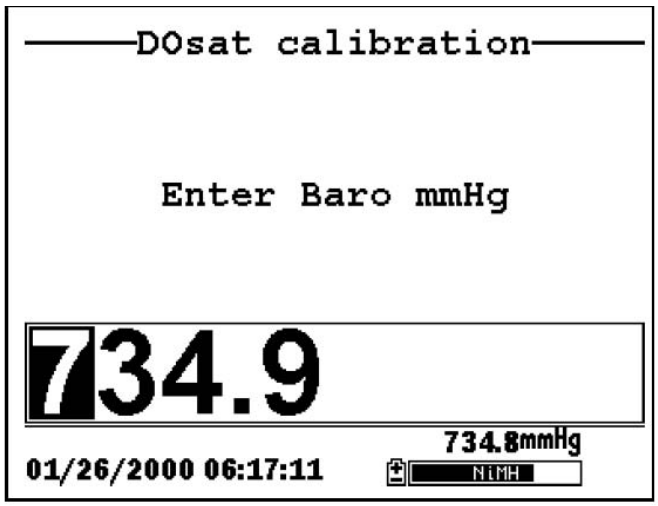

Figure 6.8 DO Barometric Pressure Entry Screen

3. Place approximately 3 mm (1/8 inch) of water in the bottom of the transport/calibration cup.

4. Place the probe module into the transport/calibration cup.

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NOTE: Make sure that the DO and temperature sensors are **not** immersed in the water.

5. Engage only 1 or 2 threads of the transport/calibration cup to ensure the DO sensor is vented to the atmosphere.

6. Use the keypad to enter the current local barometric pressure.

NOTE: If the unit has the optional barometer, no entry is required.

NOTE: Barometer readings that appear in meteorological reports are generally corrected to sea level and must be uncorrected before use (refer to Section *10.10 Calibrate Barometer, Step 2*).

7. Press **Enter**. The DO% saturation calibration screen is displayed.

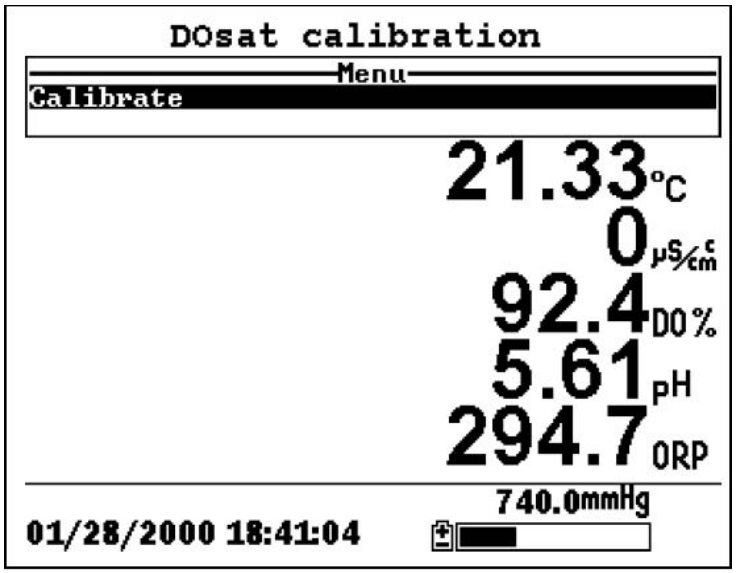

Figure 6.9 DO Sat Calibration Screen

8. Allow approximately ten minutes for the air in the transport/calibration cup to become water saturated and for the temperature to equilibrate before proceeding.

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9. Observe the reading under DO %. When the reading shows no significant change for approximately 30 seconds, press **Enter**. The screen will indicate that the calibration has been accepted and prompt you to press **Enter** again to Continue. See Figure 6.6 Calibrated.

10. Press **Enter**. This returns you to the DO calibration screen, See Figure 6.7 DO Calibration Screen.

11. Press **Escape** to return to the calibrate menu. See Figure 6.2 Calibrate Screen.

12. Rinse the probe module and sensors in tap or purified water and dry.

DO Calibration in mg/L

DO calibration in mg/L is carried out in a water sample which has a known concentration of dissolved oxygen (usually determined by a Winkler titration).

1. Go to the DO calibrate screen as described in Section *6.2.3 Dissolved Oxygen Calibration*, steps 1 through 3.

2. Use the arrow keys to highlight the **DO mg/L** selection.

3. Press **Enter**. The DO mg/L Entry Screen is displayed.

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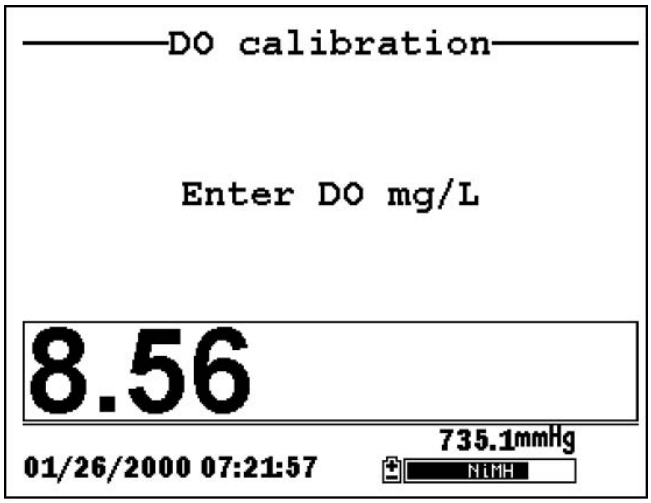

Figure 6.10 DO mg/L Entry Screen

4. Place the probe module in water with a known DO concentration.

NOTE: Be sure to completely immerse all the sensors.

5. Use the keypad to enter the known DO concentration of the water.

6. Press **Enter**. The Dissolved Oxygen mg/L Calibration Screen is displayed.

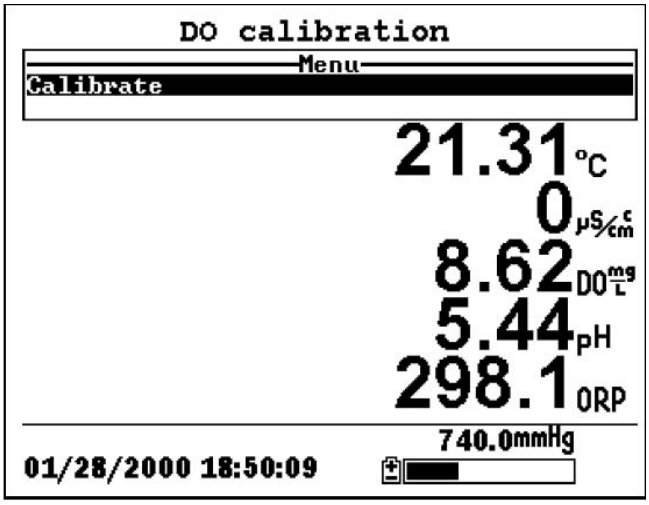

Figure 6.11 DO mg/L Calibration Screen

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7. Stir the water with a stir bar, or by rapidly moving the probe module, to provide fresh sample to the DO sensor.

8. Allow at least one minute for temperature equilibration before proceeding. The current values of all enabled sensors will appear on the screen and will change with time as they stabilize.

9. Observe the DO mg/L reading, when the reading is stable (shows no significant change for approximately 30 seconds), press **Enter**. The screen will indicate that the calibration has been accepted and prompt you to press **Enter** again to Continue.

10. Press **Enter**. This returns you to the DO calibration screen. See Figure 6.7 DO Calibration Screen.

11. Press **Escape** to return to the calibrate menu. See Figure 6.2 Calibrate Screen.

12. Rinse the probe module and sensors in tap or purified water and dry.

6.2.4 pH Calibration

1. Go to the calibrate screen as described in *Section 6.2.1 Accessing the Calibrate Screen.*

2. Use the arrow keys to highlight the **pH** selection. See Figure 6.2 Calibrate Screen.

3. Press **Enter**. The pH calibration screen is displayed.

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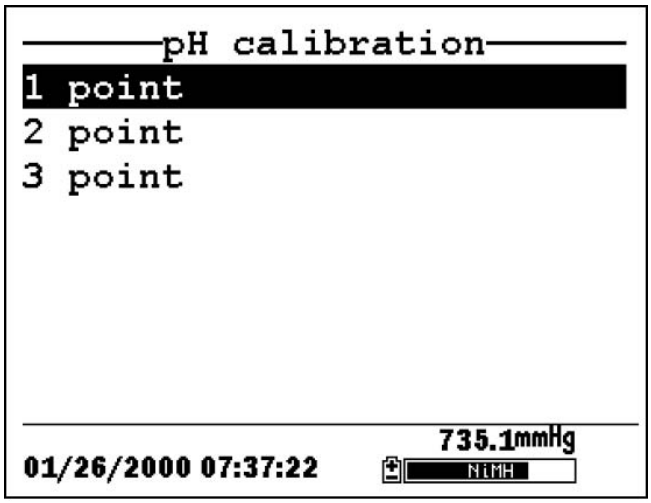

Figure 6.12 pH Calibration Screen

- Select the **1-point** option only if you are adjusting a previous calibration. If a 2-point or 3-point calibration has been performed previously, you can adjust the calibration by carrying out a one point calibration. The procedure for this calibration is the same as for a 2-point calibration, but the software will prompt you to select only one pH buffer.
- Select the **2-point** option to calibrate the pH sensor using only two calibration standards. Use this option if the media being monitored is known to be either basic or acidic. For example, if the pH of a pond is known to vary between 5.5 and 7, a two-point calibration with pH 7 and pH 4 buffers is sufficient. A three point calibration with an additional pH 10 buffer will not increase the accuracy of this measurement since the pH is not within this higher range.
- Select the **3-point** option to calibrate the pH sensor using three calibration solutions. In this procedure, the pH sensor is calibrated with a pH 7 buffer and two additional buffers. The 3-point calibration method assures maximum accuracy when the pH of the media to be monitored cannot be anticipated. The procedure for this calibration is the same as for a 2-point calibration, but the software will prompt you to select a third pH buffer.

4. Use the arrow keys to highlight the **2-point** selection.

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5. Press **Enter**. The pH Entry Screen is displayed.

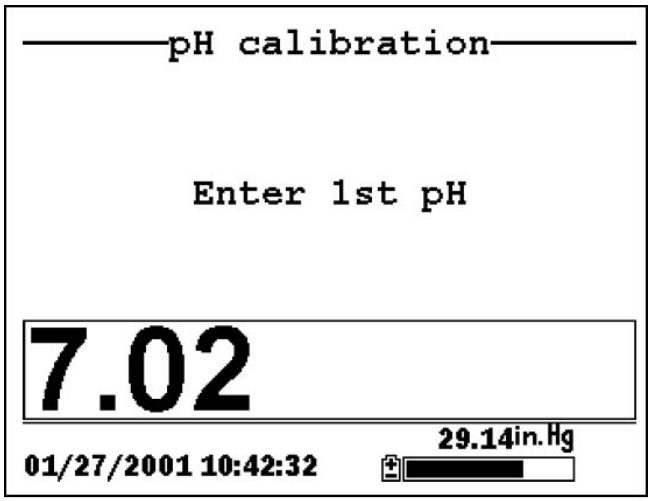

Figure 6.13 pH Entry Screen

6. Place the correct amount (see Table 6.1 Calibration Volumes) of pH buffer into a clean, dry or pre-rinsed transport/calibration cup.

NOTE: Always calibrate with buffer 7 first, regardless if performing a 1, 2, or 3 point calibration.

⚠ **WARNING**: Calibration reagents may be hazardous to your health. See *Appendix D Health and Safety* for more information.

NOTE: For maximum accuracy, the pH buffers you choose should be within the same pH range as the water you are preparing to sample.

NOTE: Before proceeding, ensure that the sensor is as dry as possible. Ideally, rinse the pH sensor with a small amount of buffer that can be discarded. Be certain that you avoid cross-contamination of buffers with other solutions.

7. Carefully immerse the sensor end of the probe module into the solution.

8. Gently rotate and/or move the probe module up and down to remove any bubbles from the pH sensor.

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NOTE: The sensor must be completely immersed. Using the recommended volumes from Table 6.1 Calibration Volumes, should ensure that the sensor is covered.

9. Screw the transport/calibration cup on the threaded end of the probe module and securely tighten

NOTE: Do not over tighten as this could cause damage to the threaded portions.

10. Use the keypad to enter the calibration value of the buffer you are using **at the current temperature**.

NOTE: pH vs. temperature values are printed on the labels of all YSI pH buffers.

11. Press **Enter**. The pH calibration screen is displayed.

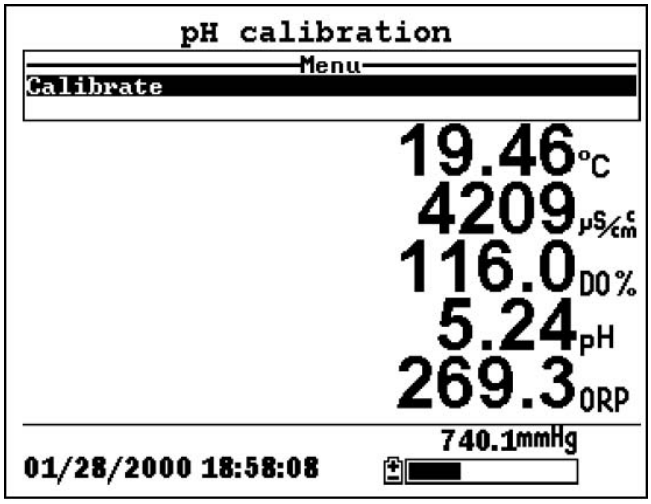

Figure 6.14 pH Calibration Screen

12. Allow at least one minute for temperature equilibration before proceeding. The current values of all enabled sensors will appear on the screen and will change with time as they stabilize.

13. Observe the reading under pH, when the reading shows no significant change for approximately 30 seconds, press **Enter**.

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The screen will indicate that the calibration has been accepted and prompt you to press **Enter** again to Continue.

14. Press **Enter**. This returns you to the specified pH Calibration Screen, See Figure 6.13 pH Entry Screen.

15. Rinse the probe module, transport/calibration cup and sensors in tap or purified water and dry.

16. Repeat steps 6 through 13 above using a second pH buffer.

17. Press **Enter**. This returns you to the pH Calibration Screen, See Figure 6.12 pH Calibration Screen.

18. Press **Escape** to return to the calibrate menu. See Figure 6.2 Calibrate Screen.

19. Rinse the probe module and sensors in tap or purified water and dry.

6.2.5 ORP Calibration

1. Go to the calibrate screen as described in Section *6.2.1 Accessing the Calibrate Screen.*

2. Use the arrow keys to highlight the **ORP** selection. See Figure 6.2 Calibrate Screen..

3. Press **Enter**. The ORP calibration screen is displayed.

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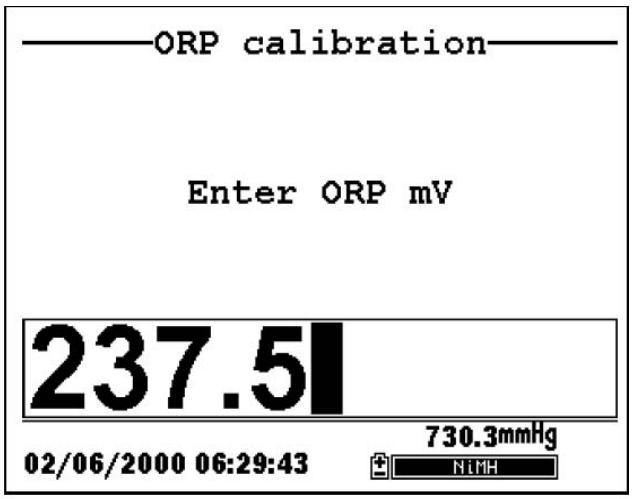

Figure 6.15 Specified ORP Calibration Screen

4. Place the correct amount (see Table 6.1 Calibration Volumes) of a known ORP solution (we recommend Zobell solution) into a clean, dry or pre-rinsed transport/calibration cup.

⚠ **WARNING**: Calibration reagents may be hazardous to your health. See *Appendix D Health and Safety* for more information.

NOTE: Before proceeding, ensure that the sensor is as dry as possible. Ideally, rinse the ORP sensor with a small amount of solution that can be discarded. Be certain that you avoid cross-contamination with other solutions.

5. Carefully immerse the sensor end of the probe module into the solution.

6. Gently rotate and/or move the probe module up and down to remove any bubbles from the ORP sensor.

NOTE: The sensor must be completely immersed. Using the recommended volumes from Table 6.1 Calibration Volumes should ensure that the sensor is covered.

7. Screw the transport/calibration cup on the threaded end of the probe module and securely tighten.

NOTE: Do not over tighten as this could cause damage to the threaded portions.

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8. Use the keypad to enter the correct value of the calibration solution you are using at the current temperature. Refer to Table 6.2 Zobell Solution Values.

Temperature °C	Zobell Solution Value, mV
-5	270.0
0	263.5
5	257.0
10	250.5
15	244.0
20	237.5
25	231.0
30	224.5
35	218.0
40	211.5
45	205.0
50	198.5

Table 6.2 Zobell Solution Values

9. Press **Enter**. The ORP calibration screen is displayed.

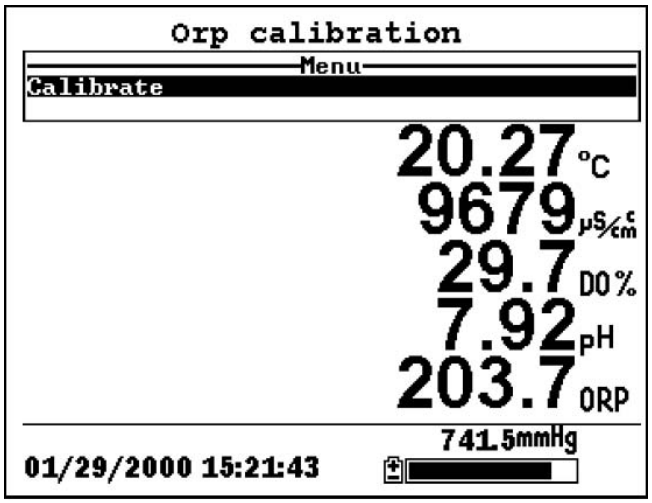

Figure 6.16 DO Cal Screen

10. Allow at least one minute for temperature equilibration before proceeding. The current values of all enabled sensors will appear on the screen and will change with time as they stabilize.

NOTE: Verify that the temperature reading matches the value you used in Table 6.2 Zobell Solution Values.

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11. Observe the reading under ORP, when the reading shows no significant change for approximately 30 seconds, press **Enter**. The screen will indicate that the calibration has been accepted and prompt you to press **Enter** again to Continue.

12. Press **Enter**. This returns you to the Calibrate Screen. See Figure 6.2 Calibrate Screen.

13. Rinse the probe module and sensors in tap or purified water and dry.

6.3 Return to Factory Settings.

1. Go to the calibrate screen as described in Section *6.2.1 Accessing the Calibrate Screen*.

2. Use the arrow keys to highlight the **Conductivity** selection. See Figure 6.2 Calibrate Screen.

NOTE: We will use the Conductivity sensor as an example; however, this process will work for any sensor.

3. Press **Enter.** The Conductivity Calibration Selection Screen is displayed. See Figure 6.3 Conductivity Calibration Selection Screen.

4. Use the arrow keys to highlight the **Specific Conductance** selection.

5. Press **Enter.** The Conductivity Calibration Entry Screen is displayed. See Figure 6.4 Conductivity Calibration Entry Screen.

6. Press and hold the **Enter** key down and press the **Escape** key.

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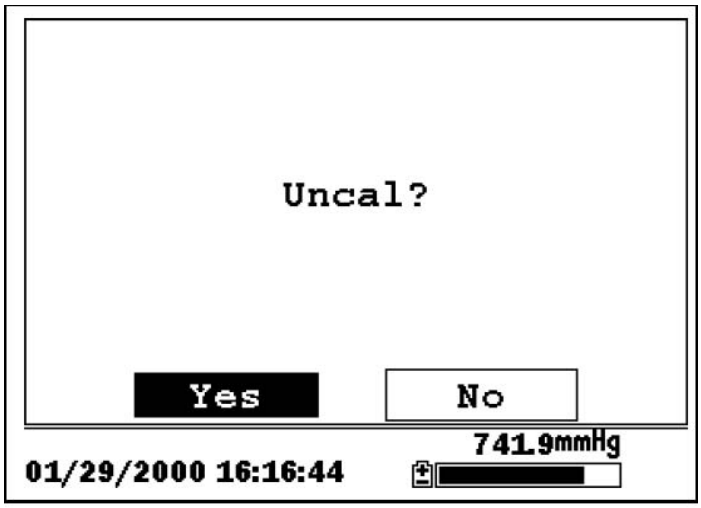

Figure 6.17 ORP Calibration Screen

7. Use the arrow keys to highlight the **YES** selection.

   CAUTION: This returns a sensor to the factory settings. For example, in selecting to return specific conductance to the factory setting, salinity and conductivity will automatically return to their factory settings.

8. Press **Enter**. This returns you to the Conductivity Calibrate Selection Screen, See Figure 6.3 Conductivity Calibration Selection Screen. .

9. Press **Escape** to return to the calibrate menu. See Figure 6.2 Calibrate Screen.

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7. Run

The Run screen displays data from the sensors in real-time and allows the user to log sample data to memory for later analysis. Refer to Section *9 Logging* for details on logging sample data.

7.1 Real-Time Data

NOTE: Before measuring samples you must prepare the probe module (refer to Section *3.4 Preparing the Probe Module*), attach the probe module to the instrument (refer to Section *3.6 Instrument/Cable Connection*) and calibrate the sensors (refer to Section *6 Calibrate*).

1. Press the On/off key.

OR select Run from the main menu to display the run screen.

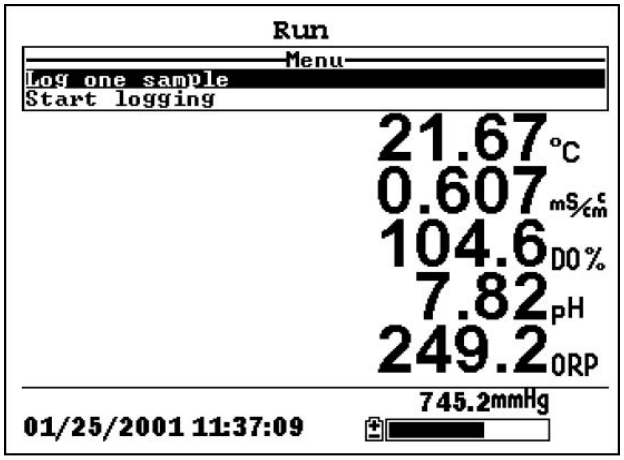

Figure 7.1 Run Screen

2. Make sure the probe sensor guard is installed.

3. Place the probe module in the sample. Be sure to completely immerse all the sensors.

4. Rapidly move the probe module through the sample to provide fresh sample to the DO sensor.

5. Watch the readings on the display until they are stable.

6. Refer to Section *9 Logging* for instructions on logging sample data.

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8. File

The File menu allows the user to view, upload or delete sample data and calibration record files stored in the YSI 556 MPS.

8.1 Accessing the File Screen

1. Press the **On/off** key to display the run screen.

2. Press the **Escape** key to display the main menu screen.

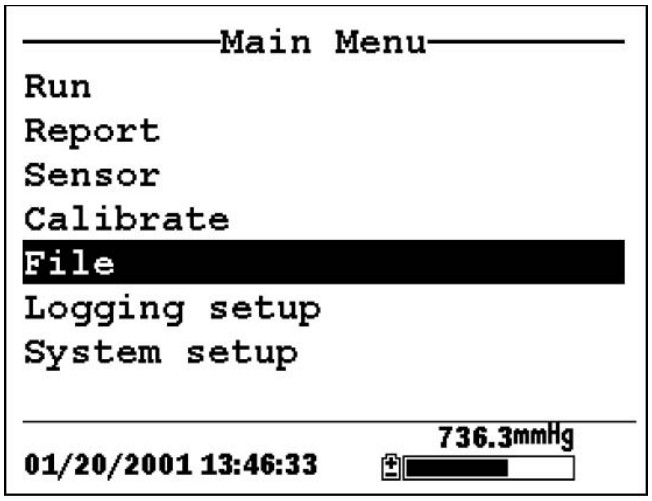

Figure 8.1 Main Menu Screen

3. Use the arrow keys to highlight the **File** selection.

4. Press the **Enter** key. The file screen is displayed.

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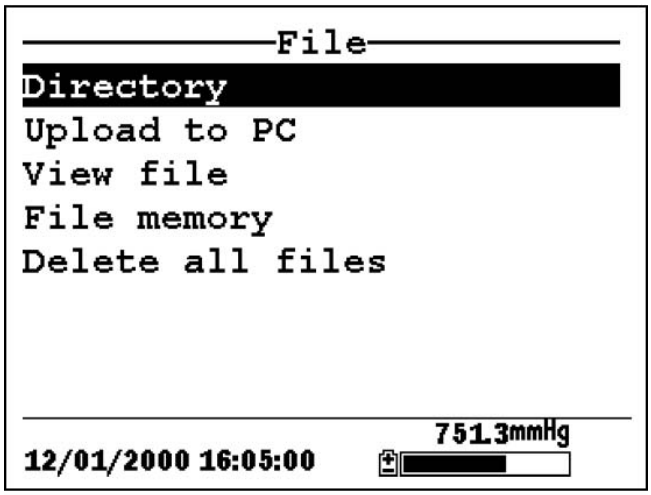

Figure 8.2 File Screen

8.2 Directory

1. Go to the file screen as described in Section *8.1 Accessing the File Screen.*

2. Use the arrow keys to highlight the **Directory** selection. See Figure 8.2 File Screen.

3. Press the **Enter** key. The file list screen is displayed.

NOTE: Files are listed in the order in which they are logged to memory. Sample Data files have the file extension **.dat**, while Calibration Record files have the file extension **.glp**.

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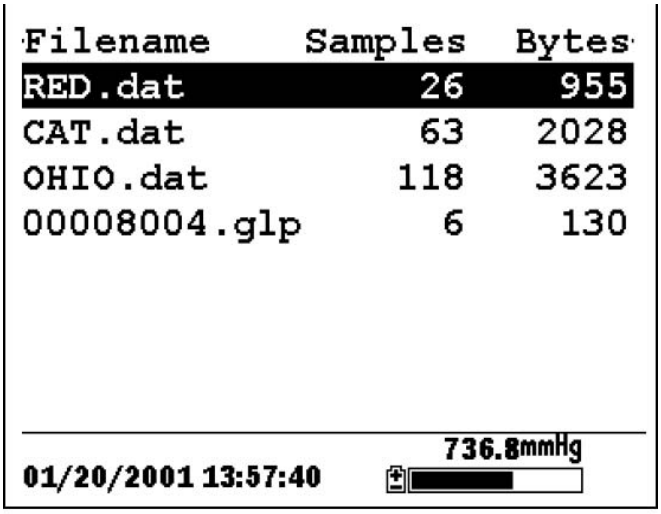

Figure 8.3 File List Screen

4. Use the arrow keys to highlight a file.

5. Press the **Enter** key. The file details screen is displayed.

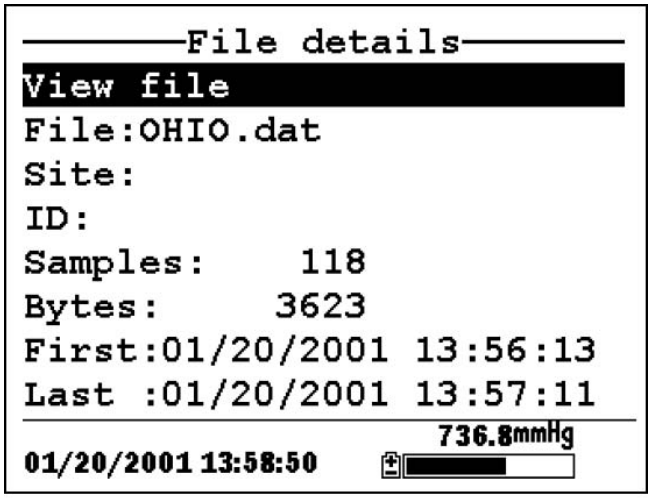

Figure 8.4 File Details Screen

6. Press the **Enter** key to view the file data. Refer to Section *8.3 View File* for details.

7. Press the **Escape** key repeatedly to return to the main menu screen.

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8.3 View File

1. Go to the file screen as described in Section *8.1 Accessing the File Screen*. See Figure 8.2 File Screen.

2. Use the arrow keys to highlight the **View file** selection.

3. Press the **Enter** key. A list of files is displayed. See Figure 8.3 File List Screen.

4. Use the arrow keys to highlight an individual file.

   NOTE: You may have to scroll down to see all the files.

5. Press the **Enter** key. The file data is displayed with the file name at t8e top of the display.

   NOTE: If no file name was specified, the data is stored under the default name NONAME1.dat.

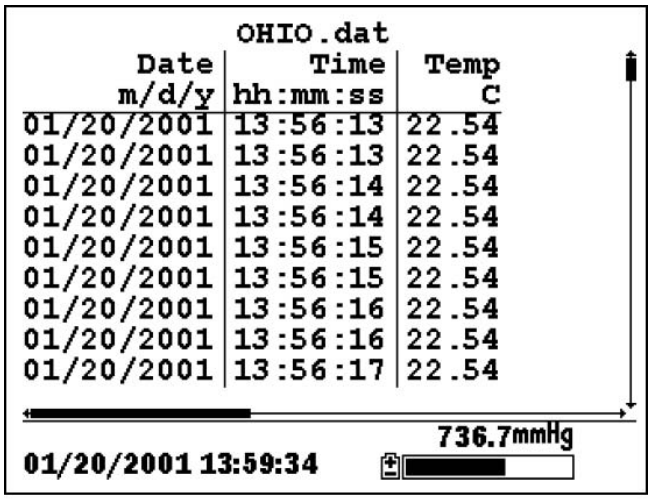

Figure 8.5 File Data Screen

6. Use the arrow keys to scroll horizontally and/or vertically to view all the data.

7. Press the **Escape** key repeatedly to return to the main menu screen.

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8.4 Upload to PC

EcoWatch™ for Windows™ must be used as the PC software interface to the YSI 556 MPS. Refer to *Appendix G EcoWatch* for more information. EcoWatch for Windows® is available at no cost via a download from the YSI Web Site (www.ysi.com) or by contacting YSI Customer Support. Refer to *Appendix E Customer Service.*

8.4.1 Upload Setup

1. Disconnect the YSI 5563 Probe Module from the YSI 556 MPS instrument.

2. Connect the YSI 556 MPS to a serial (Comm) port of your computer via the 655173 PC Interface cable as shown in the following diagram:

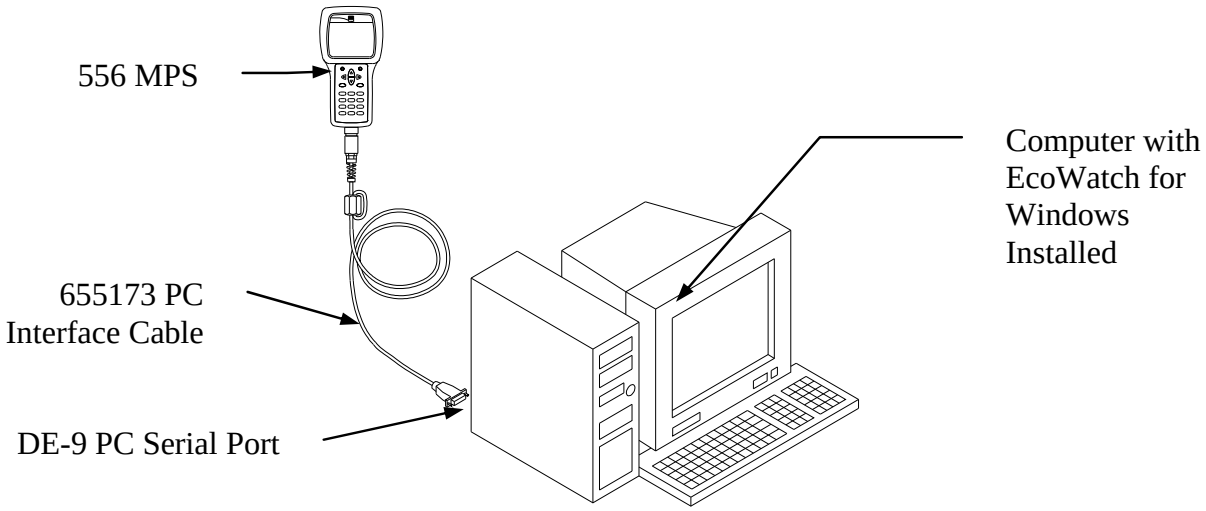

Figure 8.2 Computer/Instrument Interface

3. Open EcoWatch for Windows on your computer.

   NOTE: See *Appendix G EcoWatch* for installation instructions.

4. Click on the sonde/probe icon in the upper toolbar.

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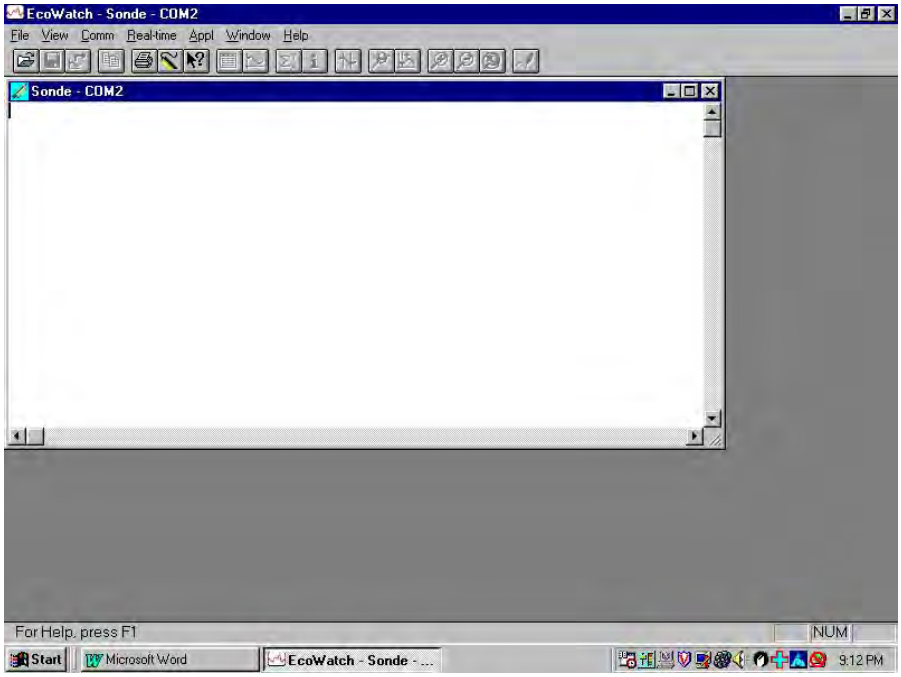
5. Set the Comm port number to match the port the YSI 556 MPS is connected to. After this setup procedure, the following screen will be present on your PC monitor:



8.4.2 Uploading a .DAT File

1. Setup the instrument as described in Section *8.4.1 Upload Setup*.

2. Go to the YSI 556 MPS file screen as described in Section *8.1 Accessing the File Screen.*

3. Use the arrow keys to highlight the **Upload to PC** selection. See Figure 8.2 File Screen.

4. Press the **Enter** key. The file list screen is displayed. See Figure 8.3 File List Screen.

5. Use the arrow keys to highlight the DAT file that you wish to transfer and press **Enter**, both the YSI 556 MPS and PC displays show the progress of the file transfer.

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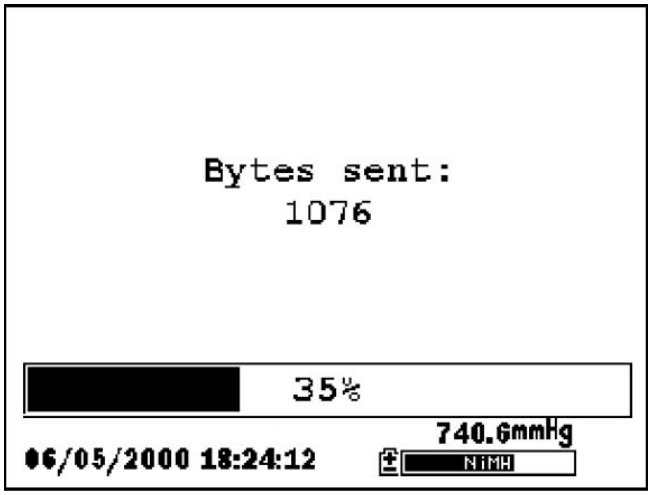
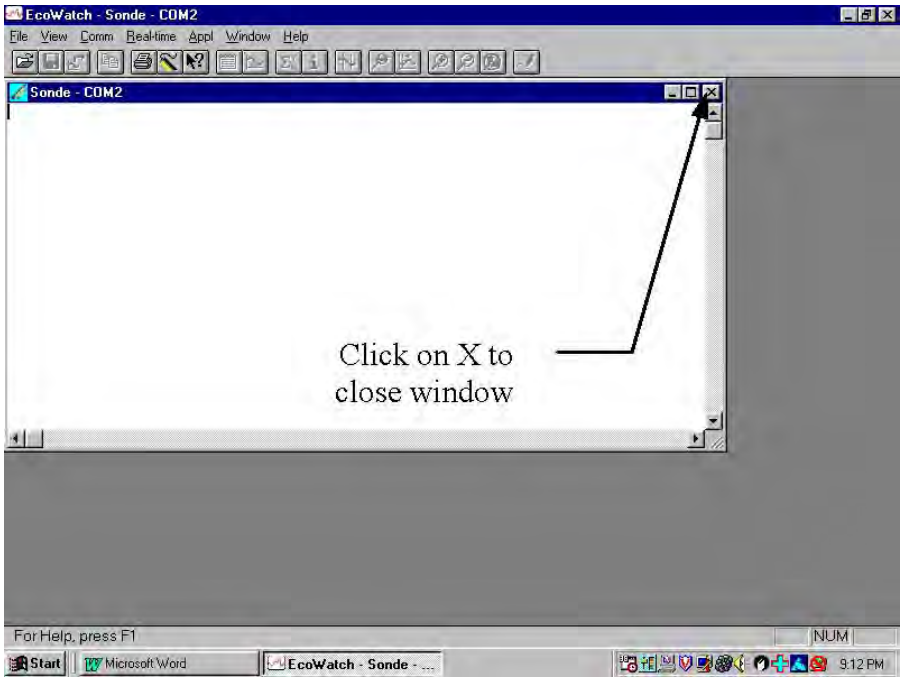


Figure 8.3 File Transfer Progress Screen

NOTE: After transfer, the file will be located in the C:\ECOWWIN\DATA folder of your PC, designated with a .DAT extension.

6. After the file transfer is complete, close the terminal window (small window on the PC) by clicking on the "X" at its upper right corner.



7. Press the **Escape** key on the YSI 556 MPS repeatedly to return

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to the main menu screen.

8.4.3 Uploading a Calibration Record (.glp) File

For more information on the calibration record, refer to *Appendix H Calibration Record Information*.

1. Setup up the instrument as described in Section *8.4.1 Upload Setup*.

2. Go to the YSI 556 MPS file screen as described in Section

3. Use the arrow keys to highlight the Upload to PC selection. See Figure 8.2 File Screen.

4. Press the **Enter** key. The file list screen is displayed. See Figure 8.3 File List Screen.

5. Use the arrow keys to highlight the calibration record file that you wish to transfer and press **Enter.**

6. You will then be given a choice of uploading the file in three formats; **Binary, Comma & "" Delimited, and ASCII Text**.

   NOTE: The binary format is reserved for future YSI software packages.

7. Choose an option and press Enter, both the YSI 556 and PC displays show the progress of the file transfer.

   NOTE: After transfer, the file will be located in the C:\ECOWWIN\DATA folder of your PC, designated with the appropriate file extension.

   NOTE: To view the Calibration Record data after upload, simply open the .txt file in a general text editor such as Wordpad or Notepad.

8. After the file transfer is complete, close the terminal window (small window on the PC) by clicking on the "X" at its upper right corner.

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9. Press the **Escape** key repeatedly to return to the main menu screen.

8.5 File Memory

1. Go to the file screen as described in Section *8.1 Accessing the File Screen.*

2. Use the arrow keys to highlight the **File memory** selection. See Figure 8.2 File Screen.

3. Press the **Enter** key. The file bytes used screen is displayed.

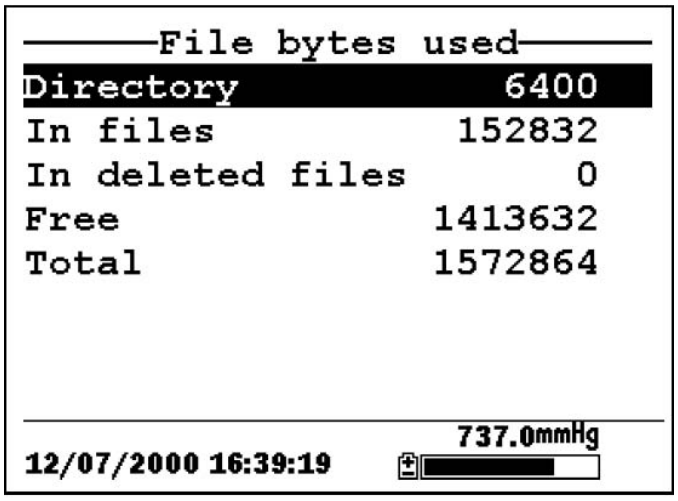

Figure 8.4 File Bytes Used Screen

4. The amount of free memory is listed in line 4 of the file bytes used screen.

   NOTE: If the amount of free memory is low, it may be time to delete all files (after first uploading all data to a PC). Refer to Section *8.6 Delete All Files.*

5. Press the **Escape** key repeatedly to return to the main menu screen.

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8.6 Delete All Files

NOTE: It is not possible to delete individual files in order to free up memory. The only way to free up memory is to delete ALL files present. Take care to transfer all files to your computer (refer to Section 8.4 Upload to PC) before deleting them.

1. Go to the file screen as described in Section *8.1 Accessing the File Screen.*

2. Use the arrow keys to highlight the **Delete all files** selection. See Figure 8.2 File Screen.

3. Press the **Enter** key. The Delete all Files screen is displayed.

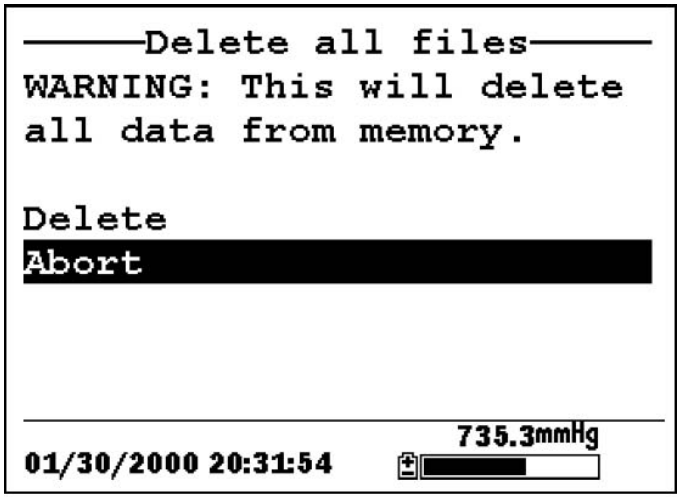

Figure 8.5 Delete All Files Screen

4. Use the arrow keys to highlight the **Delete** selection.

5. Press the **Enter** key.

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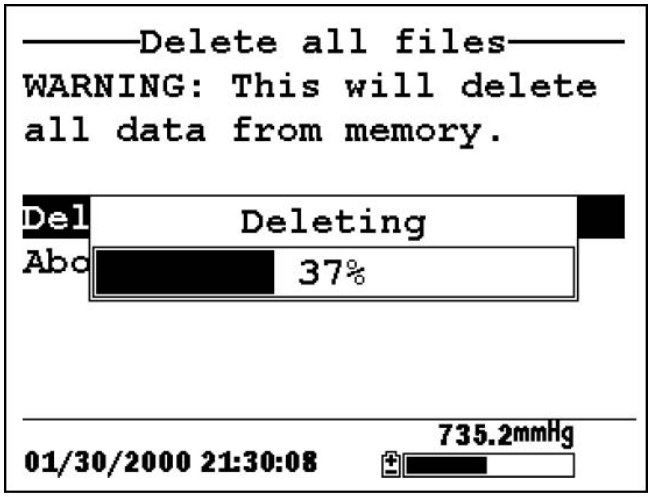

Figure 8.10 Deleting

The progress of file deletion is displayed in bar graph format.

NOTE: Deleting all files in the directory will not change any information in the site list.

6. Press the Escape key repeatedly to return to the main menu screen.

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9. Logging

9.1 Accessing the Logging Setup Screen

1. Press the **On/off** key to display the run screen.

2. Press the **Escape** key to display the main menu screen.

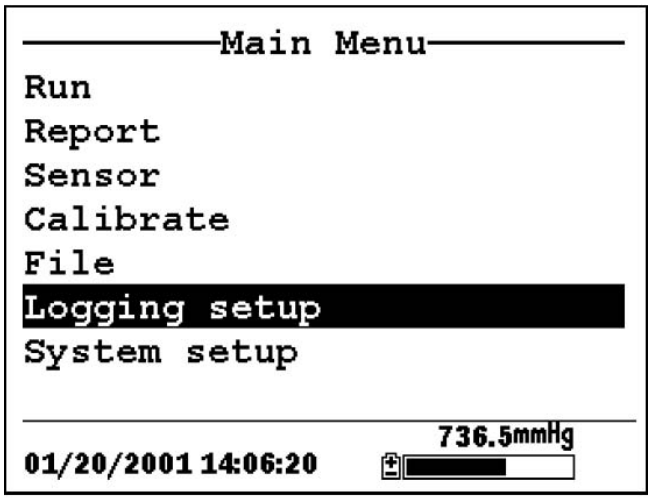

Figure 9.1 Main Menu

3. Use the arrow keys to highlight the **Logging setup** selection.

4. Press the **Enter** key. The logging setup screen is displayed.

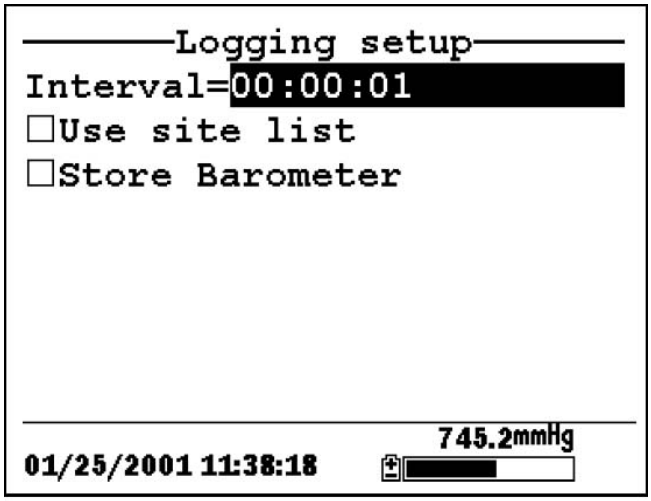

Figure 9.2 Setup Screen

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9.2 Setting Logging Interval

Follow steps below to set the interval for logging a data stream.

NOTE: If you do not specify an interval, the instrument will use a default interval setting of 1 second.

NOTE: It is not necessary to set a logging interval when logging a single sample.

1. Go to the logging setup screen as described in Section *9.1 Accessing the Logging Setup Screen*.

2. Use the keypad to enter an interval between 1 second and 15 minutes. Refer to Section *2.9 Keypad Use*.

   NOTE: The interval field has hour, minute and second entry fields. Any entry over 1 hour will change automatically to a 15-minute setting.

3. ***P***ress the **Enter** key. The data stream interval is set.

4. Press the **Escape** key repeatedly to return to the main menu screen.

9.3 Storing Barometer Readings

NOTE: The **Store barometer** option is only available on instruments that are equipped with the optional barometer.

1. Go to the logging setup screen as described in Section *9.1 Accessing the Logging Setup Screen*.

2. Use the arrow keys to highlight the **Store barometer** selection. See Figure 9.2 Logging Setup Screen.

3. Press the **Enter** key until a check mark is entered in the box next to the store barometer selection if you want to log barometric readings.

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OR press the **Enter** key until the box next to the barometer selection is empty if you do not want to log barometric readings.

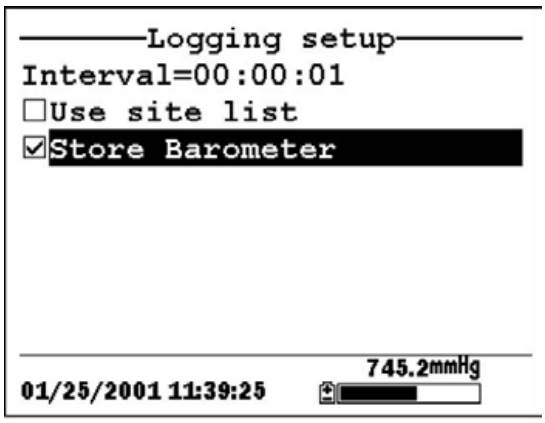

Figure 9.3 Store Barometer

4. Press the **Escape** key repeatedly to return to the main menu screen.

9.4 Creating a Site List

The site list option allows you to define file and site descriptions in the office or laboratory before moving to field logging studies. This is usually more convenient than entering the information at the site and is particularly valuable if you are visiting certain sites on a regular basis. The following section describes how to set up site lists which contain entries designated "Site Descriptions" that will be instantly available to the user in the field to facilitate the logging of data with pre-established naming of files and sites. There are two kinds of **Site Descriptions** available for use in Site lists:

• **Site Descriptions** associated with applications where data from a single site is always logged to a single file. This type is referred to as a "Single-Site Description" and is characterized by two parameters – a file name and a site name. Files logged to YSI 556 MPS memory under a **Single-Site Description** will be characterized primarily by the file name, but will also have the Site name attached, so that it is viewable in either the YSI 556 MPS **File directory** or in EcoWatch for Windows after upload to a PC

• **Site Descriptions** associated with applications where data from multiple sites are logged to a single file. This type is referred to as a "Multi-site Description" and is characterized by three parameters – a file name, a site name, and a site number. Files logged to YSI 556 MPS memory under a

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Multi-site Description are characterized by a file name, but not a site name, since multiple sites are involved. However, each data point has a Site Number attached to it so that the user can easily determine the sampling site when viewing the data from the YSI 556 MPS **File** menu or processing the data in EcoWatch for Windows after upload to a PC.

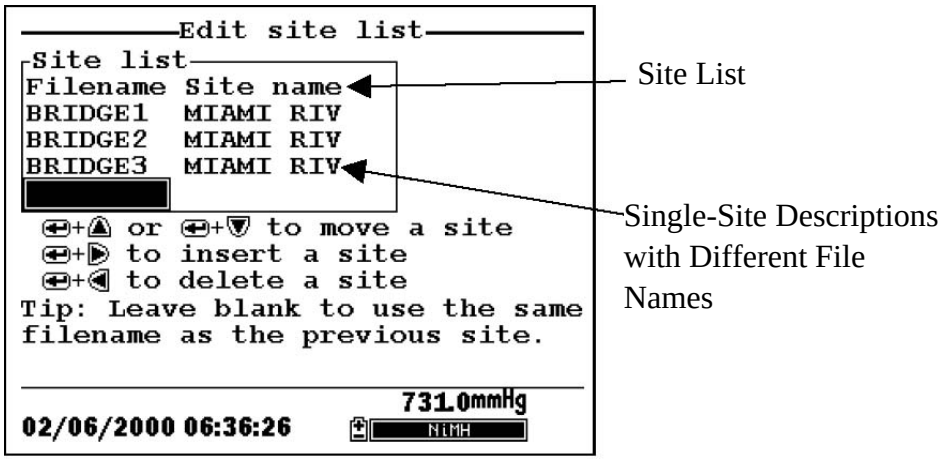

Figure 9.4 Single-Site Descriptions

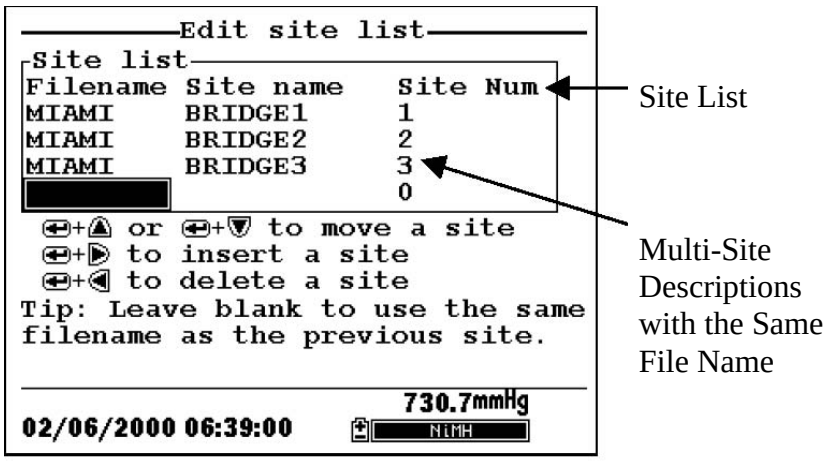

Figure 9.5 Multiple-Site Descriptions

NOTE: Site lists containing Single Site Descriptions are usually input with the designation **Store Site Number** INACTIVE in the YSI 556 MPS **Logging setup** menu. Thus, no site numbers appear in the first **Site list** example. Conversely, **Site lists** containing **Multi-Site Descriptions** MUST be input with the **Store Site Number** selection ACTIVE as shown in the second example.

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To create a site list:

1. Go to the logging setup screen as described in Section *9.1 Accessing the Logging Setup Screen.*

2. Use the arrow keys to highlight the **Use site list** selection.

3. Press the **Enter** key. A check mark is entered in the box next to the use site list selection *and* two new entries appear on the logging setup screen. See Figure 9.6 Logging Setup Screen.

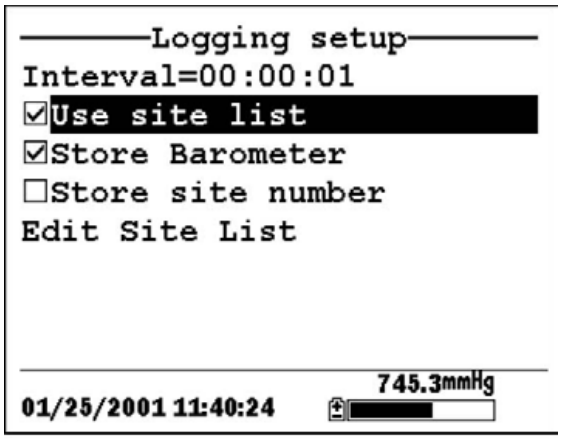

Figure 9.6 Logging Setup Screen

4. Use the arrow keys to highlight the **Store site number** selection.

5. If you are creating Multi-Site Descriptions (which require that the site **number** be stored in your data files), press the **Enter** key until a check mark appears in the box next to the store site number selection.

OR Press the **Enter** key until the box next to the store site number selection is empty, to create Single-Site Descriptions. The site **name** will be stored in the header of your data files.

6. Use the arrow keys to highlight the **Edit site list** selection.

7. Press the **Enter** key. The edit site list screen is displayed. See Figure 9.7 Edit Site List Screen. The **Filename** field is ready for input.

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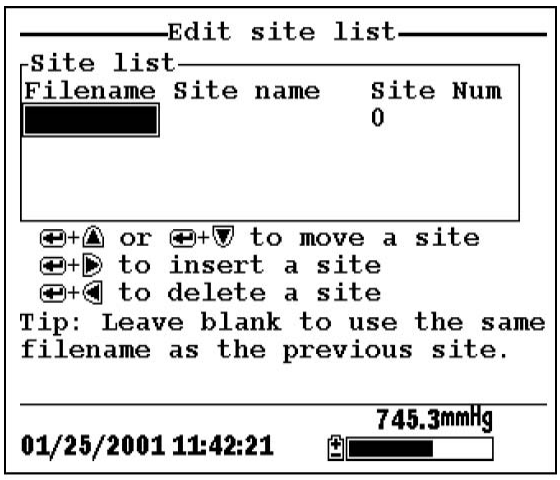

Figure 9.7 Edit Site List Screen

8. Use the keypad to enter a filename up to 8 characters in length. Refer to Section *2.9 Keypad Use*.

9. Press the **Enter** key. The cursor moves to the right for the entry of a **Site name**.

10. Use the keypad to enter a site name up to 11 characters in length. Refer to Section *2.9 Keypad Use*.

NOTE: If the store site number selection is *not* checked, skip to Step 13.

11. Press the **Enter** key. The cursor moves to the site number entry position.

12. Use the keypad to enter a site number up to 7 characters in length. Refer to Section *2.9 Keypad Use*.

13. Press **Enter**. The cursor moves to the next filename entry position.

14. Repeat Steps 8 to 13 until all filenames and sites have been entered.

15. Press **Escape** repeatedly to return to the main menu screen.

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9.5 Editing a Site List

1. Go to the logging setup screen as described in Section *9.1 Accessing the Logging Setup Screen*.

2. Use the arrow keys to highlight the **Edit Site List** selection. See Figure 9.6 Logging Setup Screen.

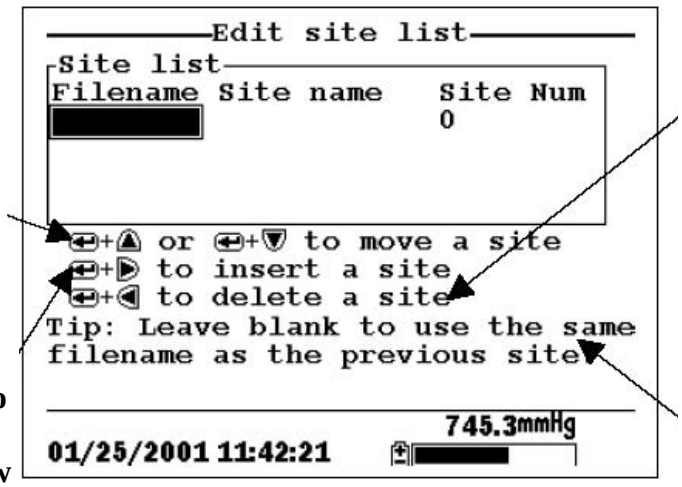
3. Press the **Enter** key. The edit site list screen is displayed.

4. Edit the site list using the keystrokes described below.

NOTE: Editing the site list will not have any effect on files stored in the instrument memory.

To MOVE a site:
Use the arrow keys to highlight a site. Press the Up or Down arrow key while holding down the Enter key.

To INSERT a site above another site:
Use the arrow keys to highlight the site. Press the Right arrow key while holding down the Enter key. Use keypad to input letters. Refer to Section 2.9 *Keypad Use*.



To DELETE a site:
Use the arrow keys to highlight a site. Press the Left arrow key while holding down the Enter key.

To use the same file name as the previous site: Leave the filename blank

Figure 9.1 Keystrokes for Editing Site List

9.6 Logging Data Without a Site List

1. Follow Steps 1 through 5 in Section 7.1 Real-Time Data.

2. Use the arrow keys to highlight the **Log one sample** selection on the run screen if only a single sample is being logged.

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OR Use the arrow keys to highlight the **Start logging** selection on the run screen if a data stream is being logged.

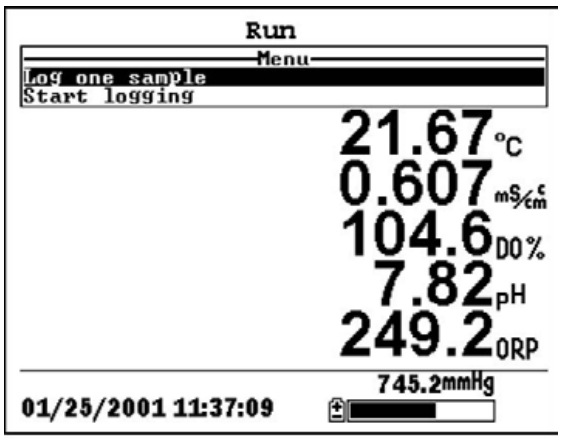

Figure 9.9 Run Screen

3. Press the **Enter** key. The Enter information screen is displayed.

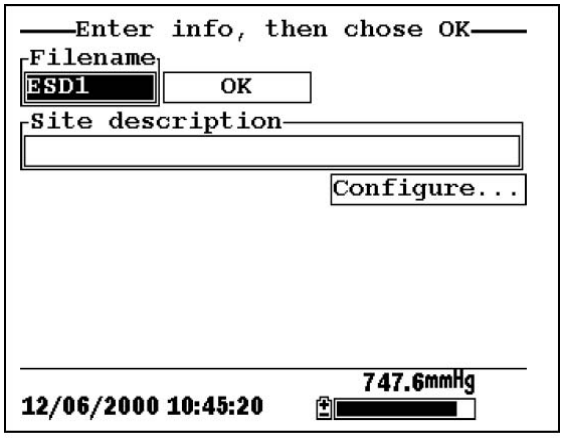

Figure 9.10 Enter Information Screen

NOTE: The last filename used will be displayed.

4. Use the keypad to enter a file name. Refer to Section *2.9 Keypad Use*.

NOTE: The instrument will assign a default file name of NONAME if no file name is specified.

5. Press the **Enter** key to input the file name.

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6. Use the arrow keys to highlight the **Site description** field in the enter information screen.

   NOTE: Entering a Site Description is optional. You may leave the Site Description blank and skip to Step 9.

7. Use the keypad to enter a site description name. Refer to Section *2.9 Keypad Use*.

8. Press the **Enter** key to input the site description.

   NOTE: If you want to change the logging setup, such as sampling interval or storing the barometer reading, use the arrow keys to highlight the **Configure** field, press the **Enter** key, then refer to Section *9.2 Setting Logging Interval* or *9.3 Storing Barometer Readings* for details.

9. Use the arrow keys to highlight the **OK** field in the center of the information screen.

10. Press the **Enter** key to start logging.

    NOTE: If the parameter mismatch screen is displayed, refer to Section *9.8 Adding Data to Existing Files*.

11. If a single point is being logged, the header on the run screen changes momentarily from **Menu** to **Sample logged** to confirm that the point was successfully logged. Skip to Step

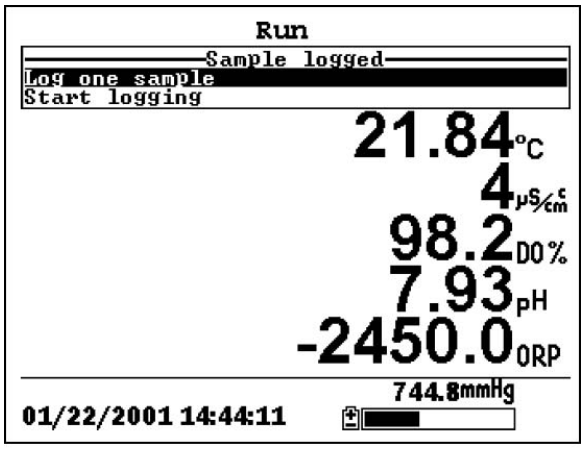

Figure 9.11 Sample Logged Screen

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If a continuous stream of points is being logged, the start logging entry in the run screen changes from **Start logging** to **Stop logging**.

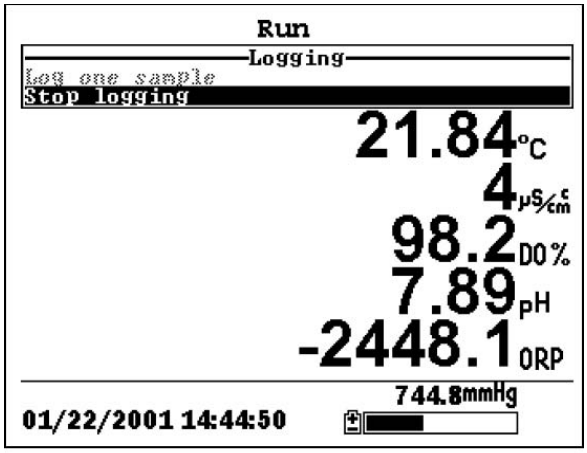

Figure 9.12 Logging Screen

12. At the end of the logging interval, press **Enter** to stop logging.

13. Refer to Section *8.3 View File* to view the data on the instrument display.

9.7 Logging Data with a Site List

1. If you have not already created a site list, refer to Section *9.4 Creating a Site List.*

2. Follow Steps 1 through 5 in Section 7.1 Real-Time Data.

3. Use the arrow keys to highlight the **Log one sample** selection on the run screen if only a single sample is being logged.

OR Use the arrow keys to highlight the **Start logging** selection on the run screen if a data stream is being logged. See Figure 9.9 Run Screen.

4. Press the **Enter** key. The Pick a site screen is displayed.

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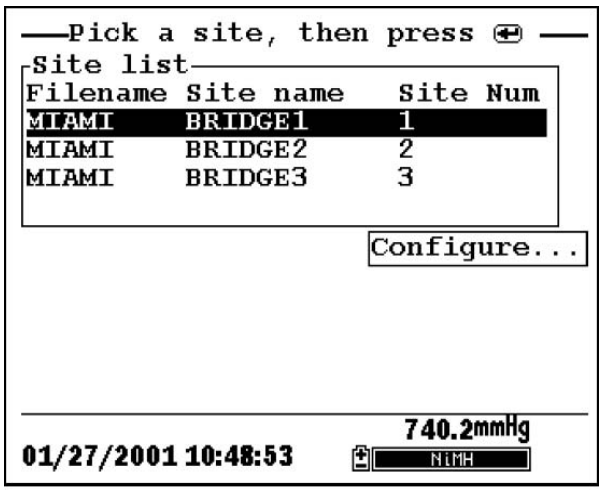

Figure 9.13 Pick a Site Screen

5. Use the arrow keys to highlight the **site** of your choice.

NOTE: If the site of your choice is grayed out in the site list, refer to Section *9.8 Adding Data to Existing Files*.

NOTE: Refer to Section *9.5 Editing a Site List* if you want to edit the site list.

6. Press the **Enter** key to start logging.

NOTE: If the parameter mismatch screen is displayed, refer to Section 9.8 Adding Data to Existing Files.

7. If a single point is being logged, the header on the run screen changes momentarily from **Menu** to **Sample logged** to confirm that the point was successfully logged. See Figure 9.11 Sample Logged Screen. Skip to Step 9.

If a continuous stream of points is being logged, the start logging entry in the run screen changes from **Start logging** to **Stop logging**. See Figure 9.12 Logging Screen.

8. At the end of the logging interval, press **Enter** to stop logging.

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9. Refer to Section *8.3 View File* to view the data on the instrument display.

9.8 Adding Data to Existing Files

In order to add new data to an existing file, the current logging and sensor setup must be *exactly* the same as when the file was created. The following settings must be the same:

- **Sensors enabled** (refer to Section *4 Sensors*)
- **Store Barometer** (refer to Section *9.3 Storing Barometer Readings*)
- **Store Site Number** (refer to Section *9.4 Creating a Site List*)

If the current logging setup is not exactly the same as when the file was created, a parameter mismatch screen is displayed.

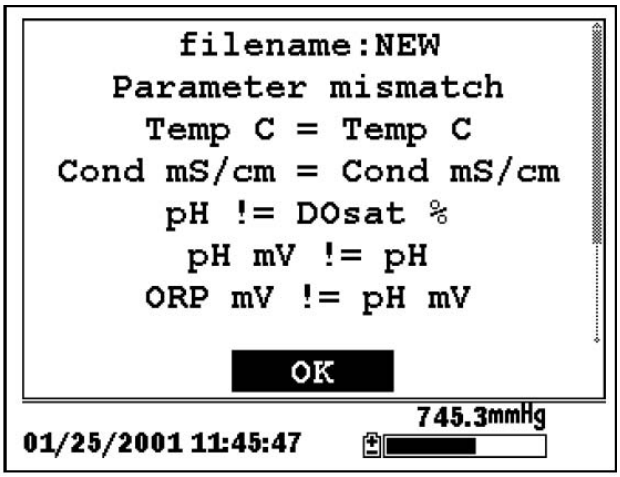

Figure 9.14 Parameter Mismatch Screen

NOTE: The right column shows parameters used when the file was created. The left column shows current parameters.

1. Press the **Down Arrow** key to scroll down and find the mismatch(es).

2. Use the following chart to resolve the mismatch(es).

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Mismatch	Action	Reference
Sensor(s) missing from left column	Enable the missing sensor(s)	Section *4 Sensors*
Extra sensor(s) listed in left column	Disable the extra sensor(s)	Section *4 Sensors*
Barometer missing from left column, but present in right column	Enable the Store Barometer setting	Section *9.3 Storing Barometer Readings*
Barometer present in left column, but missing from right column	Disable the Store Barometer setting	Section *9.3 Storing Barometer Readings*
Store Site Number missing from left column, but present in right column	Enable the Store Site Number setting	Section *9.4 Creating a Site List*
Store Site Number present in left column, but missing from right column	Disable the Store Site Number setting	Section *9.4 Creating a Site List*

3. Return to Section *9.6 Logging Data without a Site List* or *9.7 Logging Data with a Site List*.

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10. System Setup

The YSI 556 MPS has a number of features that are user-selectable or can be configured to meet the user's preferences. Most of these choices are found in the **System setup** menu.

10.1 Accessing the System Setup Screen

1. Press the **On/off** key to display the run screen. See Figure Front View of YSI 556 MPS.

2. Press the **Escape** key to display the main menu screen.

3. Use the arrow keys to highlight the **System setup** selection.

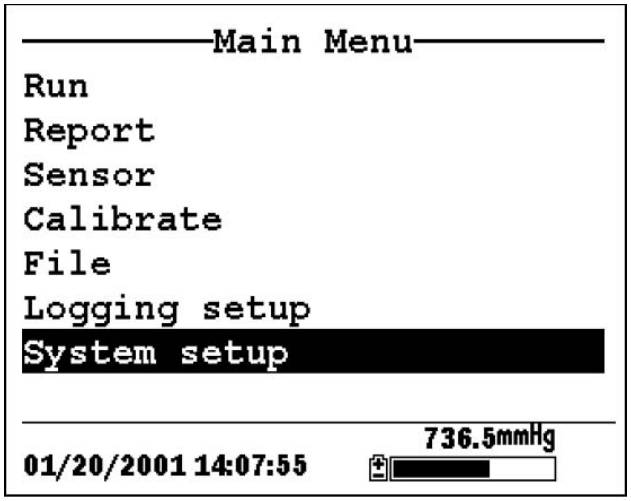

Figure 10.1 Main Menu

4. Press the **Enter** key. The system setup screen is displayed.

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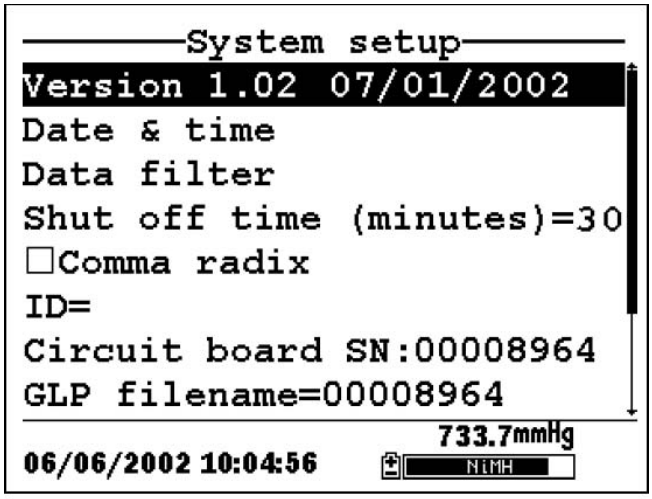

Figure 10.2 System Setup Screen

NOTE: The first line of the **System setup** menu shows the current software version of your YSI 556 MPS. As software enhancements are introduced, you will be able to upgrade your YSI 556 MPS from the YSI Web site. Refer to Section *11.2 Upgrading YSI 556 MPS* Software for details.

10.2 Language Setting

1. Go to the System Setup screen as described in Section *10.1 Accessing the System Setup Screen*.

2. Use the arrow keys to highlight **Language** on the System Setup screen. Press **Enter** to open the Language screen. .

3. Use the arrow keys to highlight your desired **Language**. Press **Enter**.

4. Press the Escape key repeatedly to return to the Main men

10.3 Date and Time Setup

1. Go to the system setup screen as described in Section *10.1 Accessing the System Setup Screen*.

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2. Use the arrow keys to highlight the **Date & time** selection on the system setup screen. See Figure 10.2 System Setup Screen.

3. Press **Enter**. The date and time setup screen is displayed.

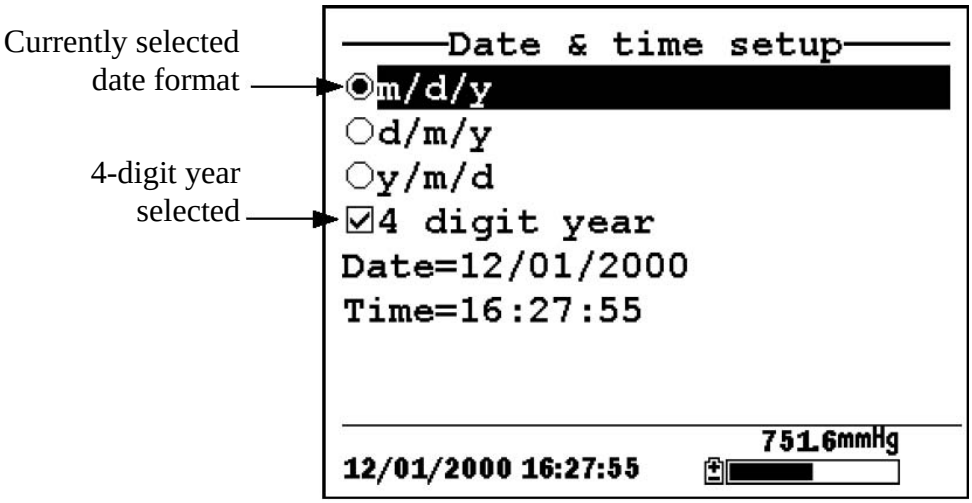

Figure 10.3 Date Setup Screen

NOTE: A black dot to the left of a date format indicates that format is selected.

4. Use the arrow keys to highlight your desired date format.

5. Press **Enter**.

6. Use the arrow keys to highlight the 4-digit year selection.

7. Press **Enter**. A check mark appears in the check box next to the 4-digit year selection.

NOTE: If unchecked, a 2-digit year is used.

8. Use the arrow keys to highlight the **Date** selection.

9. Press **Enter**. A cursor appears over the first number in the date.

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10. Enter the proper number from the keypad for the highlighted date digit. The cursor moves automatically to the next date digit. Refer to Section *2.9 Keypad Use* for more keypad information.

11. Repeat Step 10 until all date digits are correct.

12. Press **Enter** to input the specified date.

13. Use the arrow keys to highlight the **Time** selection.

14. Press **Enter**. A cursor appears over the first number in the time selection.

15. Enter the proper number from the keypad for the highlighted time digit. The cursor moves automatically to the next time digit.

    NOTE: Use military format when entering time. For example, 2:00 PM is entered as 14:00.

16. Repeat Step 15 until all time digits are correct.

17. Press **Enter** to input the correct time.

18. Press the **Escape** key repeatedly to return to the Main menu screen.

10.4 Data Filter

The Data Filter is a software filter that eliminates sensor noise and provides more stable readings.

NOTE: YSI recommends using the default values for the data filter for most field applications.

However, users who are primarily interested in a fast response from their dissolved oxygen sensor should consider a change of the default time constant setting of 8 seconds to one of 2 seconds. This change can be made according to the instructions in Section *10.3.1 Changing the Data Filter Settings* below. The disadvantage of lowering the time constant is that field pH readings may appear somewhat noisy if the cable is in motion.

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10.4.1 Changing the Data Filter Settings

1. Go to the system setup screen as described in Section *10.1 Accessing the System Setup Screen*.

2. Use the arrow keys to highlight the **Data filter** selection. See Figure 10.1 Main Menu.

3. Press the **Enter** key. The Data filter setup screen is displayed.

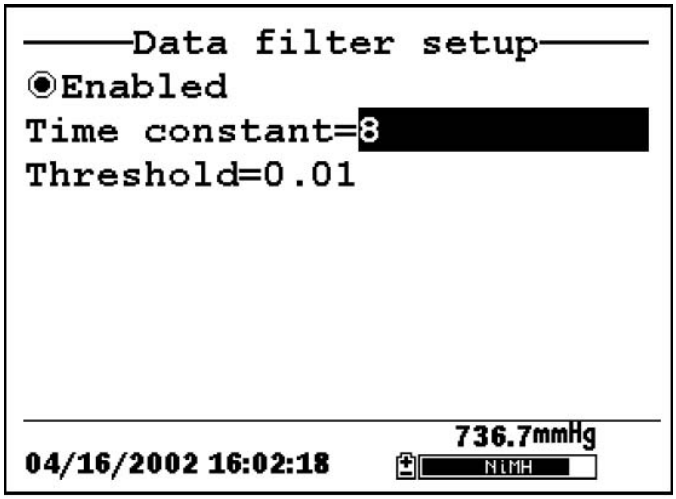

Figure 10.4 Data Filter Screen

4. With Enabled highlighted, press the **Enter** key to Enable or Disable the data filter. A black dot to the left of the selection indicates the data filter is enabled.

5. Use the arrow keys to highlight the **Time constant** field.

   NOTE: This value is the time constant in seconds for the software data filter. Increasing the time constant will result in greater filtering of the data, but will also slow down the apparent response of the sensors.

6. Use the keypad to enter a value. The default value is 8 and this value is ideal for most 556 field applications. As described in Section *10.3 Data Filter* above, users who wish to decrease the response time of the DO readings at the expense of some noise for the pH readings determined

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concurrently, should change the Time Constant to a value of 2.

7. Press the **Enter** key to enter the time constant.

8. Use the arrow keys to highlight the **Threshold** field.

   NOTE: This value determines when the software data filter will engage/disengage, speeding the response to large changes in a reading. When the difference between two consecutive readings is larger than the threshold, then the reading is displayed unfiltered. When the difference between two consecutive readings drops below the threshold, readings will be filtered again.

9. Use the keypad to enter a value. The default value is 0.01.

10. Press the **Enter** key to enter the threshold.

11. Press the **Escape** key repeatedly to return to the Main menu screen.

10.5 Shutoff Time

The YSI 556 MPS shuts off automatically after 30 minutes of inactivity. The shut off time may be changed as described below.

1. Go to the system setup screen as described in Section *10.1 Accessing the System Setup Screen*.

2. Use the arrow keys to highlight the **Shutoff time** selection on the system setup screen. See Figure 10.2 System Setup Screen.

3. Use the keypad to enter a value from 0 to 60 minutes. The default value is 30.

   NOTE: To disable the automatic shutoff feature, enter a zero (0).

4. Press the **Enter** key to enter the correct shutoff time.

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5. Press the **Escape** key repeatedly to return to the main menu screen.

10.6 Comma Radix

The user can toggle between a period (default) and comma for the radix mark by selecting this item and pressing the **Enter** key as follows:

1. Go to the system setup screen as described in Section *10.1 Accessing the System Setup Screen*.

2. Use the arrow keys to highlight the **Comma radix** selection on the system setup screen. See Figure 10.2 System Setup Screen.

3. Press the **Enter** key. A check mark appears in the check box next to the comma radix selection indicating that the radix mark is a comma.

10.7 ID

This selection allows you to enter an identification name/number for your YSI 556 MPS. This ID name/number is logged in the header of each file.

1. Go to the system setup screen as described in Section *10.1 Accessing the System Setup Screen*.

2. Use the arrow keys to highlight the **ID** selection. See Figure 10.1 Main Menu.

3. Use the keypad to enter an alphanumeric ID up to 15 characters in length. Refer to Section *2.9 Keypad Use*.

4. Press the **Enter** key to enter the ID.

5. Press the **Escape** key repeatedly to return to the main menu screen.

10.8 GLP Filename

This selection allows you to enter a different filename for the YSI 556 MPS Calibration Record file.

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NOTE: The default filename is the "556 PC board Serial Number.glp."

1. Go to the system setup screen as described in Section *10.1 Accessing the System Setup Screen*.

2. Use the arrow keys to highlight the **GLP Filename** selection. See Figure 10.1 Main Menu.

3. Use the keypad to enter a filename up to 8 characters in length. Refer to Section *2.9 Keypad Use*.

4. Press the **Enter** key to enter the new filename.

5. Press the **Escape** key repeatedly to return to the main menu screen.

10.9 TDS Constant

This selection allows you to set the constant used to calculate Total Dissolved Solids (TDS). TDS in g/L is calculated by multiplying this constant times the specific conductance in mS/cm.

10.9.1 Changing the TDS Constant

1. Go to the system setup screen as described in Section *10.1 Accessing the System Setup Screen*.

2. Use the arrow keys to highlight the **TDS Constant** selection. See Figure 10.1 Main Menu.

3. Use the keypad to enter a value. Refer to Section *2.9 Keypad Use*. The default value is 0.65.

4. Press the **Enter** key to enter the correct TDS constant.

5. Press the **Escape** key repeatedly to return to the main menu screen.

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10.10 Barometer Units

The following information is only for instruments with the barometer option.

1. Go to the system setup screen as described in Section *10.1 Accessing the System Setup Screen*.

2. Use the arrow keys to highlight the **Barometer units** selection on the system setup screen. See Figure 10.2 System Setup Screen.

3. Press the **Enter** key. The Barometer units screen will appear.

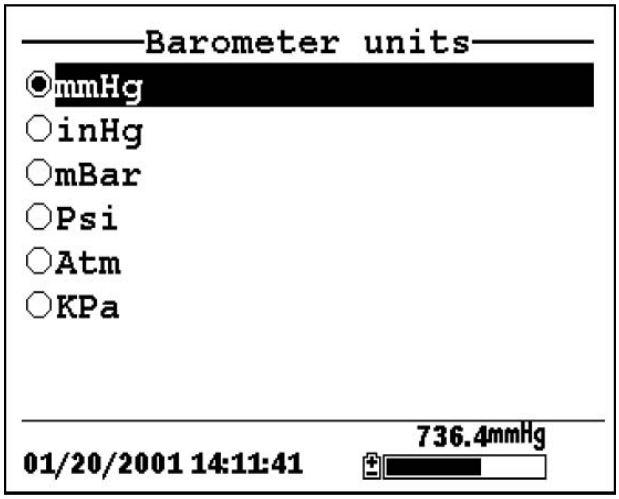

Figure 10.5 Data Filter Screen

A black dot indicates the currently selected units.

4. Use the arrow keys to highlight your desired barometric unit.

5. Press the **Enter** key to select your choice. A black dot will appear in the circle next to your selected units.

6. Press the **Escape** key repeatedly to return to the main menu screen.

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10.11 Calibrate Barometer

The optional barometer has been factory calibrated to provide accurate readings. However, some sensor drift may occur over time, requiring occasional calibration by the user, as follows:

1. Determine your local barometric pressure from an independent laboratory barometer or from your local weather service.

2. If the barometric pressure (BP) reading is from your local weather station, reverse the equation that corrects it to sea level.

   NOTE: For this equation to be accurate, the barometric pressure units must be in mmHg.

   True BP = (Corrected BP) – [2.5 * (Local Altitude/100)]

3. Go to the system setup screen as described in Section *10.1 Accessing the System Setup Screen*.

4. Use the arrow keys to highlight the **Calibrate barometer** selection on the system setup screen. See Figure 10.2 System Setup Screen.

5. Press the **Enter** key. The Calibrate Barometer screen is displayed.

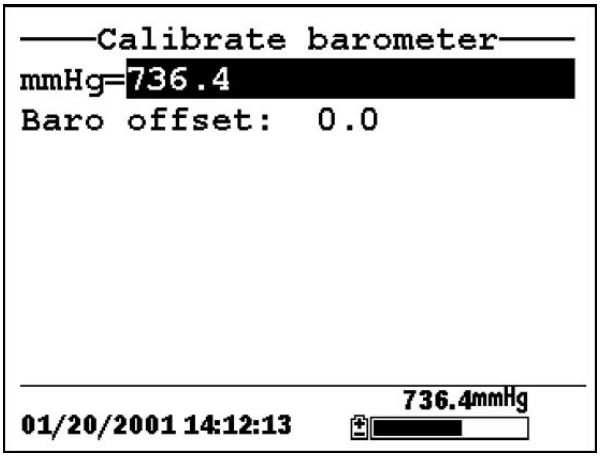

Figure 10.6 Barometer Calibration Screen

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6. Use the keypad to input the known barometric pressure value as determined in Step 2.

7. Press the **Enter** key. The new barometer reading is displayed as well as the approximate offset from the factory reading.

   NOTE: To return the sensor to the factory setting, subtract the offset amount from the current setting and repeat Steps 5 to 7.

8. Press the **Escape** key repeatedly to return to the main menu screen.

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11. Maintenance

11.1 Sensor Care and Maintenance

Once the sensors have been properly installed, remember that periodic cleaning and DO membrane changes are required.

11.1.1 DO Sensor

For best results, we recommend that the KCl solution and the membrane cap be changed at least once every 30 days.

1. It is important to recognize that oxygen dissolved in the sample is consumed during sensor operation. It is therefore essential that the sample be continuously stirred at the sensor tip. If stagnation occurs, your readings will be artificially low. Stirring may be accomplished by mechanically moving the sample around the sensor tip, or by rapidly moving the sensor through the sample. The rate of stirring should be at least 1 foot per second.

2. Membrane life depends on usage. Membranes will last a long time if installed properly and treated with care. Erratic readings are a result of loose, wrinkled, damaged, or fouled membranes, or from large (more than 1/8" diameter) bubbles in the electrolyte reservoir. If erratic readings or evidence of membrane damage occurs, you should replace the membrane and the electrolyte solution. The average replacement interval is two to four weeks.

3. If the membrane is coated with oxygen consuming (e.g. bacteria) or oxygen producing organisms (e.g. algae), erroneous readings may occur.

4. Chlorine, sulfur dioxide, nitric oxide, and nitrous oxide can affect readings by behaving like oxygen at the sensor. If you suspect erroneous readings, it may be necessary to determine if these gases are the cause.

5. Avoid any environment that contains substances that may attack the probe module and sensor materials. Some of these substances are concentrated acids, caustics, and strong solvents. The sensor materials that come in contact

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with the sample include FEP Teflon, acrylic plastic, EPR rubber, stainless steel, epoxy, polyetherimide and the PVC cable covering.

6. It is possible for the silver anode, which is the entire silver body of the sensor, to become contaminated. This will prevent successful calibration. To restore the anode, refer to Section *11.1.1 DO Sensor, Silver Anode Cleaning.*

7. For correct sensor operation, the gold cathode must always be bright. If it is tarnished (which can result from contact with certain gases), or plated with silver (which can result from extended use with a loose or wrinkled membrane), the gold surface must be restored. To restore the cathode, refer to Section *11.1.1 DO Sensor, Gold Cathode Cleaning.*

8. To keep the electrolyte from drying out, store the sensor in the transport/calibration cup with at least 1/8″ of water.

Silver Anode Cleaning

After extended use, a thick layer of AgCl builds up on the silver anode reducing the sensitivity of the sensor. The anode must be cleaned to remove this layer and restore proper performance. The cleaning can be chemical or mechanical:

Chemical Cleaning: Remove the membrane cap and soak the entire anode section in a 14% ammonium hydroxide solution for 2 to 3 minutes, followed by a thorough rinsing with distilled or deionized water. The anode should then be thoroughly wiped with a wet paper towel to remove the residual layer from the anode.

Mechanical Cleaning: Sand off the dark layer from the silver anode with 400 grit wet/dry sandpaper. Wrap the sandpaper around the anode and twist the sensor. Rinse the anode with clean water after sanding, followed by wiping thoroughly with a wet paper towel.

NOTE: After cleaning, a new membrane cap must be installed. Refer to Section *3.4.3 Membrane Cap Installation***.**

Turn the instrument on and allow the system to stabilize for at least 30 minutes. If, after several hours, you are still unable to calibrate, contact your dealer or YSI Customer Service. Refer to *Appendix E Customer Service*.

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Gold Cathode Cleaning

For correct sensor operation, the gold cathode must be textured properly. It can become tarnished or plated with silver after extended use. The gold cathode can be cleaned by using the adhesive backed sanding disc and tool provided in the YSI 5238 Probe Reconditioning Kit.

Using the sanding paper provided in the YSI 5238 Probe Reconditioning Kit, wet sand the gold with a twisting motion about 3 times or until all silver deposits are removed and the gold appears to have a matte finish. Rinse the cathode with clean water after sanding, followed by wiping thoroughly with a wet paper towel. If the cathode remains tarnished, contact your dealer or YSI Customer Service. Refer to *Appendix E Customer Service*.

NOTE: After cleaning, a new membrane cap must be installed. Refer to Section *3.4.3 Membrane Cap Installation***.**

11.1.2 DO Sensor Replacement

1. Remove the probe sensor guard.

⚠ **CAUTION:** Thoroughly dry the sensor so that no water enters the probe module sensor port when the sensor is removed.

2. Insert the long end of the hex key wrench into the small hole in the side of the probe module bulkhead. Turn the wrench counterclockwise and remove the screw. (You do not have to remove the screw all the way to release the sensor.)

3. Pull the old DO sensor module straight out of the probe module body.

   NOTE: The DO sensor is not threaded, it is keyed, so it cannot be removed by twisting.

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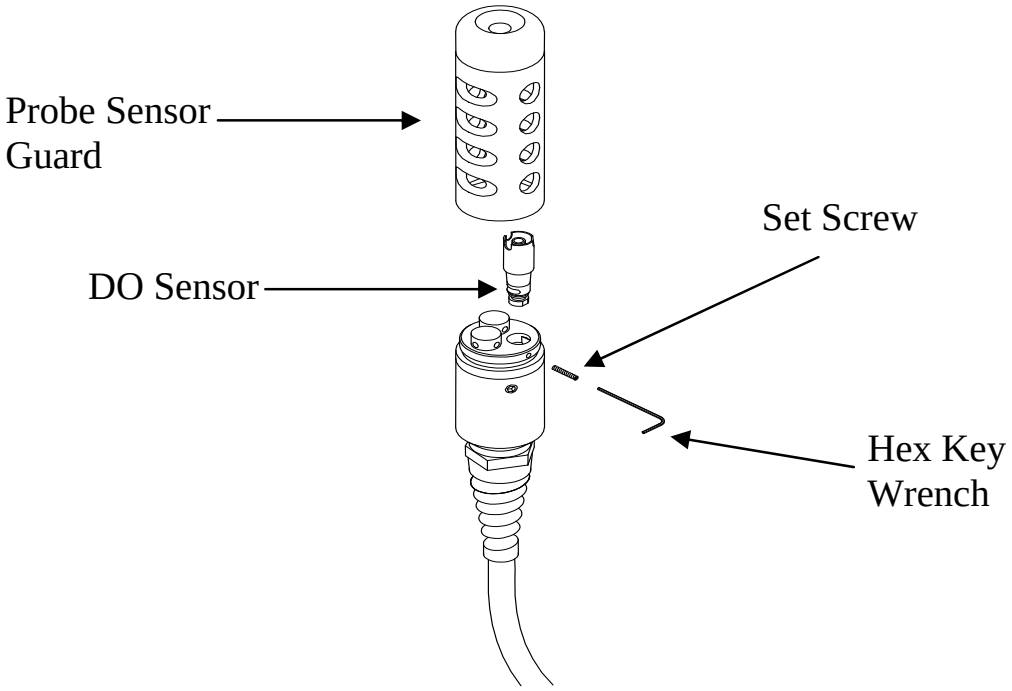

Figure 11.1 DO Sensor Replacement

4. Insert the new DO sensor module. Make sure that the inside of the probe module sensor port and the o-ring on the sensor are clean, with no contaminants, such as grease, dirt, or hair. The DO sensor is keyed, or has a flat side, so that it cannot be aligned improperly.

NOTE: Make sure the DO sensor bottoms out before the set screw is inserted.

5. Insert the set screw into the small hole in the side of the probe module bulkhead, and turn clockwise to rethread.

⚠ **CAUTION**: Make sure that you do not cross-thread the set screw. Use the hex key wrench to tighten the screw in properly, making sure that the screw does not stick out of the side of the probe module bulkhead. The probe sensor guard will not thread on properly and damage may result if the screw is allowed to stick out.

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NOTE: The YSI 5563 DO sensor is shipped dry. A shipping membrane was installed to protect the electrode. A new membrane cap must be installed before the first use. Refer to Section 3.4.1 Sensor Installation.

11.1.3 YSI 5564 pH and 5565 Combination pH/ORP Sensor Cleaning

Cleaning is required whenever deposits or contaminants appear on the glass and/or platinum surfaces of these sensors or when the response of the sensor becomes slow.

1. Remove the sensor from the probe module.

2. Initially, simply use clean water and a soft clean cloth, lens cleaning tissue, or cotton swab to remove all foreign material from the glass bulb (YSI 5564 and YSI 5565) and platinum button (YSI 5565). Then use a moistened cotton swab to carefully remove any material that may be blocking the reference electrode junction of the sensor.

⚠ **CAUTION:** When using a cotton swab with the YSI 5564 or YSI 5565, be careful NOT to wedge the swab tip between the guard and the glass sensor. If necessary, remove cotton from the swab tip, so that the cotton can reach all parts of the sensor tip without stress.

NOTE: If good pH and/or ORP response is not restored by the above procedure, perform the following additional procedure:

1. Soak the sensor for 10-15 minutes in clean water containing a few drops of commercial dishwashing liquid.

2. GENTLY clean the glass bulb and platinum button by rubbing with a cotton swab soaked in the cleaning solution.

3. Rinse the sensor in clean water, wipe with a cotton swab saturated with clean water, and then re-rinse with clean water.

NOTE: If good pH and/or ORP response is still not restored by the above procedure, perform the following additional procedure:

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1. Soak the sensor for 30-60 minutes in one molar (1 M) hydrochloric acid (HCl). This reagent can be purchased from most distributors. Be sure to follow the safety instructions included with the acid.

2. GENTLY clean the glass bulb and platinum button by rubbing with a cotton swab soaked in the acid.

3. Rinse the sensor in clean water, wipe with a cotton swab saturated with clean water, and then re-rinse with clean water. To be certain that all traces of the acid are removed from the sensor crevices, soak the sensor in clean water for about an hour with occasional stirring.

   NOTE: If biological contamination of the reference junction is suspected or if good response is not restored by the above procedures, perform the following additional cleaning step:

1. Soak the sensor for approximately 1 hour in a 1 to 1 dilution of commercially available chlorine bleach.

2. Rinse the sensor with clean water and then soak for at least 1 hour in clean water with occasional stirring to remove residual bleach from the junction. (If possible, soak the sensor for period of time longer than 1 hour in order to be certain that all traces of chlorine bleach are removed.) Then re-rinse the sensor with clean water and retest.`

11.1.4 Temperature/Conductivity Sensor Cleaning

The single most important requirement for accurate and reproducible results in conductivity measurement is a clean cell. A dirty cell will change the conductivity of a solution by contaminating it. The small cleaning brush included in the YSI 5511 Maintenance Kit is ideal for this purpose.

To clean the conductivity cell:

1. Dip the brush in clean water and insert it into each hole 1520 times.

2. Rinse the cell thoroughly in deionized or clean tap water.

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NOTE: In the event that deposits have formed on the electrodes, perform the following additional procedure:

1. Use a mild detergent solution in combination with the brush. Dip the brush in the solution and insert it into each hole 1520 times.

2. Rinse the cell thoroughly in deionized or clean tap water.

NOTE: After cleaning, check the response and accuracy of the conductivity cell with a calibration standard.

NOTE: If this procedure is unsuccessful, or if sensor performance is impaired, it may be necessary to return the sensor to a YSI authorized service center for service, Refer to *Appendix E Customer Service*.

The temperature portion of the sensor requires no maintenance.

11.2 Upgrading YSI 556 MPS Software

1. Access the YSI Environmental Software Downloads page as described in *Appendix G EcoWatch* Step 1 through 3.

2. Click on the **YSI Instruments Software Updates** link (or scroll down until you see YSI 556 MPS).

3. Click on the file icon to the right of the **YSI 556 MPS** listing and save the file to a temporary directory on your computer.

4. After the download is complete, run the file (that you just downloaded) and follow the on screen instructions to install the YSI Code Updater on your computer. If you encounter difficulties, contact YSI customer service for advice. Refer to *Appendix E Customer Service*.

5. If necessary, disconnect the YSI 5563 Probe Module from the YSI 556 MPS instrument.

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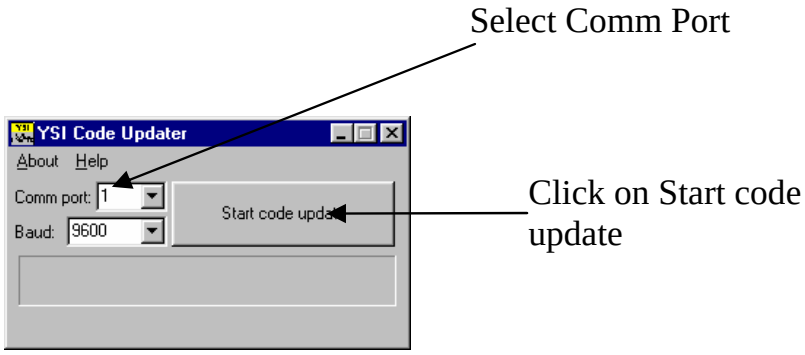
6. Connect the YSI 556 MPS to a serial port of your computer via the 655173 PC interface cable. See Figure 8.6 Computer/Instrument Interface.

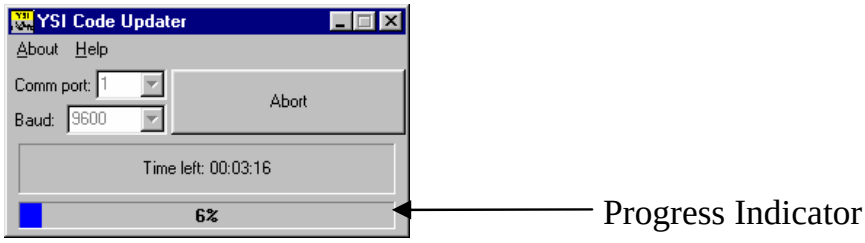
7. Press the **On/off** key on the YSI 556 MPS to display the run screen.

8. Run the YSI Code Updater software that you just installed on your computer. The following window will be displayed:



9. Set the Comm port number to match the port that you connected the 655173 PC Interface Cable to, then click on the Start Code Update button.

The YSI 556 MPS screen will blank out and a progress indicator will be displayed on the PC.



When the update is finished (indicated on the PC screen), the YSI 556 MPS will return to the Run screen. See Figure 7.1 Run Screen.

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10. Close the YSI Code Updater window (on the PC) by clicking on the "X" in the upper right corner of the window.

11. Disconnect the YSI 556 MPS from the 655173 PC interface cable and reconnect it to the YSI 5563 Probe Module. Refer to Section *3.6 Instrument/Cable Connection*.

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12. Storage

Proper storage between periods of usage will not only extend the life of the sensors, but will also ensure that the unit will be ready to use as quickly as possible in your next application.

12.1 General Recommendations for Short Term Storage

No matter what sensors are installed in the instrument, it is important to keep them moist without actually immersing them in liquid. Immersing them could cause some of them to drift or result in a shorter lifetime.

YSI recommends that short term storage of all multi-parameter instruments be done by placing approximately 1/2 inch of tap water in the transport/calibration cup that was supplied with the instrument, and by placing the probe module with all of the sensors installed into the cup. The use of a moist sponge instead of a 1/2 inch of tap water is also acceptable, as long as its presence does not compromise the attachment of the cup to the probe module. The transport/calibration cup should be sealed to prevent evaporation.

NOTE: Ensure that an o-ring is installed in the o-ring groove on the threaded end of the probe module body. See Figure 3.7 Transport/Calibration Cup Installation.

⚠ **CAUTION**: The water level has to be low enough so that none of the sensors are actually under water. Check the transport/calibration cup periodically to make certain that the water is still present or the sponge is still moist.

NOTE: If the storage water (tap water) is accidentally lost during field use, environmental water can be used.

12.2 General Recommendations for Long Term Storage

12.2.1 Probe Module Storage

1. Remove the pH or pH/ORP sensor from the probe module and store according to the individual sensor storage instructions found in Section *12.2.2 Sensor Storage.*

2. Seal the empty port with the provided port plug.

   NOTE: Leave the conductivity/temperature sensor and

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dissolved oxygen sensor, with membrane cap still on, in the probe module.

3. Place 1/2″ of water, deionized, distilled or tap, in the transport/calibration cup.

⚠ **CAUTION:** The water level has to be low enough so that none of the sensors are actually under water. Check the transport/calibration cup periodically to make certain that the water is still present or the sponge is still moist.

4. Insert the probe module into the cup.

NOTE: Ensure that an o-ring is installed in the o-ring groove on the threaded end of the probe module body. See Figure 3.7 Transport/Calibration Cup Installation.

12.2.2 Sensor Storage

Temperature/Conductivity Sensor

No special precautions are required. Sensor can be stored dry or wet, as long as solutions in contact with the thermistor and conductivity electrodes are not corrosive (for example, chlorine bleach). However, it is recommended that the sensor be cleaned with the provided brush prior to long term storage. Refer to Section *11.1.4 Temperature/Conductivity Sensor Cleaning.*

pH and Combination pH/ORP Sensor

The key to sensor storage is to make certain that the reference electrode junction does not dry out. Junctions which have been allowed to dry out due to improper storage procedures can usually be rehydrated by soaking the sensor for several hours (overnight is recommended) in a solution which is 2 molar in potassium chloride. If potassium chloride solution is not available, soaking the sensor in tap water or commercial pH buffers may restore sensor function. However in some cases the sensor may have been irreparably damaged by the dehydration and will require replacement.

⚠ **CAUTION:** Do not store the sensor in distilled or deionized water as the glass sensor may be damaged by exposure to this medium.

1. Remove the pH or pH/ORP sensor from the probe module.

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2. Seal the empty port with the provided port plug.

3. Place the sensor in the storage vessel (plastic boot or bottle) which was on the sensor at delivery. The vessel should contain a solution which is 2 molar in potassium chloride.

   NOTE: Make certain that the vessel is sealed to prevent evaporation of the storage solution.

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13. Troubleshooting

The following sections describe problems you may encounter when using the YSI 556 MPS and provides suggestions to overcome the symptom.

PROBLEM	POSSIBLE SOLUTION
Display Problems	
No display is visible after pressing the on/off key.	If C cells are used, make certain that they are installed properly with regard to polarity and that good batteries are used. If a rechargeable battery pack is used, place the pack in the instrument and charge for 30 minutes.
Instrument software appears to be locked up as evidenced by no response to keypad entries or display not changing.	First, attempt to reset the instrument by simply turning off and then on again. If this fails, remove battery power from the instrument for 30 seconds and then reapply power. When using C cells, remove the battery lid and one of the batteries; when using the rechargeable battery pack, remove the pack completely from the instrument. After 30 seconds replace the battery or battery pack and check for instrument function.
The 556 display flashes and the instrument speaker makes a continuous clicking sound.	The battery voltage is low. Change to new C cells or recharge the 6117 battery pack.
Water Damage to Instrument	
Leakage detected in battery compartment when using C cells.	Dispose of batteries properly. Dry the battery compartment using compressed air if possible. If corrosion is present on battery terminals, contact YSI Customer Service.
Water has contacted rechargeable battery pack.	Remove battery pack immediately. Send battery pack to YSI Product Service for evaluation. **CAUTION**: DO NOT REUSE BATTERY PACK UNTIL YSI PRODUCT SERVICE HAS EVALUATED IT.
Leakage suspected into the main cavity of the instrument case.	Remove the batteries immediately. Return the instrument to YSI Product Service.

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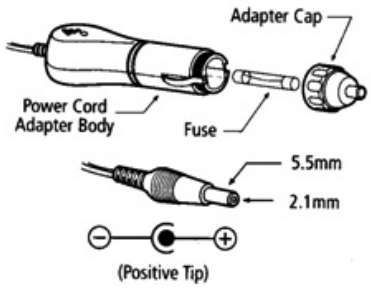
PROBLEM	POSSIBLE SOLUTIONS
Optional Cigarette Lighten Charger	
Power cord fuse blown.  	1. Unscrew adapter's cap, remove tip and pull out fuse. 2. Replace fuse with a new 2-amp fast-blow fuse from an electronics store such as Radio Shack. 3. Reassemble the adapter and securely screw the cap back onto the adapter body.
File Problems	
Upload of files from YSI 556 MPS to PC fails	1. Make sure that cable is connected properly to both 556 and PC. 2. Make certain that the proper Comm port is selected in EcoWatch for Windows.
Barometer data is not stored with sensor data file.	Make sure **Store barometer** is active in the 556 **Logging setup** menu.
Site Descriptions in the **Site List** are "grayed-out" and not available for appending files with additional data.	There is a parameter mismatch between the current 556 setup and that initially used. Change the current logging and sensor setup to match the setup that was initially used to create the file.
Sensor Problems	
Dissolved Oxygen reading is unstable or inaccurate. Out of Range message appears during calibration.	Sensor not properly calibrated. Follow DO cal procedures.
	Membrane not properly installed or may be punctured. Replace membrane cap.
	DO sensor electrodes require cleaning. Follow DO cleaning procedure. Use 5511 Maintenance kit.
	Water in sensor connector. Dry connector; reinstall sensor.
	Algae or other contaminant clinging to DO sensor. Rinse DO sensor with clean water.
	Barometric pressure entry is incorrect. Repeat DO cal procedure.
	Calibrated at extreme temperature. Recalibrate at (or near) sample temperature.
	DO sensor has been damaged. Replace sensor.
	Internal failure. Return probe module for service.

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PROBLEM	POSSIBLE SOLUTIONS
Sensor Problems	
pH or ORP readings are unstable or inaccurate. Out of Range message appears during calibration.	Sensor requires cleaning. Follow sensor cleaning procedure.
	Sensor requires calibration. Follow cal procedures.
	pH sensor reference junction has dried out from improper storage. Soak sensor in tap water or buffer 4 until readings become stable.
	Water in sensor connector. Dry connector; reinstall sensor.
	Sensor has been damaged. Replace sensor.
	Calibration solutions out of spec or contaminated with other solution. Use new calibration solutions
	ORP fails Zobell check. Take into account temperature dependence of Zobell solution readings.
	Internal failure. Return probe module for service.
Conductivity unstable or inaccurate. Out of Range message appears during calibration	Conductivity improperly calibrated. Follow calibration procedure.
	Conductivity sensor requires cleaning. Follow cleaning procedure.
	Conductivity sensor damaged. Replace sensor.
	Calibration solution out of spec or contaminated. Use new calibration solution.
	Internal failure. Return probe module for service.
	Calibration solution or sample does not cover entire sensor. Immerse sensor fully.
Temperature, unstable or inaccurate	Water in connector. Dry connector; reinstall sensor.
	Sensor has been damaged. Replace the 5560 sensor.
Installed sensor has no reading	The sensor has been disabled. Enable sensor.
	Water in sensor connector. Dry connector; reinstall sensor.
	Sensor has been damaged. Replace sensor.
	Report output improperly set up. Set up report output.
	Internal failure. Return probe module for service.

If these guidelines and tips fail to correct your problem or if any other symptoms occur, contact YSI Customer Service for Advice. Refer to *Appendix E Customer Service*.

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14. Appendix A YSI 556 MPS Specifications

For the most recent product specifications, please visit the YSI website: www.ysi.com

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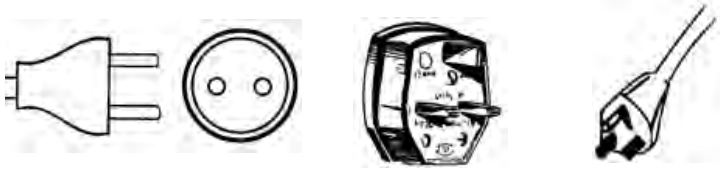
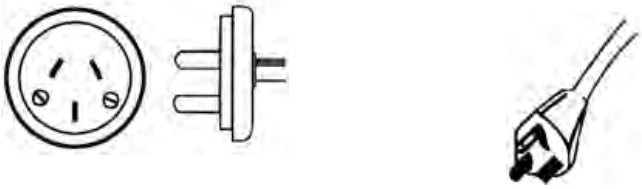
15. Appendix B Instrument Accessories

ITEM #	ACCESSORY
5563-4	4m Cable with DO/temp/conductivity
5563-10	10m Cable with DO/temp/conductivity
5563-20	20m Cable with DO/temp/conductivity
5564	pH Kit
5565	pH/ORP Kit
6118	Rechargeable Battery Pack Kit for use in US
5094	Rechargeable Battery Pack Kit with universal charger and three adapter cables for use in international applications 
5095	Rechargeable Battery Pack Kit with universal charger and two adapter cables for use in international applications 
5083	Flow Cell – probe module is secured in the flow cell and groundwater is pumped through it. Displaced volume approx. 475 ml
3059	Flow Cell, low volume. Displaced volume approx. 200 ml
116505	Battery Lid
616	Charger, Cigarette Lighter – used to power up the instrument from a car's cigarette lighter
4654	Tripod
614	Ultra Clamp, C Clamp –used to clamp the instrument to a table top or car dashboard
6081	Large Carrying Case, Hard-sided
5085	Hands-free Harness
5065	Carrying Case, Form-fitted, for use in the field – has a clear vinyl window, shoulder strap, belt loop strap and hand strap

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16. Appendix C Required Federal Communications Notice

The Federal Communications Commission defines this product as a computing device and requires the following notice.

This equipment generates and uses radio frequency energy and if not installed and used properly, may cause interference to radio and television reception. It has been type tested and found to comply with the limits for a Class A or Class B computing device in accordance with the specification in Subpart J of Part 15 of FCC Rules, which are designed to provide reasonable protection against such interference in a residential installation. However, there is no guarantee that interference will not occur in a particular installation. If this equipment does cause interference to radio or television reception, which can be determined by turning the equipment off and on, the user is encouraged to try to correct the interference by one or more of the following measures:

- Reorient the receiving antenna
- Relocate the computer with respect to the receiver
- Move the computer away from the receiver
- Plug the computer into a different outlet so that the computer and receiver are on different branch circuits.

If necessary, the user should consult the dealer or an experienced radio/television technician for additional suggestions. The user may find the following booklet, prepared by the Federal Communications Commission, helpful: "How to Identify and Resolve Radio-TV Interference Problems". This booklet is available from the U.S. Government Printing Office, Washington, D.C. 20402, Stock No.0004-000-00345-4.

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17. Appendix D Health Safety

YSI Conductivity Solutions: 3161, 3163, 3165, 3167, 3168, 3169

INGREDIENTS:
- Iodine
- Potassium Chloride
- Water

WARNING: INHALATION MAY BE FATAL

⚠ ***CAUTION:*** **AVOID INHALATION, SKIN CONTACT, EYE CONTACT OR INGESTION. MAY EVOLVE TOXIC FUMES IN FIRE.**

Harmful if ingested or inhaled. Skin or eye contact may cause irritation. Has a corrosive effect on the gastro-intestinal tract, causing abdominal pain, vomiting, and diarrhea. Hyper-sensitivity may cause conjunctivitis, bronchitis, skin rashes etc. Evidence of reproductive effects.

FIRST AID:
INHALATION: Remove victim from exposure area. Keep warm and rest. In severe cases seek medical attention.
SKIN CONTACT: Remove contaminated cloth immediately. Wash affected area thoroughly with large amounts of water. In severe cases seek medical attention.
EYE CONTACT: Wash eyes immediately with large amounts of water, (approx. 10 minutes). Seek medical attention immediately.
INGESTION: Wash out mouth thoroughly with large amounts of water. Seek medical attention immediately.

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YSI pH 4.00, 7.00, y 10.00: 3821, 3822, 3823

pH 4 INGREDIENTS:

- Potassium Hydrogen Phthalate
- Formaldehyde
- Water

pH 7 INGREDIENTS:

- Sodium Phosphate, Dibasic
- Potassium Phosphate, Monobasic
- Water

pH 10 INGREDIENTS:

- Potassium Borate, Tetra
- Potassium Carbonate
- Potassium Hydroxide
- Sodium (di) Ethylenediamine Tetraacetate
- Water

⚠ **CAUTION -AVOID INHALATION, SKIN CONTACT, EYE CONTACT OR INGESTION. MAY AFFECT MUCOUS MEMBRANES.**

Inhalation may cause severe irritation and be harmful. Skin contact may cause irritation; prolonged or repeated exposure may cause Dermatitis. Eye contact may cause irritation or conjunctivitis. Ingestion may cause nausea, vomiting and diarrhea.

FIRST AID:
INHALATION – Remove victim from exposure area to fresh air immediately. If breathing has stopped, give artificial respiration. Keep victim warm and at rest. Seek medical attention immediately.
SKIN CONTACT – Remove contaminated clothing immediately. Wash affected area with soap or mild detergent and large amounts of water (approx. 15-20 minutes). Seek medical attention immediately.
EYE CONTACT - Wash eyes immediately with large amounts of water (approx. 15-20 minutes), occasionally lifting upper and lower lids. Seek medical attention immediately.

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INGESTION – If victim is conscious, immediately give 2 to 4 glasses of water and induce vomiting by touching finger to back of throat. Seek medical attention immediately.

YSI Zobell Solution: 3682

INGREDIENTS:

- Potassium Chloride
- Potassium Ferrocyanide Trihydrate
- Potassium Ferricyanide

⚠ CAUTION -AVOID INHALATION, SKIN CONTACT, EYE CONTACT OR INGESTION. MAY AFFECT MUCOUS MEMBRANES.

May be harmful by inhalation, ingestion, or skin absorption. Causes eye and skin irritation. Material is irritating to mucous membranes and upper respiratory tract. The chemical, physical, and toxicological properties have not been thoroughly investigated.

Ingestion of large quantities can cause weakness, gastrointestinal irritation and circulatory disturbances.

FIRST AID:
INHALATION – Remove victim from exposure area to fresh air immediately. If breathing has stopped, give artificial respiration. Keep victim warm and at rest. Seek medical attention immediately.
SKIN CONTACT – Remove contaminated clothing immediately. Wash affected area with soap or mild detergent and large amounts of water (approx. 15-20 minutes). Seek medical attention immediately.
EYE CONTACT - Wash eyes immediately with large amounts of water (approx. 15-20 minutes), occasionally lifting upper and lower lids. Seek medical attention immediately.
INGESTION – If victim is conscious, immediately give 2 to 4 glasses of water and induce vomiting by touching finger to back of throat. Seek medical attention immediately.

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18. Appendix E Customer Service

18.1 Ordering and Technical Support

Telephone:	800 897 4151 (US)
	+1 937 767 7241 (Globally)
	Monday through Friday, 8:00 AM to 5:00 ET
Fax:	+1 937 767 9353 (orders)
	+1 937 767 1058 (technical support)
Email:	environmental@ysi.com or proseries@ysi.com
Mail:	YSI Incorporated
	1725 Brannum Lane
	Yellow Springs, OH 45387 USA
Website:	www.ysi.com

18.2 YSI Authorized Service Centers

YSI has authorized service centers throughout the United States and Internationally. For the nearest service center information, please visit www.ysi.com and click ‘Support’ or contact YSI Technical Support directly at 800-897-4151.

When returning a product for service, include the Product Return form with cleaning certification. The form must be completely filled out for a YSI Service Center to accept the instrument for service. The form may be downloaded from www.ysi.com by clicking on the ‘Support” tab, then the Product Return Form button.

18.3 Cleaning Instructions

Equipment exposed to biological, radioactive, or toxic materials must be cleaned and disinfected before being serviced. Biological contamination is presumed for any instrument, probe, or other device that has been used with body fluids or tissues, or with wastewater. Radioactive contamination is presumed for any instrument, probe or other device that has been used near any radioactive source.

If an instrument, probe, or other part is returned or presented for service without a Cleaning Certificate, and if in our opinion it represents a potential

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biological or radioactive hazard, our service personnel reserve the right to withhold service until appropriate cleaning, decontamination, and certification has been completed. We will contact the sender for instructions as to the disposition of the equipment. Disposition costs will be the responsibility of the sender.

When service is required, either at the user's facility or at a YSI Service Center, the following steps must be taken to ensure the safety of service personnel.

- In a manner appropriate to each device, decontaminate all exposed surfaces, including any containers. 70% isopropyl alcohol or a solution of 1/4-cup bleach to 1-gallon tap water is suitable for most disinfecting. Instruments used with wastewater may be disinfected with .5% Lysol if this is more convenient to the user.
- The user shall take normal precautions to prevent radioactive contamination and must use appropriate decontamination procedures should exposure occur.
- If exposure has occurred, the customer must certify that decontamination has been accomplished and that no radioactivity is detectable by survey equipment.
- Any product being returned to the YSI Repair Center should be packed securely to prevent damage.
- Cleaning must be completed and certified on any product before returning it to YSI.

18.4 Packing Procedure

- Clean and decontaminate items to ensure the safety of the handler.
- Complete and include the Cleaning Certificate.
- Place the product in a plastic bag to keep out dirt and packing material.
- Use a large carton, preferably the original, and surround the product completely with packing material.
- Insure for the replacement value of the product.

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18.5 Warranty

The instrument is warranted for three years against defects in workmanship and materials when used for its intended purposes and maintained according to instructions. The probe module and cables are warranted for one year. The dissolved oxygen, temperature/conductivity, pH, and pH/ORP combination sensors are warranted for one year. Damage due to accidents, misuse, tampering, or failure to perform prescribed maintenance is not covered. The warranty period for chemicals and reagents is determined by the expiration date printed on their labels. Within the warranty period, YSI will repair or replace, at its sole discretion, free of charge, any product that YSI determines to be covered by this warranty.

To exercise this warranty, write or call your local YSI representative, or contact YSI Customer Service in Yellow Springs, Ohio. Send the product and proof of purchase, transportation prepaid, to the Authorized Service Center selected by YSI. Repair or replacement will be made and the product returned transportation prepaid. Repaired or replaced products are warranted for the balance of the original warranty period, or at least 90 days from date of repair or replacement.

Limitation of Warranty

This Warranty does not apply to any YSI product damage or failure caused by (i) failure to install, operate or use the product in accordance with YSI's written instructions, (ii) abuse or misuse of the product, (iii) failure to maintain the product in accordance with YSI's written instructions or standard industry procedure, (iv) any improper repairs to the product, (v) use by you of defective or improper components or parts in servicing or repairing the product, or (vi) modification of the product in any way not expressly authorized by YSI.

THIS WARRANTY IS IN LIEU OF ALL OTHER WARRANTIES, EXPRESSED OR IMPLIED, INCLUDING ANY WARRANTY OF MERCHANTABILITY OR FITNESS FOR A PARTICULAR PURPOSE. YSI'S LIABILITY UNDER THIS WARRANTY IS LIMITED TO REPAIR OR REPLACEMENT OF THE PRODUCT, AND THIS SHALL BE YOUR SOLE AND EXCLUSIVE REMEDY FOR ANY DEFECTIVE PRODUCT COVERED BY THIS WARRANTY. IN NO EVENT SHALL YSI BE LIABLE FOR ANY SPECIAL, INDIRECT, INCIDENTAL OR CONSEQUENTIAL DAMAGES RESULTING FROM ANY DEFECTIVE PRODUCT COVERED BY THIS WARRANTY.

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19. Appendix F Ferrite Bead Installation

⚠ **WARNING:** If you are using your YSI 556 in a European Community (CE) country or in Australia or New Zealand, you must attach a ferrite bead to the 655173 PC Interface Cable and the YSI 6117 Charger Adapter Cable in order to comply with the Residential, Commercial and Light Industrial Class B Limits for radio-frequency emissions specified in EN55011 (CISPR11) for Industrial, Scientific and Medical laboratory equipment. These ferrite assemblies are supplied as part of cable kits.

1. Make a small loop (approximately 5 cm in diameter) in the cable near the YSI 556 MS-19 connector.

2. Lay the open ferrite bead assembly under the loop with the cable cross-over position within the cylinder of the ferrite bead.

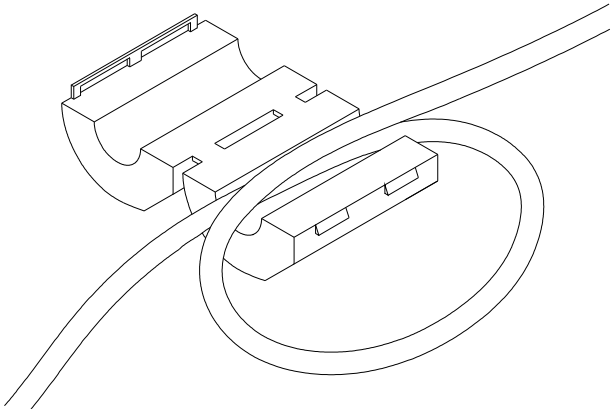

Figure 19.1 Ferrite Bead Installation

3. Snap the two pieces of the bead together making certain that the tabs lock securely.

4. When the installation is complete, the 655173 and 6117 cables should resemble the following drawings.

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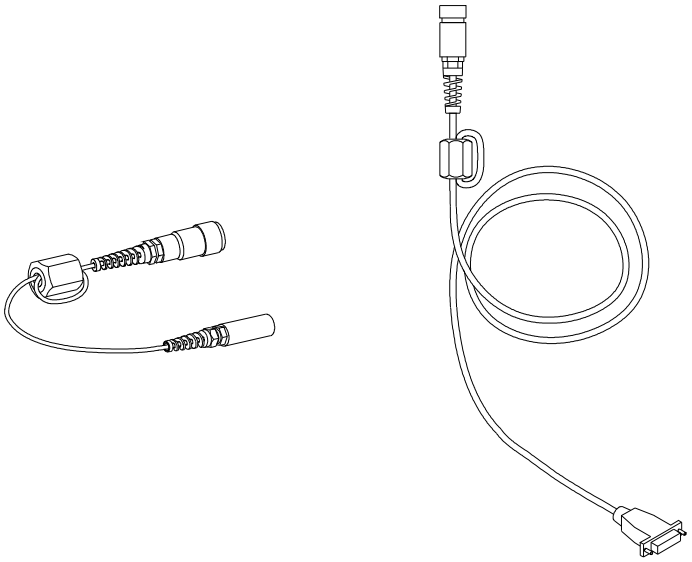

Figure 19.2 Cables with Ferrite Beads

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20. Appendix G EcoWatch

EcoWatch™ for Windows™ must be used as the PC software interface to the YSI 556 MPS. EcoWatch is a powerful tool that can also be used with YSI 6-series sondes. Many features of the software will only be utilized by advanced users or are not relevant to the 556 MPS at all. This section is designed in tutorial format to familiarize you with the commonly used features of EcoWatch so that it will be possible to:

- Upload data from a 556 MPS to a PC
- Assemble plots and reports of your data
- Zoom in on certain segments of the plots of your data to facilitate analysis
- Show statistical data for your studies
- Export data in spreadsheet-compatible formats
- Print plots and reports

The advanced features of EcoWatch can be explored by downloading a 6-series manual from the YSI Web Site (www.ysi.com), purchasing a hard copy of the manual through YSI Customer Service (Item # 069300), or utilizing the on-line help feature of the software.

20.1 Installing EcoWatch for Windows

EcoWatch for Windows is available at no cost via a download from the YSI Web Site – www.ysi.com

20.2 EcoWatch Tutorial

This EcoWatch tutorial is designed to teach you the commonly used operations associated with the software when used with your 556 MPS.

After you have uploaded a file, Refer to Section 8.4 Upload to PC, you will see two files in the C:\ECOWWIN\DATA directory; the file you transferred and a file supplied by YSI designated SAMPLE.DAT. This SAMPLE.DAT file is referred to in the remainder of this tutorial section. After following the instructions below for the analysis of SAMPLE.DAT, you apply the same analysis to the data file which was uploaded from your 556 MPS to assure that you are familiar with the basic features and capabilities of EcoWatch for Windows.

To start the analysis of the SAMPLE.DAT file, note that a shortened menu

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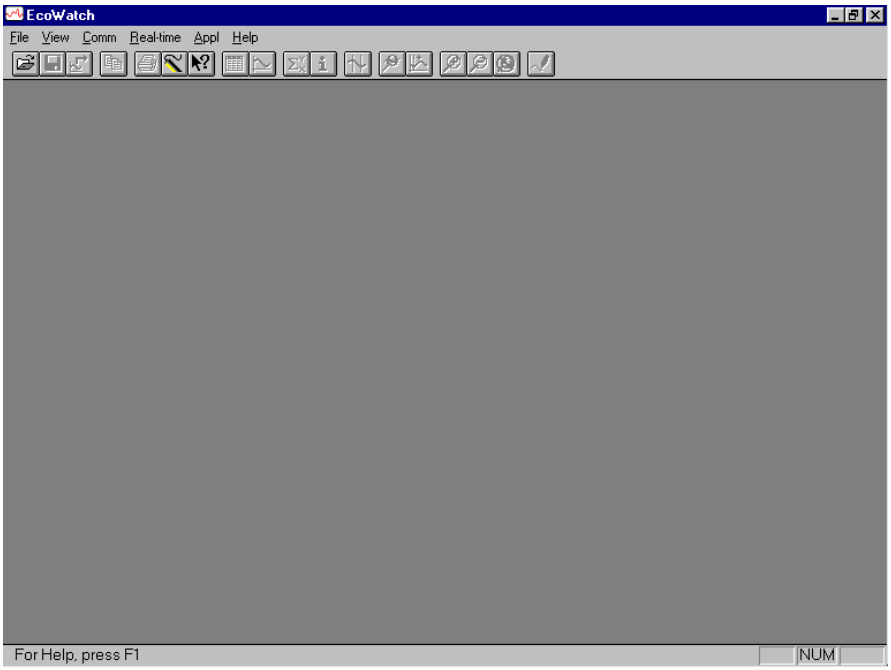
bar is visible and many of the tools in the toolbar appear dimmed or “grayed out” before any file is opened (see below).



Full activation of EcoWatch features will be realized after a file is opened.

To open the sample data file:

1. Click the **File** menu button in the toolbar.
2. Select the **SAMPLE.DAT** file.
3. Click **OK** to open the file.

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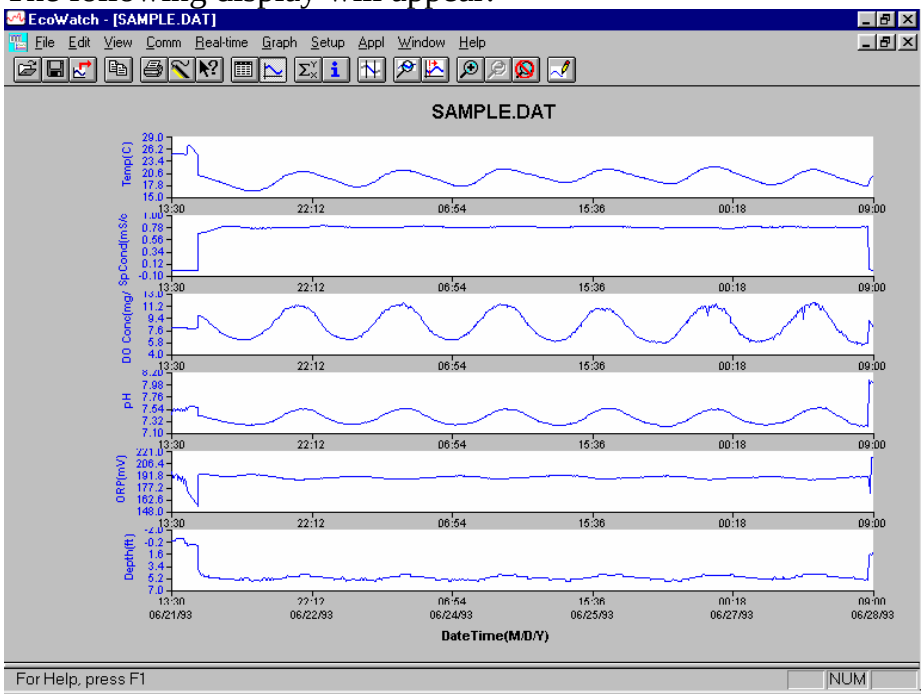
The following display will appear:



Note that the data in this file appears as a graph of temperature, specific conductance, dissolved oxygen, pH, ORP, and depth, all versus time. The graphs are scaled automatically so that all data fits comfortably on the computer screen. Note also that this data file was obtained with a 6-series sonde for which a depth sensor is available. Depth is NOT a current parameter for the 556 MPS.

The **Table** and **Graph** buttons on the toolbar are on/off switches that are used to display or hide the graph and table pages respectively. When displaying a graph and a table at the same time, you can control the relative size of the two pages by placing the cursor over the small bar that separates them and

then dragging it to the desired location. Click the **Table** button to generate the following dual display of data.

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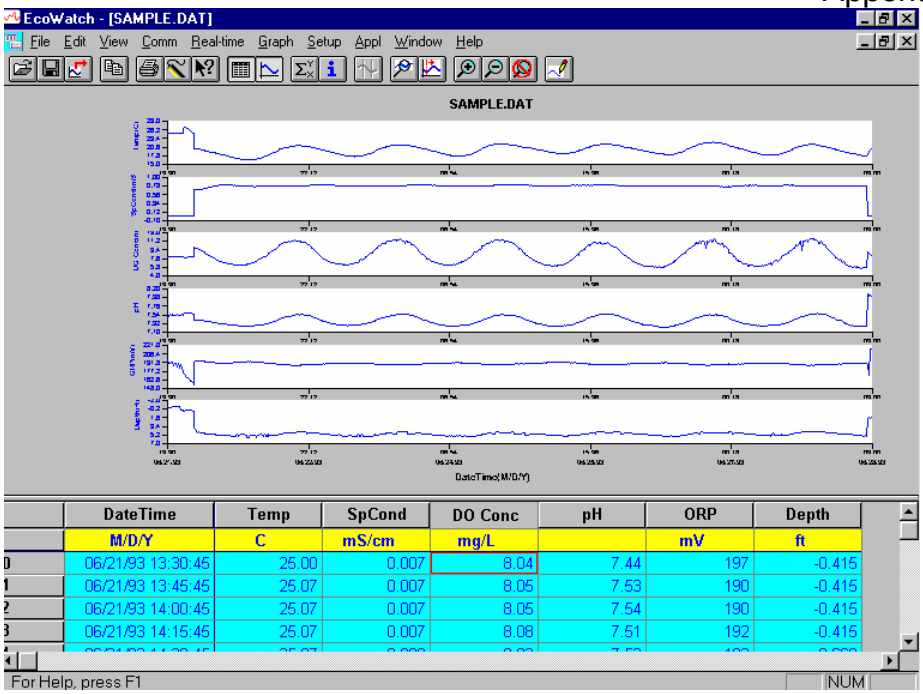
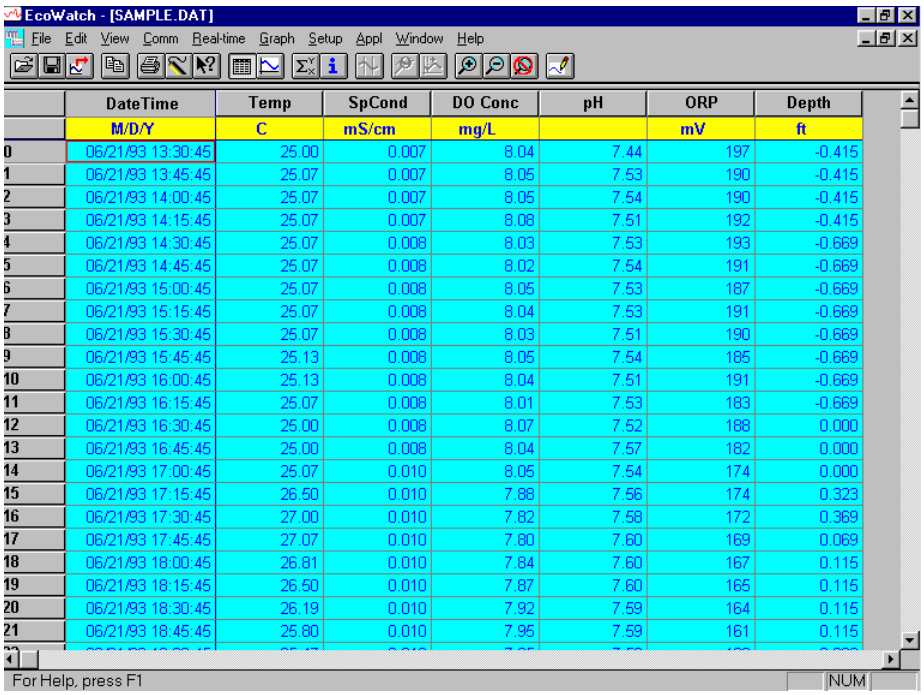


	DateTime	Temp	SpCond	DO Conc	pH	ORP	Depth
	M/D/Y	C	mS/cm	mg/L		mV	ft
0	06/21/93 13:30:45	25.00	0.007	8.04	7.44	197	-0.415
1	06/21/93 13:45:45	25.07	0.007	8.05	7.53	190	-0.415
2	06/21/93 14:00:45	25.07	0.007	8.05	7.54	190	-0.415
3	06/21/93 14:15:45	25.07	0.007	8.08	7.51	192	-0.415

For Help, press F1 NUM

Now click the **Graph** button (turn it off) to display only a report of your data as shown below. Note that the size of the report can be varied by clicking on the and buttons in the Toolbar.



	DateTime	Temp	SpCond	DO Conc	pH	ORP	Depth
	M/D/Y	C	mS/cm	mg/L		mV	ft
0	06/21/93 13:30:45	25.00	0.007	8.04	7.44	197	-0.415
1	06/21/93 13:45:45	25.07	0.007	8.05	7.53	190	-0.415
2	06/21/93 14:00:45	25.07	0.007	8.05	7.54	190	-0.415
3	06/21/93 14:15:45	25.07	0.007	8.08	7.51	192	-0.415
4	06/21/93 14:30:45	25.07	0.008	8.03	7.53	193	-0.669
5	06/21/93 14:45:45	25.07	0.008	8.02	7.54	191	-0.669
6	06/21/93 15:00:45	25.07	0.008	8.05	7.53	187	-0.669
7	06/21/93 15:15:45	25.07	0.008	8.04	7.53	191	-0.669
8	06/21/93 15:30:45	25.07	0.008	8.03	7.51	190	-0.669
9	06/21/93 15:45:45	25.13	0.008	8.05	7.54	185	-0.669
10	06/21/93 16:00:45	25.13	0.008	8.04	7.51	191	-0.669
11	06/21/93 16:15:45	25.07	0.008	8.01	7.53	183	-0.669
12	06/21/93 16:30:45	25.00	0.008	8.07	7.52	188	0.000
13	06/21/93 16:45:45	25.00	0.008	8.04	7.57	182	0.000
14	06/21/93 17:00:45	25.07	0.010	8.05	7.54	174	0.000
15	06/21/93 17:15:45	26.50	0.010	7.88	7.56	174	0.323
16	06/21/93 17:30:45	27.00	0.010	7.82	7.58	172	0.369
17	06/21/93 17:45:45	27.07	0.010	7.80	7.60	169	0.069
18	06/21/93 18:00:45	26.81	0.010	7.84	7.60	167	0.115
19	06/21/93 18:15:45	26.50	0.010	7.87	7.60	165	0.115
20	06/21/93 18:30:45	26.19	0.010	7.92	7.59	164	0.115
21	06/21/93 18:45:45	25.80	0.010	7.95	7.59	161	0.115

For Help, press F1 NUM

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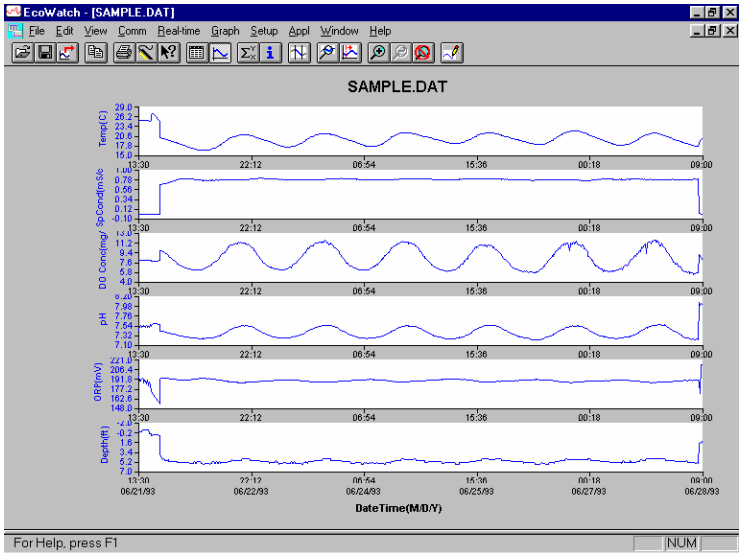
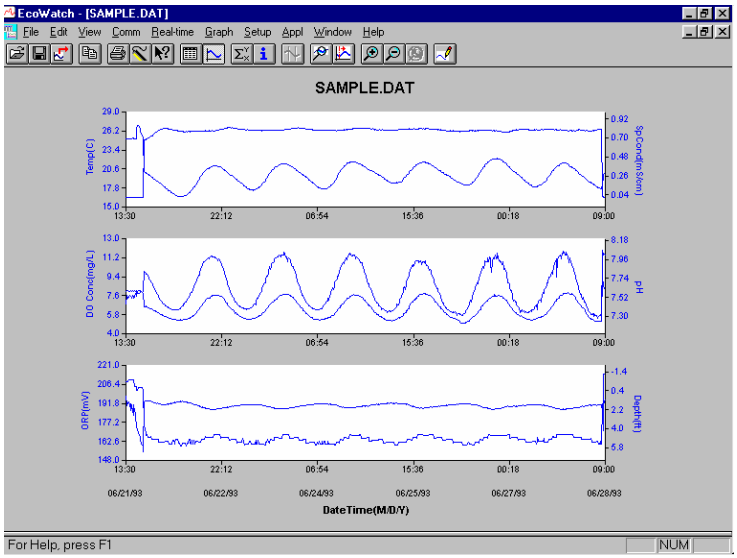
Now return to the original graphic display by toggling the **Table** button "off" and **Graph** button "on".



From the **Setup** menu, click **Graph**. Click **2 Traces per Graph** and notice that the parameters are now graphed in pairs for easy comparison of parameters.



Click **1 Trace per Graph** to return the display to the original setting. Move the cursor to any position in the graph, then click and hold the right mouse button.

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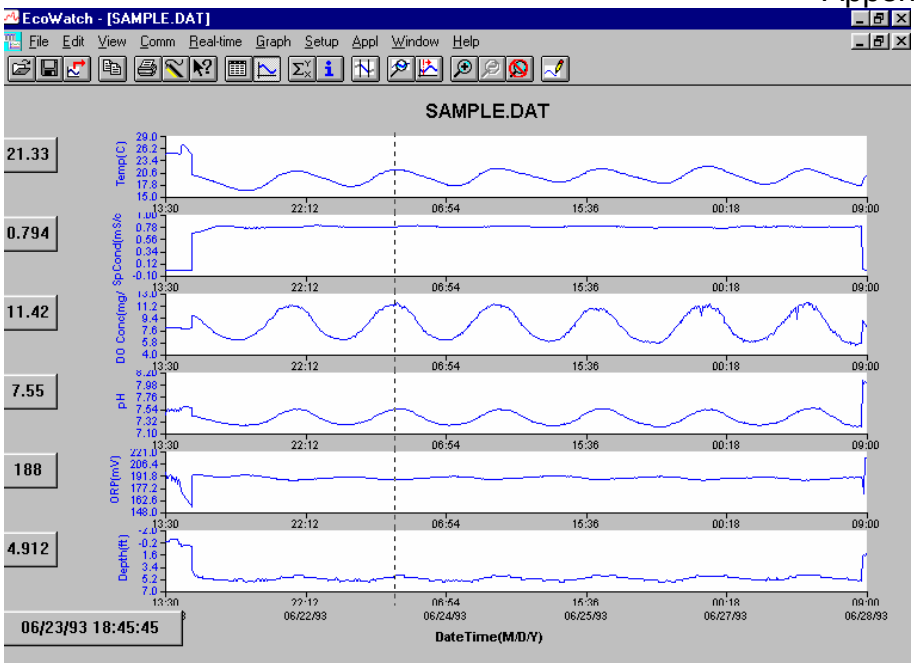

Note that the exact measurements for this point in time are displayed to the left of the graph. While holding down the right mouse button, move to another area on the graph. Notice how the measurements change as you move. When you release the mouse button, the display returns to normal.

To view statistical information for the study, click the **Statistics** button on the toolbar. On the statistics window, click on any min or max value to display the time when it occurred.

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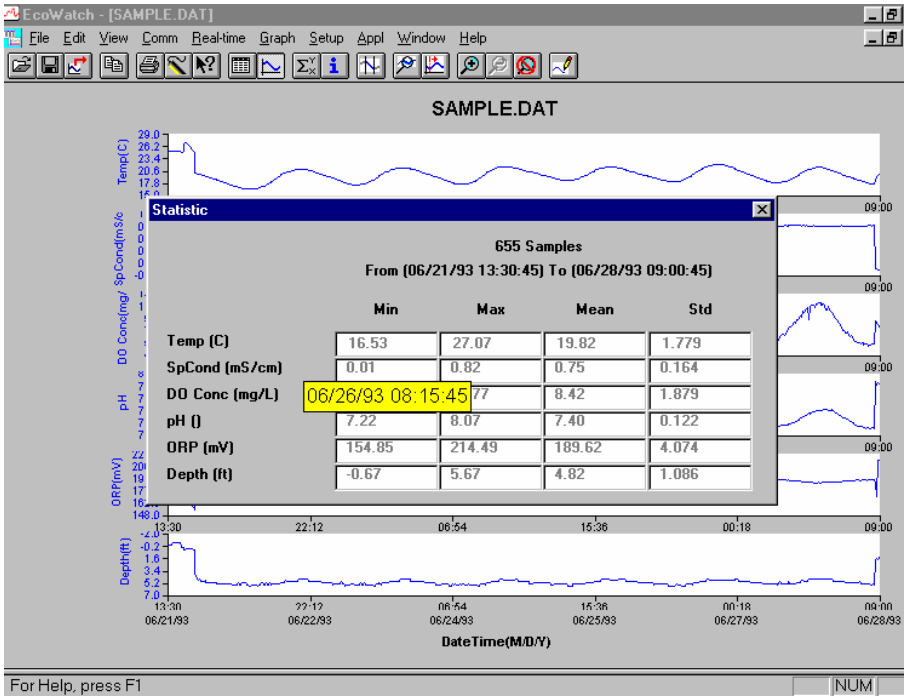
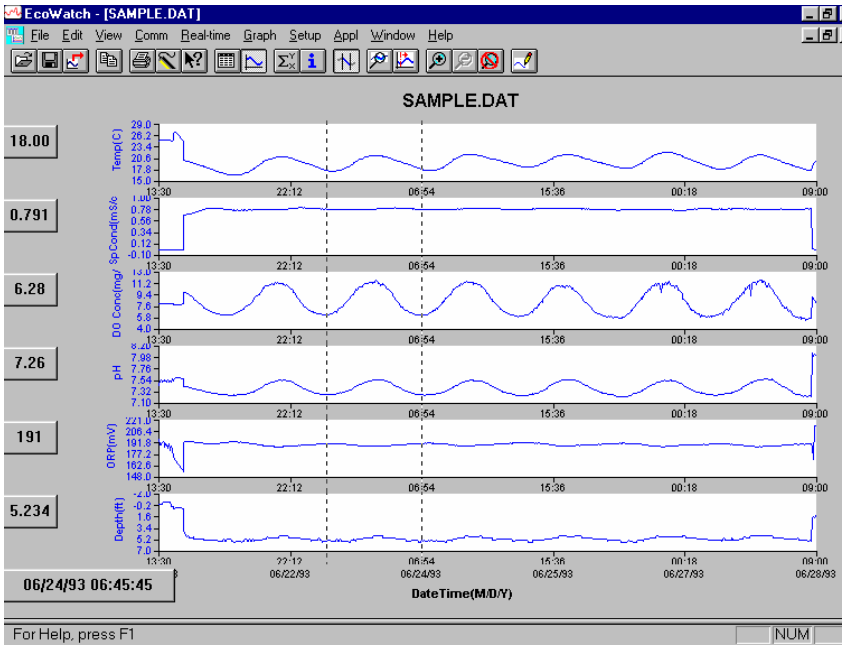


After viewing statistics, click the “x” at the upper right to close the window and return to the normal display.

Now click on the delimiter icon in the toolbar and then move the displayed icon to the graph. Click at the two points shown by dotted lines in the display below, being sure that the first click is to the left of the second.



The data between the two selected points will then be graphed in higher resolution as shown below.

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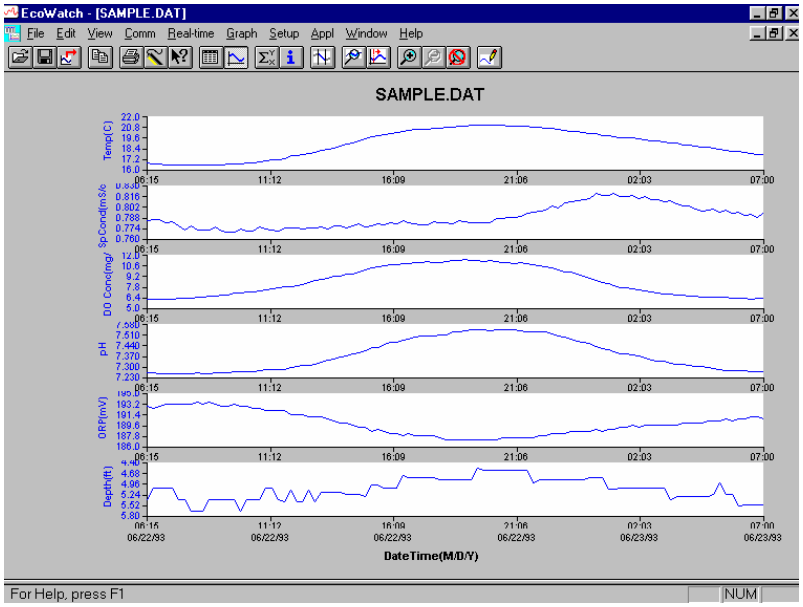
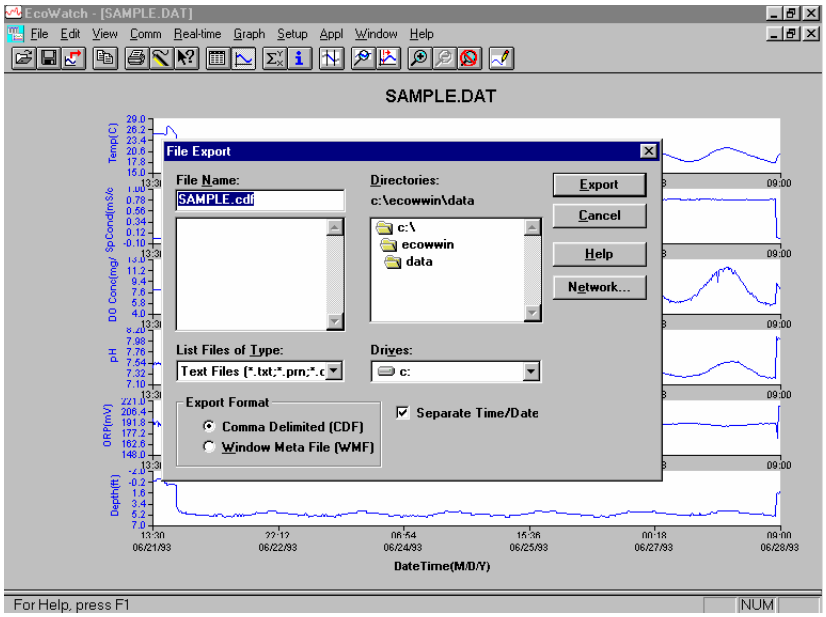


To return to the complete data set, select **Graph** from the toolbar and then click **Cancel Limits**.

Now select the icon from the Toolbar to create a new data file which will allow your data to be imported into spreadsheets. Select the default export settings for a Comma Delimited File (.CDF) and click OK. A new spreadsheet-importable file (SAMPLE.CDF) is now present in the same folder as the SAMPLE.DAT file.



Now select the icon from the toolbar to print the plot. Accept the default settings and click OK to complete the printing operation.

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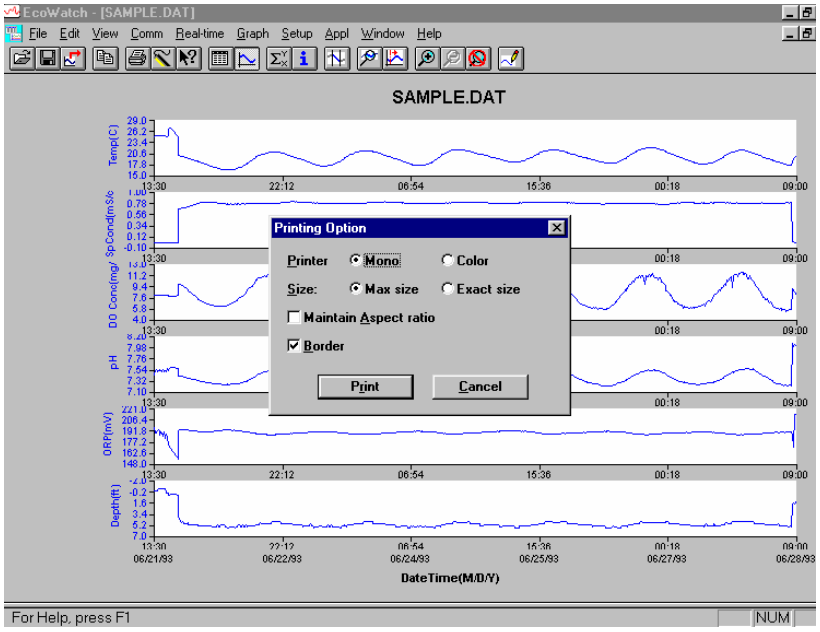
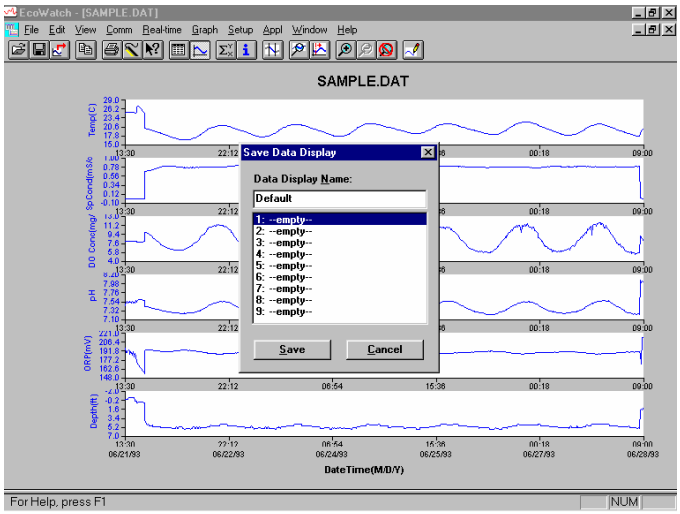


Finally, end the tutorial by saving the **Data Display** in the format shown. From the File menu, click **Save Data Display**.



Then type “Default” for the file name and click **Save**. The parameters, colors, format, and x-axis time interval associated with the current display are now saved and can be accessed any time in the future. Nine different data displays may be saved for any data file. You can easily switch between various displays of the data. The data files can be accessed by clicking **Load Data Display** from the file menu and then selecting the desired presentation.

20.2.1 Summary of Toolbar Capability

The EcoWatch toolbar includes buttons for some of the most common commands in EcoWatch, such as **File Open**. To display or hide the toolbar,

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open the **View** menu and click on the **Toolbar** command. A check mark appears next to the menu item when the toolbar is displayed.

The toolbar is displayed across the top of the application window, below the menu bar.

Click to:

Open an existing data file (.DAT). EcoWatch displays the **Open** dialog box, in which you can locate and open the desired file.

Save the working Data Display of the active data file. EcoWatch displays the **Save Data Display** dialog box in which you can overwrite existing Data Display or save to a new one.

Export data as a graph in Window Meta File (.WMF) format or as data in Comma Delimited (.CDF) format.

Copy the whole graph page or data from the selection on the table to the clipboard.

Print the active graph page or table page depending on which one is currently active.

Open a new terminal window to communicate with the sonde.

Access context sensitive help (Shift+F1).

Toggle table window during file processing.

Toggle graph window during file processing.

Display study statistics.

Display study info.

Limit the data to be processed.

Enlarge a selective portion of graph.

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Center the graph under the cursor.

Enlarge graph of table 20%.

Reduce graph of table 20%.

Return graph or table to its normal size (unzoom).

Redraw the graph.

20.2.2 Other capabilities

The above tutorial and function list for the toolbar provide basic information to allow you to view and analyze the field data which was stored in your 556 MPS. Some of the other commonly used capabilities of EcoWatch which the user may want to explore are listed below:

- Customize the units for each parameter, e.g., report uS/cm instead of mS/cm for conductivity.
- Customize the order of parameters in each plot or report.
- Customize the colors and fonts of each data display.
- Manually scale the y-axis sensitivity for each parameter.
- Merging of two or more data files with compatible parameter formats
- View information about the study such as number of points, instrument serial number, etc. which was stored in the 556 with the data.
- Print data reports in different statistical formats.
- Create plots of parameter vs. parameter rather than parameter vs. time.

These additional features of EcoWatch for Windows are explained in detail in the YSI 6-series manual (which can be downloaded at no cost from the YSI Web Site as described above) and the Help selection in the EcoWatch menu bar. To purchase a hard copy of the 6-series manual, contact YSI Customer Service using the contact information in *Appendix E Customer Service*.

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21. Appendix H Calibration Record Information

When your YSI 556 MPS sensors are initially calibrated, relevant information about the sensors will be stored in a separate file in the YSI 556 MPS memory.

NOTE: This file, by default, will have the name "556 Circuit Board Serial Number.glp." The circuit board serial number is assigned at the factory and has a hexadecimal format such as 000080A4. Thus the default calibration record file would be designated 00080A4.glp. Refer to Section *10.7 GLP Filename* to change the filename.

The information in the calibration record will track the sensor performance of your instrument and should be particularly useful for programs operating under Good Laboratory Practices (GLP) protocols.

21.1 Viewing the Calibration Record (.glp) File

NOTE: Make certain that you have performed a calibration on at least one of the sensors associated with your YSI 556 MPS.

Follow the procedures outlined in Section *8.3 View File*.

21.2 Uploading the Calibration Record (.glp) File

NOTE: Make certain that you have performed a calibration on at least one of the sensors associated with your YSI 556 MPS.

Follow the procedures outlined in Section *8.4 Upload to PC*.

21.3 Understanding the Calibration Record (.glp) File

1. Open a calibration record file. Refer to Section 8.3 View File.
2. Use the arrow keys to scroll horizontally and/or vertically to view all the data.

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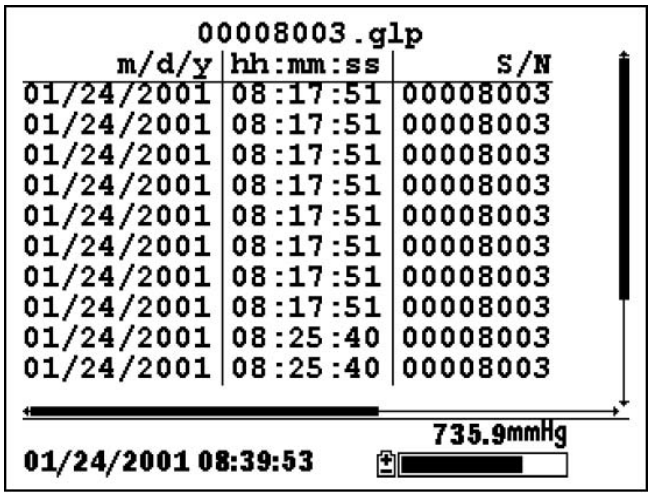

Figure 21.1Calibration Record Screen 1

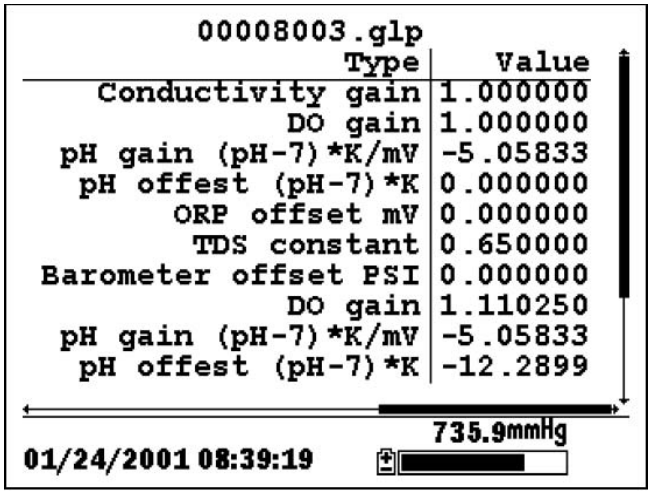

Figure 21.2 Calibration Record Screen 2

NOTE: Each sensor (not parameter) is characterized by either 1 line (Conductivity, Dissolved Oxygen, ORP, TDS, or Barometer (Optional)) or 2 lines (pH) of calibration documentation.

The left hand portion of each calibration entry shows the date and time that a calibration of a particular sensor was performed. In addition, each calibration entry is characterized by the instrument serial number, as defined by YSI. See Figure 21.1 Calibration Record Screen 1. The right hand portion shows the YSI designation of the calibration constants and their values after their calibration has been performed. A more detailed description of the calibration constants is provided below:

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- **Conductivity Gain** – A relative number which describes the sensitivity of the sensor. Basically, the value represents the calculated cell constant divided by the typical value of the cell constant ($5\ cm^{-1}$).
- **DO Gain** – A relative number which describes the sensitivity of the sensor. Basically, the value represents the sensor current at the time of calibration divided by the typical value of the sensor current (15 uA).
- **pH Gain** – A number which basically represents the sensitivity of the pH sensor. To remove the effect of temperature on the slope of the relationship of probe output in mv versus pH, the value of pH/mv is multiplied by the temperature in degrees Kelvin (K).
- **pH Offset** – A number which basically represents the offset (or intercept) of the relationship of probe output in mv versus pH, the value of pH is multiplied by the temperature in degrees Kelvin (K).

Anytime you perform a calibration, information concerning the calibration constants will be logged to the Calibration Record file (.glp file). However, if the **Delete All Files** command is used, Refer to Section *8.6 Delete All Files*, the Calibration Record file will also be lost. It is critical that this file should be uploaded to your PC prior to issuing a **Delete All Files** command. Refer to Section *8.4 Upload to PC*.

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Item # 655279
Rev D
Drawing # A655279
August 2009
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Professional *Plus*

Calibration Tips

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Introduction

This guide provides helpful instructions, tips and troubleshooting suggestions for calibrating a Professional Plus instrument. For more detailed information on calibration and information on how to setup and operate a Pro Plus, please refer to the Pro Plus User Manual.

Calibration Worksheet

The Calibration Worksheet on the following page is provided for your convenience. Utilizing the Calibration Worksheet can help document your calibration and track the performance of your sensors.

Date of Calibration: _____ Technician: _____

Instrument Serial Number:_____ Software Revision:_____ Cable Model Number:_____

Temperature Reading_____ Temperature Accurate: Y N

DO Sensor in use: Polarographic Galvanic Sensor notated in Sensor menu? Y N

DO membrane changed? Y N Color of Membrane_____ Color notated in Sensor menu? Y N

Record the following calibration values:

	Pre Cal	After Cal
Conductivity	_____	_____
ORP	_____	_____
DO	_____	_____

True Barometric Pressure at time of calibration _____

	Pre Cal		
pH 7	_____	pH mV value_____	Range 0 mV $\pm$ 50 mV
pH 4	_____	pH mV value_____	Range +165 to +180 from 7 buffer mV value
pH 10	_____	pH mV value_____	Range -165 to -180 from 7 buffer mV value

NOTE: See pH Cal tips section for additional information. Span between pH 4 and 7 and 7 and 10 mV values should be ≈ 165 to 180 mV. 177 is the ideal distance or 59 mV per pH unit.

Ammonium

1st point (1 mg/L) _____ NH4 mV value_____ Range: 0 mV +/- 20 mV (new sensor only)

2nd point (100 mg/L)_____ NH4 mV value_____ Range: 90 to 130 mV > 1 mg/L mV value

Nitrate

1st point (1 mg/L) _____ NO3 mV value_____ Range: 200 mV +/- 20 mV (new sensor only)

2nd point (100 mg/L)_____ NO3 mV value_____ Range: 90 to 130 mV < 1 mg/L mV value

Chloride

1st point (10 mg/L) _____ Cl mV value _____ Range: 225 mV +/- 20 mV (new sensor only)

2nd point (1000mg/L)_____ Cl mV value _____ Range: 80 to 130 < 10 mg/L mV value

Record the following diagnostic numbers **after** calibration, by viewing the .glp file and reading the values for the day's calibration

Conductivity Cal Cell Constant _____ Range 5.0 +/- 1.0 acceptable

DO Sensor Value (uA) _____ (Membrane dependent, see DO Cal Tips)

pH Slope _____ (≈ 55 to 60 mV/pH, 59 ideal)

pH Slope % of ideal _____

Temperature

CALIBRATION TIPS

Before calibrating any other Pro Plus sensor, verify that the temperature sensor is reading accurately by comparing it to a traceable thermometer or other known reference in a water bath. Temperature compensation is used in every other sensor measurement so its accuracy should be verified and recorded each time the Pro Plus is calibrated. Be sure to consider the specification tolerances of both the Pro Plus temperature sensor and the thermometer when comparing the measurements.

The Pro Plus temperature sensor can not be calibrated nor should calibration be required.

TROUBLESHOOTING TIPS

If the temperature sensor is not reading accurately, ensure that it is clean and free of debris. The conductivity cleaning brush and warm water with mild detergent can be used to scrub the temperature sensor if needed. Alternatively, you can use a toothbrush to clean the sensor.

Quatro Cables

Quatro cables have a replaceable combination conductivity/temperature sensor (p/n 005560). All other Pro Plus cables have integral temperature sensors. If using a Quatro cable and your temperature sensor is not reading accurately, remove the conductivity/temperature sensor from the cable. The Pro Plus should read ----- °C without a temperature sensor installed. If the instrument is reading any other value, the conductivity/temperature port on the cable may be contaminated. Refer to the Cleaning the Sensor Port section of this document for information on how to clean the port.

After cleaning the port, recheck the temperature reading. If the temperature reading is still not displaying ----- °C without the sensor installed, there may be a problem with the cable and/or instrument. In this case, contact your local YSI Representative or a YSI Authorized Service Center.

Other Pro Plus Cables

If your temperature sensor is not reading accurately after cleaning around the sensor, contact your local YSI Representative or an YSI Authorized Service Center.

Conductivity

The conductivity calibration should be verified every day the instrument is used. However, the conductivity sensor is very stable and may hold its calibration for several weeks.

CALIBRATION TIPS

1. It is not necessary to calibrate conductivity, specific conductance and salinity. Calibrating one of these parameters will simultaneously calibrate the others. YSI recommends calibrating specific conductance (temperature compensated conductivity) for greatest ease and accuracy.
2. Ensure the conductivity sensor is clean and dry before performing a specific conductance calibration.
3. Always use fresh, traceable conductivity calibration solution when calibrating the conductivity sensor.
    a. The shelf life of conductivity solution is one month after being opened. This is due to potential changes in the value of the solution caused by evaporation which can occur after opening the bottle. Be sure to write the open date on the bottle so you know that you are using good calibration solution.
    b. Never calibrate with a conductivity solution that is less than 1.0 mS/cm. You are setting the slope on a linear device so a good strong conductivity signal will give you the best performance. Use 1.0 mS/cm for fresh water, 10 mS/cm for brackish to estuarine water and 50 mS/cm for salt water. 1.0 mS (millisiemens) = 1000 uS (microsiemens).
4. Pre-rinse the cal cup and sensors with a small amount of calibration standard or rinse standard and discard.
5. When calibrating the conductivity sensor, the calibration solution must cover the top vent holes of the conductivity sensor. If using a Quatro cable, the top vent hole is located on the side of the combination conductivity/temperature sensor. If using a different cable, the conductivity sensor is integral to the cable and the sensor has two vent holes located close to the cable. Ensure the entire conductivity sensor is submerged in the solution or the instrument will read approximately half the expected value.
6. After placing the sensor into the solution, gently move the sensor up and down to remove any air bubbles that may be trapped in the conductivity sensor.
7. If calibrating Specific Conductance, enter the value of the conductivity solution as it is listed for 25°C. Make sure you are entering the correct units. 1 mS = 1,000 uS.
8. If you receive a warning message stating that the calibration is questionable, do not continue with the calibration. Instead, select 'No' and investigate what is causing the questionable results. If you accept a questionable calibration, your conductivity readings (and your DO mg/L readings) will be erroneous. Typical causes for this error message include: incorrect entries (entering 1000 uS/cm instead of 1.0 mS/cm), not using enough solution to cover the vent holes, air bubbles trapped in the sensor, calibrating in conductivity instead of specific conductance, dirty conductivity electrodes, and/or bad calibration solution.
9. After accepting a good calibration, navigate to the GLP file and check the conductivity cell constant for the calibration. For highest accuracy, the cell constant should be 5.0 +/- 0.5. However, the acceptable range is 5 +/- 1.0. A cell constant outside of this range indicates that a questionable calibration was accepted.

TROUBLESHOOTING TIPS

If you get an error message during calibration, be sure that you are:

1. Entering the correct calibration value (1 mS/cm = 1000 uS/cm).
2. Calibrating in Specific Conductance mode.
3. Using enough solution to cover the vent holes on the sensor.
4. Dislodging any air bubbles that could be trapped in the sensor.
5. Using a fresh, traceable conductivity calibration solution.

If you are following the above recommendations and still receiving an error message, check the conductivity sensor to make sure it is clean. A clean conductivity sensor should read less than 3 uS/cm in dry air. If your sensor is dry and giving you a reading higher than 3 uS/cm in air, it should be cleaned.

The conductivity calibration generates its cell constant value after calibration. The ideal cell constant is 5.0 +/-0.5 but 5.0 +/- 1.0 is acceptable. Any significant jump or change in this number from one calibration to the next usually indicates a problem with the calibration and/or sensor. If you are sure that your calibration standard is good and your calibration process is correct, then your sensor may need to be cleaned.

Cleaning the Conductivity Sensor

The openings that allow sample access to the conductivity electrodes should be cleaned regularly. The small cleaning brush included in the Maintenance Kit is intended for this purpose. Dip the brush in clean water and insert it into each hole 10 to 12 times. In the event that deposits have formed on the electrodes, it may be necessary to use a mild detergent (laboratory grade soap or bathroom foaming tile cleaner) with the brush. Rinse thoroughly with clean water, then check the response and accuracy of the conductivity sensor with calibration solution.

Quatro Cables

Quatro cables have a replaceable combination conductivity/temperature sensor (p/n 5560). All other Pro Plus cables have integral conductivity sensors. If using a Quatro cable and your conductivity sensor is not calibrating or is reading > 3 uS/cm in dry air after being cleaned, remove the conductivity/temperature sensor from the cable. The Pro Plus should read < 3 uS/cm for conductivity (not specific conductance) without a conductivity sensor installed. If the instrument is reading > 3 uS/cm without a sensor installed, the conductivity/temperature port on the cable may be contaminated. Refer to the Cleaning the Sensor Port section of this document for information on how to clean the port.

If the conductivity measurement continues to read more than 3 uS/cm without a conductivity/temperature sensor installed, there may be a problem with the cable and/or instrument. In this case, contact your local YSI Representative or a YSI Authorized Service Center.

Other Pro Plus Cables

If your conductivity sensor is not calibrating or is reading > 3 uS/cm in dry air after performing a sensor cleaning, contact your local YSI Representative or a YSI Authorized Service Center.

pH

The pH calibration should be verified every day the instrument is used. However, a new pH sensor may be capable of holding its calibration for several days.

CALIBRATION TIPS

1. If using a pH sensor in a 6051010 or Quatro cable, calibrate the sensor in port 1 prior to calibrating the sensor in port 2. The sensor in port 2 uses the reference of the sensor installed in port 1. Therefore, it is important to verify that the port 1 sensor is working properly before calibrating the port 2 sensor. See pH Troubleshooting Tips for additional info.
2. The pH sensor can be calibrated with up to six calibration points.
3. Calibration can be accomplished in any buffer order.
4. pH 7 buffer should be used regardless of how many calibration points you use; however, it does not have to be the first point.
5. In most cases, a two-point calibration is all that is required (4 and 7 or 7 and 10). You can bracket the expected in-situ pH values. Use a three-point calibration with 4, 7 and 10 if the in-situ pH values are unknown or if you expect the in-situ values to be on both sides of the pH scale.
6. Rinse the sensors and cal cup with a small amount of pH buffer. Fill the cup so that the pH sensor tip and the temperature sensor are submerged in buffer.
7. If necessary, highlight the Calibration Value and enter the pH value of the buffer solution. Note: The Pro Plus has auto buffer recognition which can be set to USA (4, 7, 10) or NIST (4.01, 6.86, 9.18) buffer values in the pH Sensor Setup menu.
8. Record the pH millivolts for each calibration point. The acceptable mV outputs for each buffer are shown below.

   pH 7 mV value = 0 mV +/- 50 mV
   pH 4 mV value = +165 to +180 from 7 buffer mV value
   pH 10 mV value = -165 to -180 from 7 buffer mV value

   - A value of +50 or -50 mVs in buffer 7 does not indicate a bad sensor.
   - The mV span between pH 4 and 7 and 7 and 10 mV values should be $\approx$ 165 to 180 mV. 177 is the ideal distance. The slope can be 55 to 60 mV per pH unit with an ideal of 59 mV per pH unit.
   - If the mV span between pH 4 and 7 or 7 and 10 drops below 160, clean the sensor and try to recalibrate.
9. Wait for the pH to stabilize in the each buffer and then press enter to accept each calibration point.
10. Rinse the sensor and cal cup with a small amount of the next buffer between calibration points.
11. After pressing enter to accept your last calibration point, press cal (Cal) to complete the calibration. Otherwise you will continue calibrating up to 6 calibration points.
12. If you receive a warning message stating that the calibration is questionable, do not continue with the calibration. Instead, select 'No' and investigate what is causing the questionable results. If you accept a questionable calibration, your pH readings will be erroneous. Typical causes for this error message include: incorrect Sensor/Port setup in the instrument, a dirty sensor or bad buffer solution.
13. After accepting a good calibration, navigate to the GLP file and check the pH Slope and Slope % of ideal. A good slope should be between 55 and 60 mVs while the ideal is 59 mV. If the slope drops below 53, the sensor should be reconditioned and recalibrated.

TROUBLESHOOTING TIPS

Typical working life for pH sensors is approximately 12-24 months depending on usage, storage and maintenance. Proper storage and maintenance generally extends the sensor's working life.

Clean and recondition the sensor if a slow response in the field has been reported or if it takes more than 90 seconds to stabilize in pH buffer.

If you get an error message during a pH calibration, check the following:

1. Ensure the pH buffers are good and not expired
2. Ensure that the pH sensor is installed in the correct port of the cable and the correct ISE is enabled in the Sensor Setup menu.
    a. If using a pH or pH/ORP combo sensor in a 6051020 cable, ensure the sensor is installed in port 1.
    b. If using a pH or pH/ORP combo sensor in a 60510, 6051020 or 6051030 cable, pH should be enabled in ISE1 of the instrument's Sensor Setup menu.
    c. If using a pH sensor in a 6051010 or Quatro cable, check to see if the pH sensor is installed in port 1 or port 2. If the pH sensor is installed in port 1, enable pH in ISE1 of the Sensor Setup menu. If the pH sensor is installed in port 2, enable pH in ISE2 of the Sensor Setup menu. Note: It is not recommended to use a pH/ORP combo sensor in 6051010 or Quatro cables. If using a pH/ORP combo sensor in a 6051010 or Quatro cable, ORP will not be measured or reported.
3. If using a 6051010 or Quatro cable, you must have a sensor installed in port 1 for port 2 to operate. Additionally, ensure that the sensor installed in port 1 is in good working order. In 6051010 and Quatro cables, the sensors installed in port 1 and port 2 use the reference from the sensor installed in port 1 only. Therefore, if the sensor installed in port 1 is not working properly, the readings from the sensor installed in port 2 will be erroneous. For greatest ease, install a pH sensor in port 1 of both 6051010 and Quatro cables and your other ISE sensor in port 2.
4. If you continue to get error messages during calibration, clean and recondition the sensor.

Cleaning and Reconditioning the pH, ORP or pH/ORP Sensor

If the pH or pH/ORP sensor has been allowed to dry out or has been stored in distilled or deionized water for an extended period of time, soak the sensor in buffer 4 overnight to try and restore functionality.

Cleaning is required whenever deposits or contaminants appear on the glass and/or platinum surfaces or when the sensor's response slows. The cleaning can be chemical and/or mechanical.

Removing the sensor from the cable may make cleaning easier. Initially, moisten a soft clean cloth, lens cleaning tissue or cotton swab to remove all foreign material from the glass bulb and/or platinum button. Then use a moistened cotton swab to carefully remove any material that may be blocking the reference electrode junction of the sensor. ***CAUTION***: When using a cotton swab, be careful NOT to wedge the swab between the guard and the glass sensor. If necessary, remove cotton from the swab tip, so that the cotton can reach all parts of the sensor tip without stress. You can also use a pipe cleaner for this cleaning if more convenient.

If good pH and/or ORP response is not restored, perform the following additional procedure:

1. Soak the sensor for 10-15 minutes in clean water containing a few drops of commercial dishwashing liquid.
2. GENTLY clean the glass bulb and platinum button by rubbing with a cotton swab soaked in the cleaning solution.
3. Rinse the sensor in clean water, wipe with a cotton swab moistened with clean water, and then re-rinse with clean water.

If good pH and/or ORP response is still not restored, perform the following additional procedure:

1. Soak the sensor for 30-60 minutes in one molar (1 M) hydrochloric acid (HCl). This reagent can be purchased from most lab supply distributors. Be sure to follow the safety instructions included with the acid.

2. Rinse the sensor in clean water, wipe with a cotton swab moistened with clean water (not DI water), and then re-rinse with clean water. To be certain that all traces of the acid are removed from the sensor crevices, soak the sensor in clean tap water for about an hour with occasional stirring.

If biological contamination of the reference junction is suspected or if good response is not restored by the above procedures, perform the following additional cleaning step:

CAUTION: Do not mix the acid from the previous step with the chlorine bleach in the following step. A toxic gaseous product can form from the reaction between the acid and the chlorine bleach. Be certain to copiously rinse the sink and drain system of acid after its disposal and before the disposal of chlorine bleach.

1. Soak the sensor for approximately 1 hour in a 1:1 dilution of commercially available chlorine bleach.
2. Rinse the sensor with clean water and then soak for at least 1 hour in clean tap water with occasional stirring to remove residual bleach from the junction. (If possible, soak the sensor for a period of time longer than 1 hour in order to be certain that all traces of chlorine bleach are removed.) Then re-rinse the sensor with clean water and retest.

Prior to reinstalling the sensor, dry the port and sensor connector with compressed air. If you suspect port contamination, follow the instructions in the Cleaning a Sensor Port section of this document before reinstalling the sensor.

If your pH sensor is still not calibrating after performing a sensor cleaning, contact your local YSI Representative or a YSI Authorized Service Center.

ORP

The ORP calibration should be verified every day the instrument is used. However, a new ORP sensor may be capable of holding its calibration for several days.

CALIBRATION TIPS

1. If using a pH/ORP combination sensor, calibrate pH first to ensure it is working.
2. If using an ORP sensor in a 6051010 or Quatro cable, calibrate the sensor in port 1 prior to calibrating the sensor in port 2. The sensor in port 2 uses the reference of the sensor installed in port 1. Therefore, it is important to verify that the port 1 sensor is working properly before calibrating the port 2 sensor. See ORP Troubleshooting Tips for additional info.
3. Rinse the sensors and cal cup with a small amount of ORP calibration solution. Fill the cup so that the ORP sensor tip and the temperature sensor are submerged in solution.
4. Enter the calibration value per the temperature reading. The value of ORP calibration solution is greatly affected by temperature. The ORP solution should include a chart of solution values per temperature. If not, contact the supplier of the ORP solution to obtain this information. The Pro Series ORP sensors use a Ag/AgCl 3.5 M KCl reference. Be sure the value you enter is for this type of reference. If using the YSI Zobell calibration solution, the Pro Plus will automatically determine the calibration value.
5. Wait for the readings to stabilize and then press enter to accept the calibration.
6. If you receive a warning message stating that the calibration is questionable, do not continue with the calibration. Instead, select 'No' and investigate what is causing the questionable results. If you accept a questionable calibration, your ORP readings will be erroneous. Typical causes for this error message include: incorrect Sensor/Port setup in the instrument, a dirty sensor or bad calibration solution.

TROUBLESHOOTING TIPS

Typical working life for ORP sensors is approximately 12-24 months depending on usage, storage and maintenance. Proper storage and maintenance generally extends the sensor's working life.

Clean and recondition the sensor if the sensor exhibits a slow response in Zobell solution, i.e. it takes more than 90 seconds to stabilize when placed in Zobell.

If you get error messages during an ORP calibration, check the following:

1. Ensure the ORP calibration solution is good and not expired.
2. Ensure that the ORP sensor is installed in the correct port of the cable and the correct ISE is enabled in the Sensor Setup menu.
    a. If using an ORP or pH/ORP combo sensor in a 6051020 cable, ensure the sensor is installed in port 1.
    b. If using an ORP sensor in a 60510, 6051020 or 6051030 cable, ORP should be enabled in ISE1 of the instrument's Sensor Setup menu.
    c. If using a pH/ORP combo sensor in a 60510, 6051020 or 6051030 cable, ORP should be enabled in ISE2 of the instrument's Sensor Setup menu.
    d. If using an ORP sensor in a 6051010 or Quatro cable, check to see if the ORP sensor is installed in port 1 or port 2. If the ORP sensor is installed in port 1, enable ORP in ISE1 of the Sensor Setup menu. If the ORP sensor is installed in port 2, enable ORP in ISE2 of the Sensor Setup menu.
5. If using a pH/ORP combo sensor in a 6051010 or Quatro cable, ORP will not be measured or reported.
6. If using a 6051010 or Quatro cable, you must have a sensor installed in port 1 for port 2 to operate. Additionally, ensure that the sensor installed in port 1 is calibrated and in good working order. In 6051010 and Quatro cables, the sensors installed in port 1 and port 2 use the reference from the sensor installed in

port 1 only. Therefore, if the sensor installed in port 1 is not working properly, the readings from the sensor installed in port 2 will be erroneous.

7. If you continue to get error messages during calibration, clean and recondition the sensor per the instructions in the pH Troubleshooting section of this document. If you suspect port contamination, follow the instructions in the Cleaning a Sensor Port section before reinstalling the sensor.
8. If you continue to have problems, you can check the offset of the ORP sensor by performing a factory reset to the ORP sensor. After resetting the sensor, compare the ORP mV readings in Zobell solution to the calibration value. The difference between values should be less than 100 mVs. If the difference is 80 mVs or higher, consider replacing the sensor as it is nearing the end of its life span.

Dissolved Oxygen

The dissolved oxygen sensor should be calibrated every day the instrument is used. It is not necessary to calibrate in both % and mg/L or ppm. Calibrating in % will simultaneously calibrate mg/L and ppm and vice versa.

CALIBRATION TIPS

1. The Pro Plus can be calibrated in air-saturated water, water-saturated air or against a Winkler Titration. You can perform a 1 or 2 point DO calibration. A 2 point calibration includes 1 point in a zero oxygen environment and the 2nd point at full saturation.
2. For both ease of use and accuracy, YSI recommends that you perform a 1 point calibration in water-saturated air.
3. Make sure that there is a good membrane with fresh electrolyte (O2 probe solution) installed on the DO sensor. The membrane should be clean and free of wrinkles. There should not be any air bubbles present under the membrane. Membranes should be changed regularly and generally last 2-8 weeks depending on use and storage.
4. To perform a 1 point calibration in water-saturated air, place the sensor in a 100% humid environment. This can be accomplished several ways:
    a. For the 60520 and 6052030 cables, moisten the sponge in the gray calibration sleeve with a *small* amount of clean water and place it over the sensor guard.
    b. For the 6051020 and Quatro cables, place a small amount of water in the calibration/storage cup and place it over the sensors. When screwing the calibration cup onto the sensor bulkhead, only engage one or two threads. Do not screw the calibration cup completely onto the sensor bulkhead. The goal is to have air exchange between inside and outside the calibration cup.

    The sponge and calibration sleeve/cup should be clean since bacterial growth may consume oxygen and interfere with the calibration. Be sure the sensor is in air, not water, and that there are not any water droplets on the membrane or temperature sensor.
5. After entering the % calibration mode, wait approximately 5 to 15 minutes for the storage container to become completely saturated and, if using a polarographic sensor, to allow the sensor to stabilize.
6. Salinity affects the ability of water to hold oxygen and is used by the instrument to calculate DO mg/L (ppm). The Salinity value displayed near the top of the DO calibration screen is either the salinity correction value entered in the Sensor menu or the Salinity value as measured by the conductivity sensor in use. If you are using a conductivity sensor, ensure that it is calibrated and reading correctly in order to obtain accurate DO mg/L (ppm) measurements. If you are not using a conductivity sensor, the Salinity correction value should be the salinity of the water you will be testing. Highlight Salinity and press enter to modify this setting if necessary. The salinity of fresh water is typically 0-0.5 ppt and seawater is typically 35 ppt.
7. After accepting the calibration, navigate to the GLP menu and record the DO sensor's value (sensor current in uA). The acceptable sensor currents when calibration is performed at 25°C, in a 100% saturated air environment at 760 mmHg are:

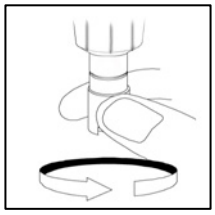
    1.25 mil PE membrane (yellow membrane): Average 6.15 uA (min. 4.31 uA, max. 8.00 uA)
    2.0 mil PE membrane (blue membrane): Average 3.38 uA (min. 2.37 uA, max. 4.40 uA)
    1 mil Teflon membrane: Average 16.29 uA (min. 11.40 uA, max. 21.18 uA)
8. If you receive a warning message stating that the calibration is questionable, do not continue with the calibration. Instead, select 'No' and investigate what is causing the questionable results. If you accept a questionable calibration, your DO readings will be erroneous. Typical causes of a calibration error message include: incorrect sensor, membrane or port setup in the instrument, incorrect barometric pressure information, a bad membrane or a sensor that needs reconditioned.

TROUBLESHOOTING TIPS

1. Ensure that the correct sensor type and membrane type are enabled in the Sensor Setup Menu. Galvanic sensors have a gray probe body and Polarographic sensors have a black probe body.
2. If using a 6051020 cable, ensure that the DO sensor is installed in port 2. If using a Quatro cable, ensure that the DO sensor is installed in the port labeled DO.
3. Ensure the Pro Plus barometer is reading accurately. The DO % Saturation calibration uses the instrument's barometric pressure reading for the DO % calibration. If the barometer is not reading accurately, the calibration will be erroneous. The barometer should be reading *true* barometric pressure. If you suspect the barometer reading is incorrect, calibrate the barometer and then recalibrate the DO sensor. Laboratory barometer readings are usually "true" (uncorrected) values of air pressure and can be used "as is" for barometer calibration. Weather service readings are usually not "true", i.e., they are corrected to sea level, and therefore cannot be used until they are "uncorrected". An approximate formula for this "uncorrection" is: True BP in mmHg = Corrected BP in mmHg – [2.5 * (Local Altitude in ft. above sea level/100)]
4. Install a new membrane with fresh electrolyte onto the DO sensor. Ensure you are using the correct electrolyte solution. Polarographic sensors use electrolyte that is in a white labeled bottle (KCl/Na_2SO_4). Galvanic sensors use electrolyte that is in a blue labeled bottle (NaCl).
5. Recondition the DO sensor and then install a new membrane.
6. If you suspect port contamination, remove the sensor and follow the instructions in the Cleaning a Sensor Port section.
7. If you continue to have trouble calibrating the DO sensor, contact your local YSI Representative or a YSI Authorized Service Center.

Membrane Cap Installation

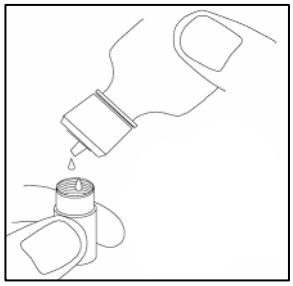
The DO membrane and electrolyte solution (O2 solution) should be changed once every 2-8 weeks depending on use and storage. In addition, the membrane and electrolyte solution should be changed if (a) bubbles are visible under the membrane; (b) significant deposits of dried electrolyte are visible on the membrane; or (c) if the sensor shows unstable readings or other sensor-related symptoms. To install a new membrane cap follow these instructions:



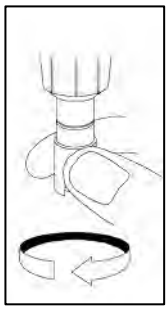
1. Remove the sensor guard or cal cup to access the sensor tip.

2. Unscrew and remove any old membrane cap by holding the sensor when unscrewing the membrane cap. Discard the used membrane cap.

3. Thoroughly rinse the sensor tip with distilled or DI water.

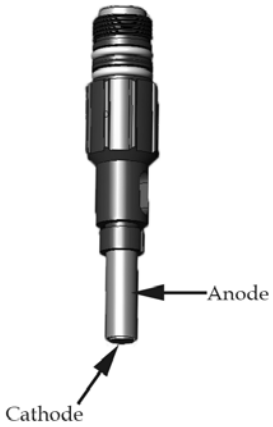


4. Fill a new membrane cap with the appropriate electrolyte solution that has been prepared according to the directions on the bottle. Polarographic sensors use electrolyte that is in a white labeled bottle (KCl/Na_2SO_4). Galvanic sensors use electrolyte that is in a blue labeled bottle (NaCl). Be very careful not to touch the membrane surface during this process. Lightly tap the side of the membrane cap to release air bubbles that may be trapped.



5. Thread the membrane cap onto the sensor. It is normal for a small amount of electrolyte to overflow.

Reconditioning the DO Sensor



Polarographic Sensors - Model # 605203

Due to the chemical reaction taking place under the membrane, deposits will form on the gold cathode and silver anode. The gold cathode will begin to appear dull and the silver anode will turn dark in color. This discoloration is normal; however, it is recommended that you remove the deposits as needed. Perform the following cleaning procedures to remove the deposits if 1.) You have troubles calibrating the sensor or the DO readings are unstable; and 2.) Changing a membrane does not correct the problem.

Silver Anode:

After extended use, a layer of Silver Chloride (AgCl) builds up on the silver anode reducing the sensitivity of the sensor. The anode must be cleaned to remove this layer and restore proper performance. The cleaning can be chemical and/or mechanical:

Chemical cleaning: Remove the membrane cap and rinse the electrodes with deionized or distilled water. Soak the sensing electrode section of the sensor in a 14% ammonium hydroxide solution for 2 to 3 minutes or in a 3% ammonia solution overnight for 8-12 hours (most household ammonia cleaners are typically around 3%). Rinse heavily in cool tap water followed by a thorough rinsing with distilled or deionized water. The anode should then be thoroughly wiped with a wet paper towel to remove the residual layer from the anode. Trapping residual ammonia under the new membrane cap can quickly tarnish the electrode and/or give false readings.

Note: Chemical cleaning should be performed as infrequently as possible (1 or 2 times per year depending on use). First attempt a membrane change and recalibrate. If a new membrane does not resolve the problem, then proceed with cleaning.

After performing a chemical cleaning, perform a mechanical cleaning on both the anode and cathode.

Mechanical cleaning: In order to sand the silver anode along the shaft of the sensor, remove the membrane and hold the sensor in a vertical position. Wet 400 grit wet/dry sand paper with a small amount of clean water then gently wrap it around the sensor anode and twist it a few times to lightly sand the anode (the goal is to sand off any build-up without scratching or removing layers of the anode itself). Usually, 3 to 4 twists of the sanding disk are sufficient to remove deposits. However, in extreme cases, more sanding may be required to remove all of the deposits.

After completing the sanding procedure, repeatedly rinse the electrode with clean water and wipe with lens cleaning tissue to remove any grit left by the sanding disk. Thoroughly rinse the entire tip of the sensor with distilled or deionized water and install a new membrane.

Gold Cathode:

For correct sensor operation, the gold cathode must be textured properly. It can become tarnished or plated with silver after extended use. Never use chemicals or abrasives not recommended or supplied by YSI.

First dry the sensor tip completely with lens cleaning tissue. Wet 400 grit wet/dry sand paper with a small amount of clean water and place it face up in the palm of your hand. Next, with your free hand, hold the sensor in a vertical position, tip down. Place the sensor tip directly down on the sanding disk and twist it in a circular motion to sand the gold cathode. The goal is to sand off any build-up and to lightly scratch the cathode to provide a larger surface area for the electrolyte solution under the membrane. Usually, 3 to 4 twists of the sanding disk are sufficient to remove deposits and for the gold to appear to have a matte finish. Rinse thoroughly and wipe the gold cathode with a wet paper towel before putting on a new membrane cap.

Note: Be sure to: (1) Only use fine 400 grit wet/dry sand paper and (2) Sand as mentioned in the above procedures. Not adhering to either of these instructions can damage the electrodes. If this procedure is unsuccessful, as indicated by improper DO sensor performance, contact your local YSI Representative or a YSI Authorized Service Center.

Galvanic Sensors – Model # 605202

The Galvanic dissolved oxygen sensor is continuously reducing oxygen even when the Pro Plus is turned off. This factor allows the sensor to be used with no warm-up time as soon as the instrument is powered on. However, because the sensor is "on" all the time, some solid from the oxidation of the zinc anode will form in the electrolyte within 1-2 weeks of activation. The Galvanic electrolyte solution will appear milky white after use but this will not affect the accuracy of the sensor unless there is excessive build up which may result in jumpy readings. Otherwise, the color change is acceptable and normal as long as DO readings remain stable. The rate of solid formation is dependent on the type of membrane installed. The formation of solids typically form more rapidly with the 5912 (black 1 mil Teflon), less rapid with 5913 (yellow 1.25 mil PE), and least rapid with 5914 (blue 2 mil PE).

When changing the membrane, rinse the anode and cathode with distilled or deionized water and wipe with a clean paper towel. If white deposits are evident on the anode after rinsing and wiping, remove the deposits by sanding the anode with 400 grit wet/dry sand paper following the "Mechanical Cleaning" instructions under the Polarographic Silver Anode maintenance section. If there are deposits on the cathode, sand the cathode with 400 grit wet/dry sand paper following the maintenance instructions listed for the Polarographic Gold Cathode.

Note: Do not perform the Polarographic chemical cleaning on a Galvanic sensor.

If this procedure is unsuccessful, as indicated by improper sensor performance, contact your local YSI Representative or a YSI Authorized Service Center.

Ammonium

The ammonium sensor should be calibrated every day the instrument is used. The ammonium sensor should only be used in fresh water (salinity < 2 ppt) and to depths of 55 feet (17 meters) of water.

Ammonia is calculated from the ammonium, temperature and pH readings. pH greatly affects the ammonia calculation. Therefore, for highest accuracy in the ammonia calculation, be sure to use a pH sensor in conjunction with an ammonium sensor during measurements. If a pH sensor is not in use, the instrument will assume the sample is neutral (pH 7) for the calculation.

CALIBRATION TIPS

1. If using an ammonium sensor with either a pH or ORP sensor on a 6051010 or Quatro cable, install the pH or ORP sensor in port 1 and the ammonium sensor in port 2.
2. If using an ammonium sensor on a 6051010 or Quatro cable, calibrate the sensor in port 1 prior to calibrating the sensor in port 2. The sensor in port 2 uses the reference of the sensor installed in port 1. Therefore, it is important to verify that the sensor in port 1 is working properly before calibrating the sensor in port 2. See ammonium Troubleshooting Tips for additional information on port configuration.
3. Exposure to the high ionic content of pH buffers can cause a significant, but temporary, drift in the ammonium sensor. Therefore, if calibrating a pH sensor, either:
    a. Remove the ammonium sensor from the cable bulkhead and plug the port. After pH calibration is complete, reinstall the ammonium sensor and proceed with its calibration with no stabilization delay.

    Or,

    b. Calibrate pH first, immersing both sensors in the pH buffers. After calibrating pH, place the sensors in 100 mg/L ammonium standard and monitor the reading. Usually, the reading starts low and may take awhile to reach a stable value. When it does, proceed with the calibration. This may take several hours.
4. The ammonium sensor can be calibrated with up to three calibration points. For highest accuracy, perform a two point calibration with 1 and 100 mg/L standards within 10°C of your sample temperature.
5. Rinse the sensors and cal cup with a small amount of ammonium solution (1 mg/L for the first point and 100 mg/L for the second point). Fill the cup so that the ammonium sensor tip and the temperature sensor are submerged in solution. If using a Quatro cable or 6051030 cable, ensure that the conductivity sensor is also submerged in the calibration solution. The salinity reading from the conductivity sensor is used in the algorithm for the ammonium measurement.
6. After entering the calibration screen, change the calibration value if necessary.
7. If not using a conductivity sensor, enter the salinity value of the calibration standard. After calibration, change the salinity correction value to the salinity value of the water you will be testing in the field in order to obtain the most accurate ammonium measurement. You can change the salinity correction value in the Sensor menu. As mentioned, the Ammonium sensor should only be used in fresh water salinity < 2 ppt). The salinity of fresh water is typically 0 to 0.5 ppt.
8. Record the NH_4 millivolts for each calibration point. The acceptable mV outputs for each calibration solution are shown below.

    NH_4 1 mg/L = 0 mV +/- 20 mV (new sensor only)

    NH_4 100 mg/L = 90 to 130 mV > 1 mg/L mV value

    - The mV span between 1 mg/L and 100 mg/L values should be $\approx$ 90 to 130 mV. The slope should be 45 to 65 mV per decade.
9. Wait for the ammonium and temperature readings to stabilize in each calibration solution and then press enter to accept each calibration point.
10. Rinse the sensor and cal cup between calibration points with a small amount of the next buffer.
11. After pressing enter to accept your last calibration point, press cal (Cal) to complete the calibration. Otherwise you will continue calibrating up to 3 calibration points.

12. If you receive a warning message stating that the calibration is questionable, do not continue with the calibration. Instead, select 'No' and investigate what is causing the questionable results. If you accept a questionable calibration, your ammonium and ammonia readings will be erroneous. Typical causes for this error message include: incorrect Sensor/Port setup in the instrument, a dirty sensor or bad buffer solution.

Preparing Ammonium Calibration solution

We recommend using YSI calibration solutions whenever possible. However, qualified users can save cost by following these recipes for 1 and 100 mg/L standards. Other concentrations can be made by altering the amount of ammonium chloride. All other ingredient concentrations should remain unchanged. It is important to note that some of these chemicals are hazardous and therefore, the standards should only be prepared by qualified chemists in laboratories where proper safety precautions are possible. It is the responsibility of the user to obtain and study the MSDS for each chemical and to follow the required instructions with regard to handling and disposal of these materials.

You will need: solid Ammonium Chloride or a certified 100 mg/L NH_4^+-N from a supplier, Lithium Acetate Dihydrate, concentrated hydrochloric acid, high purity water, a good quality analytical balance, a 1000 ml volumetric flask, accurate volumetric measuring devices for 100 ml and 10 ml of solution, and a 1000 ml glass or plastic storage vessels. **(Caution: Hydrochloric acid is highly corrosive and toxic and should therefore be handled with extreme care in a well-ventilated fume hood. The user could also add the equivalent amount of a less-hazardous, more dilute sample of the acid if preferred.)**

100 mg/L Standard: Accurately weigh 0.3817 g of ammonium chloride and transfer quantitatively into a 1000 ml volumetric flask. Add 2.6 g of lithium acetate dihydrate to the flask. Add approximately 500 ml of distilled or deionized water to the flask, swirl to dissolve all of the reagents and then dilute to the volumetric mark with distilled or deionized water. Mix well by repeated inversion and then transfer the 100 mg/L standard to a storage bottle. Add 3 drops of concentrated hydrochloric acid to the bottle, then seal and agitate to assure homogeneity. Alternatively, 100 ml of certified 100 mg/L NH_4^+-N standard can be used in place of the solid ammonium chloride.

1 mg/L Standard: Accurately measure 10.0 ml of the above 100 mg/L standard solution into a 1000 ml volumetric flask. Add 2.6 g of lithium acetate dihydrate to the flask. Add approximately 500 ml of distilled or deionized water, swirl to dissolve the solid reagents and then dilute to the volumetric mark with water. Mix well by repeated inversion and then transfer the 1 mg/L standard to a storage bottle. Add 3 drops of concentrated hydrochloric acid to the bottle, then seal and agitate to assure homogeneity.

TROUBLESHOOTING TIPS

Typical working life for ammonium sensors is approximately 3-6 months depending on use, storage and maintenance. Proper storage and maintenance generally extends the sensor's working life.

If you get error messages during an ammonium calibration, check the following:

1. Ensure the ammonium solutions are good and not expired
2. Ensure that the ammonium sensor is installed in the correct port of the cable and the correct ISE is enabled in the Sensor Setup menu.
    a. If using an ammonium sensor in a 6051020 cable, ensure the sensor is installed in port 1.
    b. If using an ammonium sensor in a 60510, 6051020 or 6051030 cable, ammonium should be enabled in ISE1 in the instrument's Sensor Setup menu.
    c. If using an ammonium sensor in a 6051010 or Quatro cable, check to see if the ammonium sensor is installed in the port 1 or port 2. If the ammonium sensor is installed in port 1, enable ammonium in ISE1 of the Sensor Setup menu. If the ammonium sensor is installed in port 2, enable ammonium in ISE2 of the Sensor Setup menu. Note: If using with a pH or ORP sensor, it is recommended to install the pH or ORP sensor in port 1 and the ammonium sensor in port 2.

3. If using a 6051010 or Quatro cable, you must have a sensor installed in port 1 for port 2 to operate. Additionally, ensure that the sensor installed in port 1 is in good working order. In 6051010 and Quatro cables, the sensors installed in port 1 and port 2 use the reference from the sensor installed in port 1 only. Therefore, if the sensor installed in port 1 is not working properly, the readings from the sensor installed in port 2 will be erroneous as well.
4. If you continue to get error messages during calibration, clean the sensor.
5. If you continue to get error messages during calibration, soak the sensor in 100 mg/L ammonium standard for several hours or overnight.
6. If you suspect port contamination, follow the instructions in the Cleaning a Sensor Port section.
7. If you continue to have trouble calibrating the ammonium sensor, contact your local YSI Representative or a YSI Authorized Service Center.

Cleaning the Ammonium Sensor

The ammonium sensor uses a PVC membrane. As always, when handling a sensor, care should be taken to avoid damaging the membrane. After extensive use, the membranes may become coated with a deposit or scoured with fine scratches which may cause a slow or reduced response (low slope) or unstable readings. Deposits may be removed with a fine jet of deionized water or rinsing in alcohol followed by soaking in 100 mg/L ammonium calibration standard.

The sensor may require soaking in the high ammonium calibration solution to recover its performance. Soak in 100 mg/L for several hours or overnight.

Nitrate

The nitrate sensor should be calibrated every day the instrument is used. The nitrate sensor should only be used in fresh water (salinity < 2 ppt) and to depths of 55 feet (17 meters) of water.

CALIBRATION TIPS

1. If using a nitrate sensor with either a pH or ORP sensor on a 6051010 or Quatro cable, install the pH or ORP sensor in port 1 and the nitrate sensor in port 2.
2. If using a nitrate sensor on a 6051010 or Quatro cable, calibrate the sensor in port 1 prior to calibrating the sensor in port 2. The sensor in port 2 uses the reference of the sensor installed in port 1. Therefore, it is important to verify that the sensor in port 1 is working properly before calibrating the sensor in port 2. See nitrate Troubleshooting Tips for additional information on port configuration.
3. Exposure to the high ionic content of pH buffers can cause a significant, but temporary, drift in the nitrate sensor. Therefore, if calibrating a pH sensor, either:
    a. Remove the nitrate sensor from the cable bulkhead and plug the port. After pH calibration is complete, reinstall the nitrate sensor and proceed with its calibration with no stabilization delay.

    Or

    b. Calibrate pH first, immersing both sensors in the pH buffers. After calibrating pH, place the sensors in 100 mg/L nitrate standard and monitor the reading. Usually, the reading starts low and may take awhile to reach a stable value. When it does, proceed with the calibration. This may take several hours.
4. The nitrate sensor can be calibrated with up to three calibration points. For highest accuracy, perform a two point calibration with 1 and 100 mg/L standards within 10°C of your sample temperature.
5. Rinse the sensors and cal cup with a small amount of nitrate solution (1 mg/L for the first point and 100 mg/L for the second point). Fill the cup so that the nitrate sensor tip and the temperature sensor are submerged in solution. If using a Quatro cable or 6051030 cable, ensure that the conductivity sensor is also submerged in the calibration solution. The salinity reading from the conductivity sensor is used in the algorithm for the nitrate measurement.
6. After entering the calibration screen, change the calibration value if necessary.
7. If not using a conductivity sensor, enter the salinity value of the calibration standard. After calibration, change the salinity correction value to the salinity value of the water you will be testing in the field in order to obtain the most accurate nitrate measurement. You can change the salinity correction value in the Sensor menu. As mentioned, the nitrate sensor should only be used in fresh water (salinity < 2 ppt). The salinity of fresh water is typically 0 to 0.5 ppt.
8. Record the NO_3 millivolts for each calibration point. The acceptable mV outputs for each calibration solution are shown below.

    NO_3 1 mg/L = 200 mV +/- 20 mV (new sensor only)

    NO_3 100 mg/L = 90 to 130 mV < 1 mg/L mV value

    - The mV span between 1 mg/L and 100 mg/L values should be $\approx$ 90 to 130 mV. The slope should be -45 to -65 mV per decade.
9. Wait for the nitrate and temperature readings to stabilize in each calibration solution and then press enter to accept each calibration point.
10. Rinse the sensor and cal cup between calibration points with a small amount of the next buffer.
11. After pressing enter to accept your last calibration point, press cal (Cal) to complete the calibration. Otherwise you will continue calibrating up to 3 calibration points.
12. If you receive a warning message stating that the calibration is questionable, do not continue with the calibration. Instead, select 'No' and investigate what is causing the questionable results. If you accept a questionable calibration, your nitrate readings will be erroneous. Typical causes for this error message include: incorrect Sensor/Port setup in the instrument, a dirty sensor or bad buffer solution.

Preparing Nitrate Calibration Solution

We recommend using YSI calibration solutions whenever possible. However, qualified users can save cost by following these recipes for 1 and 100 mg/L nitrate standards. Other concentrations can be made by altering the amount of potassium nitrate. All other concentrations should remain unchanged. It is important to note that some of these chemicals are hazardous and therefore, the standards should only be prepared by qualified chemists in laboratories where proper safety precautions are possible. It is the responsibility of the user to obtain and study the MSDS for each chemical and to follow the required instructions with regard to handling and disposal of these materials.

You will need: Solid Potassium Nitrate or a certified 1000 mg/l NO^-_3-N from a supplier, Magnesium Sulfate, high purity water, good quality analytical balance, 1000 ml volumetric flask, accurate volumetric measuring devices for 100 ml, 10 ml and 1 ml of solution, and 1000 ml glass or plastic storage vessels.

100 mg/L standard: Accurately weigh 0.7222 g of anhydrous potassium nitrate and transfer quantitatively into a 1000 ml volumetric flask. Add 1.0 g of anhydrous magnesium sulfate to the flask. Add approximately 500 ml of water to the flask, swirl to dissolve all of the reagents, and then dilute to the volumetric mark with distilled or deionized water. Mix well by repeated inversion and then transfer the 100 mg/L standard to a storage bottle. Rinse the flask extensively with water prior to its use in the preparation of the 1 mg/l standard. Alternatively, 100 mL of certified 1000 mg/L NO^-_3-N standard can be used in place of the solid potassium nitrate.

1 mg/L standard: Accurately measure 10.0 mL of the above 100 mg/L standard solution into a 1000 mL volumetric flask. Add 1.0 g of anhydrous magnesium sulfate to the flask. Add approximately 500 mL of distilled or deionized water, swirl to dissolve the solid reagents, and then dilute to the volumetric mark with water. Mix well by repeated inversion and then transfer the 1 mg/L standard to a storage bottle.

Recipes are given for 1 and 100 mg/L. Other concentrations can be made by altering the amount of potassium nitrate. All other concentrations should remain unchanged.

TROUBLESHOOTING TIPS

Typical working life for nitrate sensors is approximately 3-6 months depending on use, storage and maintenance. Proper storage and maintenance generally extends the sensor's working life.

If you get error messages during a nitrate calibration, check the following:

1. Ensure the nitrate solutions are good and not expired
2. Ensure that the nitrate sensor is installed in the correct port of the cable and the correct ISE is enabled in the Sensor Setup menu.
    a. If using a nitrate sensor in a 6051020 cable, ensure the sensor is installed in port 1.
    b. If using a nitrate sensor in a 60510, 6051020 or 6051030 cable, nitrate should be enabled in ISE1 of the instrument's Sensor Setup menu.
    c. If using a nitrate sensor in a 6051010 or Quatro cable, check to see if the nitrate sensor is installed in port 1 or port 2. If the nitrate sensor is installed in port 1, enable nitrate in ISE1 of the Sensor Setup menu. If the nitrate sensor is installed in port 2, enable nitrate in ISE2 of the Sensor Setup menu. Note: If using with a pH or ORP sensor, it is recommended to install the pH or ORP sensor in port 1 and the nitrate sensor in port 2.
3. If using a 6051010 or Quatro cable, you must have a sensor installed in port 1 for port 2 to operate. Additionally, ensure that the sensor installed in port 1 is in good working order. In 6051010 and Quatro cables, the sensors installed in port 1 and port 2 use the reference from the sensor installed in port 1 only. Therefore, if the sensor installed in port 1 is not working properly, the readings from the sensor installed in port 2 will be erroneous as well.

4. If you continue to get error messages during calibration, clean the sensor.
5. If you continue to get error messages during calibration, soak the sensor in 100 mg/L nitrate standard for several hours or overnight.
6. If you suspect port contamination, follow the instructions in the Cleaning a Sensor Port section.
7. If you continue to have trouble calibrating the nitrate sensor, contact your local YSI Representative or a YSI Authorized Service Center.

Cleaning and Reconditioning the Nitrate Sensor

The nitrate sensor uses a PVC membrane. As always, when handling a sensor, care should be taken to avoid damaging the membrane. After extensive use the membranes may become coated with a deposit or scoured with fine scratches which may cause a slow or reduced response (low slope) or unstable readings. Deposits may be removed with a fine jet of deionized water or rinsing in alcohol followed by soaking in 100 mg/L nitrate calibration standard.

The sensor may require soaking in the high nitrate calibration solution to recover its performance. Soak in 100 mg/L for several hours or overnight.

Chloride

The chloride sensor should be calibrated every day the instrument is used. The chloride sensor should only be used in fresh water (salinity < 2 ppt) and to depths of 55 feet (17 meters) of water.

CALIBRATION TIPS

1. If using a chloride sensor with either a pH or ORP sensor on a 6051010 or Quatro cable, install the pH or ORP sensor in port 1 and the chloride sensor in port 2.
2. If using a chloride sensor on a 6051010 or Quatro cable, calibrate the sensor in port 1 prior to calibrating the sensor in port 2. The sensor in port 2 uses the reference of the sensor installed in port 1. Therefore, it is important to verify that the sensor in port 1 is working properly before calibrating the sensor in port 2. See Chloride Troubleshooting Tips for additional information on port configuration.
3. Exposure to the high ionic content of pH buffers can cause a significant, but temporary, drift in the chloride sensor. Therefore, if calibrating a pH sensor, either:
    c. Remove the chloride sensor from the cable bulkhead and plug the port. After pH calibration is complete, reinstall the chloride sensor and proceed with its calibration with no stabilization delay.

    Or,

    d. Calibrate pH first, immersing both sensors in the pH buffers. After calibrating pH, place the sensors in 1,000 mg/L chloride standard and monitor the reading. Usually, the reading starts low and may take awhile to reach a stable value. When it does, proceed with the calibration. This may take several hours.
4. The chloride sensor can be calibrated with up to three calibration points. For highest accuracy, perform a two point calibration with 10 and 1000 mg/L standards within 10°C of your sample temperature.
5. Rinse the sensors and cal cup with a small amount of chloride solution (10 mg/L for the first point and 1,000 mg/L for the second point). Fill the cup so that the chloride sensor tip and the temperature sensor are submerged in solution. If using a Quatro cable or 6051030 cable, ensure that the conductivity sensor is also submerged in the calibration solution. The salinity reading from the conductivity sensor is used in the algorithm for the chloride measurement.
6. After entering the calibration screen, change the calibration value if necessary.
7. If not using a conductivity sensor, enter the salinity value of the calibration standard. After calibration, change the salinity correction value to the salinity value of the water you will be testing in the field in order to obtain the most accurate chloride measurement. You can change the salinity correction value in the Sensor menu. As mentioned, the chloride sensor should only be used in fresh water (salinity < 2 ppt). The salinity of fresh water is typically 0 to 0.5 ppt.
8. Record the Cl millivolts for each calibration point. The acceptable mV outputs for each calibration solution are shown below.

    Cl 10 mg/L = 225 mV +/- 20 mV (new sensor only)

    Cl 1,000 mg/L = 80 to 130 mV < 10 mg/L mV value

    - The mV span between 10 mg/L and 1000 mg/L values should be ≈ 80 to 130 mV. The slope should be -40 to -65 mV per decade.
9. Wait for the chloride and temperature readings to stabilize in each calibration solution and then press enter to accept each calibration point.
10. Rinse the sensor and cal cup between calibration points with a small amount of the next buffer.
11. After pressing enter to accept your last calibration point, press cal (Cal) to complete the calibration. Otherwise you will continue calibrating up to 3 calibration points.
12. If you receive a warning message stating that the calibration is questionable, do not continue with the calibration. Instead, select 'No' and investigate what is causing the questionable results. If you accept a questionable calibration, your chloride readings will be erroneous. Typical causes for this error message include: incorrect Sensor/Port setup in the instrument, a dirty sensor or bad buffer solution.

Preparing Chloride Calibration Solution

The following recipes are provided for preparation of 10 and 1000 mg/L chloride reagents.

It is important to note that some of the chemicals required for these solutions could be hazardous under some conditions. It is the responsibility of the user to obtain and study the MSDS for each chemical and to follow the required instructions with regard to handling and disposal of these chemicals.

You will need: Solid sodium chloride or a certified 1000 mg/L chloride solution from a supplier, magnesium sulfate, high purity water, a good quality analytical balance, 1000 ml volumetric flask, an accurate 10 ml measuring devices, and 1000 ml glass or plastic storage vessels.

1000 mg/L standard: Accurately weigh 1.655 grams of anhydrous sodium chloride and transfer into a 1000 ml volumetric flask. Add 0.5 grams of anhydrous magnesium sulfate to the flask. Add 500 ml of distilled or deionized water to the flask, swirl to dissolve all of the reagents, and then dilute to the volumetric mark with water. Mix well by repeated inversion and then transfer the 1000 mg/L standard to a storage bottle. Rinse the flask extensively with water prior to its use in the preparation of the 10 mg/L standard. Alternatively, simply add 0.5 grams of magnesium sulfate to a liter of a 1000 mg/L chloride standard from a certified supplier.

10 mg/L standard: Accurately measure 10 ml of the above 1000 mg/L standard solution into a 1000 ml volumetric flask. Add 0.5 grams of anhydrous magnesium sulfate to the flask. Add 500 ml of distilled or deionized water, swirl to dissolve the solid reagents, and then dilute to the volumetric mark with water. Mix well by repeated inversion and then transfer the 10 mg/L standard to a storage bottle.

TROUBLESHOOTING TIPS

Typical working life for chloride sensors is approximately 3-6 months depending on use, storage and maintenance. Proper storage and maintenance generally extends the sensor's working life.

If you get error messages during a chloride calibration, check the following:

1. Ensure the chloride solutions are good and not expired
2. Ensure that the chloride sensor is installed in the correct port of the cable and the correct ISE is enabled in the Sensor Setup menu.
    a. If using a chloride sensor in a 6051020 cable, ensure the sensor is installed in port 1.
    b. If using a chloride sensor in a 60510, 6051020 or 6051030 cable, chloride should be enabled in ISE1 of the instrument's Sensor Setup menu.
    c. If using a chloride sensor in a 6051010 or Quatro cable, check to see if the chloride sensor is installed in port 1 or port 2. If the chloride sensor is installed in port 1, enable chloride in ISE1 of the Sensor Setup menu. If the chloride sensor is installed in port 2, enable chloride in ISE2 of the Sensor Setup menu. Note: If using with a pH or ORP sensor, it is recommended to install the pH or ORP sensor in port 1 and the chloride sensor in port 2.
3. If using a 6051010 or Quatro cable, you must have a sensor installed in port 1 for port 2 to operate. Additionally, ensure that the sensor installed in port 1 is in good working order. In 6051010 and Quatro cables, the sensors installed in port 1 and port 2 use the reference from the sensor installed in port 1 only. Therefore, if the sensor installed in port 1 is not working properly, the readings from the sensor installed in port 2 will be erroneous as well.
4. If you continue to get error messages during calibration, clean the sensor.
5. If you continue to get error messages during calibration, soak the sensor in 1000 mg/L chloride standard for several hours or overnight.
6. If you suspect port contamination, follow the instructions in the Cleaning a Sensor Port section.
7. If you continue to have trouble calibrating the chloride sensor, contact your local YSI Representative or a YSI Authorized Service Center.

Cleaning and Reconditioning the Chloride Sensor

The chloride sensor is considered a pellet membrane ISE. As always, when handling sensors, care should be taken to avoid damaging the membrane. This sensor can be regenerated by washing with alcohol and/or gently polishing with fine emery paper in a circular motion to remove any deposits or discoloration, then thoroughly washing with deionized water to remove any debris.

The sensor may require soaking in the high chloride calibration solution to recover its performance. Soak in 1000 mg/L for several hours or overnight.

Installing and Uninstalling Sensors

GENERAL PRECAUTIONS

It is important that the entire sensor connector and cable connector be dry when installing, removing or replacing sensors. This will prevent water from entering the port. Once a sensor is removed, examine the connector inside the port. If any moisture is present, use compressed air to completely dry the connector or place directly in front of a steady flow of fresh air. If you suspect port contamination, follow the port cleaning procedures listed under Cleaning a Sensor Port.

Remove sensors upside down (facing the ground) to help prevent water from entering the port upon removal.

The instrument utilizes o-rings as seals to prevent water from entering the sensor ports. When the sensors are removed, the o-rings that provide the seal should be carefully inspected for contamination (e.g. debris, grit, etc.) and cleaned if necessary.

If no dirt or damage to the o-rings is evident, wipe the o-rings with a lint free cloth or lens cloth to remove the old o-ring grease. Then, lightly apply new o-ring grease (provided in the maintenance kit) to the o-rings without removing them from their groove. If there is any indication of damage, the o-ring should be replaced with an identical o-ring. At the time of o-ring replacement, the entire o-ring assembly should be cleaned.

Do not over-grease the o-rings. The purpose of the o-ring grease it to keep the o-ring in good condition. Excess grease may collect grit particles that can compromise the seal. Excess grease can also cause the waterproofing capabilities of the o-ring to diminish, potentially causing leaks. If excess grease is present, remove it using a lens cloth or lint-free cloth.

To remove the o-rings:
Use a small, flat-bladed screwdriver or similar blunt-tipped tool to remove the o-ring from its groove. Do not use a sharp object to remove the o-rings. Using a sharp object could damage the o-ring groove which would allow water to enter the port resulting in permanent damage to the port and sensor. Check the o-ring and the groove for any excess grease or contamination. If contamination is evident, clean the o-ring and nearby plastic parts with lens cleaning tissue or equivalent lint-free cloth. Alcohol can be used to clean the plastic parts, but use only water and mild detergent on the o-ring itself. Using alcohol on o-rings may cause a loss of elasticity and may promote cracking. Also, inspect the o-rings for nicks and imperfections.

Before re-installing the o-rings, make sure to use a clean workspace, clean hands, and avoid contact with anything that may leave fibers on the o-ring or grooves. Even a very small amount of contamination (hair, grit, etc.) may cause a leak.

To re-install the o-rings:
Place a small amount of o-ring grease between your thumb and index finger. Draw the o-ring through the grease while pressing the fingers together to place a very light covering of grease to the o-ring. Place the o-ring into its groove making sure that it does not twist or roll. Do no excessively stretch the o-ring during installation.

Use your grease-coated finger to once again lightly go over the mating surface of the o-ring.

Do not over-grease the o-rings. The excess grease may collect grit particles that can compromise the seal. Excess grease can also cause the waterproofing capabilities of the o-ring to diminish, potentially causing leaks. If excess grease is present, remove it using a lens cloth or lint-free cloth.

UNINSTALLING DO, PH, ORP, PH/ORP AND ISE SENSORS

First, ensure that the entire sensor and cable bulkhead are clean and dry. Remove sensors upside down (facing the ground) to help prevent water from entering the port upon removal.

Simply unscrew the sensor from the cable by holding the sensor port end of the cable (bulkhead) in one hand and the sensor in the other hand. Twist the sensor counter-clockwise to unscrew the sensor from the port.

INSTALLING DO, PH, ORP, PH/ORP AND ISE SENSORS

First, ensure both the sensor connector and sensor port on the cable are clean and dry. If any moisture is present, use compressed air to completely dry the connector or place directly in front of a steady flow of fresh air. If you suspect port contamination, follow the port cleaning procedures listed under Cleaning a Sensor Port.

To connect the sensor, grasp the sensor with one hand and the sensor port end of the cable (bulkhead) in the other. Push the sensor into the connector on the cable until it is properly seated and only one o-ring is visible. Failure to properly seat the sensor may result in damage. Twist the sensor clockwise to engage threads and finger tighten. Do not use a tool. This connection is waterproof. Please refer to the sensor installation sheet that is included with each sensor for detailed instructions.

UNINSTALLING A CONDUCTIVITY/TEMPERATURE SENSOR IN A QUATRO CABLE

First, ensure that the entire sensor and cable bulkhead are clean and dry. Remove sensors upside down (facing the ground) to help prevent water from entering the port upon removal.

Remove the conductivity/temperature sensor using the installation tool to loosen the stainless steel retaining nut. Insert the tool into one of the holes in the stainless steel retaining nut. Next, use the installation tool to turn the stainless steel retaining nut counter-clockwise to loosen. Do not allow the sensor to be turned with the tool. Turning the sensor with the tool will likely damage the sensor connector. Once the stainless steel retaining nut has been completely loosened from the bulkhead, remove the sensor from the bulkhead by pulling the sensor straight out of the port.

INSTALLING A CONDUCTIVITY/TEMPERATURE SENSOR IN A QUATRO CABLE

First, ensure both the sensor connector and sensor port on the cable are clean and dry. If any moisture is present, use compressed air to completely dry the connector or place directly in front of a steady flow of fresh air. If you suspect port contamination, follow the port cleaning procedures listed under Cleaning a Sensor Port.

1. Align the connectors of the sensor and the port. With connectors aligned, push the sensor in towards the bulkhead until you feel the sensor seat in its port. You will experience some resistance as you push the sensor inward, this is normal
2. Once you feel the sensor seat into the port, gently rotate the stainless steel sensor nut clockwise with your fingers, do not use the tool.
3. The nut must be screwed in by hand. If the nut is difficult to turn, STOP, as this may indicate cross threading. If you feel resistance or cross threading at any point, unscrew the nut and try again until you are able to screw the nut down completely without feeling any resistance. Damage to your cable/sensor may occur if you force the parts together.
4. Once completely installed, the nut will seat flat against the bulkhead. At this point, use the installation tool that was included with the sensor to turn the nut an additional ¼ to ½ turn. Do not over tighten.
5. Please refer to the sensor installation sheet that is included with the conductivity/temperature sensor for detailed instructions.

Cleaning a Sensor Port

If you suspect port contamination, you can clean the port on the cable by filling the port with Isopropyl Alcohol for 30 seconds and then dumping it out. Next, allow the port to air dry completely or blow it out with compressed air. Installing a sensor into a port that is not completely dry is likely to cause erratic and erroneous readings.

If the connector is corroded, contact your local YSI Representative or a YSI Authorized Service Center.

Verifying Sensor Accuracy and Calibration

Sensor accuracy and calibration can be verified by immersing a sensor into calibration solution or YSI Confidence Solution®. Compare the readings on the Pro Plus display to the value of the solution. If the readings have drifted more than the accuracy specification of the sensor, perform a calibration before taking field measurements.

YSI Confidence Solution can be used to check the accuracy and calibration of the conductivity, pH and ORP sensors. However, to maintain the highest accuracy of the instrument, it should not be used to perform a calibration.

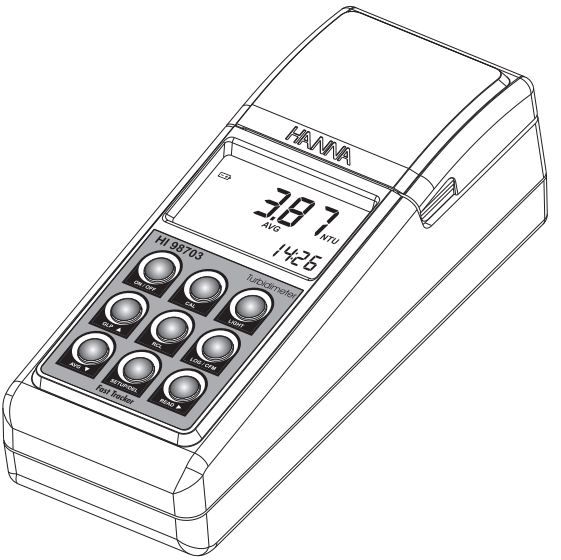
Resetting a Sensor to Factory Default

Occasionally, it may be necessary to reset the instrument to its factory calibration default values. To reset the calibration values, press the Cal key (Cal), highlight **Restore Default Cal** and press enter. Highlight the parameter you wish to reset to default and press enter. Next, you will be asked to confirm the operation. Highlight **Yes** and press enter to confirm.

Instruction Manual

HI 98703

Portable Turbidimeter



HANNA® instruments

www.hannainst.com

Dear Customer,
Thank you for choosing a Hanna Instruments product.
Please read this instruction manual carefully before using this instrument.
This manual will provide you with the necessary information for correct use of this instrument, as well as a precise idea of its versatility.
If you need additional technical information, do not hesitate to e-mail us at tech@hannainst.com or view our worldwide contact list at www.hannainst.com.

WARRANTY

HI 98703 is guaranteed for two years against defects in workmanship and materials when used for its intended purpose and maintained according to instructions. This warranty is limited to repair or replacement free of charge.
Damage due to accidents, misuse, tampering or lack of prescribed maintenance is not covered.
If service is required, contact the dealer from whom you purchased the instrument. If under warranty, report the model number, date of purchase, serial number and the nature of the problem. If the repair is not covered by the warranty, you will be notified of the charges incurred. If the instrument is to be returned to Hanna Instruments, first obtain a Returned Goods Authorization number from the Technical Service department and then send it with shipping costs prepaid. When shipping any instrument, make sure it is properly packed for complete protection.
To validate your warranty, fill out and return the enclosed warranty card within 14 days from the date of purchase.

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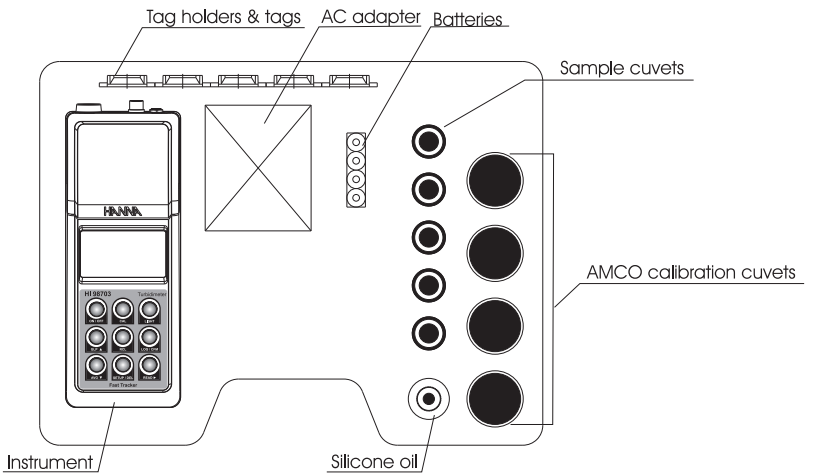
PRELIMINARY EXAMINATION

Please examine this product carefully. Make sure that the instrument is not damaged. If any damage occurred during shipment, please notify your local Hanna Office.

Each **HI 98703** Portable Turbidimeter is supplied complete with:

- Five Sample Cuvettes and Caps
- Calibration Cuvettes (**HI 98703-11**)
- Silicone Oil (**HI 93703-58**)
- Tissue for wiping the cuvettes
- Five Tag holders with Tags (**HI 920005**)
- Batteries (4 pcs.)
- AC Adapter
- Instruction Manual
- Instrument Quality Certificate
- Rigid carrying case



Note: Save all packing material until you are sure that the instrument functions correctly. Any defective item must be returned in its original packing with the supplied accessories.

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GENERAL DESCRIPTION

HI 98703 is a high accuracy EPA compliant portable turbidimeter that benefits from Hanna's years of experience as manufacturer of analytical instruments. The **HI 98703** meets and exceeds the requirements of the **USEPA Method 180.1** for wastewater and **Standard Method 2130 B** for drinking water.

The instrument is specially designed for water quality measurements, providing a reliable and accurate reading on low turbidity values.

The **HI 98703** instrument measures the turbidity of a sample in the 0.00 to 1000 NTU (Nephelometric Turbidity Units) range. An effective algorithm calculates and converts the readings in NTU.

The instrument has an EPA compliance reading mode which rounds the reading to meet EPA reporting requirements.

Depending on the measured probe and needed accuracy, normal measurement, continuous measurement, or signal averaging measurement can be selected.

The instrument is based on a state-of-the-art optical system, which guarantees accurate results. The optical system, consisting in a tungsten filament lamp and two detectors (scattered and transmitted), assures long term stability and minimizes stray light and color interferences. It also compensates for variations in intensity of the lamp, minimizing the need of frequent calibration.

The 25 mm round cuvettes made from special optical glass guarantee the repeatability and consistency of the measurements.

Calibration can be easily performed at any time in two, three ot four points (<0.1, 15, 100 and 750 NTU-adjustable calibration points), using the supplied or user prepared standards.

HI 98703 has complete GLP (Good Laboratory Practice) functions that allows traceability of the calibration conditions. The last calibration points, time and date can be checked at any time by a single touch.

HI 98703 has a very user-friendly interface, with an easy to read, large LCD (Liquid Crystal Display). The displayed codes guide the user step by step with routine operation and through calibration. Confirmation and acoustic signals help the user during instrument operation.

The **HI 98703** turbidimeter is a truly splash proof portable instrument. It is supplied with a rigid carrying case that offers protection for harsh environments.

One battery set is enough for at least 1500 measurements. The battery charging percentage and low battery condition are displayed on the LCD to avoid unexpected battery failure. In order to save the battery life, the instrument has an auto shut-off feature and will turn off after 15 minutes of non-use.

In addition, the instrument is equipped with backlight and the current time is continuously displayed on the LCD.

The instrument also provides a logging function. Up to 200 measurements can be stored in the internal memory and consulted at any time. Data can be downloaded to a PC for storing or further analysis through one of the two available ports: RS232 or USB.

For advanced field applications, the **HI 98703** turbidimeter is equipped with Tag Identification System (TIS) that makes data collecting and management simpler than ever.

TAG IDENTIFICATION SYSTEM

Hanna is the first manufacturer of turbidity instruments that has decided to add the unique T.I.S. - Tag Identification System to our Portable Turbidimeters, to meet the more restrictive needs of the users and fit all advantages of this system to the turbidity measurements and data management.

The system is designed for scientific and industrial applications, or to prove during safety audits and inspections that samples have been truly taken on pre-established locations.

The system is as easy to install as to operate. Just fix the so-called iButton® tags near your sampling sites that need to be checked often, and with this the T.I.S. is setup. The tag contains a computer chip embedded in a durable stainless steel can. It is designed to withstand the harsh environments, indoors or outdoors. The number of tags that can be installed is practically unlimited, because each tag has a unique identification code.

Immediately after tags installation you can start collecting data. Use the Portable Turbidimeter to take measurements and memorize the test result by pressing the Log-on-Demand key. Then, the instrument will ask for the tag identification. Simply touching the iButton® with the matching connector on the Portable Turbidimeter does identify and authenticate logging, by storing the iButton® serial number, time and date stamp.

The power of the T.I.S. features resides in the PC application. Download all test data to your PC and use our **HI 92000** Windows® compatible application software for further data management. You can sort or filter all your collected test data on different criteria like on a specific sampling location, parameter, date and time intervals, or fix range to filter measured values. The data can be plotted in a graph, exported to other common Windows® applications or printed for reporting purpose.

It is also possible to add new tags later on, thus increasing an already existing database. Each time the PC software recognizes a new added tag, it will ask for a description of the new sampling location.

ABBREVIATIONS

NTU	Nephelometric Turbidity Units
JTU	Jackson Turbidity Units
FTU	Formazin Turbidity Units
USEPA	US Environmental Protection Agency
LCD	Liquid Crystal Display
RTC	Real Time Clock
RH	Relative Humidity
TIS	Tag Identification System
ID	Identification

iButton® is registered Trademark of "MAXIM/DALLAS semiconductor Corp."

PRINCIPLE OF OPERATION

Turbidity of the water is an optical property that causes light to be scattered and absorbed, rather than transmitted. The scattering of the light that passes through a liquid is primarily caused by the suspended solids. The higher the turbidity, the greater the amount of scattered light. Because even the molecules in a very pure fluid scatter light to a certain degree, no solution will have zero turbidity.

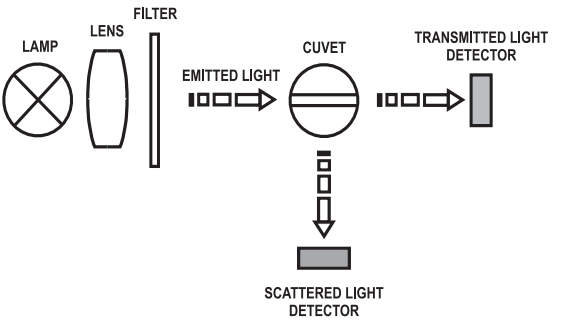
The **USEPA Method 180.1** specify the key parameters for the optical system to measure turbidity for drinking, saline and surface water in a 0 to 40 NTU range, using the nephelometric method.

The **HI 98703** Portable Turbidimeter is designed to meet or exceed the criteria specified by the **USEPA Method 180.1** and **Standard Method 2130 B**.

The light beam that passes through the sample is scattered in all directions. The intensity and pattern of the scattered light is affected by many variables like wavelenght of the incident light, particle size, shape, refractive index and color.

The Hanna's **HI 98703** is based on a state-of-the-art optical system that guarantee both high performance and reliable results.

This optical system includes a tungsten filament lamp, a scattered light detector (90^0) and a transmitted light detector (180^0). The microprocessor of the instrument calculates from the signals that reaches the two detectors, the NTU value, using an effective algorithm. This algorithm corrects and compensates for interferences of color, making the **HI 98703** turbidimeter color-compensated.



The optical system and measuring technique alow the compensation of lamp intensity fluctuations, minimizing the need of frequent calibration.

The lower detection limit of a turbidimeter is determined by the so called "stray light". Stray light is the light detected by the sensors, that is not caused by light scattering from suspended particles. The optical system of **HI 98703** turbidimeter is designed to have very low stray light, providing accurate results for low turbidity samples. However, special care must be taken when measuring low turbidities (see General Tips for an Accurate Measurement for sample preparation and measuring techniques).

MEASUREMENT UNITS

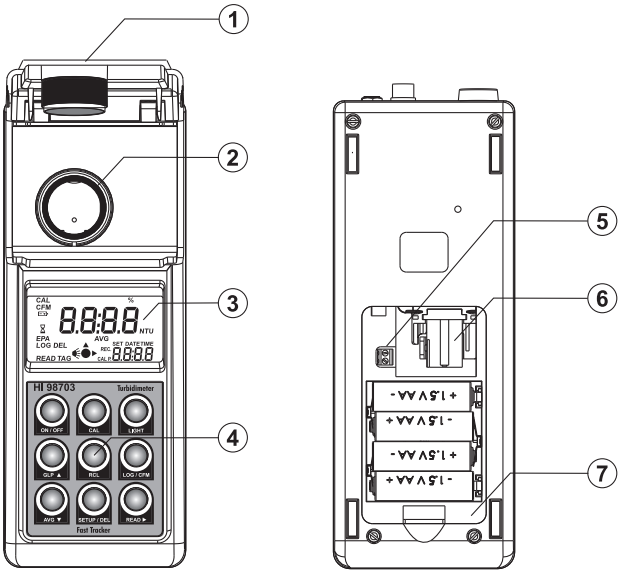
Many methods were used to measure turbidity over the years. The Jackson Candle Turbidimeter was used to measure turbidity as Jackson turbidity units (JTU). The Secchi Disk is commonly used to measure turbidity in lakes and other deep waters (mg/L SiO_2). Both methods are visual and are not considered very accurate. To obtain more accurate readings a nephelometer should be used as a turbidity reading instrument.

The **HI 98703** turbidimeter reports the measurements only in NTU (Nephelometric Turbidity Units). NTU units are equal to FTU units (Formazine Turbidity Units). The conversion table between these measurement units is shown bellow:

	JTU	NTU/FTU	SiO_2 (mg/L)
JTU	1	19	2.50
NTU/FTU	0.053	1	0.13
SiO_2 (mg/L)	0.4	7.5	1

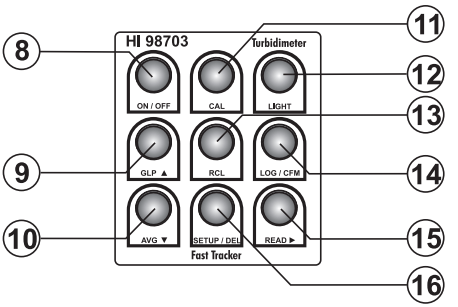
FUNCTIONAL DESCRIPTION

INSTRUMENT DESCRIPTION



1) Cuvette Lid. Close the cuvette lid prior to start a measurement.
2) Cuvette Holder. Insert the cuvette into the holder with the cuvette mark matching the case mark.
3) Liquid Crystal Display (LCD). The LCD has backlight for better visibility in dark environments.
4) Keypad. Splash proof resistant.
5) Lamp connector. Connect the new lamp using a screwdriver during lamp changing procedure.
6) Lamp. Replacable tungsten lamp.
7) Battery Lid. Remove the battery lid in order to change batteries or replace the lamp.

KEYPAD DESCRIPTION



8) **ON/OFF**, press to turn the instrument ON/OFF. If no key is pressed for more than 15 minutes, the instrument automatically shuts off.

9) **GLP ▲**, press to enter/exit GLP feature. In SETUP it is used to increase the set values. In Log Recall it is used to select a newer record (scroll up).

10) **AVG ▼**, press to set the average reading mode ON/OFF. In SETUP it is used to decrease the set values. In Log Recall it is used to select an older record (scroll down).

11) **CAL**, press to enter/exit calibration. During setup it is used to start/stop editing a parameter.

12) **LIGHT**, press to turn ON/OFF the backlight.

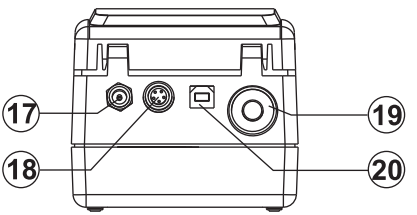
13) **RCL**, press to enter/exit viewing log content.

14) **LOG/CFM**, press to save the log records or to confirm the selected option.

15) **READ ▶**, press to start a measurement. Press and hold, to make a continuous measurement. In Log Recall it is used to see the content of a record. In GLP it is used to see all available informations. In SETUP, during date or time editing, it is used to move the focus on the next setting item.

16) **SETUP/DEL**, press to enter/exit setup. The DEL function is available in Log Recall to delete one or all records. In GLP it is used to delete the user calibration.

CONNECTORS DESCRIPTION



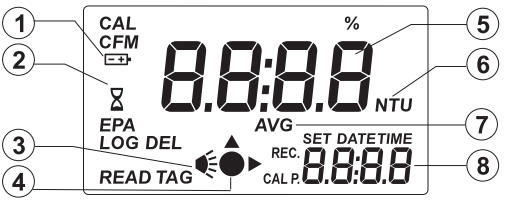
17) AC adapter connector, used to connect an external AC Adapter.

18) RS232 connector, used to transfer data through the RS232 connection. Use **HI 920011** serial cable to connect to the PC.

19) Tag reader connector. Touch the tag with the connector to read the location identification number during logging.

20) USB connector, used to transfer data to the PC.

DISPLAY DESCRIPTION



1) Battery icon. When it is ON, it shows that the instrument works on battery. When blinking, the batteries are almost empty and need to be replaced.
2) Wait icon. It is displayed when the instrument performs an internal checkup.
3) Lamp icon. The lamp icon is shown when the lamp is turned on.
4) Measurement icon. The icon shows the measuring scheme of the instrument.
5) Four digit main display. The main display shows the turbidity value after one measurement. Depending on the instrument working mode, other values or messages are displayed.
6) Measurement units. The turbidity is measured in NTU. When average or continuous mode is selected, the "**NTU**" tag blinks for each new displayed value. For conversions in other units see Measurement Units section.
7) AVG icon. When selected, the measurement will be taken in average mode. The "**NTU**" tag will blink for each new displayed value.
8) Four digit secondary display. The secondary display shows the current time (if selected) or other values/messages.

BEEPER

A beeper is used to make the user interface more friendly. An error or invalid key press is signaled by a long beep. A confirmation beep is signaled by a short beep. The beeper is selectable as ON or OFF in Setup Menu.

SPECIFICATIONS

Range	0.00 to 9.99 NTU 10.0 to 99.9 NTU 100 to 1000 NTU
Range Selection	Automatically
Resolution	0.01 NTU from 0.00 to 9.99 NTU 0.1 NTU from 10.0 to 99.9 NTU 1 NTU from 100 to 1000 NTU
Accuracy	±2% of reading plus 0.02 NTU
Repeatibility	±1% of reading or 0.02 NTU, whichever is greater
Stray Light	< 0.02 NTU
Light Source	Tungsten filament lamp
Lamp Life	Greater than 100,000 readings
Light Detector	Silicon Photocell
Method	Ratio Nephelometric signal (90') scatter light ratio transmitted light Adaptation of the **USEPA Method 180.1** and **Standard Method 2130 B**
Display	60 x 90 mm LCD with backlight
Standards	15, 100 and 750 NTU
Calibration	One, two or three point calibration
LOG Memory	200 records
Serial Interface	RS232 or USB 1.1
Environment	0 to 50 °C (32 to 122 °F); max 95% RH non-condensing
Power supply	4 x 1.5V AA alkaline batteries or AC adapter
Auto Shut-off	After 15 minutes of non-use
Dimensions	224 x 87 x 77 mm (8.8 x 3.4 x 3.0")
Weight	512 g (18 oz.)

GENERAL TIPS FOR AN ACCURATE MEASUREMENT

HI 98703 is a highly accurate turbidimeter. To meet the instrument performance and fully benefit of its properties it is very important that the analyst perform accurate, precise and repeatable readings using proper measurement techniques. Special care must be taken during sample preparation and handling.
The instructions listed below should be carefully followed during measurement and calibration to ensure best accuracy.

CUVETTE

The cuvette is part of the optical system in all measurements. The light reaches the sample by passing through the cuvette glass. As a result, the measurement can be affected by the glass imperfections, dirt, dust, scratches, or fingerprints present on the cuvette surface.

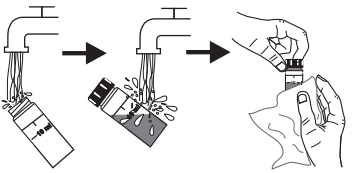
CUVETTE HANDLING

The cuvettes should be free of scratches or cracks. Any cuvette with visible scratches will be discarded. The cuvettes should be periodically washed with acid. After washing, the cuvettes should be well rinsed many times with distilled or deionized water. Allow cuvettes to air-dry and store them for long periods of time with caps, to avoid dirt entering inside. Always handle the cuvette by touching only the cap or its top side (over the horizontal line).

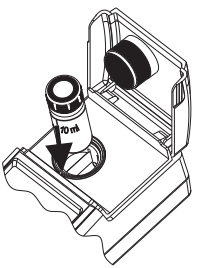
Always store the cuvettes in separate boxes or with separators between them to avoid scratches on the surface.

CUVETTE PREPARATION

Whenever a cuvette is used, it must be clean inside and outside. When it is placed into the instrument, it must be dry outside, completely free of fingerprints or dirt.



If the cuvette is not indexed, put the cuvette with the factory mark aligned with the sign on the instrument top.



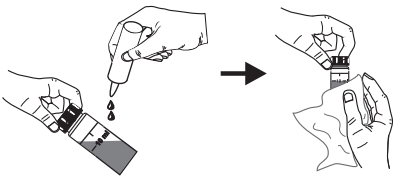
CUVETTE OILING

To hide minor imperfections and scratches, the cuvettes should be oiled outside with the supplied silicone oil. This is very important, especially for low turbidity samples (< 1 NTU), otherwise scratches can contribute and alter turbidity readings.

The silicone oil has the same refractive index as the glass and will not alter the turbidity readings. It is important to apply only a thin layer of silicone oil.

Warning: Do not apply the oil in excess, it may retain dirt or contaminate the cuvette holder of the instrument, altering the turbidity readings.

It is very important to apply the silicone oil on a clean, dry cuvette. Apply a few drops of oil and wipe the cuvette thoroughly with a lint-free cloth. Wipe off the excess of oil till you obtain a thin, uniform layer. If the procedure is correctly followed, the cuvette should appear nearly dry with no visible oil.



Note: The supplied cloth for oiling should be stored together with the silicone oil bottle and cuvettes, taking care to avoid contamination with dirt. After a few oiling procedures the cloth will contain enough oil to wipe the bottle with it without adding more oil. From time to time add some drops of oil on the cuvette to provide the necessary oil quantity in the cloth.

INDEXING A CUVETTE

It is very important for low turbidity readings to always insert the cuvette into the instrument in the same position.

All cuvettes are factory indexed. This index can be used to put the cuvette with the factory mark on the cuvette aligned with the sign on the instrument top.

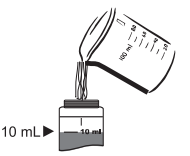
To further reduce the effect of glass imperfections, the cuvette can be indexed and use this new index as the position mark.

For indexing one cuvette or matching multiple cuvettes the continuous reading mode is suggested. In this mode if **READ ▶** is kept pressed, multiple successive readings are taken without turning off the lamp. After first reading is displayed, it is possible to open the cuvette lid and rotate the cuvette without generating an error condition. The turbidity is immediately displayed, reducing drastically the measurement time. The lamp of the instrument will turn off only when **READ ▶** is released.

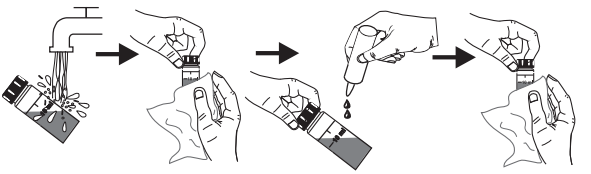
Note: The instrument can not perform continuous readings if the average mode is on.

In order to index a cuvette follow the next steps:

- Fill the cuvette with high quality water (<0.1 NTU) up to the line.

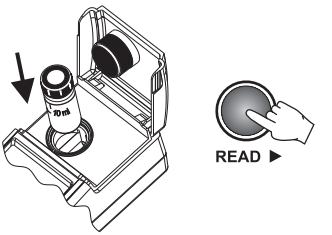


- Clean and oil the cuvette as described before.

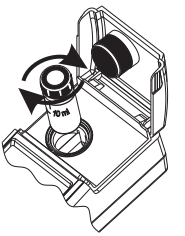


- Turn the instrument ON.

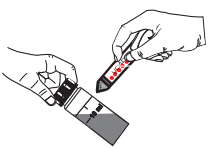
- Insert the cuvette into the instrument and press **READ ▶**. Record the reading.



- Open the instrument lid, slightly rotate the cuvette and take a new reading.



- Repeat the last step until you read the lowest NTU value. Alternatively, keep **READ ▶** pressed and, after the first value is displayed, open the lid and start rotating the cuvette until the lowest NTU value is displayed.
- Mark this position on the thicker white band on the top of the cuvette with a water resistant pencil.
- Always use this position to align it with the sign on the instrument top.

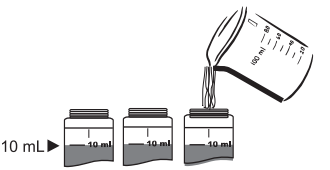


MATCHING MULTIPLE CUVETTES

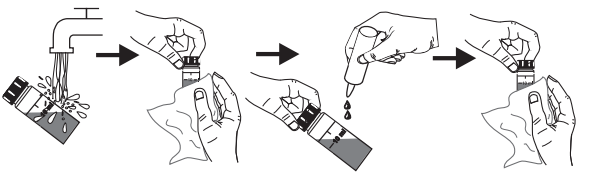
Precise measurements require the use of a single cuvette. If it is not possible, the cuvette selection and matching must be performed before taking measurements.

In order to match multiple cuvettes follow the next steps:

- Fill some cuvettes with high quality water (<0.1 NTU) up to the line.

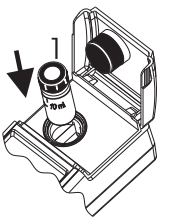


- Clean and oil the cuvettes as described before.



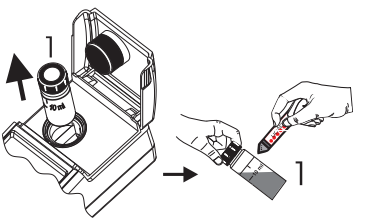
- Turn the instrument ON.

- Insert the first cuvette into the instrument and press **READ** ▶. Record the reading.

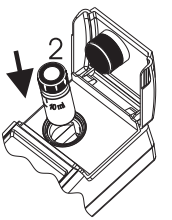


- Record the position of the cuvette and the displayed reading.

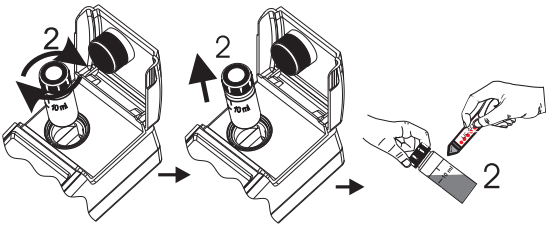
- Mark this position on the thicker white band on the top of the cuvette with a water resistant pencil.



- Insert the second cuvette into the instrument and take a reading.



- Open the instrument lid, slightly rotate the cuvette and take a new reading.



- Repeat the last step for the second cuvette until the reading is within 0.01 NTU of the value obtained for the first cuvette.
- Alternatively, keep **READ ▶** pressed and, after the first value is displayed, open the lid and start rotating the cuvette until the displayed value matches the first cuvette.
- Mark this position on the second cuvette with a water resistant pencil.
- Follow the same procedure for all the necessary cuvettes.

Note: If the cuvette is indexed, use the index to position it in the instrument.

SAMPLING TECHNIQUE

When taking turbidity measurements it is very important to select a representative sample. For consistent results, follow the next tips when sampling:

- Gently mix the water before taking the sample.
- If the sample is taken from a pipe, discard the first few liters.
- If measuring a non uniform source, collect samples from different places and mix them.

When measuring the collected sample, keep in mind the following:

- Samples should be analyzed immediately after collection because the turbidity can change in time.
- To avoid dilution of the sample it is better to rinse the cuvette with a quantity of sample and then discard. Only after this you can fill the cuvette with sample.
- Pay attention that cold samples do not condense on the sample cell.

REMOVING AIR BUBBLES

Any air bubbles present in the sample will cause high turbidity readings. To obtain accurate measurements, remove the air bubbles using one of these methods:

- Application of a partial vacuum;
- Addition of a surfactant, such as Triton X-100;
- Use of an ultrasonic bath;
- Heating the sample.

Sometimes it is necessary to combine two or more methods for efficient air bubble removal.

Note: Each method can alter the sample turbidity, if misused, so they have to be used with caution.

APPLICATION OF VACUUM

Vacuum works by decreasing the atmospheric pressure. In this way the bubbles from the solution came out to the surface.

Application of vacuum is a very simple procedure and can be applied with any vacuum source at hand. The simplest equipment at hand is a syringe and a rubber stopper for vacuum degassing.

Notes:
- Pay attention that the vacuum equipment be clean and oil-free.
- It is not recommended to apply vacuum to a viscous sample that contains volatile components. In such cases the vacuum can determine the volatile component of the viscous sample to increase the bubbles from the sample.

ADDITION OF SURFACTANT

Surfactant addition works by changing the surface tension of the water. In this way bubbles are released from the sample. This method is effective in samples that are supersaturated with air.

The procedure consists in the addition of a drop of surfactant in the cuvette before adding the sample to be analyzed.

A convenient surfactant to use for degassing is Triton X-100.

Warning: Pay attention that changing the surface tension will cause a rapid settling of particles that cause turbidity. To avoid this problem, analyze as soon as possible the sample.

Do not shake vigorously the sample because the surfactant may foam. If you are using the same cuvette, rinse it before adding a new sample in order to avoid surfactant accumulation.

Surfactant contribution to the turbidity readings is negligible.

Note: Surfactant addition should be used for degassing only when other methods are ineffective.

USE OF AN ULTRASONIC BATH

The ultrasonic waves are very effective in removing air bubbles from samples. However, ultrasonic waves should be used with care because they can alter sample turbidity characteristics, by modifying the shape and size of particles which cause turbidity. The ultrasonic waves can also break the existing air bubbles, leading to a complication of the degassing process.

In order to avoid excess application of the ultrasonic waves you can apply ultrasound until all visible air bubbles are removed, and then measure the sample turbidity. This is the most used procedure for degassing.

If you are not sure that all air bubbles were removed, apply ultrasonic waves again for a short period of time and then measure the turbidity. Repeat this procedure until the turbidity is increasing instead of decreasing, sign that turbidity of the sample was altered.

In order to degas a sample fill a clean cuvette with sample and immerse it (1/2 to 2/3 immersed) in an ultrasonic bath. Follow the degassing procedure described above. Only after the degassing procedure is finished, the cuvette can be capped.

HEATING THE SAMPLE

Use of heat to remove air bubbles, although very effective in some cases, should be handled with care because it can alter the turbidity of the sample. When heating a sample, the volatile components from the sample can vaporize, the suspended components can dissolve or the sample characteristics can change.

Therefore, the heating procedure should be used with extreme care.

The best way is to use a warm water bath and immerse the cuvette with sample into the bath. Heat the sample only until the visible bubbles are removed.

Note: Always cool the heated sample to the original sample temperature before measurement.

The heating procedure can be used in combination with vacuum or ultrasonic waves application for a more effective air bubble removal.

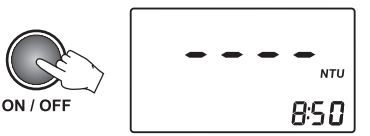
MEASUREMENT PROCEDURE

When taking any turbidity measurements several basic rules should be followed:

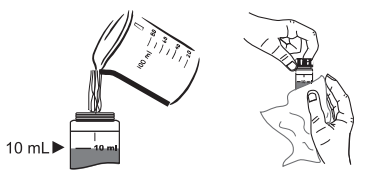
- Use always cuvettes without scratches or cracks because they can cause inaccurate readings.
- Cap always the cuvettes to avoid spillage of the sample into the instrument.
- Close always the lid of the instrument during measurement.
- Keep the lid of the instrument closed when it is not used to prevent dust or dirt entering.
- Put always the instrument on a flat, rugged surface when taking measurements.
- Do not operate in direct sunlight.
- Do not use too much oil to prevent contamination of the optical system.

To take turbidity measurements, follow the next steps:

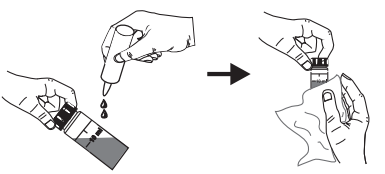
- Turn the instrument ON by pressing **ON/OFF**. When dashes are displayed on the LCD, the instrument is ready. On the secondary LCD the current time appears, if selected in SETUP menu.



- Fill a clean, dry cuvette with 10 mL of sample up to the mark, taking care to handle the cuvette by the top.
- Replace the cap.
- Wipe the cuvette thoroughly with a lint-free cloth to remove any fingerprints, dirt or water spots.

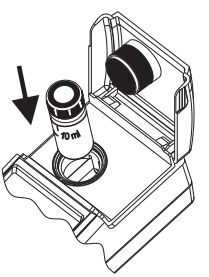


- Apply silicone oil on the cuvette and wipe with a lint-free cloth to obtain an even film over the entire surface of the cuvette.



Note: It is very important to oil the cuvette, especially for low turbidity values (< 1 NTU) to hide the glass imperfections that can influence the reading.

- Place the cuvette into the instrument. Align the mark from the cuvette with the sign on the instrument case and close the lid.

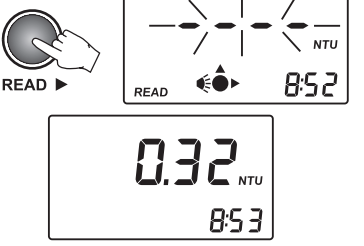


Note: If you have a cuvette with orientation mark, place the cuvette into the instrument with the orientation mark aligned with the sign on the instrument top.

NORMAL MEASUREMENT

This type of measurement can be used for regular measurements, when the sample is stable and normal accuracy is required. In normal measurement mode, the lamp is ON for a minimum period of time (about 7 seconds), saving the battery life. Normal measurement takes about 10 seconds.
If normal measurement is selected, the "**AVG**" tag will not be displayed.

- Press **READ ▶** to start the measurement. The display will show blinking dashes and the icons for cuvette, detectors and lamp will appear during measurement.



- At the end of the measurement, the instrument directly displays turbidity in NTU.

CONTINUOUS MEASUREMENT

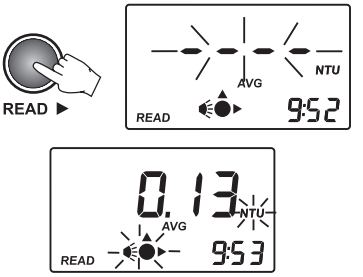
This measurement mode can be used when many measurements have to be taken in a short period of time. The feature is also useful to evaluate a very fast settling sample. This measurement mode is recommended for indexing cuvettes. After the first reading is taken, the lid opening will not generate any errors.
The first value is displayed after about 10 seconds and then a new reading is displayed each second. In order to make a continuous measurement keep **READ ▶** pressed until the desired number of measurements are taken. The display will show blinking dashes and the icons for cuvette, detectors and lamp will appear. When a new value is displayed, the cuvette icon and the measurement unit will briefly blink.
The last value remains on the display after the **READ ▶** is released.

AVERAGED MEASUREMENT

Select this measurement mode when samples that cause unstable readings are analyzed. By averaging several readings, the random noise generated by the sample is reduced and accurate measurements can be taken.
This mode can also be selected when high accuracy measurements are desired. In the average mode 10 measurements are averaged in a short period of time (about 20 seconds). The initial value is displayed after 10 seconds and the display is updated every second with an intermediate value.

- To select the averaged measurement mode press **AVG ▼**. When this mode is selected, the "**AVG**" icon will be displayed on the LCD.

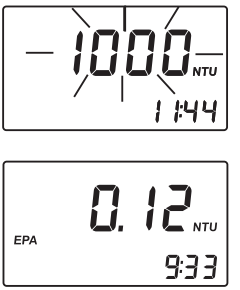
- Press **READ ▶** to start the average reading mode. The display will show blinking dashes and the icons for cuvette, detectors and lamp will appear during measurement. When a new partial value is displayed, the cuvette icon and the measurement unit will blink shortly.
- When the measurement is ended, the final averaged result is displayed directly in NTU.



RANGE AND UNITS

HI 98703 automatically selects the correct range to display the results with the highest accuracy. If the measured value is higher than 1000 NTU (over range), the display will show the maximum value blinking.

The instrument has an EPA compliance reading mode. If this feature is activated in SETUP, "**EPA**" tag will appear on the LCD and the readings will be rounded to meet EPA reporting requirements, as shown in the table:



NTU	Record to Nearest
0.0-1.0	0.05
1-10	0.1
10-40	1
40-100	5
100-400	10
400-1000	50
>1000	100

CALIBRATION PROCEDURE

HI 98703 has a powerful calibration function that compensates for lamp aging or changing. The calibration can be done using the suplied calibration solutions or user prepared standards.
HI 98703 turbidimeter is supplied with 4 AMCO standards: <0.1 NTU, 15 NTU, 100 NTU and 750 NTU. The Hanna standards are specially designed for this instrument. The turbidity standards have a shelf life and should not be used after the expiration date.
Alternatively, formazin standards can be used. It is recommended that the prepared calibration solutions to be close to the default calibration points.
The first point should be near 0 NTU. The second point can be chosen between 10 and 20 NTU, the third point between 50 and 150 NTU and the fourth point between 600 and 900 NTU.

FORMAZIN PREPARATION

In order to prepare formazin 4000 NTU stock solution, follow the next procedure:

Solution I : Dissolve 1.000 grams of hydrazine sulfate, $(NH_2)_2\ H_2SO_4$, in distilled, deionized water and dilute to 100 mL in a volumetric flask.

Warning: Handle hydrazine sulfate with care because it is a carcinogen reagent. Avoid inhalation, ingestion, or skin contact. Formazin solution can also contain some hydrazine traces.

Solution II : Dissolve 10.000 grams of hexamethylenetetramine, $(CH_2)_6N_4$, in distilled, deionized water and dilute to 100 mL in a volumetric flask.

Stock solution Mix 10 mL Solution I and 10 mL Solution II in a flask. Let the stock solution stays 48 hours at 25 ±3 °C (77 ±5 °F). This will result in a 4000 NTU formazin suspension. It is very important for the formation of the formazin polymer to maintain the same temperature.

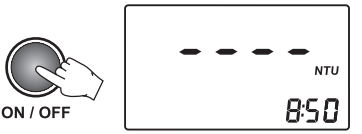
The stock solution (4000 NTU) can be stored up to one year in proper conditions. Store formazin in amber glass bottle or any UV-light blocking bottle.
To obtain a high quality formazin always use pure reagents and high-purity water.
To prepare the calibration standards, dilute the stock solution with the same high-purity water you used for the preparation of the stock solution.
The diluted formazin solutions are not stable. They should be used immediately after preparation and discard immediately after use.
If the prepared formazin is used, enter the actual standard value by pressing ▲ or ▼ key to edit the value of the second, third or fourth calibration point.

CALIBRATION

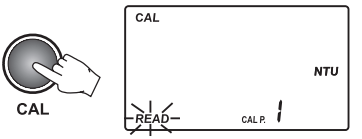
For best results, the measurement techniques must be followed during calibration. If formazin standards are used, mix the cuvettes gently for about 1 minute and then allow the standard to settle for one more minute before calibration.
Calibration can be performed in two, three or four points. It is possible to interupt calibration procedure at any time by pressing **CAL** or **ON/OFF**.

TWO-POINT CALIBRATION

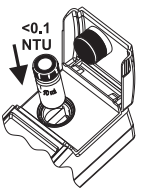
- Turn the instrument on by pressing **ON/OFF**. When the LCD displays dashes, the instrument is ready.



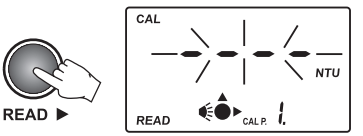
- Enter calibration mode by pressing **CAL**. The display will show "**CAL P.1**" and no suggested value. This first point is used to check the optical system.



- Place the <0.1 NTU standard cuvette into the holder and ensure that the cuvette mark is aligned with the sign on the instrument top.

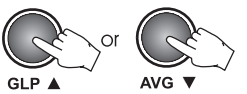


- Close the lid and press **READ ▶**. The display will show blinking dashes and the icons for cuvette, detectors and lamp will appear during measurement. Alternatively, press **LOG/CFM** to skip the first point.

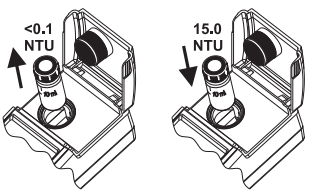


- The second calibration point (15.0 NTU) is then displayed on the primary LCD, "**CAL P.2**" on the secondary LCD, and "**READ**" tag will blink.

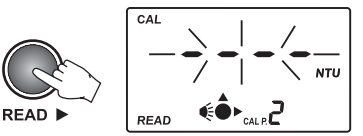
- If the prepared formazin is used, edit the displayed value by pressing ▲ or ▼ keys until the display shows the correct value.



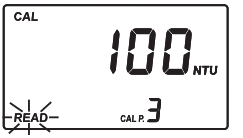
- Remove the first standard cuvette and place the 15.0 NTU standard cuvette (or the prepared one) into the holder and ensure that the cuvette mark is aligned with the sign on the instrument top.



- Close the lid and press **READ ▶**. The display will show blinking dashes and the icons for cuvette, detectors and lamp will appear during measurement.



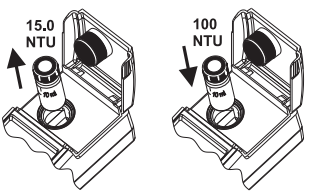
- At the end of the measurement, the third calibration point (100 NTU) is displayed on the primary LCD, "**CAL P.3**" on the secondary LCD, and "**READ**" tag will blink.
- At this moment it is possible to exit calibration by pressing **CAL**. The instrument will memorize the two-point calibration data and will return to measurement mode.

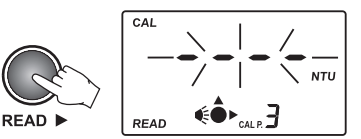


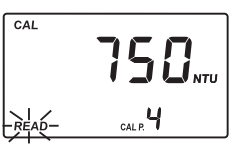
THREE-POINT CALIBRATION

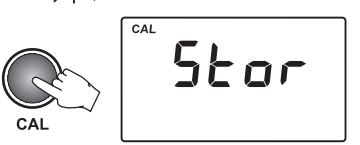
To perform a three-point calibration, continue the procedure with the following steps:

- Remove the second standard cuvette.
- Place the 100 NTU standard cuvette (or the prepared formazin standard) into the holder, with the cuvette mark aligned with the sign on the instrument.
- Close the lid and press **READ ▶**. The display will show blinking dashes and the icons for cuvette, detectors and lamp will appear during measurement.
- At the end of the measurement, the fourth calibration point (750 NTU) is displayed on the primary LCD and "**CAL P.4**" on the secondary LCD.
- At this moment it is possible to exit calibration by pressing **CAL**. The instrument will memorize the three-point calibration data and will return to measurement mode.





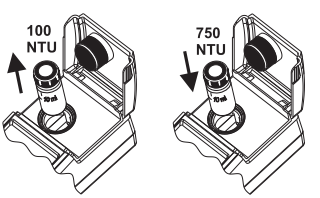




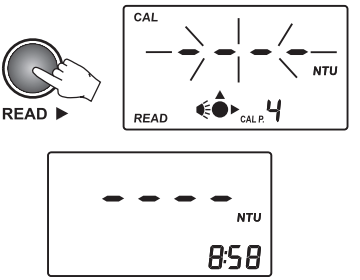
FOUR-POINT CALIBRATION

To perform a four-point calibration, continue the procedure with the following steps:

- Remove the third standard cuvette.
- Place the 750 NTU standard cuvette (or the prepared formazin standard) into the holder, with the cuvette mark aligned with the sign on the instrument.



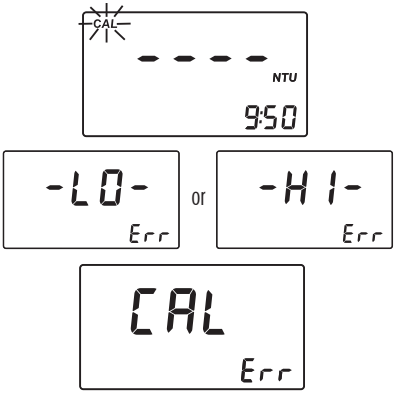
- Close the lid and press **READ ▶**. The display will show blinking dashes and the icons for cuvette, detectors and lamp will appear during measurement.
- At the end of the measurement, the four-point calibration is completed and the instrument returns automatically to measurement mode.



OUT CAL RANGE FUNCTION

The instrument has an **Out Cal Range** function to prevent taking measurements in a range where the calibration does not assure the best results. The range where the calibration assures correct measurements is up to 40 NTU for two-point calibration and up to 150% of the third point value for three-point calibration.

The display will show a blinking "**CAL**" tag each time the measurements are taken outside the calibration range.



CALIBRATION ERRORS

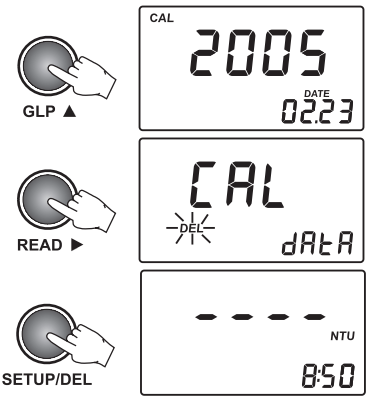
- If the read value during calibration is too far from the set value, the instrument will show "**-LO-**" or "**-HI-**" error.
- If the calculated calibration coefficients are outside a certain range, the "**CAL Err**" message is displayed.

CALIBRATION DELETION

HI 98703 is factory calibrated. It is possible to restore factory calibration by deleting last performed calibration.

To delete last calibration, follow the next steps:

- Enter the GLP feature by pressing **GLP ▲**. The date of the last calibration will be displayed on the LCD.
- Press **READ ▶** to see the information related to calibration. The last panel is the one with delete calibration.
- Press **SETUP/DEL** to delete the current calibration. After deletion the instrument will automatically return to measurement mode.



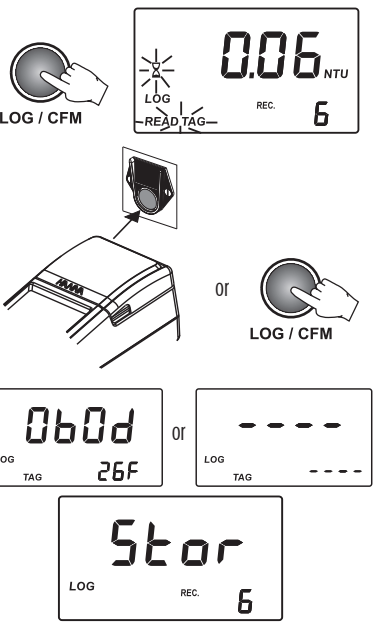
LOGGING

HI 98703 has a log space for up to 200 records. With each measurement, the date, time and tag ID is stored. In this way, each record is fully characterized and can be easily analyzed when downloading data on the PC application (**HI 92000**).

LOGGING

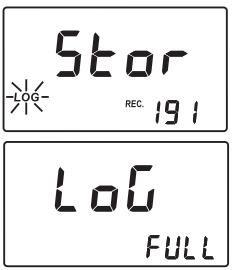
The log function is active after a valid measurement is obtained (no errors).

- To log a value, press **LOG/CFM** when the measurement result is displayed. The instrument asks to "**READ TAG**" for identification of the sampling location. The location for the new record is also displayed on the secondary LCD.
- To read the ID code for the sampling location identification, simply touch the iButton® tag with the matching connector, located on the back of the instrument (see Connectors Description, page 9). Alternatively, press again **LOG/CFM** to store the record without the tag ID code.
- If the tag is successfully read, the instrument will beep once, displaying the unique hexadecimal code of the tag, and store the data. After data is stored, the instrument returns to measurement mode.



Notes:
- If the tag is not read within 20 seconds, the logging procedure is canceled.
- A measurement can be stored only once. Also an over range value can be stored.

- If less than ten free records are available, the "**LOG**" tag will blink while storing data.
- If the log memory is full, the "**LoG FULL**" message will appear for a few seconds on the LCD and the instrument will return to measurement mode without storing the new record.



To store a new record, delete one or more records.

VIEW LOGGED DATA

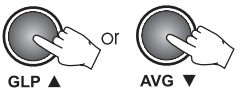
The stored records can be viewed at any moment by pressing **RCL**. To return to normal measurement mode, press **RCL** again.

LOG SEARCHING

The log records are stored in chronological order. The first displayed record is the last stored one.

- Press ▲ or ▼ keys to scroll the log memory record by record. By keeping pressed the ▲ or ▼ keys, the scrolling speed will increase. The scrolling of the log is possible from any panel of the record, except "Delete last log" and "Delete all logs" panels.
- When scrolling the log, the number of the record is displayed for one second on the secondary LCD, together with "**TAG**" if the identification of the sampling location was made.

When the end of the log is reached, an error beep is heard.



RECORD VIEWING

Each record contains more information than the measured value. The additional information is grouped in several panels.

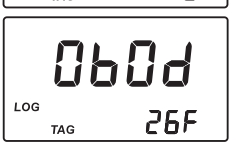
Press **READ** ▶ to scroll through the record panels. The record panels are displayed one by one in a circular way.

Each record contains the following panels:

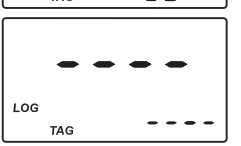
- The record value (turbidity value) and record number.

Note: If the logged sample value is an over range reading, the maximum value (1000) will be displayed blinking.

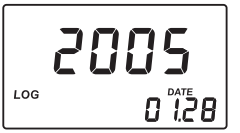
- The hexadecimal string of the tag for the sampling location ID.



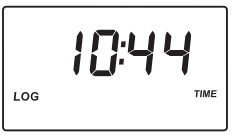
Note: If the ID data are missing, dashes are displayed instead.



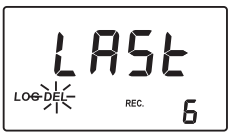
- Measurement date in YYYY.MM.DD format.



- Measurement time in hh:mm format.



- Delete the last record panel (only for last record).

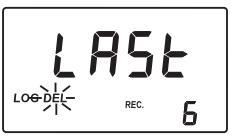


- Delete all records.

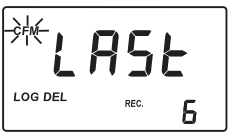
DELETE LAST RECORD

To log other values, the last record or all records have to be deleted.

- To delete the last record, press **SETUP/DEL** while in delete last records panel.



- The instrument asks for confirmation and if **LOG/CFM** is pressed, the last record is deleted. To abort the delete function, press **READ ▶** instead of **LOG/CFM**.



- After the record is deleted, the instrument goes immediately to the first panel of the previous record. If the log becomes empty, dashes will be displayed for one second and the instrument will return to idle mode.

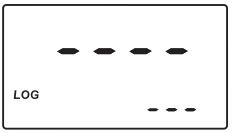
DELETE ALL RECORDS

To delete all records, scroll the log until delete all records panel is displayed on the LCD.

- To delete all records press **SETUP/DEL** while in delete all records panel.

- The instrument asks for confirmation and if **LOG/CFM** is pressed, all records are deleted. To abort the delete function, press **READ ▶** instead of **LOG/CFM**.

- After all records are deleted, dashes are displayed for one second and the instrument returns to idle mode.



GOOD LABORATORY PRACTICE (GLP)

The GLP feature allows the user to view last calibration data. Also, the user calibration can be deleted.

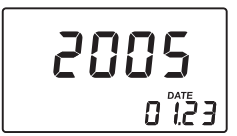
Press **GLP ▲** to enter or exit GLP data consulting. Several functions are available when in GLP menu.

Press **READ ▶** to scroll the following GLP data:

- The last calibration date, in YYYY.MM.DD format. If no calibration was performed, the factory calibration message, "**F.CAL**", will be displayed on the LCD.

or

- The time of the last calibration in hh:mm format.



- First calibration point: 0.00 NTU if skipped or the actual read value (e.g. 0.01 NTU).

or

- Second calibration point.

- Third calibration point (if available).

- Fourth calibration point (if available).

- Delete calibration panel.

To delete calibration:

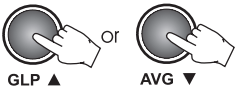
- Press **SETUP/DEL** while in the delete calibration panel of the GLP. The user calibration will be deleted and the factory calibration will be restored. The instrument will enter automatically in idle mode.

SETUP

Setup mode allows viewing and modifying the instrument parameters.
The blinking "**CAL**" tag during setup mode suggest to press **CAL** for parameters editing.

- To enter/exit SETUP, press **SETUP/DEL**.

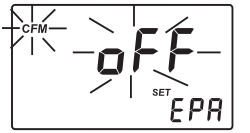
- To select the parameter to be edit, press ▲ or ▼ keys until the desired panel is displayed.



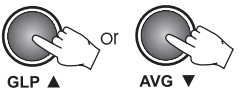
SET EPA COMPLIANCE MODE

When EPA compliance reading is ON, "**EPA**" message is displayed on the secondary LCD and the reported values are rounded to meet EPA reporting requirements.

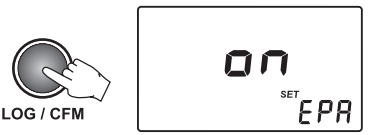
- To edit the EPA mode, press **CAL** when "**EPA**" compliance reading panel is displayed. The parameter setting and "**CFM**" tag will start blinking.



- Press the ▲ or ▼ keys to set ON or OFF the EPA compliance mode.



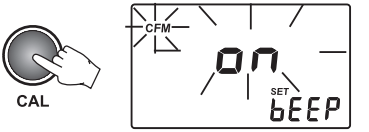
- Press **LOG/CFM** to save the setting. The new selected option of the parameter will be displayed on the LCD. Alternatively, press **CAL** to exit without saving the new settings.



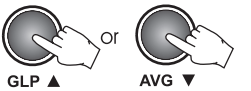
SET BEEPER

The **HI 98703** has a built-in beeper that signals the tag read, the key press and the error conditions. The beeper can be selected to be ON or OFF.

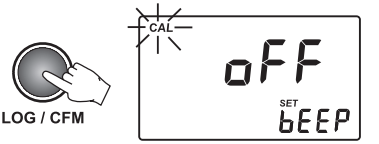
- To set the beeper **ON/OFF**, press **CAL** when set beeper panel is displayed. The beeper status and "**CFM**" tag will start blinking.



- Press the ▲ or ▼ keys to set the beeper ON/OFF.



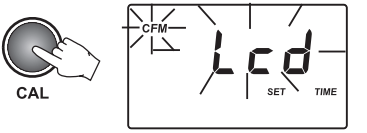
- Press **LOG/CFM** to save the change. The new selected option will be displayed on the LCD. Alternatively, press **CAL** to exit without saving the changes.



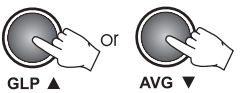
SHOW / HIDE THE TIME

You can choose between showing or hiding the current hour and minutes on the LCD.

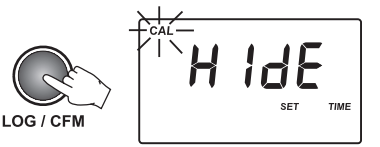
- To set hiding or showing the time, press **CAL** when show/hide time panel is displayed. The time show status and "**CFM**" tag will start blinking.



- Press the ▲ or ▼ keys to set lcd / hide for time.



- Press **LOG/CFM** to save the change. The new selected option will be displayed on the LCD. Alternatively, press **CAL** to exit without saving the changes.

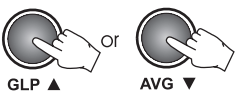


SET THE DATE

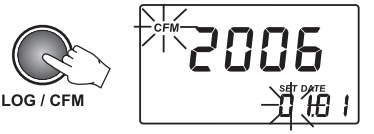
The **HI 98703** turbidimeter has a built-in real time clock (RTC). The RTC time is used to generate a unique time stamp for each recorded value and to automatically store the last calibration date. The current time can be displayed on the LCD when the instrument is in idle mode.

- To set the current date, press **CAL** when set date panel is displayed. The date format is YYYY.MM.DD. The last two digits of the year value and "**CFM**" tag will start blinking.

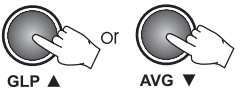
- Press the ▲ or ▼ keys to set the year value.



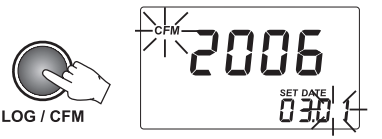
- Press **LOG/CFM** or **READ ▶** to start editing the month value. The month value will start blinking.



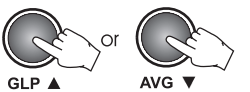
- Press the ▲ or ▼ keys to set the month value.



- Press **LOG/CFM** or **READ ▶** to start editing the day value. The day value will start blinking.

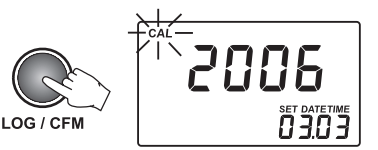


- Press the ▲ or ▼ keys to set the day value.



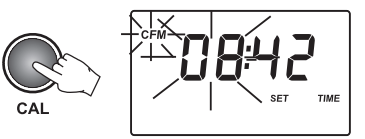
Note: To edit the year again, after the day was set, press **READ ▶**.

- Press **LOG/CFM** to save the new date. The new date will be displayed on the LCD. Alternatively, press **CAL** to exit without saving the changes.

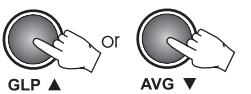


SET THE TIME

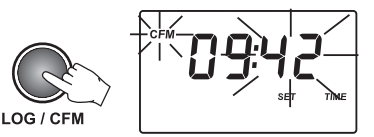
- To set the current time, press **CAL** when set time panel is displayed. The time format is hh:mm. The hour value and "**CFM**" tag will start blinking.



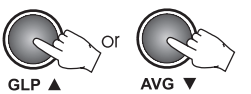
- Press the ▲ or ▼ keys to set the hour value.



- Press **LOG/CFM** or **READ ▶** to start editing the minutes. The minutes value will start blinking.

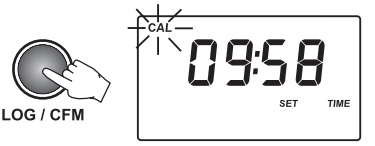


- Press the ▲ or ▼ keys to set the minutes value.



Note: To edit the hour again, after the minutes were edited, press **READ ▶**.

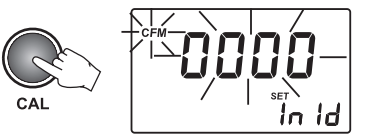
- Press **LOG/CFM** to save the new time. The new set time will be displayed. Alternatively, press **CAL** to exit without saving the changes.



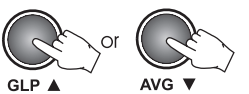
SET INSTRUMENT ID

The instrument ID is a four digit number that can be edited by the user. The instrument ID is downloaded on the PC application, together with the logged data. By setting a different ID for each instrument it is possible to mix information from many turbidimeters into the same database.

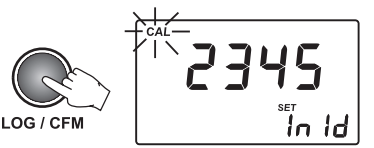
- To set the instrument ID, press **CAL** when set instrument ID panel is displayed. The default instrument ID is 0000. The existing ID value and "**CFM**" tag will start blinking.



- Press the ▲ or ▼ keys to set the new instrument ID. By pressing and holding the ▲ or ▼ keys, the changing speed wil increase.



- Press **LOG/CFM** to save the change. The new instrument ID will be displayed. Alternatively, press **CAL** to exit without saving the changes.

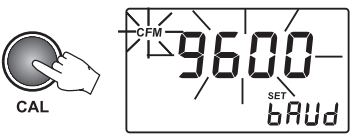


SET BAUD RATE

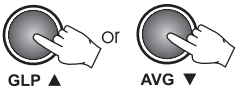
The **HI 98703** has a RS232 and a USB link. When the USB connection is used, the RS232 connection becomes inactive.

To successfully communicate with the PC, the same baud rate must be selected on the instrument and on the PC application. The available baud rates are 1200, 2400, 4800 and 9600.

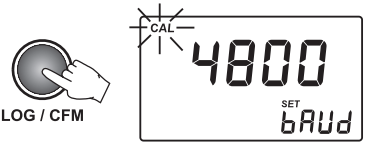
- To set the baud rate, press **CAL** when set baud rate panel is displayed. The parameter value and "**CFM**" tag will start blinking.



- Press the ▲ or ▼ keys to select the new baud rate value.



- Press **LOG/CFM** to save the change. The new selected baud rate will be displayed. Alternatively, press **CAL** to exit without saving the changes.



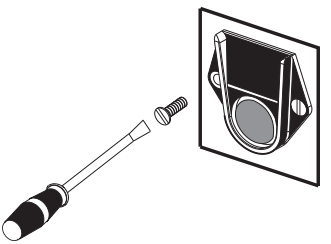
LCD BACKLIGHT

The LCD can be illuminated to allow the user to see the readings even in dark environments.
To turn ON or OFF the backlight, press **LIGHT**.
The backlight will automatically shut-off after 25 seconds of non-use to save the battery life.

TAG INSTALLATION

The tag is housed in a rugged metal that can withstand harsh environments. However, it is better to protect the tag from direct rain.

Place the tag near a sampling point. Fix it securely with the provided screws, in such a way that the metallic iButton® is easily accessible for reading the tag.



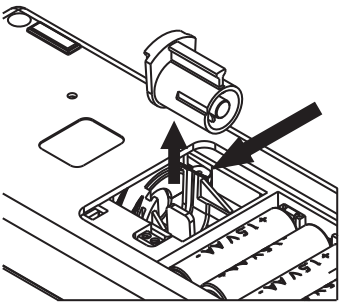
The number of tags that can be installed is practically unlimited. Additional tags can be ordered (**HI 920005** - five tag holders with tags).

LAMP REPLACEMENT

The instrument tungsten lamp has a life longer than 100,000 measurements. In case of lamp failure, the defective lamp can be easily replaced. When the lamp is broken, the instrument displays "**no L**" error message.

To replace the lamp follow the next steps:

- Remove the battery lid.
- Unscrew the lamp connection using a screwdriver.
- Unlock the lamp and extract it by pulling it out from the lamp holder handler.
- Place the new lamp in the right position and push it until is securely locked.
- Insert the lamp leads into the connector and tight them using a screwdriver.

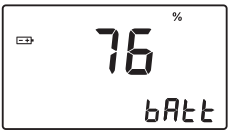


Warning: After lamp replacement the meter needs to be recalibrated.

BATTERIES MANAGEMENT

For field measurements, **HI 98703** is powered by 4 AA batteries. The battery life is enough for 1500 normal measurements.

When the instrument is started, the remaining battery life is estimated and reported in percents.

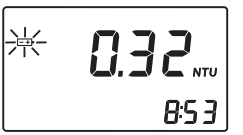


To preserve the battery it is better to use normal instead of averaged measurements.

Continuous measurements keep the lamp on and should be used with caution if the battery life is an issue.

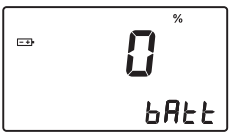
To further save the battery life, the instrument will turn off after 15 minutes of non-use. The backlight will be turn off after 25 seconds since the last key was pressed.

The battery life is measured each time the lamp is turned on and if the remaining battery life is less than 10%, the battery tag will be displayed blinking on the LCD to warn the user that the batteries need to be replaced.



When the batteries are completely discharged, "**0% bAtt**" message will be displayed for one second and the instrument will turn off.

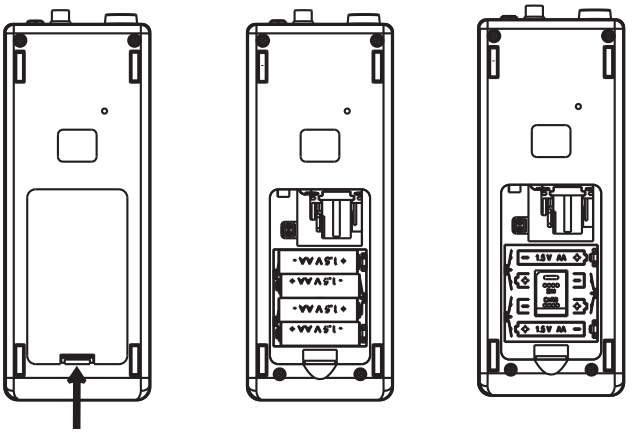
In order to use the instrument again, replace the batteries with new ones or use an AC adapter.



BATTERIES REPLACEMENT

To replace the batteries follow the next steps:

- Press **ON/OFF** to turn OFF the instrument.
- Open the batteries cover by pressing the locking clip.



- Take out the used batteries and insert 4 new 1.5 AA size batteries, while paying attention to the correct polarity as indicated on the battery compartment.
- Replace the cover and press it until it locks.
- Turn the instrument ON.

Warning: Replace batteries only in a non-hazardous area.

USING AN AC ADAPTER

The **HI 98703** can be powered from the AC adapter when used in laboratory. See the Accessories section to select the correct AC adapter.

To power the instrument, simply connect the AC adapter to the instrument (see Connectors Description, page 9).

It is not necessary to turn the instrument off when connecting the external adapter.

Note: The connection to the external adapter will not recharge the batteries.

PC INTERFACE

To fully use the instrument tag identification system function, the measured data has to be downloaded to a computer. The instrument can use RS232 or USB connection to communicate with the PC.

When using the RS232 protocol, simply connect a **HI 920011** serial cable between the instrument and the computer.

To use the USB protocol, simply connect a regular USB cable between instrument and PC.

In both cases, the PC must run the **HI 92000** application for successful data transfer.

ERROR CODES

HI 98703 has a powerful diagnostic system. The common errors are detected and reported for easy diagnostic and maintenance.

ERROR	DESCRIPTION	ACTION
Err1 – Err3; Err6; Err7; Err8	Critical errors. The instrument beeps and shuts down.	Call Hanna service
Err4	The instrument beeps shortly twice and shuts down after 10 seconds.	Press simultaneously UP and DOWN to reset the EEPROM contents.
CAP	The lid is not closed.	Close the lid. If the error persists, return the instrument.
no L	Lamp broken or no light.	Replace the lamp. Check the optical system for obstructions.
L Lo	Not enough light.	Check the optical system for obstructions.
-LO-	The standard used for current calibration point is too low.	Check the standard and use the correct one.
-HI-	The standard used for current calibration point is too high.	Check the standard and use the correct one.
Battery tag blinking	The remaining battery life is too low.	Replace batteries.
bAtt	The batteries are too discharged for correct measurements.	Replace batteries.

ACCESSORIES

HI 710005	Voltage adapter from 115V to 12 Vdc (USA plug)
HI 710006	Voltage adapter from 230V to 12 Vdc (European plug)
HI 710012	Voltage adapter from 240V to 12 Vdc (UK plug)
HI 710013	Voltage adapter from 230V to 12 Vdc (South Africa plug)
HI 710014	Voltage adapter from 230V to 12 Vdc (Australia plug)
HI 731318	Tissue for wiping cuvettes (4 pcs.)
HI 731331N	Glass cuvettes (4 pcs.)
HI 731335N	Caps for cuvettes (4 pcs.)
HI 740027P	1.5V AA battery (12 pcs.)
HI 740234	Replacement lamp for EPA turbidimeter (1 pc.)
HI 92000	Windows® compatible software
HI 920005	5 tag holders with tags
HI 920011	5 to 9 pins RS232 connection cable
HI 93703-50	Cuvettes cleaning solution (230 mL)
HI 98703-58	Silicon oil (15 mL)

RECOMMENDATIONS FOR USERS

Before using this product, make sure that it is entirely suitable for your specific application and for the environment in which it is used.

Operation of this instrument may cause unacceptable interferences to other electronic equipment, requiring the user to follow all necessary steps to correct interferences.

Any variation introduced by the user to the supplied equipment may degrade the instrument's EMC performance.

To avoid damage or burns, do not put the instrument in microwave ovens. For your own and the instrument safety do not use or store the instrument in hazardous environments.

Hanna Instruments reserves the right to modify the design, construction or appearance of its products without advance notice.

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Printed in ROMANIA

MAN98703 06/14

Appendix C

Field Equipment Calibration Log

FIELD EQUIPMENT CALIBRATION LOG

Station No:_____ Calibrated by:_____

Location:_____ Date:_____ Time:_____

TEMPERATURE

Meter MAKE/MODEL _____ S/N _____ Thermister S/N _____ Thermometer ID _____

Calibration criteria: ± 1 percent or ± 0.5 ÛC for liquid-filled thermometers ± 0.2 ÛC for thermisters

Lab Tested against NIST Thermometer/Thermister? N Y Date: _____ ±_____ °C

Measurement Location: SINGLE POINT AT _____ ft. DEEP STREAMSIDE _____ FT FROM LEFT RIGHT BANK VERTICAL AVG/MEDIAN OF _____ POINTS

pH

Meter MAKE/MODEL _____ S/N _____ Electrode No. _____ Type: GEL LIQUID OTHER_____

Sample: FILTERED UNFILTERED CHURN SPLITTER SINGLE POINT AT _____ FT DEEP VERTICAL AVG. OF _____ POINTS CONE SPLITTER

pH BUFFER	BUFFER TEMP	THEO-RETICAL pH FROM TABLE	pH BEFORE ADJ.	pH AFTER ADJ.	SLOPE	MILLI-VOLTS

TEMPERATURE CORRECTION FACTORS FOR BUFFERS APPLIED? Y N

BUFFER LOT NUMBERS :

pH 7: _____

pH _____: _____

CHECK pH _____: _____

BUFFER EXPIRATION DATES:

pH 7: _____

pH _____ : _____

CHECK pH _____: _____

Calibration Criteria: ± 0.1 pH units

SPECIFIC CONDUCTANCE

Meter MAKE/MODEL _____ S/N _____ Sensor Type: DIP FLOW-THRU OTHER_____

Sample: CHURN SPLITTER SINGLE POINT AT _____ft. DEEP VERTICAL AVG. OF_____POINTS CONE SPLITTER

Std Value µS/cm	Std Temp	SC Before Adj.	SC After Adj.	Std Lot No.	Std type (KCl; NaCl)	Std Exp. Date

AUTO TEMPCOMPENSATED METER _____

MANUALTEMPCOMPENSATED METER _____

CORRECTION FACTOR APPLIED? Y N

CORRECTION FACTOR= _____

Calibration Criteria: ± 5 % for SC <100 PS/ cm or 3% for SC >100 PS/cm

DISSOLVED OXYGEN

Meter MAKE/MODEL _____ S/N _____

Sensor Type: Polarographic Luminescent Sensor ID _____

Water-Saturated Air Air-Saturated Water Air Calibration Chamber in Water Air Calibration Chamber in Air Winkler Titration Other_____

Sample: SINGLE POINT AT _____ ft. DEEP VERTICAL AVG. OF _____ POINTS BOD BOTTLE OTHER_____ Stirrer Used? Y N

WATER TEMP °C	BAROMETRIC PRESSURE mm Hg	DO TABLE READING mg/L	SALINITY CORR. FACTOR	DO BEFORE ADJ.	DO AFTER ADJ.

Zero DO Check _____mg/lL Adj. to _____ mg/L Date: _____

Zero DO Solution Date_____ Thermistor Check? Y N Date_____

Membrane Changed? N Y Date: _____ Time: _____

Barometer Calibrated? N Y Date: _____ Time: _____

Battery Check: REDLINE _____ RANGE _____

Calibration Criteria: ± 0.2 mg/L

TURBIDITY

Meter MAKE/MODEL _____ S/N _____

Date	Name	Standard Used	Temp of Standard	Pre-Calibration Conductivity	Post Calibration Conductivity	Comments

STANDARDS (NTU) LOT NUMBERS:

<0.1: _____

15: _____

100: _____

750: _____

STANDARDS (NTU) EXPIRATION DATES:

<0.1: _____

15: _____

100: _____

750: _____

ATLANTIC COAST PIPELINE, LLC
ATLANTIC COAST PIPELINE

Response to Virginia Department of Environmental Quality Request for Information for the Section 401 Water Quality Certification

APPENDIX G

Karst Survey Report

February 21, 2017

Karst Survey Report
Revision 1

Atlantic Coast Pipeline
Augusta, Bath and Highland Counties, VA & Pocahontas and Randolph Counties, WV

GeoConcepts Engineering, Inc.

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GeoConcepts Engineering, Inc.

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February 21, 2017

Colin Olness, PE
Contractor
Atlantic Coast Pipeline - Construction
99 Edmiston Way
Buckhannon, WV 26201

Subject: **Karst Survey Report, Revision 1: Atlantic Coast Pipeline (ACP), Augusta, Bath and Highland Counties, VA & Pocahontas and Randolph Counties, WV (GeoConcepts Project No. 11002.04)**

Dear Mr. Olness:

GeoConcepts Engineering, Inc. (GeoConcepts) is pleased to present the following karst survey report prepared for the ACP, located in Augusta, Bath and Highland Counties, VA, and Pocahontas and Randolph Counties, WV. This report summarizes the results of the remote sensing and data review for the entire ACP alignment that intercepts karst terrain, and the field survey results for all parcels where access permission was granted by the landowners.

We appreciate the opportunity to serve as your geotechnical consultant on this project. Please do not hesitate to contact me if you have any questions or want to meet to discuss the findings and recommendations contained in the report.

Sincerely,

GEOCONCEPTS ENGINEERING, INC.

Tadeusz (Ted) W. Lewis, PE
Principal
tlewis@geoconcepts-eng.com

GeoConcepts Engineering, Inc.

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Executive Summary

GeoConcepts conducted a karst survey of the proposed alignment of the Atlantic Coast Pipeline[1] (ACP) natural gas pipeline located in Augusta, Bath and Highland Counties Virginia, and Pocahontas and Randolph Counties, West Virginia. The survey was performed in two phases: a data review and remote sensing phase to identify karst surface features (sinkholes, caves, swallets or sinking streams, springs, etc.) prior to field assessment; and a field survey phase to verify, characterize and document karst features identified in the data review as well as documenting previously unidentified karst features.

The data review phase examined the length of the entire proposed ACP alignment mapped as underlain by karst-forming bedrock (59.8 miles), and/ or within areas of known karst terrain (based on the presence of karst surface features), encompassing a total karst survey length of 71.3 linear miles. Features identified in the data review were:

1. 300-Foot Corridor Closed Depressions/Features (identified as "cCD"), defined as any closed depression which occurred within, touched or received drainage (based on topography) from a 300 foot wide corridor concurrent with the planned pipeline right of way (ROW);
2. Suspect Closed Depressions (identified as "sCD"), defined as any closed depression occurring within a ¼-mile wide "karst review area" concurrent with the ROW;
3. Cave entrance locations;

The data review identified approximately 265 cCD Features, 54 sCD, and eight caves (three in WV and five in VA), located within or inferred to receive drainage from the 300 foot corridor.

The field survey was limited to those parcels where the survey personnel had been granted access permission by the landowners. To date, 62.3 miles of the proposed alignment mapped in karst and inferred karst terrain has been completed. However, access has been prohibited for approximately 9 miles of the alignment, which remain to be assessed. Within the 62.3 miles where the field survey phase has been completed, a total of 339 karst features were identified and documented within the 300-foot corridor, or which received drainage from the corridor. Each feature was assigned a unique identifier utilizing the parcel number and an integer, and a risk ranking based on the following criteria:

1. Located on or immediately adjacent to the proposed construction trench;
2. Presence of an open "throat" leading into the subsurface;
3. Drainage characteristics (i.e. showing evidence of receiving surface drainage);
4. Evidence of active soil raveling, tension cracks or collapse.

Risk ranking was assigned as follows:

High Risk – Presence of any combination of two or more of the above criteria

Moderate Risk – Presence of any one of the above criteria

Low Risk – Absence of any of the above criteria

Of the field documented features (sinkholes, closed depressions, caves, swallets, springs, etc.) 107 were classified as "high" risk, 72 as "moderate risk", and 32 as "low" risk.

This report summarizes the methods and procedures used to conduct the karst survey, detailed descriptions of the regional and local geology, and a summary of findings based on both the data review and field survey phases. Previous experience has indicated that the number and types of karst features identified during the data review portion of the project may vary significantly from the number of karst features

[1]ACP is owned by Atlantic Coast Pipeline, LLC (Atlantic). Atlantic has contracted with Dominion Transmission Inc., a subsidiary of Dominion Resources, Inc. to construct and operate the ACP on the behalf of Atlantic.

identified during the field survey portion of the project. Once the remaining field survey is completed this report should be updated by supplement or addendum.

Introduction

Based on the National Karst Map (Weary and Doctor, 2014) and landscape feature analysis, the ACP route is planned to cross approximately 71.3 miles of karst terrain, characterized by the presence of closed depressions, sinkholes, caves, sinking streams, and large springs. Karst is a known geohazard, and any infrastructure development in karst terrain must be carefully planned and managed. In addition, the karst environment could provide habitat for rare, threatened and endangered species, and is an important source of drinking water for municipalities and private landowners. In order to conserve this important natural resource, and also to protect the integrity of the pipeline, in October 2014 Dominion Transmission Incorporated (DTI) staff contracted GeoConcepts to conduct a survey of the karst features which could potentially affect the construction of the pipeline and/or be impacted by the proposed construction.

This report summarizes the methods and procedures used to conduct the karst survey, detailed descriptions of the regional and local geology, and a summary of findings based on both the data review and field survey phases.

Scope of Services

The ACP project involves the proposed installation of a gas pipeline extending through West Virginia and Virginia. Referencing the currently proposed pipeline construction alignment information sent to us (hereinafter referred to as "the alignment"), we estimated that the route currently being considered for the pipeline passed across approximately 59.8 miles of terrain underlain by karst-forming bedrock[2] located in Randolph and Pocahontas Counties in West Virginia, and Highland, Bath and Augusta Counties, Virginia, based on regional geological mapping. The "Area of Interest" for the survey (hereinafter referred to as the "AOI") was thus divided into two sections: a "Karst Review Area" (KRA) which extended ¼-mile from either side of the proposed centerline; and a 300-foot corridor (300FC) which extended 150 feet from either side of the centerline which would be examined in the field. Only features located within, or which touched the 300FC, would be documented; however, if observed or mapped karst features received drainage from the 300FC then these features would also be delineated and documented to the extent possible and included in the assessment.

Specifically, GeoConcepts provided the following services and deliverables:

- Locate and delineate surface karst features (e.g. sinkholes and karst related subsidence, cave entrances, closed depressions, and sinking and losing streams) within the KRA and 300FC as described above, with particular emphasis on features that have direct communication with the phreatic zone such as "open-throat" sinkholes, karst windows, cave entrances, abandoned wells, sinking streams and areas that could affect the integrity of the pipeline itself such as actively forming cover-collapse sinkholes, areas of soil subsidence, or caves which had passages that extend below the proposed ROW at elevations less than 15 feet below the surface. Direct field observations will be made by walking the entire 300FC and any adjacent areas where the KRA data indicated a feature might receive drainage from the 300FC.
- Delineate zones of karst terrain, subsidence and drainages based on the surface karst features assessment.
- A report summarizing the methods and findings of the assessment.

[2]However it became apparent during the data review phase of the project that numerous karst features, in particular cave entrances and closed depressions (sinkholes), were present outside of the areas indicated as "karst terrain" by the USGS map, and that the total area which would need to be surveyed was more than 71.3 miles in length. The details of the discrepancy between the National Karst Map and the presence of karst terrain are discussed in more detail in the following sections of this report.

Methodology

The above scope of services was accomplished by the following means:

Phase 1: Existing Data Review and Analysis – GeoConcepts conducted a review of existing karst feature locations within a ½-mile wide KRA (i.e. ¼-mile from either side of the proposed centerline) that were available from the following sources:

1. The (proprietary) Cave Databases of the Virginia Speleological Survey (VSS) and the West Virginia Speleological Survey (WVSS);
2. Caves of Virginia (Douglass, 1964);
3. Caverns of West Virginia (Davies, 1958);
4. Maps of selected karst features (sinkholes, caves, springs) available from the Virginia Division of Mines and Mineral Resources and the United State Geological Survey (Hubbard, 1988; 2003);
5. Two-foot and 4-foot contour interval maps for the AOI (to determine the presence of surface karst features not included in the above listed databases based on the presence of closed, descending contours or other suspect karst "fingerprint" features) derived from county level digital terrain models (DTMs), and 1- and 3-meter contour maps derived from state level digital elevation models (DEMs);
6. Aerial photographs (both recent and historical);
7. USGS Topographic 7.5-minute topographic quadrangles;
8. Sinkhole and depression locations available from the USDA-NRCS soil studies for the counties through which the project will pass;
9. LIDAR data (where available).

In addition, GeoConcepts reviewed the readily available geological literature for bedrock and structural characteristics. The closest resolution mapping that existed for the particular area being examined was relied on when conducting the review.

Phase 2: Field Survey – Concurrent with the Phase 1 activities, GeoConcepts conducted the field survey activities. Typically, the field survey phase immediately followed the routing and civil survey activities by DTI's staff. Specifically, the field survey entailed:

1. Location and verification of surface karst features identified in the Phase 1 review that fall within, contact, or receive drainage from the 300FC along the proposed centerline;
2. Location of uncatalogued or previously unidentified surface karst features, specifically sinkholes, cave entrances, dry runs and sinking streams within the 300FC as described above.

The field survey placed particular emphasis on locations where pathways existed to phreatic groundwater such as open-throat sinkholes, cave entrances, karst "windows", and sinking streams.

The 300FC was delineated and then examined during the field survey for karst features (both features previously located during the data review phase and features which were previously unidentified). This entailed conducting a site reconnaissance of the 300FC (i.e. the proposed pipeline route) in a systematic manner, to observe any existing surface karst features that fit the criteria. The locations and outlines of all relevant features were recorded using a sub-meter accurate GPS device. For the purpose of this study, the outline (parapet) of sinkholes was defined by the last closed descending contour at mapping interval available for the area under study. Cave entrances were identified as single points, unless the entrance was located within a larger sinkhole structure, in which case the cave entrance was indicated as a point within the sinkhole's parapet. Sinking streams were located as points of entry into the subsurface; however, losing streams were identified as linear features. The features were each assigned a unique identifier, and the feature data was subsequently recorded on an individual "karst description sheet".

Phase 3: Data Analysis – The data analysis phase followed the field survey phase for each routed area. Based on the field survey observations any feature that was indicated as present in the 300FC, touched it, or received drainage from it was documented and described.

In many cases sinkholes and/or cave entrances have been filled, graded and or obliterated; thus if a 300FC feature could not be found in the field, this was noted and the feature was eliminated. If a feature was present, but the data review indicated an error in its position, the accurate data was recorded and the feature's coordinates were corrected accordingly.

Upon review of all available data, each field located feature was assigned a "risk rank" based on the following criteria:

1. Located on or immediately adjacent to the proposed construction trench;
2. Presence of an open "throat" leading into the subsurface;
3. Drainage characteristics (i.e. presence of a clear-cut drainage path leading into the structure);
4. Evidence of active soil raveling, tension cracks or collapse.

Risk ranking was assigned as follows:

High Risk – Presence of any combination of two or more of the ranking criteria

Moderate Risk – Presence of any one of the ranking criteria

Low Risk – Absence of any ranking criteria

Definitions

(Adapted from Field, 2002: "A Lexicon of Cave and Karst Terminology, with special reference to Environmental Karst Hydrology)

Cave – A natural hole in the ground, large enough for human entry. This covers the enormous variety of caves that do occur, but eliminates the many artificial tunnels and galleries incorrectly named caves. The size criterion is arbitrary and subjective, but practical, as it eliminates narrow openings irrelevant to explorers but very significant hydrologically, that may be better referred to as *proto-caves*, *sub-conduits*, or *fissures*. A cave may be a single, short length of accessible passage, or an extensive and complex network of tunnels as long as hundreds of kilometers.

Doline; Sinkhole – A basin- or funnel-shaped hollow or depression in limestone, dolostone or other soluble bedrock, ranging in diameter from a few meters up to a kilometer and in depth from a few to several hundred meters. Some dolines are gentle grassy hollows or depressions; others are rocky cliff-bounded basins. A distinction may be made by direct solution of the limestone surface zone (solution dolines), and those formed by collapse over a cave (collapse dolines), but it is generally not possible to establish the origin of individual examples. Generally referred to as a "sinkhole" in the United States, the term doline is more widely accepted by the international geology community.

Throat – An opening within a sinkhole leading into the subsurface through which material passes or has passed from the sinkhole into underlying solutional voids and conduits, which is generally too small to qualify as a cave and often called a *proto-cave*, *sub-conduit*, or *fissure*. Throats may be "open" (i.e. air-filled or water-filled), or "closed/clogged" (filled with debris including but not limited to: loose-soil; gravel; rock; dead-fall wood or brush; or trash).

Parapet – The outer edge or perimeter of a doline (sinkhole).

Ponor – a) Hole or opening in the bottom or side of a depression where a surface stream or lake flows either partially or completely underground into the karst groundwater system; b) Hole in the bottom or side of a doline through which water passes to or from an underground channel. Also known as a swallow hole or swallet.

Solution Cavity – A natural cavity or depression formed by the dissolution of soluble bedrock, typically not large enough to allow the entry of a human being and, therefore, not classified as a cave.

Breccia – Angular fragments of rock commonly, but not always, cemented by finer-grained materials including silica, iron minerals, and calcite to form a new rock. Many fault planes are marked by zones of broken rock, either loose or re-cemented, forming a fault breccia.

Non-Karst Closed Depression – A natural or non-natural topographic depression that is not formed by karst processes and is not floored by bedrock. Examples include (but are not limited to) construction-related soil subsidence, silage pits, farm ponds, scour pools, animal wallows, large animal burrows, and pits created by removal of tree stumps.

Sinking Stream/Swallet – A perennial or intermittent stream whose bed and bank disappear entirely underground, usually through an open throat sinkhole or cave entrance.

Losing Stream – A perennial or intermittent stream which loses flow volume into its bed due to the presence of sub-channel (hyporheic) solution cavities or conduits.

Geological Setting

Overview of Karst Terrain along the Project Alignment

The term "karst" refers to a type of landform or terrain, just like "desert", "marsh", "tundra", "steppe" or "montane". It was named for a province in Slovenia where it was first described in the late 17th and early 18th century by geologists of the former Austro-Hungarian Empire. Simply stated, the karst terrain is characterized by the presence of sinkholes, caverns, an irregular "pinnacled" bedrock surface, and many large springs; however, the development of karst terrain is a result of the presence of soluble bedrock such as limestone, dolomite, marble or gypsum. Any landscape that is underlain by soluble bedrock has the potential to develop a karst terrain landform.

As in any region where soluble bedrock is present, a karst landform regime has developed in a portion of the planned route for the ACP. Folding and faulting of the local carbonate rocks has opened up numerous fractures both parallel with the axis of the geologic structures, as well as perpendicular to them. Surface fractures and joints weather differentially, producing a pinnacled or "saw-tooth" profile at the bedrock/soil interface (referred to as the "epikarst" zone). In contrast, rock-enclosed fractures can be secondarily enlarged by the action of carbon dioxide charged groundwater, in some cases forming water-filled or air-filled conduits. As the regional terrain is "mature" karst, nearly all the fractures have undergone successive cycles of sediment filling and flushing (Ford & Williams, 1989), (Moore & Moore, 2019).

Sinkholes - Sinkholes fall into two broad categories, "vault-collapse" sinkholes, and "cover-collapse" sinkholes. Vault-collapse type sinkholes were not observed in the project area (i.e. where the cavern "vault" or roof had failed catastrophically), and these structures are regionally quite rare. (Campbell, et al., 2006)

In contrast, cover-collapse sinkholes are relatively common regionally. Cover-collapse sinkholes develop by the raveling of fines from the soil overburden into solution channels within the bedrock mass, in which water is the transport medium for the movement of the soil fines. The natural raveling process is generally a very slow one, such that sinkhole development generally occurs over a very long time span. However, various changes at a site can sometimes lead to the very sudden development of sinkholes. The most common changes that will exacerbate sinkhole development are:

1. Increase or redirection of overland or subsurface water flow paths, which accelerates the raveling of soil fines;
2. Removal of vegetation cover and topsoil (i.e. stripping and grubbing), which can reduce the cohesive strength of the soils overlying a conduit;
3. Sudden changes in the elevation of the water table (such as drought, over-pumping of wells, or quarry dewatering), which removes the neutral buoyancy of the water supporting a conduit's soil plug, and can often result in rapid and catastrophic soil collapse.

Regional Geology

The ACP Project will cross three distinct provinces of karst geology (see Figure 1), from east to west:

1. The **Great Valley subsection of the Valley and Ridge physiographic province**, extending from the Blue Ridge on the east to Little North Mountain on the west, the majority of the proposed alignment in Augusta County is located within the Great Valley Province.
2. The **Folded Appalachian subsection of the Ridge and Valley province**, encompassing western Augusta County, and all of Bath County and Highland County, VA, this province extends from the North Mountain area on the east to Allegheny Mountain on the west;
3. The **Allegheny Front and Appalachian Plateau** provinces of West Virginia, encompassing Pocahontas and Randolph Counties, West Virginia.

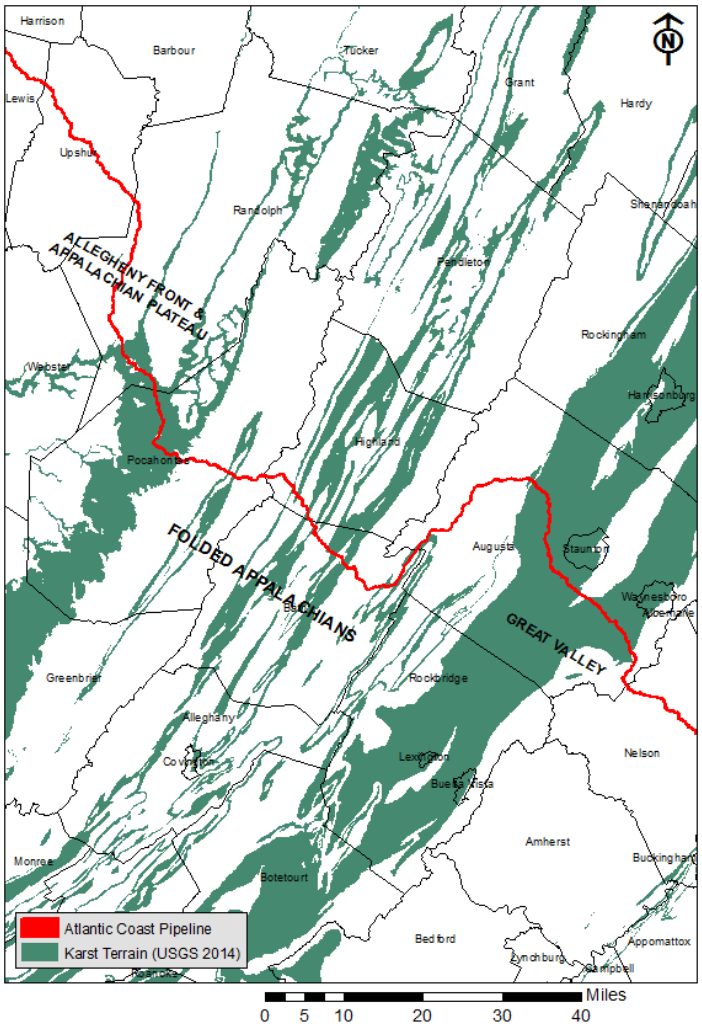

Figure 1. Map showing the karst geology provinces along the ACP Alignment.

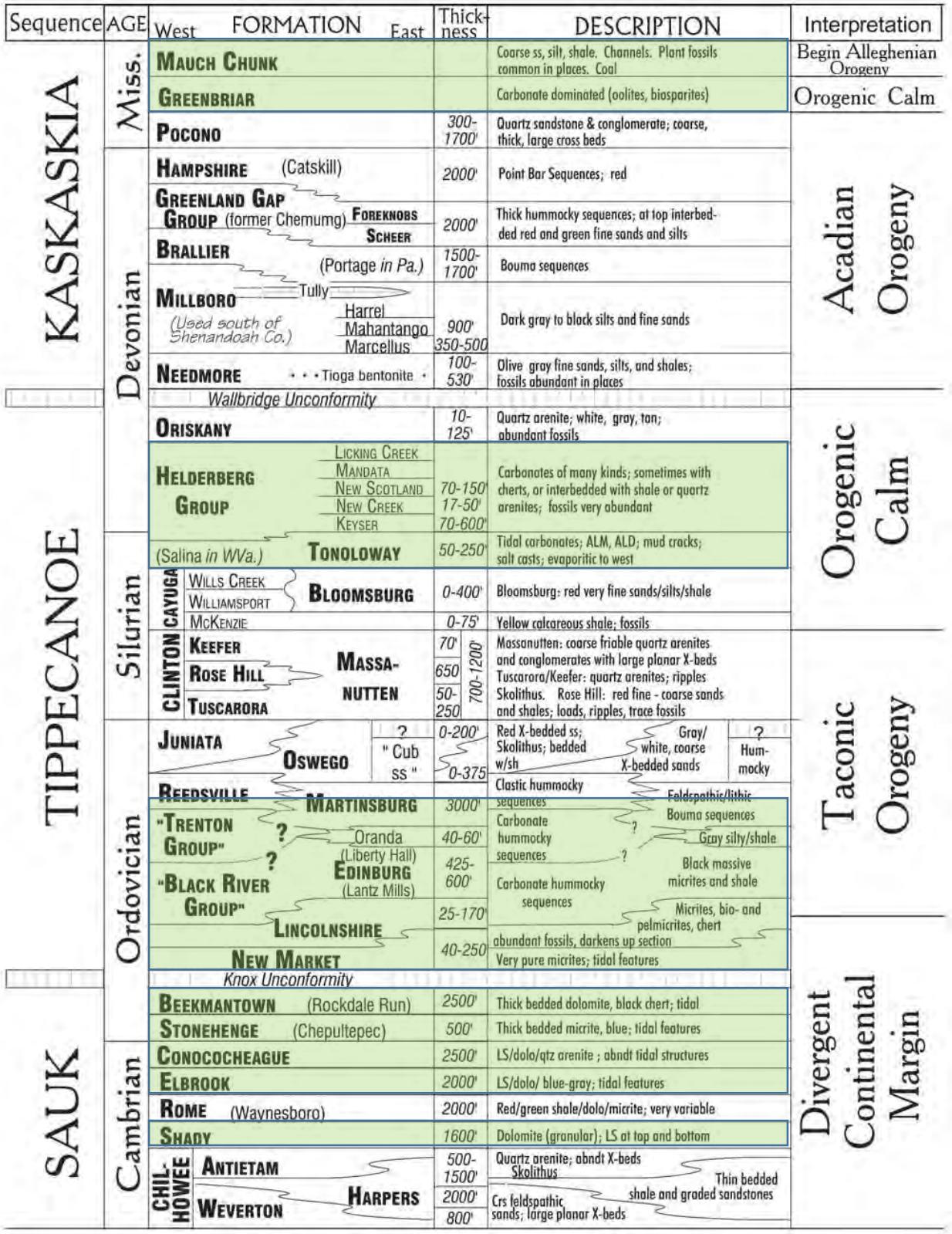

Figure 2. Stratigraphic Column of the central Virginia Great Valley, Folded Appalachians, and eastern Allegheny Front of west central Virginia and eastern West Virginia. (Fichter, 2010). Karst-forming units are highlighted in green.

The Great Valley (Augusta County, VA)

Appendix A, Maps 38-48

The Great Valley section is a generally downwarped trough (synclinorium) of Paleozoic limestones, shales and sandstones, that lie between the Blue Ridge Massif on the east, and the Allegheny Mountains to the west. The Valley extends between the two mountain uplands from northeast to southwest, parallel with the average strike of the bedrock.

The karst terrain of the Great Valley section of the project is characterized by numerous circular to oval-shaped sinkholes, ranging in size from a few feet to several hundred feet in diameter, the majority of which are completely vegetated and lack any (visible) opening to the subsurface ("throat") at their base. Sinkhole depths can vary, but are usually controlled by the angle of repose of the sediments lining their walls. Steep, rock-walled sinkholes are rare in this section, but generally occur in the small hills and uplands that are erosional remnants of the prior valley floor.

The Great Valley section contains some of the largest karst springs in the region. It is also characterized by sinkholes called "estavelles", which are insurgences for water during dry periods, and flood or act as springs (resurgences) during wet seasons. There are also numerous caves (i.e. air-filled voids large enough to permit the entry of a human being that have an entrance to the surface) and subsurface cavernous voids (air-filled voids large enough for human entry with no connection to the surface) in the region.

A unique type of karst terrain has developed in the eastern portion of Augusta County along the base of the Blue Ridge Mountains. Here, the characteristic karst terrain has been buried beneath a mantle of unconsolidated sediments (gravel, sand, silt and clay) which were eroded from the mountains to the east. These sediments range in age from less than 1 million years (Quaternary Period) to over 50 million years (Paleogene Period). The unconsolidated sediment thins towards the west, and disappears completely west of Waynesboro, VA. Although the primary karst terrain is covered by these sediments, numerous shallow broad sinkholes are present and suggest the presence of large karst features in the underlying bedrock. (Southworth, et al., 2009; Rader & Gathright, 2001; Hubbard, 1988)

Bedrock Geology of the Karst-forming Units

Specifically, the proposed ACP alignment in the Great Valley section has been mapped (VDMR, 1993) as being underlain by a series of karst-forming carbonate and calcareous clastic rocks ranging in age from the Lower Cambrian to Middle Ordovician geological periods (Campbell et al., 2006; DMME, 1993; Rader & Gathright, 2001; Rader & Wilkes, 2001; Hubbard, 1988). The individual geological units are described from youngest to oldest as follows:

Ordovician Period

Martinsburg Formation (Om) – The upper 100 to 200 feet of this formation is a brown, medium-to coarse-grained, fossiliferous sandstone. An olive-green silty shale and dark-gray siltstone comprises the middle portion of this formation, along with a medium-to coarse-grained, locally pebbly sandstone. The Stickley Run Member exists as the lower 400 to 900 feet of the formation. This is a medium-gray to grayish-black, very-fine-grained (aphanitic), very-thin- to thin-bedded, argillaceous limestone with interbedded medium- to dark-gray, calcareous shale.

Edinburg Formation (Oeln) – A black, fine-grained to aphanitic limestone with layered black shale that commonly contains pyrite, and medium- to light-gray, fine- to coarse-grained, nodular limestone with thin partings of black shale. This formation lies in thicknesses ranging from 450 to 1,000 feet throughout the three subject areas. The Edinburg is typically divided into two distinct members based on lithology, the Liberty Hall and Lantz Mill.

Lincolnshire Limestone (Oeln) – The Lincolnshire has a gradational contact with the overlying Edinburg. The Lincolnshire is a light- to very-dark-gray, fine- to coarse-grained, medium to very-thick-bedded limestone with black chert nodules. The Murat Limestone Member, generally found at the top of the

formation, is a light colored, coarse-grained limestone composed of fossil fragments. Thicknesses throughout our subject areas range from 50 to 250 feet.

New Market Limestone (Oeln) – Unconformable upper contact with the Lincolnshire. The upper unit of this formation is a medium-gray, aphanitic, thick-bedded, limestone with scattered calcite crystals. The lower unit is a medium- to dark-gray, fine-grained, thin-bedded, argillaceous, bioturbated limestone that is dolomitic in parts, with its base being a carbonate pebble conglomerate. Formation thicknesses throughout the subject areas range from 100 to 250 feet.

Beekmantown Group (Note – This group consists collectively of the Pinesburg Station Dolomite, Rockdale Run Formation, and the Stonehenge Limestone)

Pinesburg Station Dolomite (Ob) – This formation is a medium-to light gray, fine-grained, medium- to thick-bedded dolostone, with sparse fossils. When weathered, this dolomite is very-light-gray, and exhibits a "butcher-block" structure. A medium-gray, fine-grained limestone exists as the base of this unit. The formation's average thickness is 400 feet.

Rockdale Run Formation (Ob) – The upper contact with the overlying Pinesburg Station is unconformable. This formation is comprised of a medium-gray, fine-grained, fossiliferous limestone and a light- to medium-gray, fine-grained, laminated dolomitic limestone and dolostone with mottled beds. Thin lenses of gray chert are common near the base of the formation. Formation thickness ranges from 1500 to 2400 feet.

Stonehenge Limestone (Ob) – Upper contact with the Rockdale Run Formation is gradational. The upper 400 to 500 feet is comprised of a medium- to dark-gray and black, fine- to medium-grained limestone, with thin beds of macerated fossil debris. The lower 50 to 150 feet (Stoufferstown Member) is a dark-gray to black, fine-grained limestone with thin sheet-like, crinkly partings due to cleavage, and thin beds of coarse-grained, bioclastic limestone.

Ordovician/Cambrian Period

Conococheague Formation (O_co) – The upper contact with the Stonehenge Limestone of the Beekmantown Group is unconformable. The upper 2,000 feet of this formation is a light- to dark-gray, fine-grained, laminated limestone, dolomitic limestone, and dolostone with flat-pebble conglomerate beds. Some cross laminated sandstone beds occur in the uppermost part of this unit. The Lower 200 to 500 feet (Big Spring Station Member) consists of a light-gray, fine-grained dolostone, medium- to dark-gray, fine-grained laminated limestone and dolomitic limestone, and gray, coarse-grained sandstone and dolomitic sandstone. Beds of flat-pebble conglomerate occur in the dolomite. It is of note that although the majority of the Conococheague is considered Cambrian in age, the upper part is dated to the Ordovician Period based on biostratigaphy .

Cambrian Period

Elbrook Formation (_e) – This unit's thickness ranges from 2,000 to 2,500 feet. It has a conformable contact with the overlying Conococheague Formation and in places the contact is not easily distinguishable in the field. The Elbrook is a dark- to medium-gray, fine- to medium-grained limestone, with dolomitic limestone, dolostone, and dolomitic shale. These lithologies commonly occur as erosion-surface-bounded sequences of algal limestone overlain by laminated dolomite. Decalcified, red ocherous shale-like chips on the ground surface characterize this unit. The lower 300 to 400 feet is green to greenish-gray, fine-grained dolostone, dolomitic limestone, and shale.

Waynesboro Formation (_w) – The upper contact with the Elbrook Formation is gradational. A dusky-red to olive-gray, fine- to medium-grained sandstone and dusky-red to gray shale exists as the upper 300 feet. The middle 400 feet is a medium- to dark-gray, saccharoidal dolomite and fine-grained limestone. The lower 500 feet is dusky-red, olive-gray, and dark-gray shale and dusky-red to brownish-gray, fine- to medium-grained sandstone. Overall thickness is approximately 1,200 feet.

Tomstown Dolomite/Shady Dolomite (_t/_s) – The upper 600 feet is light- to dark-gray, fine- to coarse-grained, medium- to thick-bedded, locally laminated dolostone with white chert rosettes and nodules in the upper 50 feet. The middle unit (about 210 feet) is very-light- to medium-gray, medium-grained, very-thick-bedded dolostone and high-magnesium dolostone. The lower unit (about 325 feet) is dark-gray to black, very-fine-grained, thin- to very-thin-bedded limestone and dolomitic limestone with argillaceous laminations. The overall unit thickness ranges from 1,100 to 1,200 feet. The Shady Dolomite is the homologous unit in the southeastern Great Valley at the base of the western edge of the Blue Ridge Mountains.

The Folded Appalachians (Highland County, Bath County VA, and Eastern Pocahontas County, WV)

Appendix A, Maps 37 – 20

The western edge of the Great Valley is demarcated by the North Mountain Fault, and the ridges of Little North and Great North Mountain. Further to the west, Highland and Bath Counties are divided from Augusta County by a series of high mountain ridges and deep intervening valleys, collectively referred to as "Shenandoah Mountain". The rocks underlying the Shenandoah Mountain section are younger than those of the Great Valley, dating primarily from the Late Ordovician through the Middle Silurian periods in age, and are all clastic rocks (e.g. sandstone, siltstone, shale, etc.) and not prone to the development of karst terrain (Hubbard, 1988; Rader & Wilkes, 2001; DMME, 1993). The ACP alignment passes over the last section of the folded Appalachians as it crosses Michael Mountain in eastern Pocahontas County.

Bedrock Geology of the Karst-forming Units

The ACP in the Folded Appalachians section has been mapped (DMME, 1993) as being underlain by a series of karst-forming carbonate rocks ranging in age from the Lower Ordovician to Lower Devonian geological periods. The individual geological units are described from youngest to oldest as follows:

Devonian Period

Helderberg Group (Dh) – This group consists of thick- to massive-bedded, dark gray/black micritic limestone with reef structures. The limestone shows some degree of recrystallization. The uppermost Helderberg is typically silicified near its contact with the overlying Oriskany sandstone. In many areas the Helderberg gives off a distinct petroliferous odor when freshly broken. The contact with the overlying Oriskany Sandstone is poorly exposed regionally, but the contact with the underlying Tonoloway Formation is distinct and often unconformable, where the massive bedding of the Helderberg gives way to the thin-bedding of the Tonoloway Formation. The contact can be identified in places by a lag deposit consisting of flat, packstone rip-ups and pebble conglomerate.

The group is a major cave forming unit of the Folded Appalachian section; however, it is of note that the stratigraphy of this unit has been the subject of a much detailed study in recent years (Haynes, et al., 2014). The Helderberg Group consists of a series of individual formations, from oldest to youngest, respectively: the Keyser Limestone, New Creek Limestone, Corriganville Limestone, and Licking Creek Limestone formations. It should be noted that based on biostratigraphic analysis the Keyser Limestone, the basal formation of the Helderberg Group, is considered to straddle the boundary of the Silurian and Devonian periods (Denkler and Harris, 1988a).

Silurian Period

Tonoloway Limestone (Sto) – Extremely thin bedded (1 cm or less) dark gray micritic limestone interbedded with fissile, calcareous shale. Gives off a distinct petroliferous odor when freshly broken. The contact with the overlying Helderberg is distinct; however, it grades into the underlying Wills Creek Limestone. Thickness is approximately 300 feet.

Wills Creek Limestone (Swc) – Thin bedded (less than 10 cm) dark gray calcareous shale and fossiliferous micrite. Poorly exposed in the survey area. Thickness is approximately 200 feet.

The above units are sometimes referred to collectively as members of the "Cayugan Group".

Ordovician Period

Juniata, Oswego, Reedsville, Dolly Ridge, and Eggleston Formations (Oun)
Karst-forming unit present only in the westernmost Valley and Ridge section of the ACP alignment (Highland and Bath Counties). The Dolly Ridge and Eggleston Formations are the only karst-forming units and consist of a medium-gray, fine-grained, thin-bedded, argillaceous limestone with interbedded olive-gray calcareous claystone, silt argillaceous limestone, gray shale, and K-bentonite beds. Thickness is about 400 feet in Bath and Highland Counties. The unit is laterally equivalent to the Middle Ordovician ("Trenton Group") limestones and part of the lower Martinsburg Formation.

Middle Ordovician Limestones, Undivided (Olm)
Consists of the Edinburg Formation, the Lincolnshire Formation and the New Market Limestone. The Edinburg is a black, fine-grained to aphanitic limestone with layered black shale that commonly contains pyrite, and medium- to light-gray, fine- to coarse-grained, nodular limestone with thin partings of black shale. Thickness is 400 feet to 500 feet. The Edinburg grades downward into the Lincolnshire Formation, a light- to very-dark-gray, fine- to coarse-grained, medium to very-thick-bedded limestone with black chert nodules. Thicknesses throughout our subject areas range from 25 feet to 250 feet. This unit is underlain by the New Market Limestone. Upper contact with the Lincolnshire is generally unconformable. The upper unit of this formation is a medium-gray, aphanitic, thick-bedded, limestone with scattered calcite crystals. The lower unit is a medium- to dark-gray, fine-grained, thin-bedded, argillaceous, bioturbated limestone that is dolomitic in parts, with its base being a carbonate pebble conglomerate. Formation thicknesses throughout the subject areas range from 0 to 150 feet.

Beekmantown Formation (Ob) – This formation is a medium-to light gray, fine-grained, medium- to thick-bedded dolostone, with sparse fossils. When weathered, this dolomite is very-light-gray, and exhibits a "butcher-block" structure. A medium-gray, fine-grained limestone exists as the base of this unit. This formation is comprised of a medium-gray, fine-grained, fossiliferous limestone and a light- to medium-gray, fine-grained, laminated dolomitic limestone and dolostone with mottled beds. Thin lenses of gray chert are common near the base of the formation. Formation thickness ranges from 1,500 feet to 2,400 feet. The Beekmantown Formation typically consists of three members, which although distinct in the Great Valley region are hard to distinguish in the Folded Appalachian province.

The Allegheny Front and Appalachian Plateau (Pocahontas and Randolph Counties, WV)

Appendix A, Maps 1 - 19

The proposed alignment crosses the last section of the folded Appalachian karst in eastern Pocahontas County along the flanks of Michael Mountain, and then enters the relatively flat-bedded geology of the Allegheny Front and Appalachian Plateau provinces. The alignment crosses the karst-forming Greenbrier Group limestone on the as it climbs the east face of Cloverlick Mountain and eventually passes over the clastic rocks and limestone of the Mauch Chunk Group on the uplands of the Appalachian Plateau.

In general, the Mauch Chunk and Greenbrier group carbonates exhibit a high density of caves relative to the other two karst section along the pipeline. There are several factors that contribute to this, the main one being that the units act as a drain system for groundwater infiltrating downward through the fractured clastic rocks above them. Where they are exposed along the mountain flanks, the steep groundwater gradients have enhanced this cavern development. In many places surface water plunges directly into the carbonates via steep-walled, open throat sinkholes (swallets). Most of the caves are linear networks, and exhibit conduit flow, capturing surface streams upgradient which then emerge as springs at the downgradient end.

Bedrock Geology of the Karst-forming Units

The ACP alignment in the Appalachian Plateau section has been mapped (Cardwell, et al., 1968; Davies, 1958) as being underlain by the karst-forming carbonate rocks of the Greenbrier and Mauch Chunk groups, exclusively. The geology is described from youngest to oldest as follows:

Mississippian Period

Mauch Chunk Group – Includes the Bluestone and Princeton Formations (Mbp), Hinton Formation (Mh), and Bluefield Formation (Mbf). The group is predominantly red, green and medium-gray shale and sandstone, with a few thin limestone lenses in each formation. Although the limestone strata in the unit are considered secondary, the topographic position of the Mauch Chunk along the edges of the eroded upland of the Allegheny Plateau where there is a relatively steep downward hydraulic gradient has enhanced water flow through the carbonate lenses, forming karst conduit networks with high transmissivity (Kozar & Mathes, 2001), thus from a karst hydrology viewpoint this unit is significant.

Greenbrier Group (Mg) – In the project area the Greenbrier Group (or "Big Lime" as it is known locally) is up to 400 feet in thickness. It is primarily a gray to dark gray, massively bedded marine limestone, with interbeds of red and green marine and nonmarine shale and thin discontinuous beds of sandstone. The Group is divided into six stratigraphic units; from oldest to youngest they are: the Denmar Limestone, Taggard Shale, Pickaway Limestone, Union Limestone, Greenville Shale, and Alderson Limestone. The principle cave forming units are the Pickaway and Union limestones.

Survey Results and Discussion

Surface Karst Concentrations – For the purposes of coordinating the data review and field survey services, and to facilitate the discussion of the survey findings, the ACP alignment is discussed by county (see Figure 1). The findings of both the data review and field survey phases of the assessment are summarized in the following section. The county sections are described from west to east. Geology of the mapped features is included as Appendix A; topography of mapped features is included as Appendix B, and a summary of data in tabular form is included as Appendix C.

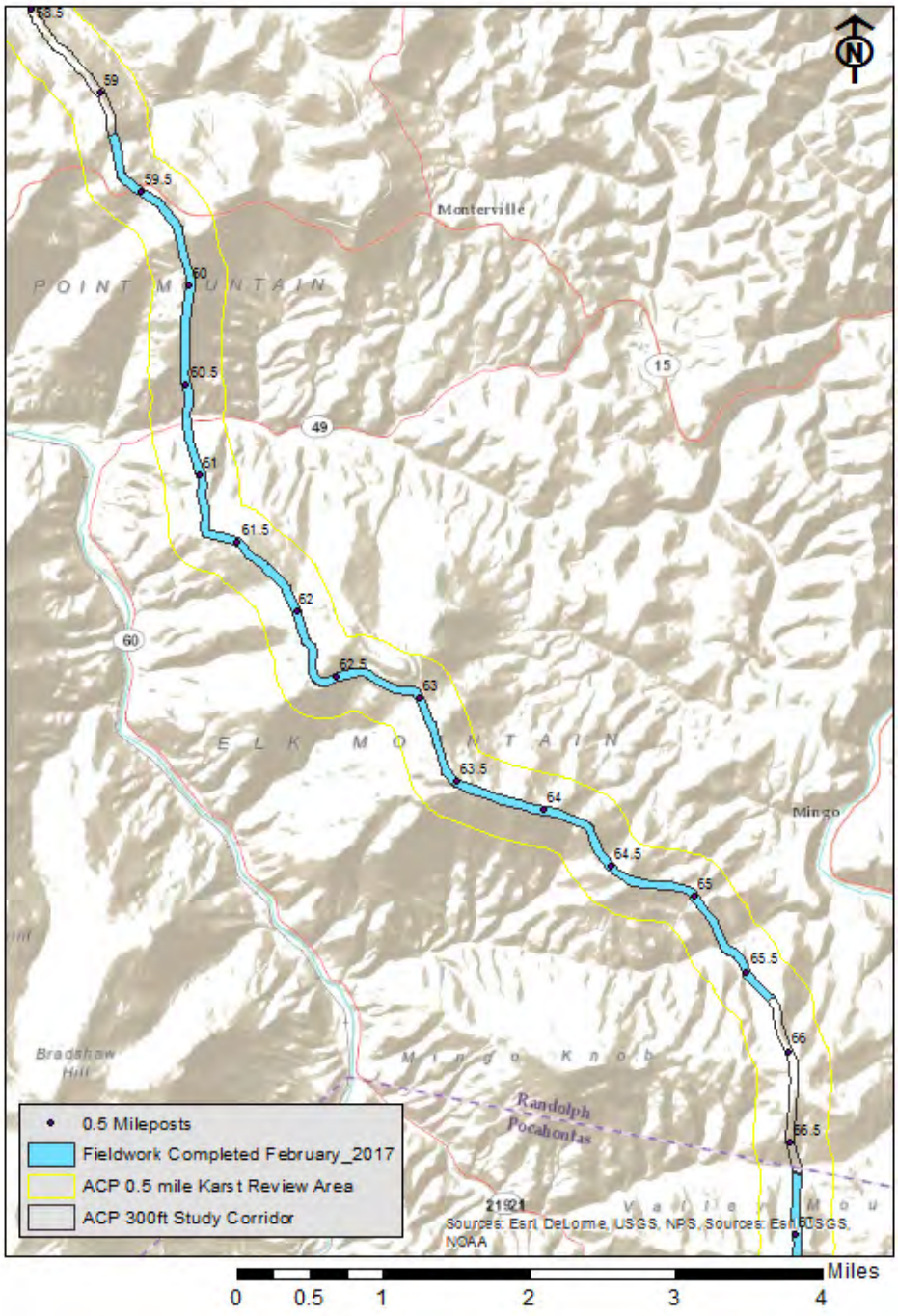

Figure 3. Map of completed field survey section in Randolph County, WV

Randolph County, West Virginia (Allegheny Front and Appalachian Plateau)

Milepost 59.2 to 66.7 – Appendix B: Maps 1-14

The Randolph County, West Virginia section of the survey extends from milepost 59.2 on the eastern end of Point Mountain, to milepost 66.7. Elevations range from over EL 3,500 feet on the summit of Point Mountain, to EL 2,300 in the valley of the Elk River, approximately 2.2 miles southwest of Monterville, WV.

Data Review – The largest scale mapping available for Randolph County was 1/9-arc Digital Elevation Models (DEMs) obtained from the USGS National Elevation Dataset, which were converted to 1 meter interval contour maps for terrain analysis using GIS software. LIDAR provided by the DTI staff was available from mileposts 59.6 to 60.6. The Data review indicated the presence of a total of 29 closed depressions. Of these, 26 were classified as cCD features and three were classified as sCD features; however it should be noted that two of the cCD features (cCD49 and cCD50) were subsequently shown to be abandoned strip mines and not karst features. All 29 features were mapped as being located within the clastic and carbonate rocks of the Mauch Chunk Group and the overlying Pottsville Group.

Review of the literature also indicated 10 cave entrances were located in the Randolph County section (Medville & Medville, 1995). All of the cave entrances were located outside of the 300FC, but within the KRA. Based on analysis of the topography, none of these cave entrances are downgradient from the 300FC. Survey data suggest that none of the cave passages extend into the 300FC. Surveyed cave lengths were short, ranging from 35 feet to 220 feet. A total of nine of the caves are developed in the Greenbrier Group limestone, the remaining cave (County Line Pit) is developed in the Bluefield Formation of the Mauch Chunk Group.

Field Survey (Fig. 3.) – The field survey for the West Virginia section was performed in summer 2016. The field survey extended from milepost 59.2 to milepost 65.7, which comprised approximately 87 percent of the proposed alignment in Randolph County located in mapped or inferred karst terrain. Landowner permission was not granted to survey the remaining 13 percent.

A total of 38 karst features were identified in the Randolph County section: 29 point features; and nine area features. A total of 23 of the identified features were located in the Mauch Chunk Group, and 15 in the overlying New River Formation of the Pottsville Group.

Pocahontas County, West Virginia (Allegheny Front and Appalachian Plateau/Folded Appalachians)

Milepost 66.7 to 83.9 – Appendix B: Maps 15 - 43

The Pocahontas County, West Virginia section of the survey extends from milepost 66.7 on the northern pediment of Valley Mountain, to milepost 83.9 on Allegheny Mountain. Elevations range from over EL 4,300 feet on the summit of Tallow Knob, to EL 2,290 in the valley of the Greenbrier River, in Cloverlick, West Virginia.

Data Review – The largest scale mapping available for Pocahontas County was 1/9-arc Digital Elevation Models (DEMs) obtained from the USGS National Elevation Dataset, which were converted to 1 meter interval contour maps for terrain analysis using GIS software. LIDAR data provided subsequently by DTI staff covered the majority of the survey corridor (300FC) in Pocahontas County. The Data review indicated the presence of a total of 91 closed depressions, all of which were classified as cCD. There were no sCD features identified in the data review in Pocahontas County. A total of 45 of the cCD features were located in the karst-forming Greenbrier and Mauch Chunk group rocks. A total of 24 features were located in the karst-forming Silurian age Tonoloway Formation. One cCD (ID = cCD44) was located in the Pocono Group, a non-karst forming clastic unit. This feature was subsequently identified as a depression in alluvium associated with a stream meander. A total of five other cCD features were identified on the flanks of Michael Mountain, two in the carbonate-rich Oriskany Sandstone of the Helderberg Group and three in the clastic Brallier Formation.

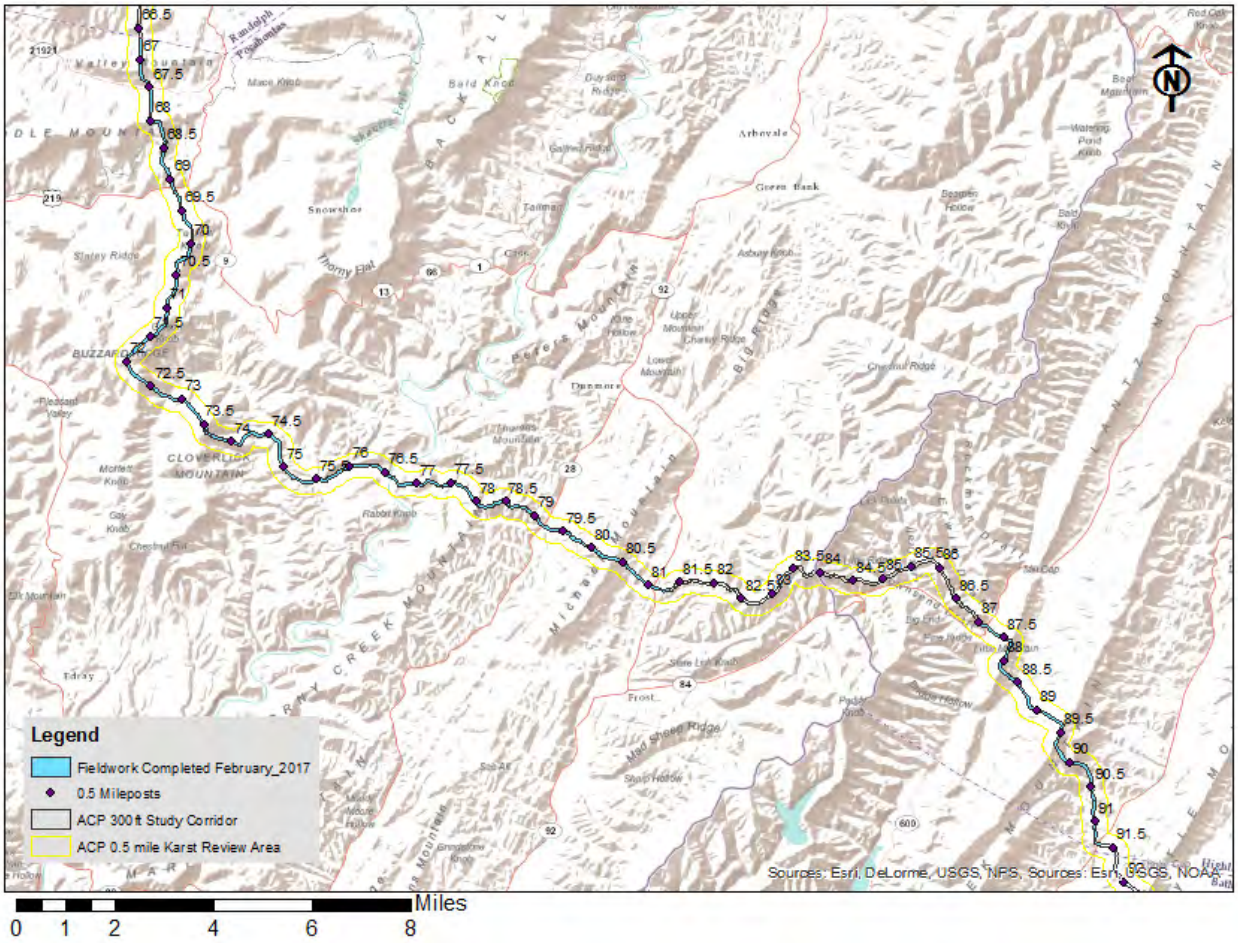

Figure 4. Map of completed field survey section in Pocahontas County, WV

Review of the literature indicated 18 cave entrances were located in the Pocahontas County section (Medville & Medville, 1976; Storrick, 1992). All of the cave entrances were located outside of the 300FC with the exception of Tapp's Trap; however, the entrance could not be located by the field crew and reportedly the WVASS could not locate the entrance during a reconnaissance survey of the county in the 1990s (Springer, verb.comm., 2017). Analysis of the topography showed that none of these cave entrances are downgradient from the 300FC centerline. Surveyed cave lengths ranged from 8 feet to 12,612 feet. A total of three of the caves are developed in the Bluefield Formation of the Mauch Chunk Group, with the remaining 15 caves being developed in the Greenbrier Group limestones. The two longest caves are Piddling Pit and Canis Majoris, at 12,612 feet and 5,800 feet in length, respectively (Fig. 5). Piddling Pit, the larger of the two extends towards the south, based on mapping provided by the WVSS, and does not underlie the 300FC. However Canis Majoris Cave extends roughly horizontally for approximately 2,400 feet to the north, and passes underneath the 300FC from south to north. The highest ceiling in the cave is 70 feet, and is located in a chamber south of the 300FC. The mapped cave passages below the 300FC have a maximum ceiling height of 25 feet, and are at least 170 to 175 vertical feet below the ground surface (Medville and Medville, 1976).

Field Survey (Fig. 4) – The Field survey for the Pocahontas County section was performed in summer and early autumn 2016. The field survey extended from milepost 66.7 in the valley between Mingo Knob and Valley Mountain, to milepost 81.3. The survey comprised all of the mapped and inferred karst terrain in the Pocahontas County section.

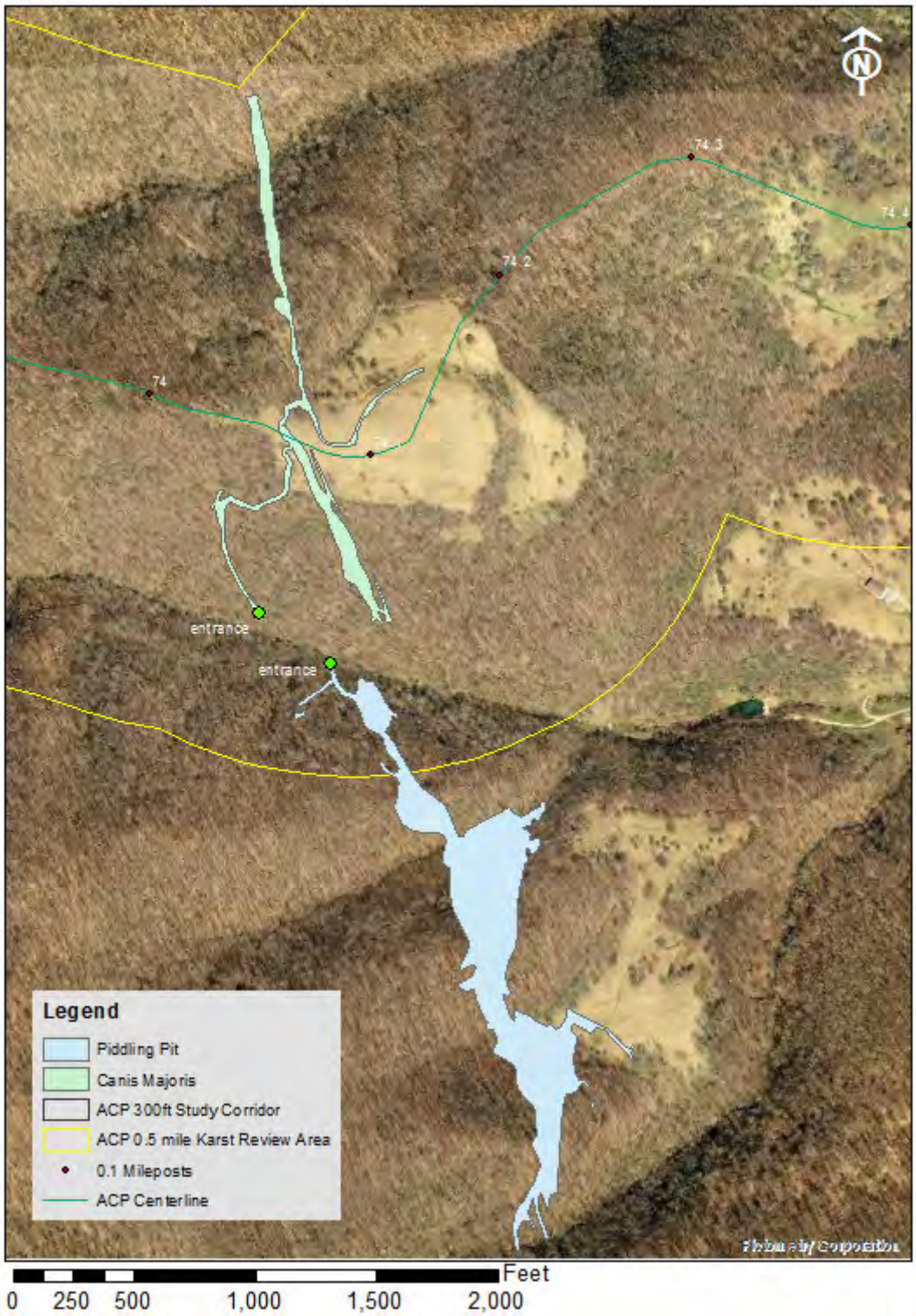

Figure 5. Outline maps of Canis Majoris Cave and Piddling Pit Cave with respect to the ACP Centerline

A total of 87 karst features were identified in the Pocahontas County section: 61 point features; and 26 area features. The majority of features were located in the Mississippian age Greenbrier and Mauch Chunk group rocks.

Highland County, Virginia (Folded Appalachians)

Milepost 83.9 to 91.6 – Appendix B: Maps 43 - 57

The Highland County, Virginia section of the survey extends from milepost 83.9 to milepost 91.6 in the valley of the Jackson River 1.2 miles west of Bolar, Virginia. Elevations range from approximately EL 3,800 feet on the crest of Allegheny Mountain, to EL 2,090 in the Jackson River valley.

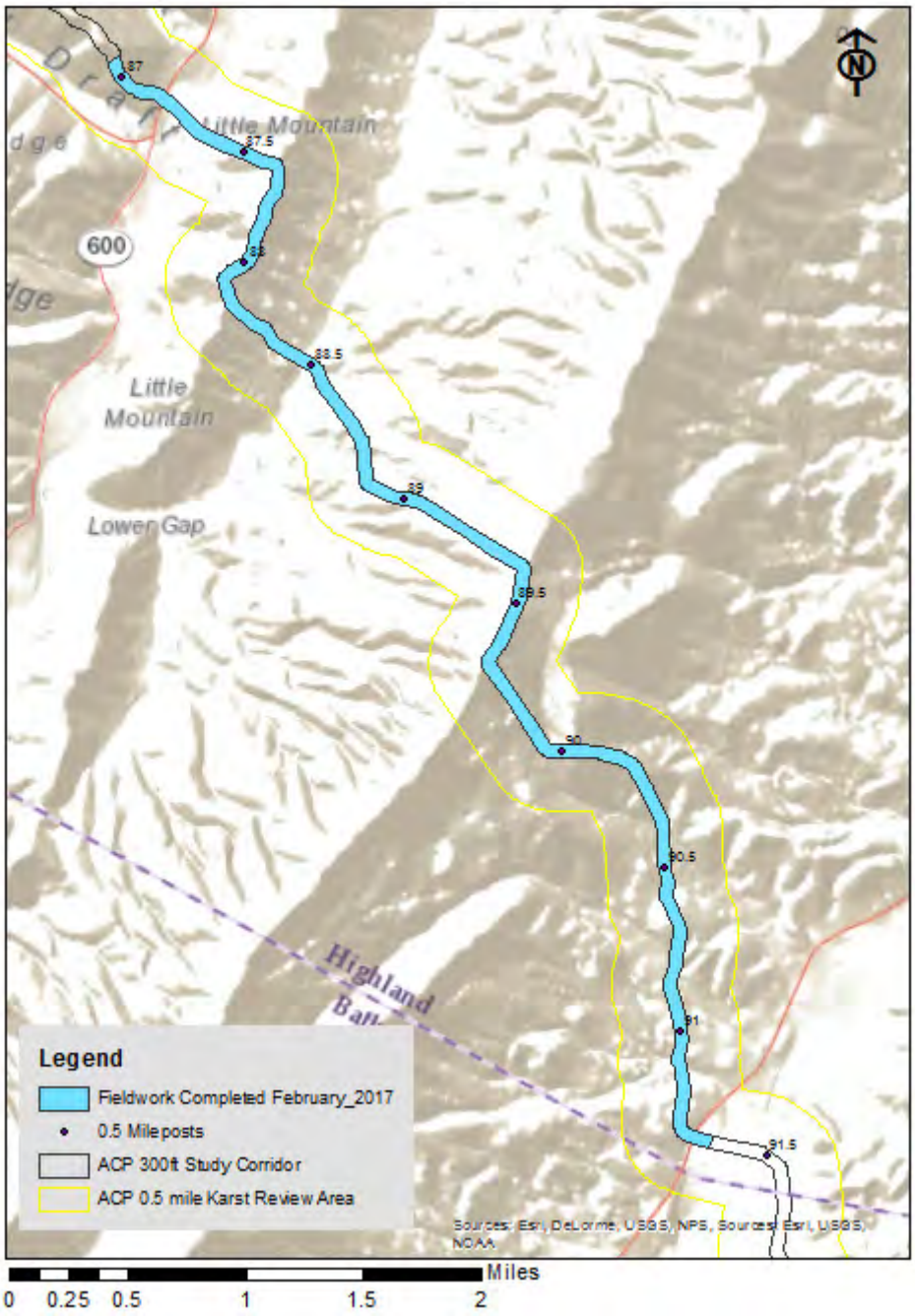

Figure 6. Map of completed field survey sections in Highland County, VA

Data Review – The largest scale maps available initially for terrain analysis for Highland County were 2-foot interval contour maps derived from county level DTMs using GIS software. However subsequently DTI staff provided LIDAR data for the entire karst section of Highland County. The data review indicated the presence of a total of 53 closed depressions, all of which were classified as cCD. There were no sCD features identified in the data review in Highland County. One of the features was located in the Ordovician

age Moccasin and Bays Formation unit just west of Valley Center, and the other two were located on the eastern flank of Back Creek Mountain in the Silurian age Tuscarora Formation. The Moccasin and Bays Formations are karst-forming units equivalent to the Middle Ordovician Limestones of the Great Valley. However, the Tuscarora Formation is not a karst-forming unit and the feature may represent areas where the Tuscarora has collapsed into underlying karst structures.

Referencing proprietary cave location data provided by the Virginia Speleological Survey (VSS) four cave entrances were located in the Highland County section. All of the caves were listed as very short (less than 250 feet). Two of the cave entrances were verified and located in the field (Rock Well Cave and Sinking Stream Cave); however the entrance of a third cave (Impatient Pit) could not be found and may have been filled-in by the landowner.

Field Survey (Fig. 6) – The field survey for the Highland County, VA section was performed in June, 2016. The field survey extended from milepost 83.9 to milepost 91.3, which comprised approximately 96 percent of the proposed alignment in Highland County, and covering 100 percent of the areas mapped as karst terrain.

A total of 56 karst features were identified in the Highland County section: 18 point features; and 38 area features. The majority of features were located in the Valley Center area. The remaining features were located in the Tuscarora Formation outcrop zone on the eastern flank of Back Creek Mountain.

Bath County, Virginia (Folded Appalachians)

Milepost 91.6 to 106.8 – Appendix B: Maps 58 - 83

The Bath County, Virginia section of the survey extends from milepost 91.6 near Bolar, Virginia to milepost 106.8 in the Mill Creek Valley. Elevations range from approximately EL 3,600 feet on the crest of Jack Mountain, to EL 1,600 in the Cowpasture River valley.

Data review – The largest scale maps available for terrain analysis for Bath County were 2 foot interval contour maps derived from county level DTMs using GIS software and LIDAR data provided by DTI. The Data review indicated the presence seven sCD features, and 44 cCD, all of which were located in the Helderberg Group rocks along the western pediment of Walker Mountain.

Referencing proprietary cave location data provided by the Virginia Speleological Survey (VSS) two small caves were located on the east flank of Tower Mountain; however, the survey crew did not have landowner permission to survey this section of the alignment, so the cave entrance locations could not be verified.

Field survey (Fig. 7) – The field survey for the Bath County, Virginia section was performed in June, 2016 and February 2017. The field survey was conducted in four discontinuous sections: mileposts 94.6 to 95.9, 101.4 to 101.8, 103.0 to 104.2 and 105.2 to 106.7. Landowner permissions was not granted for the remaining areas of either mapped or inferred karst terrain. This includes the section of the proposed alignment southwest of Burnsville Cove from milepost 96.8 to 97.2 within the known recharge area of the extensive cavern systems located in that internally-drained karst valley, and the southern section of the Deerfield Valley from milepost 102.2 to 103. With the exception of the aforementioned sections, all of the remaining mapped or inferred karst terrain in the Bath County section were surveyed.

A total of 44 karst features were identified in the Bath County section, 43 of which were point features and one area feature. The majority of field identified features were located along the western pediment of Walker Mountain in the valley of the Mill Creek. It is of note that over half of these features, located primarily in the southern section of the Mill Creek Valley area, were mapped as being in the Millboro Shale and Needmore Formation, neither of which are considered karst-forming units. However throughout the Bath and Highland County area, numerous sinkholes are known to form in these units, and a small cave has been discovered in the Needmore Formation in Berkeley County, West Virginia. Both of these units are primarily shale; however, they are highly calcitic and can be prone to dissolution. In addition, where the pyritic Millboro Shale is exposed at the surface, the sulfide minerals in it oxidize forming sulfuric acid,

which can accelerate the groundwater dissolution process of the underlying Needmore Formation. Finally, both of these shales are located directly above the karst-forming Helderberg Group rocks, and can collapse into large cavernous voids which may be located in the Helderberg carbonates below.

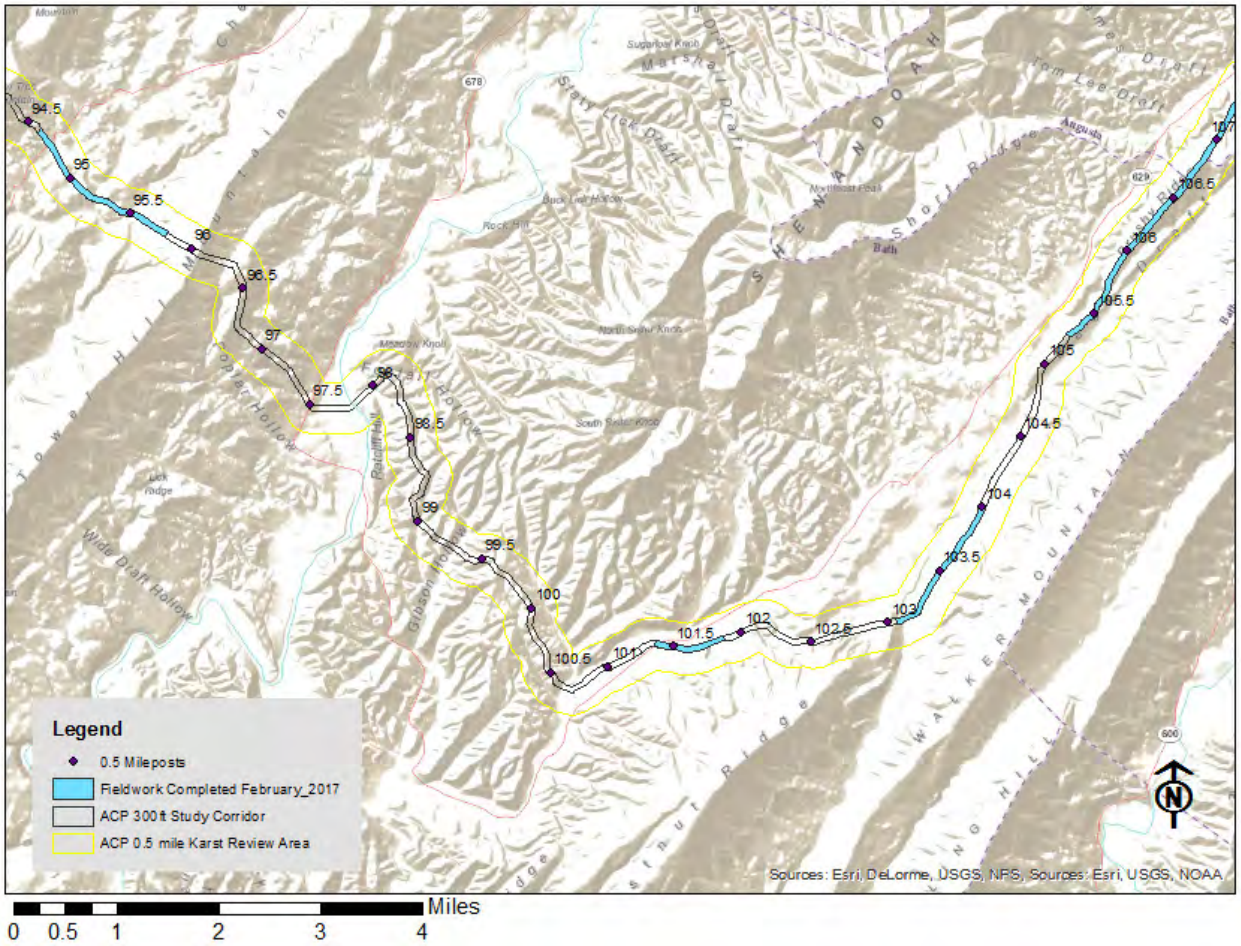

Figure 7. Map of completed field survey sections in Bath County, VA.

Augusta County, Virginia (Great Valley)

Milepost 106.8 to 158.2 – Appendix B: Maps 83 - 154

The Augusta County, Virginia section of the survey extends from milepost 106.8 southwest of Deerfield, Virginia, to milepost 158.2, southeast of Waynesboro, Virginia. Elevations range from approximately EL 2,798 on the crest of Chestnut Oak Knob, to EL 1,380 in the valley of the South River.

Data Review – The largest scale maps available for terrain analysis for Augusta County were LIDAR generated DEMs for selected areas of the central and southern portion of the survey, and 2-foot interval contour maps derived from county level DTMs using GIS software with LIDAR provided by DTI for the northern section. The Data review indicated the presence 44 sCD features, and 51 cCD. In addition, 20 small suspected sinkhole features were located during the analysis of the LIDAR data.

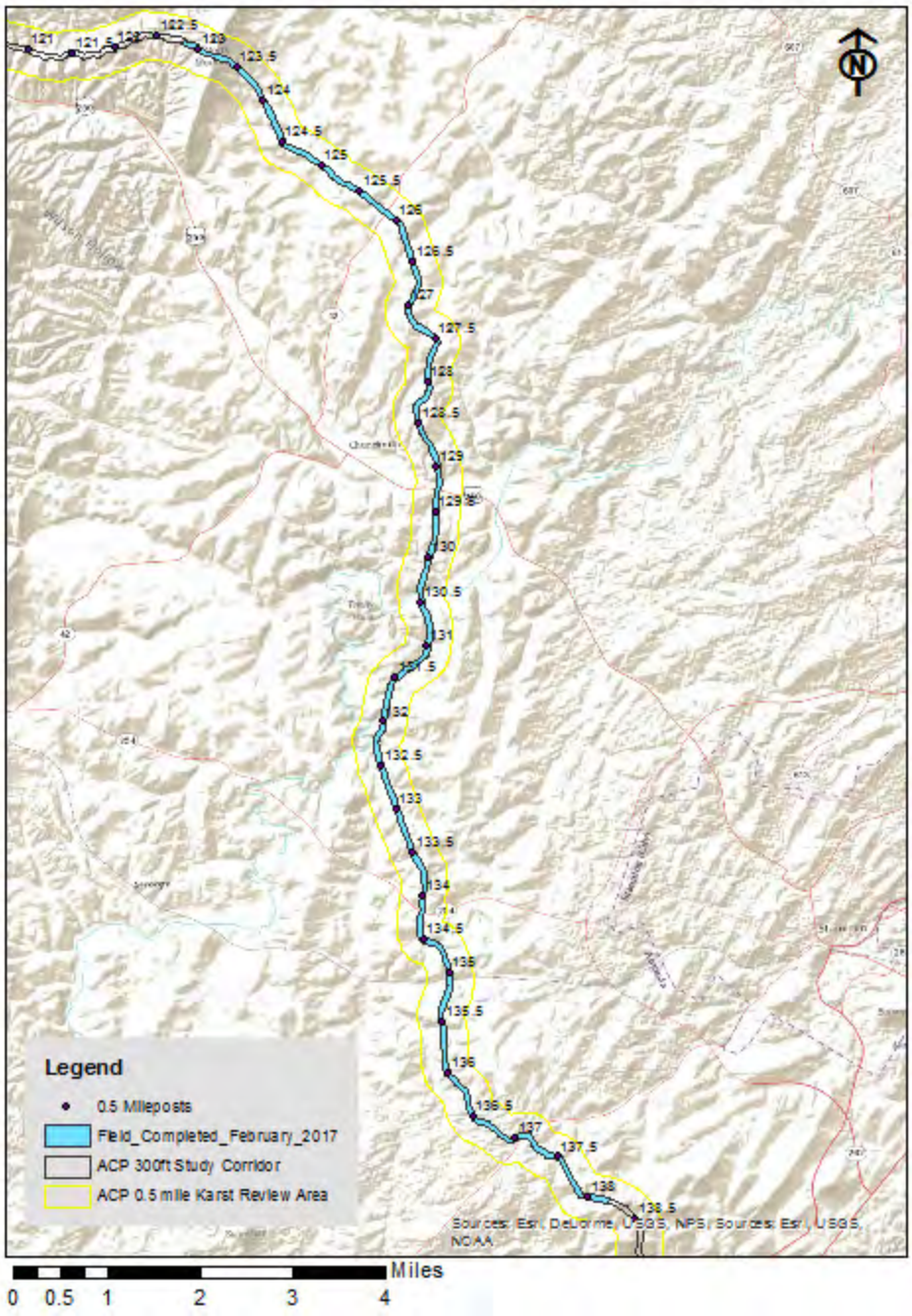

Figure 8. Map of completed field survey sections in northern Augusta County, VA

Referencing proprietary cave location data provided by the Virginia Speleological Survey (VSS) two caves were located in Augusta County within the KRA: Cochran's Cave No. 2 and Cochran's Cave No. 3, the former of which is classified as a significant cave by the VSS and for which a conservation area has been delineated by the Karst Program of the Virginia Division of Conservation and Recreation – Natural Heritage Program (DCR-NHP).

Field Survey (Fig. 8-9) – The field survey for the Augusta County, VA section was performed during October through early November 2014, May – June 2015, June 2016 and September 2016. It is of note that based on the USGS National Karst Map (2014) the karst terrain extended from milepost 122.9 to 153.2, with an inferred section running parallel with the base of the Blue Ridge from milepost 153.2 to 156.7 in the Back Creek Valley. This section was included because several suspect features had been reported by

the ACP routing crews, and it was located immediately east of the known karst area of the Shady Dolomite. Of the 33.8 miles of mapped or inferred karst terrain in Augusta County, 31.6 miles have been surveyed (approximately 93.4 percent) in four discontinuous sections of varying length where landowner permission was obtained.

A total of 111 features were identified and located during the field survey, which included 85 point features and 26 area features. Nearly half of the features were located in the Beekmantown Group carbonates, including the cluster of sinkholes, springs and cave entrances in the Cochran Cave area southwest of Staunton, Virginia. A second concentration of features was identified in the Cambrian age units (the Elbrook, Waynesboro and Shady Dolomite formations) in a section from just southeast of Stuart's Draft and extending southward towards Sherando Camp.

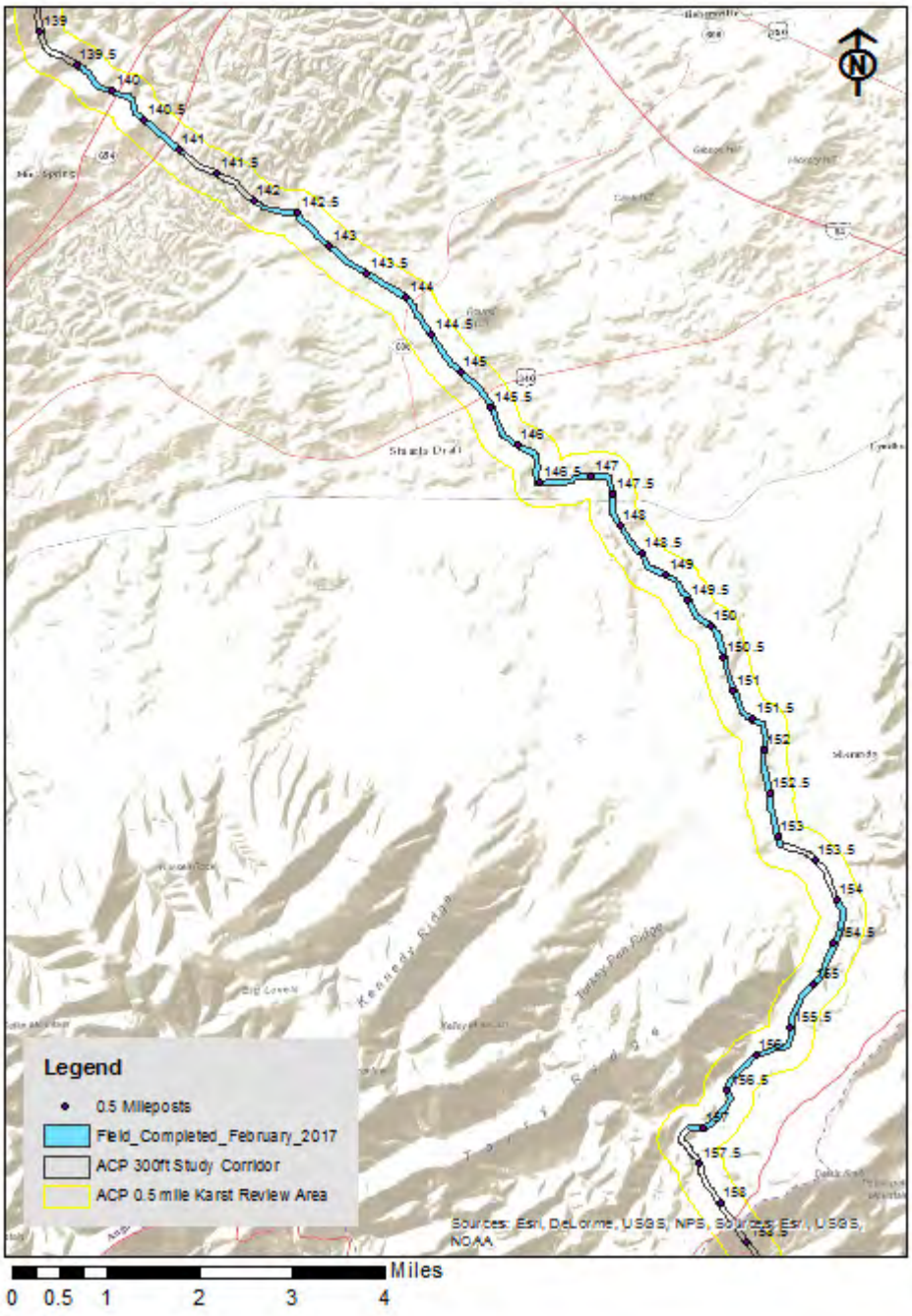

Figure 9. Map of completed field survey sections in southern Augusta County, VA

Summary of Findings

The findings of the data review and field survey are summarized as a series of tables in Appendix C. Each table includes the Feature ID, coordinates (system = UTM in US feet), geologic formation (abbreviation and full name), geologic age (period name), karst feature type and risk ranking (field survey data only).

General Limitations

Findings contained in this report are based upon the data obtained from the data review and field survey services detailed herein. It is essential that on-site observations as per the Karst Survey and Mitigation Plan be performed during the construction period to determine if re-evaluation of the recommendations in this report must be made.

This report was prepared in accordance with generally accepted geologic and geotechnical engineering practices. No warranties, expressed or implied, are made as to the professional services included in this report.

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APPENDIX A
Geologic Maps

GeoConcepts Engineering, Inc.

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This information is for environmental review purposes only.

Mileposts (1.0 mile)

Rev 12 Centerline

Rev 12 0.50 KRA

Geologic Maps

0 10,000 20,000

Feet

INDEX GEOLOGIC MAP I
ATLANTIC COAST PIPELINE
11002.04

Dominion

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GeoConcepts Engineering, Inc.

Mileposts (1.0 mile)

Rev 12 Centerline

Rev 12 0.50 KRA

Geologic Maps

0 10,000 20,000

Feet

INDEX GEOLOGIC MAP II
ATLANTIC COAST PIPELINE
11002.04

Dominion

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- Mileposts (1.0 mile)
- Rev 12 Centerline
- Rev 12 0.50 KRA
- Geologic Maps

0 10,000 20,000
Feet

INDEX GEOLOGIC MAP III
ATLANTIC COAST PIPELINE
11002.04

Dominion

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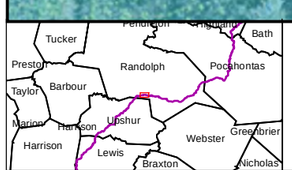
New River

New River

Kanawha

48

47



Mileposts (1.0 mile)
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Rev 12 300' Corridor
Rev 12 0.50 KRA
All Point Features
All Area Features
300' Corridor Closed Depressions
Suspect Closed Depressions
Virginia Caves
Randolph Caves
Pocahontas Caves

0 1,000 2,000
Feet

Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics,

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GEOLOGIC MAP 1

ATLANTIC COAST PIPELINE

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Kanawha

New River

New River

New River

New River

Source: Esri, DigitalGlobe, GeoEye, Earthstar Geogr

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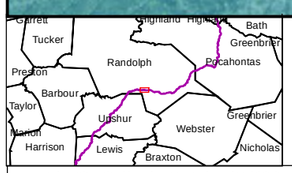

Mileposts (1.0 mile)

Rev 12 Centerline

Rev 12 300' Corridor

Rev 12 0.50 KRA

All Point Features

All Area Features

300' Corridor Closed Depressions

Suspect Closed Depressions

Virginia Caves

Randolph Caves

Pocahontas Caves

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GEOLOGIC MAP 2

ATLANTIC COAST PIPELINE

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New River

Kanawha

51

52

53

Kanawha

Bluestone, Princeton

Hinton

Source: Esri, DigitalGlobe, GeoF

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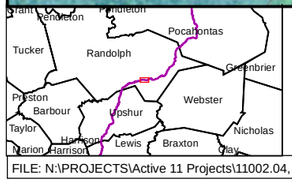

- Mileposts (1.0 mile)
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- Rev 12 300' Corridor
- Rev 12 0.50 KRA
- All Point Features
- All Area Features
- 300' Corridor Closed Depressions
- Suspect Closed Depressions
- Virginia Caves
- Randolph Caves
- Pocahontas Caves

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Feet

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GEOLOGIC MAP 3

ATLANTIC COAST PIPELINE

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New River

Kanawha

Kanawha

Kanawha

55

54

53

New River

Bluestone, Princeton

Kanawha

Source: Esri, DigitalGlobe, Ger

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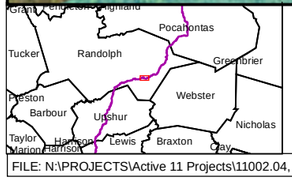

- Mileposts (1.0 mile)
- Rev 12 Centerline
- Rev 12 300' Corridor
- Rev 12 0.50 KRA
- All Point Features
- All Area Features
- 300' Corridor Closed Depressions
- Suspect Closed Depressions
- Virginia Caves
- Randolph Caves
- Pocahontas Caves

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Feet

GEOLOGIC MAP 4

ATLANTIC COAST PIPELINE

11002.04

FILE: N:\PROJECTS\Active 11 Projects\11002.04, Dominion Resources Pipeline - Randolph and Pocahontas Co\Final\GIS Data for Final\reportmap Geologic.mxd | REVISED: 02/14/2017 | SCALE: 1:12,000 when printed at 11x17

DRAWN BY: JDV

GeoConcepts Engineering, Inc.

New River

Bluestone, Princeton

New River

56

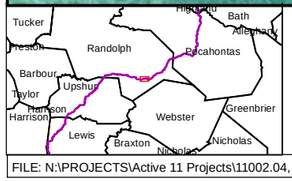
57

Kanawha

New River

Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographi

This information is for environmental review purposes only.



- Mileposts (1.0 mile)
- Rev 12 Centerline
- Rev 12 300' Corridor
- Rev 12 0.50 KRA
- All Point Features
- All Area Features
- 300' Corridor Closed Depressions
- Suspect Closed Depressions
- Virginia Caves
- Randolph Caves
- Pocahontas Caves

0 1,000 2,000
Feet

GEOLOGIC MAP 5

ATLANTIC COAST PIPELINE

11002.04

FILE: N:\PROJECTS\Active 11 Projects\11002.04, Dominion Resources Pipeline - Randolph and Pocahontas Co\Final\GIS Data for Final\reportmap Geologic.mxd | REVISED: 02/14/2017 | SCALE: 1:12,000 when printed at 11x17

DRAWN BY: JDV

GeoConcepts Engineering, Inc.

Kanawha

New River

New River

New River

Bluestone, Princeton

59

58

Kanawha

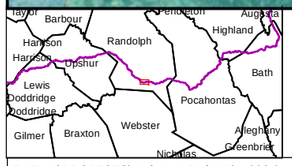
Kanawha

New River

New River

Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User

Not to be used for navigation purposes.



Mileposts (1.0 mile)

Rev 12 Centerline

Rev 12 300' Corridor

Rev 12 0.50 KRA

All Point Features

All Area Features

300' Corridor Closed Depressions

Suspect Closed Depressions

Virginia Caves

Randolph Caves

Pocahontas Caves

0 1,000 2,000

Feet

GEOLOGIC MAP 6

ATLANTIC COAST PIPELINE

11002.04

FILE: N:\PROJECTS\Active 11 Projects\11002.04, Dominion Resources Pipeline - Randolph and Pocahontas Co\Final\GIS Data for Final\reportmap Geologic.mxd | REVISED: 02/14/2017 | SCALE: 1:12,000 when printed at 11x17

DRAWN BY: JDV

GeoConcepts Engineering, Inc.

New River

Kanawha

Bluestone, Princeton

60

Bluefield

Hinton

61

Bluestone, Princeton

New River

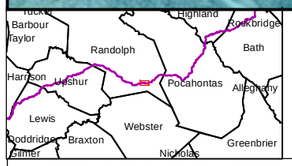
Hinton

Bluestone, Princeton

Hinton

Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, ...

This information is for environmental review purposes only.



- Mileposts (1.0 mile)
- Rev 12 Centerline
- Rev 12 300' Corridor
- Rev 12 0.50 KRA
- All Point Features
- All Area Features
- 300' Corridor Closed Depressions
- Suspect Closed Depressions
- Virginia Caves
- Randolph Caves
- Pocahontas Caves

0 1,000 2,000
Feet

GEOLOGIC MAP 7

ATLANTIC COAST PIPELINE

11002.04

FILE: N:\PROJECTS\Active 11 Projects\11002.04, Dominion Resources Pipeline - Randolph and Pocahontas Co\Final\GIS Data for Final\reportmap Geologic.mxd | REVISED: 02/14/2017 | SCALE: 1:12,000 when printed at 11x17

DRAWN BY: JDV

GeoConcepts Engineering, Inc.

Bluefield

New River

sCD35

sCD34

62

63

Bluestone, Princeton

sCD36

Bluefield

Bluefield

Hinton

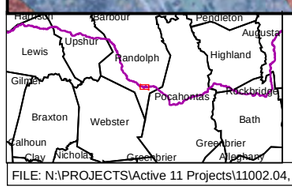
Bluefield

Hinton

Bluefield

Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

Not to be used for environmental review purposes only.



- Mileposts (1.0 mile)
- Rev 12 Centerline
- Rev 12 300' Corridor
- Rev 12 0.50 KRA
- All Point Features
- All Area Features
- 300' Corridor Closed Depressions
- Suspect Closed Depressions
- Virginia Caves
- Randolph Caves
- Pocahontas Caves

0 1,000 2,000
Feet

GEOLOGIC MAP 8

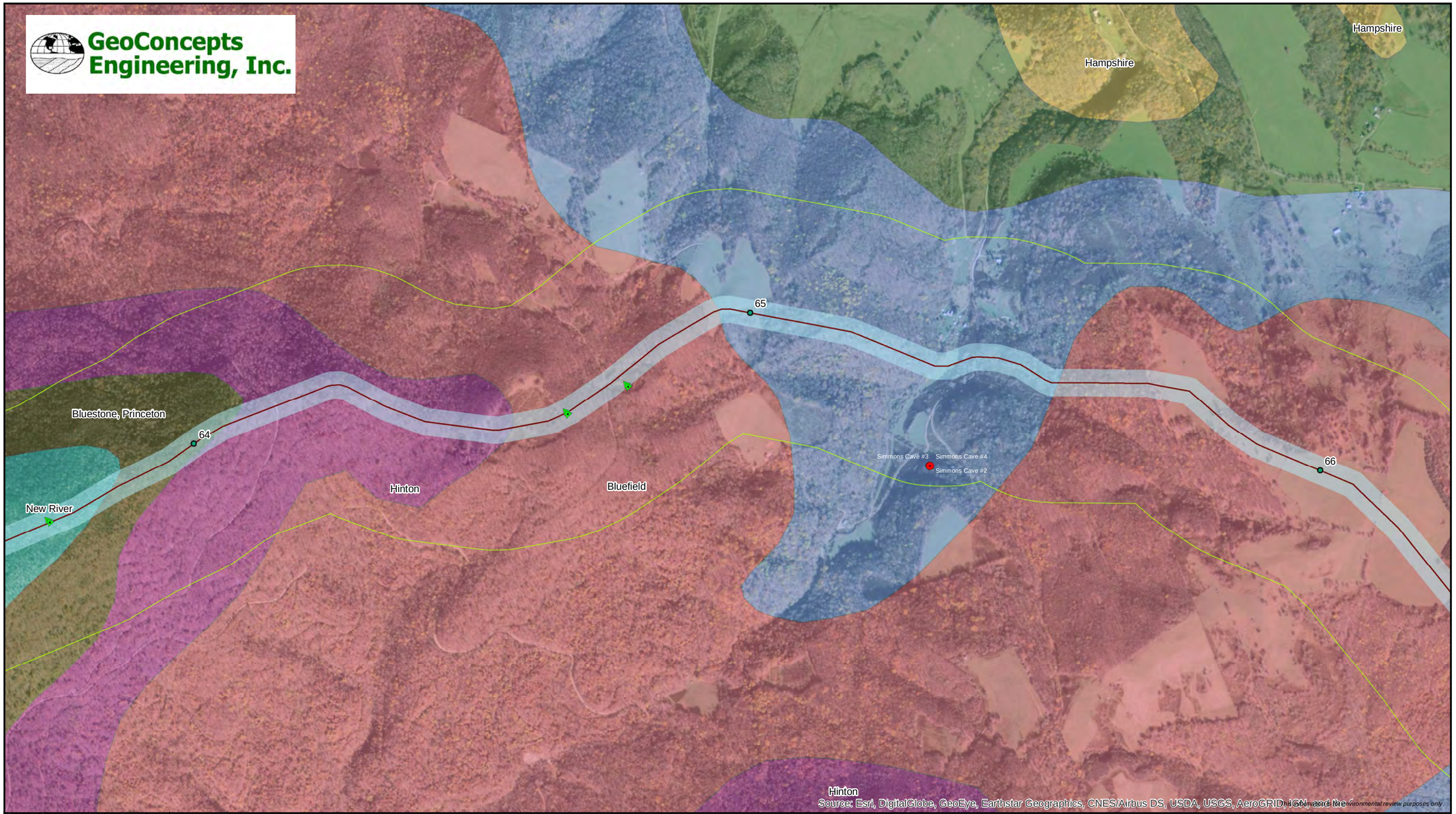
ATLANTIC COAST PIPELINE

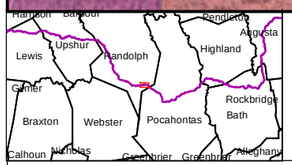
11002.04

FILE: N:\PROJECTS\Active 11 Projects\11002.04, Dominion Resources Pipeline - Randolph and Pocahontas Co\Final\GIS Data for Final\reportmap Geologic.mxd | REVISED: 02/14/2017 | SCALE: 1:12,000 when printed at 11x17

DRAWN BY: JDV

GeoConcepts Engineering, Inc.





- Mileposts (1.0 mile)
- Rev 12 Centerline
- Rev 12 300' Corridor
- Rev 12 0.50 KRA
- All Point Features
- All Area Features
- 300' Corridor Closed Depressions
- Suspect Closed Depressions
- Virginia Caves
- Randolph Caves
- Pocahontas Caves

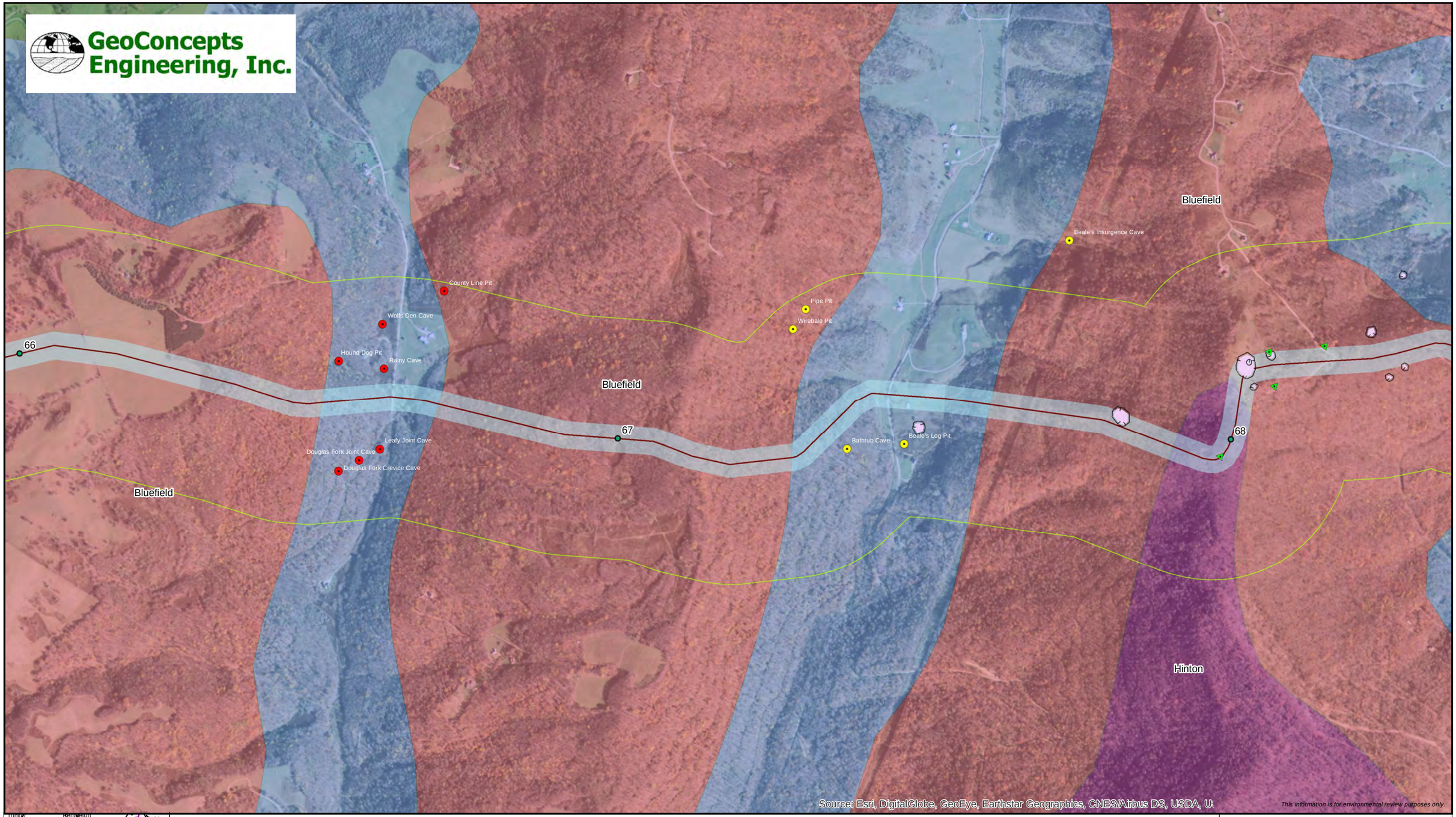
0 1,000 2,000
Feet

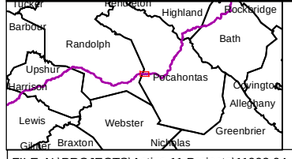
GEOLOGIC MAP 9
ATLANTIC COAST PIPELINE
11002.04

FILE: N:\PROJECTS\Active 11 Projects\11002.04, Dominion Resources Pipeline - Randolph and Pocahontas Co\Final\GIS Data for Final\reportmap Geologic.mxd | REVISED: 02/14/2017 | SCALE: 1:12,000 when printed at 11x17

DRAWN BY: JDV

GeoConcepts Engineering, Inc.





- Mileposts (1.0 mile)
- Rev 12 Centerline
- Rev 12 300' Corridor
- Rev 12 0.50 KRA
- All Point Features
- All Area Features
- 300' Corridor Closed Depressions
- Suspect Closed Depressions
- Virginia Caves
- Randolph Caves
- Pocahontas Caves

0 1,000 2,000
Feet

GEOLOGIC MAP 10
ATLANTIC COAST PIPELINE
11002.04

FILE: N:\PROJECTS\Active 11 Projects\11002.04, Dominion Resources Pipeline - Randolph and Pocahontas Co\Final\GIS Data for Final\reportmap Geologic.mxd | REVISED: 02/14/2017 | SCALE: 1:12,000 when printed at 11x17 DRAWN BY: JDV

GeoConcepts Engineering, Inc.

Hinton

Bluefield

Bluefield

Linwood Pit

Linwood Cave

Field FRO Cave

Vandevener's Garbage Pit

Boulder Cave FRO

Hi-Up Holes

70

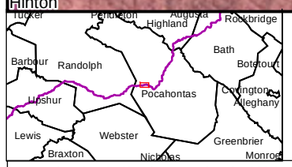
69

Hinton

Bluefield

Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA

This information is for environmental review purposes only.



Mileposts (1.0 mile)

Rev 12 Centerline

Rev 12 300' Corridor

Rev 12 0.50 KRA

All Point Features

All Area Features

300' Corridor Closed Depressions

Suspect Closed Depressions

Virginia Caves

Randolph Caves

Pocahontas Caves

0 1,000 2,000

Feet

N

GEOLOGIC MAP 11

ATLANTIC COAST PIPELINE

11002.04

FILE: N:\PROJECTS\Active 11 Projects\11002.04, Dominion Resources Pipeline - Randolph and Pocahontas Co\Final\GIS Data for Final\reportmap Geologic.mxd | REVISED: 02/14/2017 | SCALE: 1:12,000 when printed at 11x17

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GeoConcepts Engineering, Inc.

Hinton

Bluefield

71

Bluestone, Princeton

73

Tapps Trap

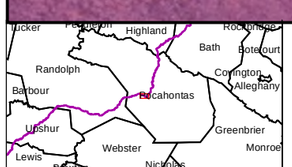
Hinton

72

Bluefield

Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES

This information is for environmental review purposes only.



- Mileposts (1.0 mile)
- Rev 12 Centerline
- Rev 12 300' Corridor
- Rev 12 0.50 KRA
- All Point Features
- All Area Features
- 300' Corridor Closed Depressions
- Suspect Closed Depressions
- Virginia Caves
- Randolph Caves
- Pocahontas Caves

0 1,000 2,000
Feet

GEOLOGIC MAP 12
ATLANTIC COAST PIPELINE
11002.04

FILE: N:\PROJECTS\Active 11 Projects\11002.04, Dominion Resources Pipeline - Randolph and Pocahontas Co\Final\GIS Data for Final\reportmap Geologic.mxd | REVISED: 02/14/2017 | SCALE: 1:12,000 when printed at 11x17 DRAWN BY: JDV

GeoConcepts Engineering, Inc.

Bluefield

Maccrady

Hinton

Smith Crawl Cave

Eight Foot Pit

Tapps Trap

73

74

75

Skunk Cave

Canis Majoris Cave

Piddling Pit

Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the

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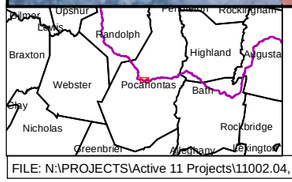

Mileposts (1.0 mile)

Rev 12 Centerline

Rev 12 300' Corridor

Rev 12 0.50 KRA

All Point Features

All Area Features

300' Corridor Closed Depressions

Suspect Closed Depressions

Virginia Caves

Randolph Caves

Pocahontas Caves

0 1,000 2,000

Feet

μ

GEOLOGIC MAP 13

ATLANTIC COAST PIPELINE

11002.04

FILE: N:\PROJECTS\Active 11 Projects\11002.04, Dominion Resources Pipeline - Randolph and Pocahontas Co\Final\GIS Data for Final\reportmap Geologic.mxd | REVISED: 02/14/2017 | SCALE: 1:12,000 when printed at 11x17

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GeoConcepts Engineering, Inc.

Maccrady

75

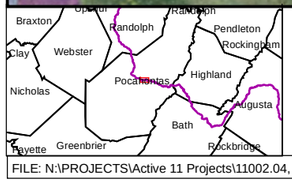
76

77

Maccrady

Hampshire

Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community



- Mileposts (1.0 mile)
- Rev 12 Centerline
- Rev 12 300' Corridor
- Rev 12 0.50 KRA
- All Point Features
- All Area Features
- 300' Corridor Closed Depressions
- Suspect Closed Depressions
- Virginia Caves
- Randolph Caves
- Pocahontas Caves

0 1,000 2,000
Feet

μ

GEOLOGIC MAP 14

ATLANTIC COAST PIPELINE

11002.04

FILE: N:\PROJECTS\Active 11 Projects\11002.04, Dominion Resources Pipeline - Randolph and Pocahontas Co\Final\GIS Data for Final\reportmap Geologic.mxd | REVISED: 02/14/2017 | SCALE: 1:12,000 when printed at 11x17

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GeoConcepts Engineering, Inc.

Hampshire

Brallier

77

78

79

Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the G

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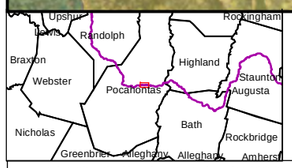

- Mileposts (1.0 mile)
- Rev 12 Centerline
- Rev 12 300' Corridor
- Rev 12 0.50 KRA
- All Point Features
- All Area Features
- 300' Corridor Closed Depressions
- Suspect Closed Depressions
- Virginia Caves
- Randolph Caves
- Pocahontas Caves

0 1,000 2,000
Feet

μ

GEOLOGIC MAP 15

ATLANTIC COAST PIPELINE

11002.04

FILE: N:\PROJECTS\Active 11 Projects\11002.04, Dominion Resources Pipeline - Randolph and Pocahontas Co\Final\GIS Data for Final\reportmap Geologic.mxd | REVISED: 02/14/2017 | SCALE: 1:12,000 when printed at 11x17

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GeoConcepts Engineering, Inc.

Brallier

Harrell, Mahantango, Marcellus

80

Oriskany Sandstone

Tonoloway, Wills Creek, Williamsport

McKenzie

Tuscarora Sandstone

McKenzie

Oriskany Sandstone

Tonoloway, Wills Creek, Williamsport

Harrell, Mahantango, Marcellus

81

Brallier

Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

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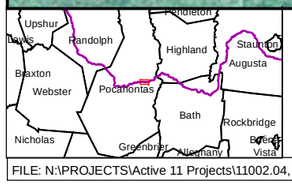

Mileposts (1.0 mile)

Rev 12 Centerline

Rev 12 300' Corridor

Rev 12 0.50 KRA

All Point Features

All Area Features

300' Corridor Closed Depressions

Suspect Closed Depressions

Virginia Caves

Randolph Caves

Pocahontas Caves

0 1,000 2,000

Feet

GEOLOGIC MAP 16

ATLANTIC COAST PIPELINE

11002.04

FILE: N:\PROJECTS\Active 11 Projects\11002.04, Dominion Resources Pipeline - Randolph and Pocahontas Co\Final\GIS Data for Final\reportmap Geologic.mxd | REVISED: 02/14/2017 | SCALE: 1:12,000 when printed at 11x17

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GeoConcepts Engineering, Inc.

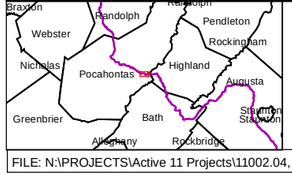
Harrell, Mahantango, Marcellus

Brallier

Hampshire

82

83



Mileposts (1.0 mile)
Rev 12 Centerline
Rev 12 300' Corridor
Rev 12 0.50 KRA
All Point Features
All Area Features
300' Corridor Closed Depressions
Suspect Closed Depressions
Virginia Caves
Randolph Caves
Pocahontas Caves

0 1,000 2,000
Feet

μ

GEOLOGIC MAP 17

ATLANTIC COAST PIPELINE

11002.04

This information is for environmental review purposes only.

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DRAWN BY: JDV

GeoConcepts Engineering, Inc.

Hampshire Formation

Hampshire

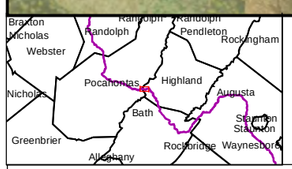
84

Chemung Formation

85

Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

This information is for environmental review purposes only.



- Mileposts (1.0 mile)
- Rev 12 Centerline
- Rev 12 300' Corridor
- Rev 12 0.50 KRA
- All Point Features
- All Area Features
- 300' Corridor Closed Depressions
- Suspect Closed Depressions
- Virginia Caves
- Randolph Caves
- Pocahontas Caves

0 1,000 2,000
Feet

μ

GEOLOGIC MAP 18

ATLANTIC COAST PIPELINE

11002.04

FILE: N:\PROJECTS\Active 11 Projects\11002.04, Dominion Resources Pipeline - Randolph and Pocahontas Co\Final\GIS Data for Final\reportmap Geologic.mxd | REVISED: 02/14/2017 | SCALE: 1:12,000 when printed at 11x17

DRAWN BY: JDV

GeoConcepts Engineering, Inc.

86

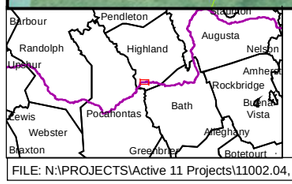
Chemung Formation

Brallier Formation

87

88

Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Com... Esri, HERE, DeLorme, MapmyIndia, © OpenStreetMap contributors, and the GIS User Community



Mileposts (1.0 mile)

Rev 12 Centerline

Rev 12 300' Corridor

Rev 12 0.50 KRA

All Point Features

All Area Features

300' Corridor Closed Depressions

Suspect Closed Depressions

Virginia Caves

Randolph Caves

Pocahontas Caves

0 1,000 2,000

Feet

GEOLOGIC MAP 19

ATLANTIC COAST PIPELINE

11002.04

FILE: N:\PROJECTS\Active 11 Projects\11002.04, Dominion Resources Pipeline - Randolph and Pocahontas Co\Final\GIS Data for Final\reportmap Geologic.mxd | REVISED: 02/14/2017 | SCALE: 1:12,000 when printed at 11x17

DRAWN BY: JDV

GeoConcepts Engineering, Inc.

Jeremys Cave

Mocassin Formation, Bays Formation, Unit C, Unit B, Unit A

Keefer Sandstone, Rose Hill and Tuscarora Formations

Inpatient Pit

Rock Well Cave

Sinking Stream Cave

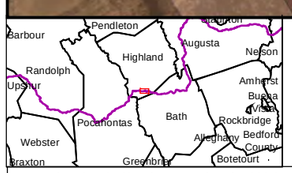
88

89

90

Juniata, Oswego, Martinsburg (Reedsville and Dolly Ridge), Eggleston Formation

Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Comm...



- Mileposts (1.0 mile)
- Rev 12 Centerline
- Rev 12 300' Corridor
- Rev 12 0.50 KRA
- All Point Features
- All Area Features
- 300' Corridor Closed Depressions
- Suspect Closed Depressions
- Virginia Caves
- Randolph Caves
- Pocahontas Caves

0 1,000 2,000
Feet

GEOLOGIC MAP 20

ATLANTIC COAST PIPELINE

11002.04

FILE: N:\PROJECTS\Active 11 Projects\11002.04, Dominion Resources Pipeline - Randolph and Pocahontas Co\Final\GIS Data for Final\reportmap Geologic.mxd | REVISED: 02/14/2017 | SCALE: 1:12,000 when printed at 11x17

DRAWN BY: JDV

GeoConcepts Engineering, Inc.

Ridgeley Sandstone, Helderber and Cayuga Groups

Millboro Shale and Needmore Formation

Keefer Sandstone, Rose Hill and Tuscarora Formations

91

92

Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and ... for environmental review purposes only.

- Mileposts (1.0 mile)
- Rev 12 Centerline
- Rev 12 300' Corridor
- Rev 12 0.50 KRA
- All Point Features
- All Area Features
- 300' Corridor Closed Depressions
- Suspect Closed Depressions
- Virginia Caves
- Randolph Caves
- Pocahontas Caves

0 1,000 2,000
Feet

GEOLOGIC MAP 21
ATLANTIC COAST PIPELINE
11002.04

FILE: N:\PROJECTS\Active 11 Projects\11002.04, Dominion Resources Pipeline - Randolph and Pocahontas Co\Final\GIS Data for Final\reportmap Geologic.mxd | REVISED: 02/14/2017 | SCALE: 1:12,000 when printed at 11x17

DRAWN BY: JDV

GeoConcepts Engineering, Inc.

94

Keefer Sandstone, Rose Hill and Tuscarora Formations

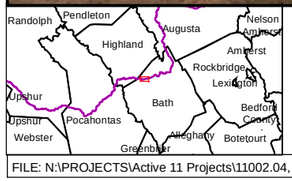
93

Juniata, Oswego, Martinsburg (Reedsville and Dolly Ridge), Eggleston Formation

Millboro Shale and Needmore Formation

Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

Image shown is for view purposes only.



- Mileposts (1.0 mile)
- Rev 12 Centerline
- Rev 12 300' Corridor
- Rev 12 0.50 KRA
- All Point Features
- All Area Features
- 300' Corridor Closed Depressions
- Suspect Closed Depressions
- Virginia Caves
- Randolph Caves
- Pocahontas Caves

0 1,000 2,000
Feet

GEOLOGIC MAP 22

ATLANTIC COAST PIPELINE

11002.04

FILE: N:\PROJECTS\Active 11 Projects\11002.04, Dominion Resources Pipeline - Randolph and Pocahontas Co\Final\GIS Data for Final\reportmap Geologic.mxd | REVISED: 02/14/2017 | SCALE: 1:12,000 when printed at 11x17

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GeoConcepts Engineering, Inc.

Ridgeley Sandstone, Helderber and Cayuga Groups

Keefer Sandstone, Rose Hill and Tuscarora Formations

95

96

sCD48

sCD49

sCD50

sCD51

Keefer Sandstone, Rose Hill and Tuscarora Formations

Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and t

This map is for environmental review purposes only.

- Mileposts (1.0 mile)
- Rev 12 Centerline
- Rev 12 300' Corridor
- Rev 12 0.50 KRA
- All Point Features
- All Area Features
- 300' Corridor Closed Depressions
- Suspect Closed Depressions
- Virginia Caves
- Randolph Caves
- Pocahontas Caves

0 1,000 2,000

Feet

GEOLOGIC MAP 23

ATLANTIC COAST PIPELINE

11002.04

FILE: N:\PROJECTS\Active 11 Projects\11002.04, Dominion Resources Pipeline - Randolph and Pocahontas Co\Final\GIS Data for Final\reportmap Geologic.mxd | REVISED: 02/14/2017 | SCALE: 1:12,000 when printed at 11x17

DRAWN BY: JDV

GeoConcepts Engineering, Inc.

Deuces Wild Cave

Jesse Fox Cave

Ridgeley Sandstone, Helderber and Cayuga Groups

Millboro Shale and Needmore Formation

Brallier Formation

97

98

99

Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

Not to be used for environmental review purposes only.

- Mileposts (1.0 mile)
- Rev 12 Centerline
- Rev 12 300' Corridor
- Rev 12 0.50 KRA
- All Point Features
- All Area Features
- 300' Corridor Closed Depressions
- Suspect Closed Depressions
- Virginia Caves
- Randolph Caves
- Pocahontas Caves

0 1,000 2,000
Feet

GEOLOGIC MAP 24
ATLANTIC COAST PIPELINE
11002.04

FILE: N:\PROJECTS\Active 11 Projects\11002.04, Dominion Resources Pipeline - Randolph and Pocahontas Co\Final\GIS Data for Final\reportmap Geologic.mxd | REVISED: 02/14/2017 | SCALE: 1:12,000 when printed at 11x17

DRAWN BY: JDV

GeoConcepts Engineering, Inc.

99

100

101

Brallier Formation

Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

Not to be used for environmental review purposes only.

Mileposts (1.0 mile)

Rev 12 Centerline

Rev 12 300' Corridor

Rev 12 0.50 KRA

All Point Features

All Area Features

300' Corridor Closed Depressions

Suspect Closed Depressions

Virginia Caves

Randolph Caves

Pocahontas Caves

0 1,000 2,000

Feet

GEOLOGIC MAP 25

ATLANTIC COAST PIPELINE

11002.04

FILE: N:\PROJECTS\Active 11 Projects\11002.04, Dominion Resources Pipeline - Randolph and Pocahontas Co\Final\GIS Data for Final\reportmap Geologic.mxd | REVISED: 02/14/2017 | SCALE: 1:12,000 when printed at 11x17

DRAWN BY: JDV

GeoConcepts Engineering, Inc.

Brallier Formation

Millboro Shale and Needmore Formation

102

Millboro Shale and Needmore Formation

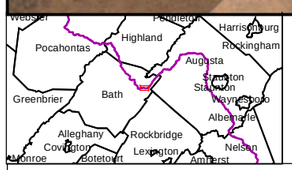
103

Ridgeley Sandstone, Helderber and Cayuga Groups

Keefer Sandstone, Rose Hill and Tuscarora Formations

Source: Esri, Digital...

This information is for environmental review purposes only.



Mileposts (1.0 mile)

Rev 12 Centerline

Rev 12 300' Corridor

Rev 12 0.50 KRA

All Point Features

All Area Features

300' Corridor Closed Depressions

Suspect Closed Depressions

Virginia Caves

Randolph Caves

Pocahontas Caves

0 1,000 2,000

Feet

μ

GEOLOGIC MAP 26

ATLANTIC COAST PIPELINE

11002.04

FILE: N:\PROJECTS\Active 11 Projects\11002.04, Dominion Resources Pipeline - Randolph and Pocahontas Co\Final\GIS Data for Final\reportmap Geologic.mxd | REVISED: 02/14/2017 | SCALE: 1:12,000 when printed at 11x17

DRAWN BY: JDV

GeoConcepts Engineering, Inc.

Millboro Shale and Needmore Formation

Ridgeley Sandstone, Helderber and Cayuga Groups

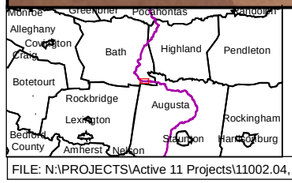
Keefer Sandstone, Rose Hill and Tuscarora Formations

104

105

Source: Esri, DigitalGlobe, GeoEye,

This information is for environmental review purposes only.



Mileposts (1.0 mile)

Rev 12 Centerline

Rev 12 300' Corridor

Rev 12 0.50 KRA

All Point Features

All Area Features

300' Corridor Closed Depressions

Suspect Closed Depressions

Virginia Caves

Randolph Caves

Pocahontas Caves

0 1,000 2,000

Feet

GEOLOGIC MAP 27

ATLANTIC COAST PIPELINE

11002.04

FILE: N:\PROJECTS\Active 11 Projects\11002.04, Dominion Resources Pipeline - Randolph and Pocahontas Co\Final\GIS Data for Final\reportmap Geologic.mxd | REVISED: 02/14/2017 | SCALE: 1:12,000 when printed at 11x17

DRAWN BY: JDV

GeoConcepts Engineering, Inc.

Brallier Formation

Millboro Shale and Needmore Formation

Ridgeley Sandstone, Helderber and Cayuga Groups

sCD52

sCD53

sCD54

105

106

107

Millboro Shale and Needmore Formation

Source: Esri, DigitalGlobe, This information is for environmental review purposes only.

Mileposts (1.0 mile)

Rev 12 Centerline

Rev 12 300' Corridor

Rev 12 0.50 KRA

All Point Features

All Area Features

300' Corridor Closed Depressions

Suspect Closed Depressions

Virginia Caves

Randolph Caves

Pocahontas Caves

0 1,000 2,000

Feet

GEOLOGIC MAP 28

ATLANTIC COAST PIPELINE

11002.04

FILE: N:\PROJECTS\Active 11 Projects\11002.04, Dominion Resources Pipeline - Randolph and Pocahontas Co\Final\GIS Data for Final\reportmap Geologic.mxd | REVISED: 02/14/2017 | SCALE: 1:12,000 when printed at 11x17

DRAWN BY: JDV

GeoConcepts Engineering, Inc.

Brallier Formation

Millboro Shale and Needmore Formation

Ridgeley Sandstone, Helderber and Cayuga Groups

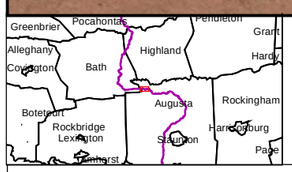
Keefer Sandstone, Rose Hill and Tuscarora Formations

107

108

Source: Esri, DigitalGlobe

This information is for environmental review purposes only.



Mileposts (1.0 mile)

Rev 12 Centerline

Rev 12 300' Corridor

Rev 12 0.50 KRA

All Point Features

All Area Features

300' Corridor Closed Depressions

Suspect Closed Depressions

Virginia Caves

Randolph Caves

Pocahontas Caves

0 1,000 2,000

Feet

GEOLOGIC MAP 29

ATLANTIC COAST PIPELINE

11002.04

FILE: N:\PROJECTS\Active 11 Projects\11002.04, Dominion Resources Pipeline - Randolph and Pocahontas Co\Final\GIS Data for Final\reportmap Geologic.mxd | REVISED: 02/14/2017 | SCALE: 1:12,000 when printed at 11x17

DRAWN BY: JDV

GeoConcepts Engineering, Inc.

Brallier Formation

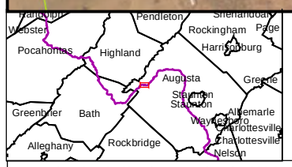
109

Millboro Shale and Needmore Formation

110

Brallier Formation

Ridgeley Sandstone, Helderber and Cayuga Groups



Mileposts (1.0 mile)

Rev 12 Centerline

Rev 12 300' Corridor

Rev 12 0.50 KRA

All Point Features

All Area Features

300' Corridor Closed Depressions

Suspect Closed Depressions

Virginia Caves

Randolph Caves

Pocahontas Caves

0 1,000 2,000

Feet

μ

GEOLOGIC MAP 30

ATLANTIC COAST PIPELINE

11002.04

This information is for environmental review purposes only.

FILE: N:\PROJECTS\Active 11 Projects\11002.04, Dominion Resources Pipeline - Randolph and Pocahontas Co\Final\GIS Data for Final\reportmap Geologic.mxd | REVISED: 02/14/2017 | SCALE: 1:12,000 when printed at 11x17

DRAWN BY: JDV

GeoConcepts Engineering, Inc.

Chemung Formation

Millboro Shale and Needmore Formation

111

112

Brallier Formation

Source: Esri, DigitalGlobe

This information is for environmental review purposes only.

- Mileposts (1.0 mile)
- Rev 12 Centerline
- Rev 12 300' Corridor
- Rev 12 0.50 KRA
- All Point Features
- All Area Features
- 300' Corridor Closed Depressions
- Suspect Closed Depressions
- Virginia Caves
- Randolph Caves
- Pocahontas Caves

0 1,000 2,000
Feet

GEOLOGIC MAP 31

ATLANTIC COAST PIPELINE

11002.04

FILE: N:\PROJECTS\Active 11 Projects\11002.04, Dominion Resources Pipeline - Randolph and Pocahontas Co\Final\GIS Data for Final\reportmap Geologic.mxd | REVISED: 02/14/2017 | SCALE: 1:12,000 when printed at 11x17

DRAWN BY: JDV

GeoConcepts Engineering, Inc.

Chemung Formation

Brallier Formation

113

114

Source: Esri, DigitalGlobe, Ger

This information is for environmental review purposes only.

- Mileposts (1.0 mile)
- Rev 12 Centerline
- Rev 12 300' Corridor
- Rev 12 0.50 KRA
- All Point Features
- All Area Features
- 300' Corridor Closed Depressions
- Suspect Closed Depressions
- Virginia Caves
- Randolph Caves
- Pocahontas Caves

0 1,000 2,000
Feet

GEOLOGIC MAP 32
ATLANTIC COAST PIPELINE
11002.04

FILE: N:\PROJECTS\Active 11 Projects\11002.04, Dominion Resources Pipeline - Randolph and Pocahontas Co\Final\GIS Data for Final\reportmap Geologic.mxd | REVISED: 02/14/2017 | SCALE: 1:12,000 when printed at 11x17

DRAWN BY: JDV

GeoConcepts Engineering, Inc.

Millboro Shale and Needmore Formation

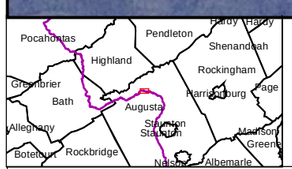
Brallier Formation

Chemung Formation

115

116

117



Mileposts (1.0 mile)

Rev 12 Centerline

Rev 12 300' Corridor

Rev 12 0.50 KRA

All Point Features

All Area Features

300' Corridor Closed Depressions

Suspect Closed Depressions

Virginia Caves

Randolph Caves

Pocahontas Caves

0 1,000 2,000

Feet

This information is for environmental review purposes only.

GEOLOGIC MAP 33

ATLANTIC COAST PIPELINE

11002.04

FILE: N:\PROJECTS\Active 11 Projects\11002.04, Dominion Resources Pipeline - Randolph and Pocahontas Co\Final\GIS Data for Final\reportmap Geologic.mxd | REVISED: 02/14/2017 | SCALE: 1:12,000 when printed at 11x17

DRAWN BY: JDV

GeoConcepts Engineering, Inc.

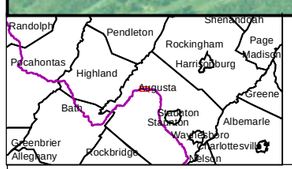
118

119

120

Chemung Formation

Brallier Formation



Mileposts (1.0 mile)

Rev 12 Centerline

Rev 12 300' Corridor

Rev 12 0.50 KRA

All Point Features

All Area Features

300' Corridor Closed Depressions

Suspect Closed Depressions

Virginia Caves

Randolph Caves

Pocahontas Caves

0 1,000 2,000

Feet

μ

GEOLOGIC MAP 34

ATLANTIC COAST PIPELINE

11002.04

Source: Esri, DigitalGlobe, ...

This information is for environmental review purposes only.

FILE: N:\PROJECTS\Active 11 Projects\11002.04, Dominion Resources Pipeline - Randolph and Pocahontas Co\Final\GIS Data for Final\reportmap Geologic.mxd | REVISED: 02/14/2017 | SCALE: 1:12,000 when printed at 11x17

DRAWN BY: JDV

GeoConcepts Engineering, Inc.

Chemung Formation

Brallier Formation

landslides with intact stratigraphic units - undivided

123

122

121

Chemung Formation

Elbrook Formation

Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

Not to be used for engineering purposes only.

Mileposts (1.0 mile)

Rev 12 Centerline

Rev 12 300' Corridor

Rev 12 0.50 KRA

All Point Features

All Area Features

300' Corridor Closed Depressions

Suspect Closed Depressions

Virginia Caves

Randolph Caves

Pocahontas Caves

0 1,000 2,000

Feet

μ

GEOLOGIC MAP 35

ATLANTIC COAST PIPELINE

11002.04

FILE: N:\PROJECTS\Active 11 Projects\11002.04, Dominion Resources Pipeline - Randolph and Pocahontas Co\Final\GIS Data for Final\reportmap Geologic.mxd | REVISED: 02/14/2017 | SCALE: 1:12,000 when printed at 11x17

DRAWN BY: JDV

GeoConcepts Engineering, Inc.

124

125

126

Elbrook Formation

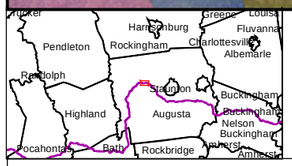
Conococheague Formation

Beekmantown Group

sCD31
sCD26
sCD30
sCD28
sCD27
sCD29
sCD25
sCD24
sCD33
sCD23
sCD13
sCD12
sCD32

Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

Not to be used for environmental review purposes only.



Mileposts (1.0 mile)
Rev 12 Centerline
Rev 12 300' Corridor
Rev 12 0.50 KRA
All Point Features
All Area Features
300' Corridor Closed Depressions
Suspect Closed Depressions
Virginia Caves
Randolph Caves
Pocahontas Caves

0 1,000 2,000
Feet

GEOLOGIC MAP 36

ATLANTIC COAST PIPELINE

11002.04

FILE: N:\PROJECTS\Active 11 Projects\11002.04, Dominion Resources Pipeline - Randolph and Pocahontas Co\Final\GIS Data for Final\reportmap Geologic.mxd | REVISED: 02/14/2017 | SCALE: 1:12,000 when printed at 11x17

DRAWN BY: JDV

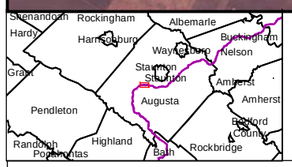
GeoConcepts Engineering, Inc.

Beekmantown Group

Conococheague Formation

127 128 129

SCD07 SCD08 SCD09 SCD10 SCD11



Mileposts (1.0 mile)
Rev 12 Centerline
Rev 12 300' Corridor
Rev 12 0.50 KRA
All Point Features
All Area Features
300' Corridor Closed Depressions
Suspect Closed Depressions
Virginia Caves
Randolph Caves
Pocahontas Caves

0 1,000 2,000
Feet

Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS,

This information is for environmental review purposes only.

GEOLOGIC MAP 37
ATLANTIC COAST PIPELINE
11002.04

FILE: N:\PROJECTS\Active 11 Projects\11002.04, Dominion Resources Pipeline - Randolph and Pocahontas Co\Final\GIS Data for Final\reportmap Geologic.mxd | REVISED: 02/14/2017 | SCALE: 1:12,000 when printed at 11x17

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GeoConcepts Engineering, Inc.

Beekmantown Group

131

130

132

SCD06

Conococheague Formation

Source: Esri, DigitalGlobe, GeoEye, Earthstar Geo

This information is for environmental review purposes only.

- Mileposts (1.0 mile)
- Rev 12 Centerline
- Rev 12 300' Corridor
- Rev 12 0.50 KRA
- All Point Features
- All Area Features
- 300' Corridor Closed Depressions
- Suspect Closed Depressions
- Virginia Caves
- Randolph Caves
- Pocahontas Caves

0 1,000 2,000
Feet

GEOLOGIC MAP 38
ATLANTIC COAST PIPELINE
11002.04

FILE: N:\PROJECTS\Active 11 Projects\11002.04, Dominion Resources Pipeline - Randolph and Pocahontas Co\Final\GIS Data for Final\reportmap Geologic.mxd | REVISED: 02/14/2017 | SCALE: 1:12,000 when printed at 11x17 DRAWN BY: JDV

GeoConcepts Engineering, Inc.

Beekmantown Group

Conococheague Formation

133

134

135

sCD02

sCD03

sCD04

sCD05

sCD14

sCD15

sCD16

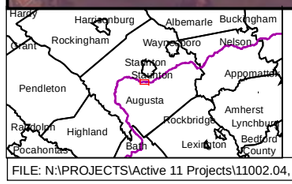
sCD17

sCD18

sCD19

Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, Ae

This information is for environmental review purposes only.



Mileposts (1.0 mile)

Rev 12 Centerline

Rev 12 300' Corridor

Rev 12 0.50 KRA

All Point Features

All Area Features

300' Corridor Closed Depressions

Suspect Closed Depressions

Virginia Caves

Randolph Caves

Pocahontas Caves

0 1,000 2,000

Feet

GEOLOGIC MAP 39

ATLANTIC COAST PIPELINE

11002.04

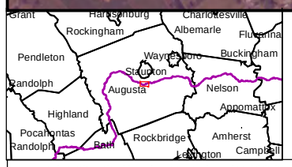
FILE: N:\PROJECTS\Active 11 Projects\11002.04, Dominion Resources Pipeline - Randolph and Pocahontas Co\Final\GIS Data for Final\reportmap Geologic.mxd | REVISED: 02/14/2017 | SCALE: 1:12,000 when printed at 11x17

DRAWN BY: JDV

GeoConcepts Engineering, Inc.

sCD18
135
sCD01
sCD19
sCD20
Conococheague Formation
136
137
Elbrook Formation
138
Beekmantown Group
sCD21

Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community



- Mileposts (1.0 mile)
- Rev 12 Centerline
- Rev 12 300' Corridor
- Rev 12 0.50 KRA
- All Point Features
- All Area Features
- 300' Corridor Closed Depressions
- Suspect Closed Depressions
- Virginia Caves
- Randolph Caves
- Pocahontas Caves

0 1,000 2,000
Feet

GEOLOGIC MAP 40
ATLANTIC COAST PIPELINE
11002.04

FILE: N:\PROJECTS\Active 11 Projects\11002.04, Dominion Resources Pipeline - Randolph and Pocahontas Co\Final\GIS Data for Final\reportmap Geologic.mxd | REVISED: 02/14/2017 | SCALE: 1:12,000 when printed at 11x17

DRAWN BY: JDV

GeoConcepts Engineering, Inc.

Edinburg Formation, Lincholnshire and New Market Limestones

Cochran Spring Cave
Cochrans Cave No. 2
Cochrans Cave No. 3

Conococheague Formation

Elbrook Formation

Beekmantown Group

138
139
140
SCD22

Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User

Not to be used for review purposes only.

Mileposts (1.0 mile)
Rev 12 Centerline
Rev 12 300' Corridor
Rev 12 0.50 KRA
All Point Features
All Area Features
300' Corridor Closed Depressions
Suspect Closed Depressions
Virginia Caves
Randolph Caves
Pocahontas Caves

0 1,000 2,000
Feet

GEOLOGIC MAP 41
ATLANTIC COAST PIPELINE
11002.04

FILE: N:\PROJECTS\Active 11 Projects\11002.04, Dominion Resources Pipeline - Randolph and Pocahontas Co\Final\GIS Data for Final\reportmap Geologic.mxd | REVISED: 02/14/2017 | SCALE: 1:12,000 when printed at 11x17

DRAWN BY: JDV

GeoConcepts Engineering, Inc.

Martinsburg and Orando Formations

Edinburg Formation, Lincholnshire and New Market Limestones

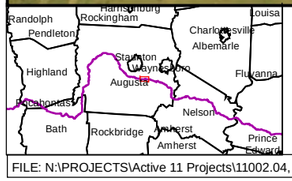
Beekmantown Group

141

142

143

Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and ... for environmental review purposes only.



Mileposts (1.0 mile)

Rev 12 Centerline

Rev 12 300' Corridor

Rev 12 0.50 KRA

All Point Features

All Area Features

300' Corridor Closed Depressions

Suspect Closed Depressions

Virginia Caves

Randolph Caves

Pocahontas Caves

0 1,000 2,000

Feet

GEOLOGIC MAP 42

ATLANTIC COAST PIPELINE

11002.04

FILE: N:\PROJECTS\Active 11 Projects\11002.04, Dominion Resources Pipeline - Randolph and Pocahontas Co\Final\GIS Data for Final\reportmap Geologic.mxd | REVISED: 02/14/2017 | SCALE: 1:12,000 when printed at 11x17

DRAWN BY: JDV

GeoConcepts Engineering, Inc.

Edinburg Formation, Lincholnshire and New Market Limestones

144

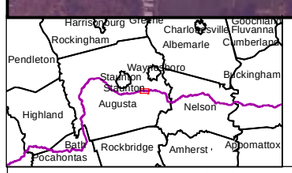
145

146

Conococheague Formation

Beekmantown Group

Elbrook Formation



Mileposts (1.0 mile)

Rev 12 Centerline

Rev 12 300' Corridor

Rev 12 0.50 KRA

All Point Features

All Area Features

300' Corridor Closed Depressions

Suspect Closed Depressions

Virginia Caves

Randolph Caves

Pocahontas Caves

0 1,000 2,000

Feet

Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS U... *Review purposes only.*

GEOLOGIC MAP 43

ATLANTIC COAST PIPELINE

11002.04

FILE: N:\PROJECTS\Active 11 Projects\11002.04, Dominion Resources Pipeline - Randolph and Pocahontas Co\Final\GIS Data for Final\reportmap Geologic.mxd | REVISED: 02/14/2017 | SCALE: 1:12,000 when printed at 11x17

DRAWN BY: JDV

GeoConcepts Engineering, Inc.

147

148

149

150

Elbrook Formation

Waynesboro Formation

sCD37

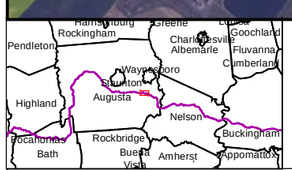
sCD38

sCD39

sCD40

sCD41

Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and th... environmental review purposes only.



- Mileposts (1.0 mile)
- Rev 12 Centerline
- Rev 12 300' Corridor
- Rev 12 0.50 KRA
- All Point Features
- All Area Features
- 300' Corridor Closed Depressions
- Suspect Closed Depressions
- Virginia Caves
- Randolph Caves
- Pocahontas Caves

0 1,000 2,000
Feet

GEOLOGIC MAP 44
ATLANTIC COAST PIPELINE
11002.04

FILE: N:\PROJECTS\Active 11 Projects\11002.04, Dominion Resources Pipeline - Randolph and Pocahontas Co\Final\GIS Data for Final\reportmap Geologic.mxd | REVISED: 02/14/2017 | SCALE: 1:12,000 when printed at 11x17

DRAWN BY: JDV

GeoConcepts Engineering, Inc.

Chilhowee Group

150

151

152

153

Waynesboro Formation

Shady Dolomite

sCD42

sCD43

sCD44

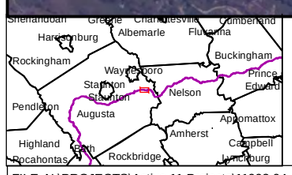
sCD45

sCD46

sCD47

Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

Information is for environmental review purposes only.



- Mileposts (1.0 mile)
- Rev 12 Centerline
- Rev 12 300' Corridor
- Rev 12 0.50 KRA
- All Point Features
- All Area Features
- 300' Corridor Closed Depressions
- Suspect Closed Depressions
- Virginia Caves
- Randolph Caves
- Pocahontas Caves

0 1,000 2,000
Feet

GEOLOGIC MAP 45

ATLANTIC COAST PIPELINE

11002.04

FILE: N:\PROJECTS\Active 11 Projects\11002.04, Dominion Resources Pipeline - Randolph and Pocahontas Co\Final\GIS Data for Final\reportmap Geologic.mxd | REVISED: 02/14/2017 | SCALE: 1:12,000 when printed at 11x17

DRAWN BY: JDV

GeoConcepts Engineering, Inc.

Catoctin Formation - metabasalt

Chilhowee Group

Shady Dolomite

154

155

156

153

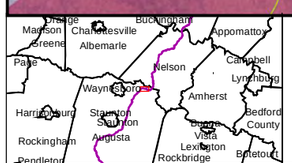
sCD47

sCD45

sCD46

Source: Esri, DigitalGlobe, GeoEye, Earth

This information is for environmental review purposes only.



- Mileposts (1.0 mile)
- Rev 12 Centerline
- Rev 12 300' Corridor
- Rev 12 0.50 KRA
- All Point Features
- All Area Features
- 300' Corridor Closed Depressions
- Suspect Closed Depressions
- Virginia Caves
- Randolph Caves
- Pocahontas Caves

0 1,000 2,000
Feet

GEOLOGIC MAP 46

ATLANTIC COAST PIPELINE

11002.04

FILE: N:\PROJECTS\Active 11 Projects\11002.04, Dominion Resources Pipeline - Randolph and Pocahontas Co\Final\GIS Data for Final\reportmap Geologic.mxd | REVISED: 02/14/2017 | SCALE: 1:12,000 when printed at 11x17

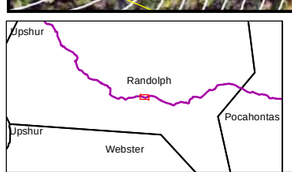
DRAWN BY: JDV

GeoConcepts Engineering, Inc.

APPENDIX B
Contour Maps

GeoConcepts Engineering, Inc.

59.1 59.2 59.3 59.4 59.5 59.6



Mileposts (0.1 mile)
Centerline
300' Corridor
0.50 KRA
All Point Features
All Area Features
300' Corridor Closed Depressions
Suspect Closed Depressions
Randolph Caves
Pocahontas Caves
Virginia Caves

0 250 500
Feet

CONTOUR MAP 1

ATLANTIC COAST PIPELINE

11002.04

Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User

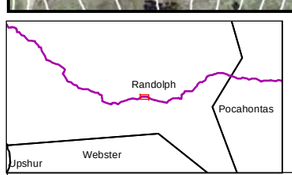
FILE: N:\PROJECTS\Active 11 Projects\11002.04, Dominion Resources Pipeline - Randolph and Pocahontas Co\Final\GIS Data for Final\reportmap Contour.mxd | REVISED: 02/14/2017 | SCALE: 1:3,000 when printed at 11x17

DRAWN BY: JDV

GeoConcepts Engineering, Inc.

59.6
59.7
59.8
59.9
60
cCD265
cCD47
cCD48

Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IC



- Mileposts (0.1 mile)
- Centerline
- 300' Corridor
- 0.50 KRA
- All Point Features
- All Area Features
- 300' Corridor Closed Depressions
- Suspect Closed Depressions
- Randolph Caves
- Pocahontas Caves
- Virginia Caves

0 250 500
Feet

CONTOUR MAP 2
ATLANTIC COAST PIPELINE
11002.04

FILE: N:\PROJECTS\Active 11 Projects\11002.04, Dominion Resources Pipeline - Randolph and Pocahontas Co\Final\GIS Data for Final\reportmap Contour.mxd | REVISED: 02/14/2017 | SCALE: 1:3,000 when printed at 11x17

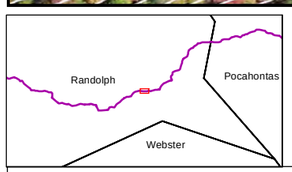
DRAWN BY: JDV

GeoConcepts Engineering, Inc.

60.1 60.2 60.3 60.4 60.5

CD264 CD263 CD129

Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS



- Mileposts (0.1 mile)
- Centerline
- 300' Corridor
- 0.50 KRA
- All Point Features
- All Area Features
- 300' Corridor Closed Depressions
- Suspect Closed Depressions
- Randolph Caves
- Pocahontas Caves
- Virginia Caves

0 250 500
Feet

CONTOUR MAP 3
ATLANTIC COAST PIPELINE
11002.04

FILE: N:\PROJECTS\Active 11 Projects\11002.04, Dominion Resources Pipeline - Randolph and Pocahontas Co\Final\GIS Data for Final\reportmap Contour.mxd | REVISED: 02/14/2017 | SCALE: 1:3,000 when printed at 11x17

DRAWN BY: JDV

GeoConcepts Engineering, Inc.

60.6 60.7 60.8 60.9 61 61.1

B074-1 B074-2 B074-3 B074-4

Mileposts (0.1 mile)
Centerline
300' Corridor
0.50 KRA
All Point Features
All Area Features
300' Corridor Closed Depressions
Suspect Closed Depressions
Randolph Caves
Pocahontas Caves
Virginia Caves

0 250 500
Feet

Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA,

CONTOUR MAP 4

ATLANTIC COAST PIPELINE

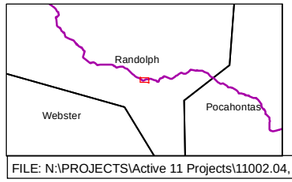
11002.04

FILE: N:\PROJECTS\Active 11 Projects\11002.04, Dominion Resources Pipeline - Randolph and Pocahontas Co\Final\GIS Data for Final\reportmap Contour.mxd | REVISED: 02/14/2017 | SCALE: 1:3,000 when printed at 11x17

DRAWN BY: JDV

GeoConcepts Engineering, Inc.

B074-1 B074-2 B074-3 B074-4 B074-5
b074-1 b074-2 b074-4 b074-5
b025-1 b025-2 b025-3 b025-4
61.1 61.2 61.3 61.4 61.5 61.6 61.7



- Mileposts (0.1 mile)
- Centerline
- 300' Corridor
- 0.50 KRA
- All Point Features
- All Area Features
- 300' Corridor Closed Depressions
- Suspect Closed Depressions
- Randolph Caves
- Pocahontas Caves
- Virginia Caves

0 250 500
Feet

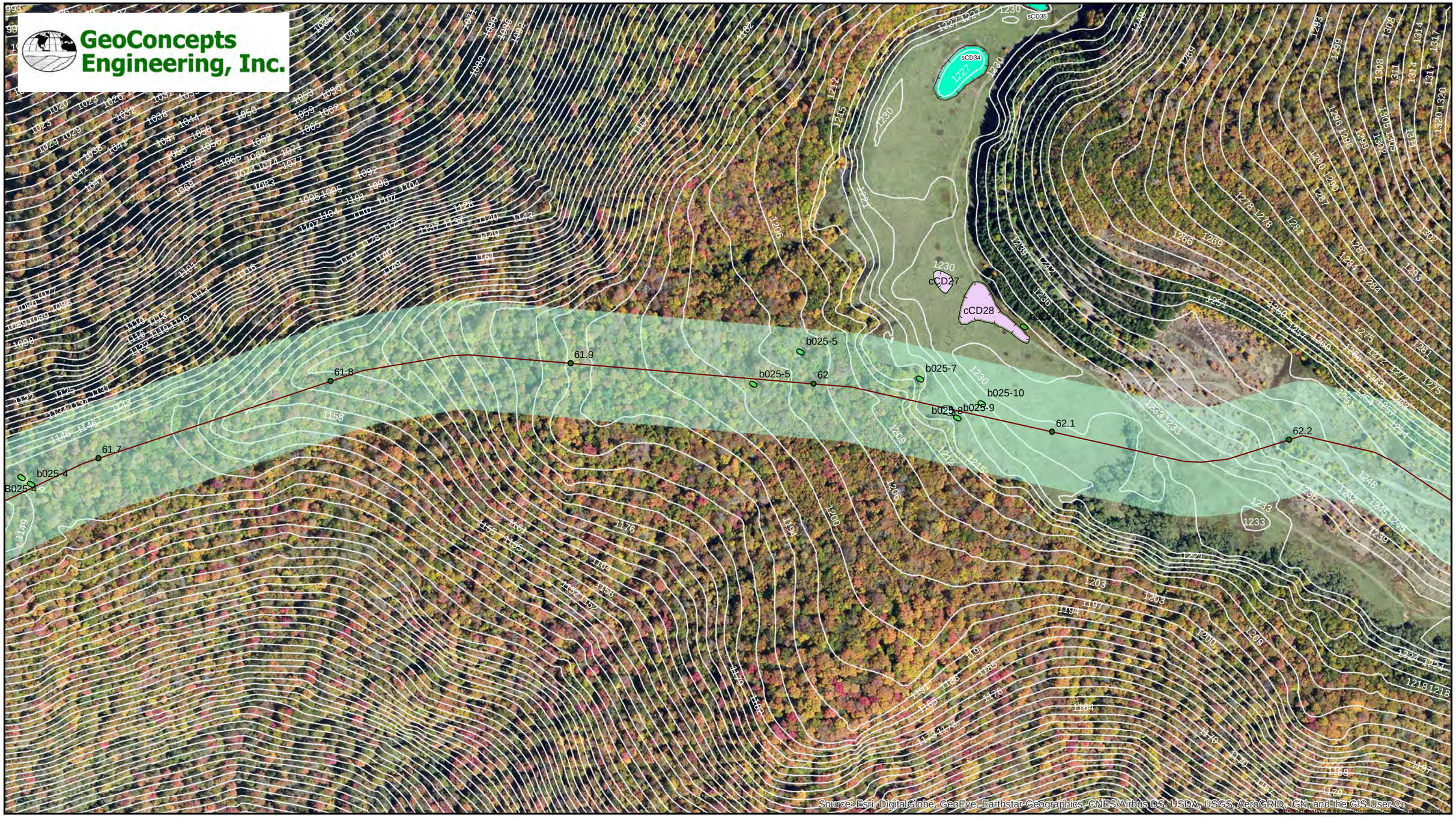
CONTOUR MAP 5
ATLANTIC COAST PIPELINE
11002.04

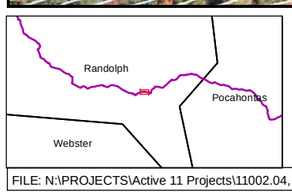
FILE: N:\PROJECTS\Active 11 Projects\11002.04, Dominion Resources Pipeline - Randolph and Pocahontas Co\Final\GIS Data for Final\reportmap Contour.mxd | REVISED: 02/14/2017 | SCALE: 1:3,000 when printed at 11x17

DRAWN BY: JDV

Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS Us

GeoConcepts Engineering, Inc.





- Mileposts (0.1 mile)
- Centerline
- 300' Corridor
- 0.50 KRA
- All Point Features
- All Area Features
- 300' Corridor Closed Depressions
- Suspect Closed Depressions
- Randolph Caves
- Pocahontas Caves
- Virginia Caves

0 250 500
Feet

CONTOUR MAP 6

ATLANTIC COAST PIPELINE

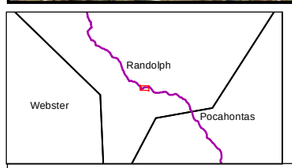
11002.04

FILE: N:\PROJECTS\Active 11 Projects\11002.04, Dominion Resources Pipeline - Randolph and Pocahontas Co\Final\GIS Data for Final\reportmap Contour.mxd | REVISED: 02/14/2017 | SCALE: 1:3,000 when printed at 11x17

DRAWN BY: JDV

GeoConcepts Engineering, Inc.

62.2
62.3
62.4
62.5
62.6
62.7
b025-13
b025-14
62.8
62.9



Mileposts (0.1 mile)
Centerline
300' Corridor
0.50 KRA
All Point Features
All Area Features
300' Corridor Closed Depressions
Suspect Closed Depressions
Randolph Caves
Pocahontas Caves
Virginia Caves

0 250 500
Feet

CONTOUR MAP 7
ATLANTIC COAST PIPELINE
11002.04

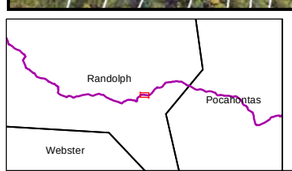
FILE: N:\PROJECTS\Active 11 Projects\11002.04, Dominion Resources Pipeline - Randolph and Pocahontas Co\Final\GIS Data for Final\reportmap Contour.mxd | REVISED: 02/14/2017 | SCALE: 1:3,000 when printed at 11x17

DRAWN BY: JDV

Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the

GeoConcepts Engineering, Inc.

63
63.1
63.2
63.3
63.4
62.9
cOD29
b025-15
B025-15



- Mileposts (0.1 mile)
- Centerline
- 300' Corridor
- 0.50 KRA
- All Point Features
- All Area Features
- 300' Corridor Closed Depressions
- Suspect Closed Depressions
- Randolph Caves
- Pocahontas Caves
- Virginia Caves

0 250 500
Feet

CONTOUR MAP 8
ATLANTIC COAST PIPELINE
11002.04

FILE: N:\PROJECTS\Active 11 Projects\11002.04, Dominion Resources Pipeline - Randolph and Pocahontas Co\Final\GIS Data for Final\reportmap Contour.mxd | REVISED: 02/14/2017 | SCALE: 1:3,000 when printed at 11x17

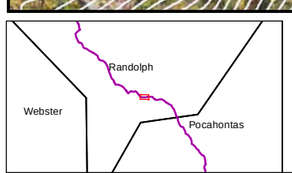
DRAWN BY: JDV

Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User

GeoConcepts Engineering, Inc.

b025-15
B025-15
63.5
b025-16
B025-16
63.6
63.7
B025-18
b025-18
63.8
63.9
64
b025-17
B025-17
sCD36

Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the G



- Mileposts (0.1 mile)
- Centerline
- 300' Corridor
- 0.50 KRA
- All Point Features
- All Area Features
- 300' Corridor Closed Depressions
- Suspect Closed Depressions
- Randolph Caves
- Pocahontas Caves
- Virginia Caves

0 250 500
Feet

CONTOUR MAP 9

ATLANTIC COAST PIPELINE

11002.04

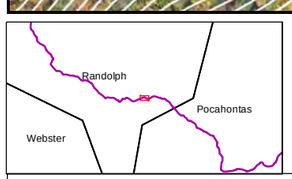
FILE: N:\PROJECTS\Active 11 Projects\11002.04, Dominion Resources Pipeline - Randolph and Pocahontas Co\Final\GIS Data for Final\reportmap Contour.mxd | REVISED: 02/14/2017 | SCALE: 1:3,000 when printed at 11x17

DRAWN BY: JDV

GeoConcepts Engineering, Inc.

64.1
64.2
64.3
64.4
64.5
64

Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and th



- Mileposts (0.1 mile)
- Centerline
- 300' Corridor
- 0.50 KRA
- All Point Features
- All Area Features
- 300' Corridor Closed Depressions
- Suspect Closed Depressions
- Randolph Caves
- Pocahontas Caves
- Virginia Caves

0 250 500
Feet

CONTOUR MAP 10
ATLANTIC COAST PIPELINE
11002.04

FILE: N:\PROJECTS\Active 11 Projects\11002.04, Dominion Resources Pipeline - Randolph and Pocahontas Co\Final\GIS Data for Final\reportmap Contour.mxd | REVISED: 02/14/2017 | SCALE: 1:3,000 when printed at 11x17

DRAWN BY: JDV

GeoConcepts Engineering, Inc.

64.6
64.7
64.8
64.9
65
65.1
B075-1
b075-1
B075-2
b075-2

Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the

- Mileposts (0.1 mile)
- Centerline
- 300' Corridor
- 0.50 KRA
- All Point Features
- All Area Features
- 300' Corridor Closed Depressions
- Suspect Closed Depressions
- Randolph Caves
- Pocahontas Caves
- Virginia Caves

0 250 500
Feet

CONTOUR MAP 11

ATLANTIC COAST PIPELINE

11002.04

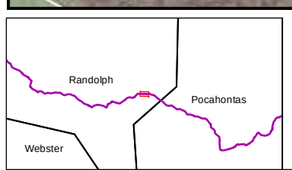
FILE: N:\PROJECTS\Active 11 Projects\11002.04, Dominion Resources Pipeline - Randolph and Pocahontas Co\Final\GIS Data for Final\reportmap Contour.mxd | REVISED: 02/14/2017 | SCALE: 1:3,000 when printed at 11x17

DRAWN BY: JDV

GeoConcepts Engineering, Inc.

65.1
65.2
65.3
65.4
65.5
65.6

Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Cor



- Mileposts (0.1 mile)
- Centerline
- 300' Corridor
- 0.50 KRA
- All Point Features
- All Area Features
- 300' Corridor Closed Depressions
- Suspect Closed Depressions
- Randolph Caves
- Pocahontas Caves
- Virginia Caves

0 250 500
Feet

CONTOUR MAP 12

ATLANTIC COAST PIPELINE

11002.04

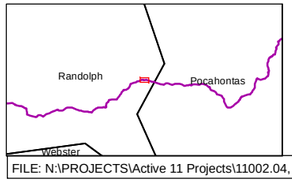
FILE: N:\PROJECTS\Active 11 Projects\11002.04, Dominion Resources Pipeline - Randolph and Pocahontas Co\Final\GIS Data for Final\reportmap Contour.mxd | REVISED: 02/14/2017 | SCALE: 1:3,000 when printed at 11x17

DRAWN BY: JDV

GeoConcepts Engineering, Inc.

65.7
65.8
65.9
66
66.1
66.2

Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID



- Mileposts (0.1 mile)
- Centerline
- 300' Corridor
- 0.50 KRA
- All Point Features
- All Area Features
- 300' Corridor Closed Depressions
- Suspect Closed Depressions
- Randolph Caves
- Pocahontas Caves
- Virginia Caves

0 250 500
Feet

CONTOUR MAP 13
ATLANTIC COAST PIPELINE
11002.04

FILE: N:\PROJECTS\Active 11 Projects\11002.04, Dominion Resources Pipeline - Randolph and Pocahontas Co\Final\GIS Data for Final\reportmap Contour.mxd | REVISED: 02/14/2017 | SCALE: 1:3,000 when printed at 11x17

DRAWN BY: JDV

GeoConcepts Engineering, Inc.

Wolfs Den Cave

Hound Dog Pit

Rainy Cave

Leady Joint Cave

Douglas Fork Joint Cave

Douglas Fork Greyce Cave

66.2

66.3

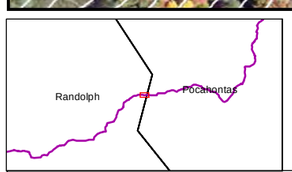
66.4

66.5

66.6

66.7

Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus



- Mileposts (0.1 mile)
- Centerline
- 300' Corridor
- 0.50 KRA
- All Point Features
- All Area Features
- 300' Corridor Closed Depressions
- Suspect Closed Depressions
- Randolph Caves
- Pocahontas Caves
- Virginia Caves

0 250 500
Feet

CONTOUR MAP 14
ATLANTIC COAST PIPELINE
11002.04

FILE: N:\PROJECTS\Active 11 Projects\11002.04, Dominion Resources Pipeline - Randolph and Pocahontas Co\Final\GIS Data for Final\reportmap Contour.mxd | REVISED: 02/14/2017 | SCALE: 1:3,000 when printed at 11x17

DRAWN BY: JDV

GeoConcepts Engineering, Inc.

66.8
66.9
67
67.1
67.2
67.3

Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus

- Mileposts (0.1 mile)
- Centerline
- 300' Corridor
- 0.50 KRA
- All Point Features
- All Area Features
- 300' Corridor Closed Depressions
- Suspect Closed Depressions
- Randolph Caves
- Pocahontas Caves
- Virginia Caves

0 250 500
Feet

CONTOUR MAP 15

ATLANTIC COAST PIPELINE

11002.04

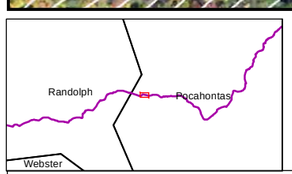
FILE: N:\PROJECTS\Active 11 Projects\11002.04, Dominion Resources Pipeline - Randolph and Pocahontas Co\Final\GIS Data for Final\reportmap Contour.mxd | REVISED: 02/14/2017 | SCALE: 1:3,000 when printed at 11x17

DRAWN BY: JDV

GeoConcepts Engineering, Inc.

67.3
67.4
67.5
67.6
67.7
67.8
cCD46
cCD198
Bathtub Cave
Beale's Log Pit

Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID



- Mileposts (0.1 mile)
- Centerline
- 300' Corridor
- 0.50 KRA
- All Point Features
- All Area Features
- 300' Corridor Closed Depressions
- Suspect Closed Depressions
- Randolph Caves
- Pocahontas Caves
- Virginia Caves

0 250 500
Feet

CONTOUR MAP 16

ATLANTIC COAST PIPELINE

11002.04

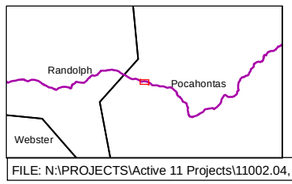
FILE: N:\PROJECTS\Active 11 Projects\11002.04, Dominion Resources Pipeline - Randolph and Pocahontas Co\Final\GIS Data for Final\reportmap Contour.mxd | REVISED: 02/14/2017 | SCALE: 1:3,000 when printed at 11x17

DRAWN BY: JDV

GeoConcepts Engineering, Inc.

67.8
cCD198
cCD197
e086-3
e086-4
68.1
e086-6
cCD194
cCD196
68.2
e086-5
68.3
67.9
68
e086-2
cCD193
cCD192
cCD186

Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Com...



- Mileposts (0.1 mile)
- Centerline
- 300' Corridor
- 0.50 KRA
- All Point Features
- All Area Features
- 300' Corridor Closed Depressions
- Suspect Closed Depressions
- Randolph Caves
- Pocahontas Caves
- Virginia Caves

0 250 500
Feet

CONTOUR MAP 17

ATLANTIC COAST PIPELINE

11002.04

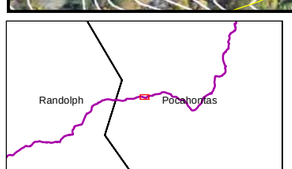
FILE: N:\PROJECTS\Active 11 Projects\11002.04, Dominion Resources Pipeline - Randolph and Pocahontas Co\Final\GIS Data for Final\reportmap Contour.mxd | REVISED: 02/14/2017 | SCALE: 1:3,000 when printed at 11x17

DRAWN BY: JDV

GeoConcepts Engineering, Inc.

cCD195
cCD181
cCD182
cCD180
cCD179
e086-13
cCD174
cCD177
cCD178
e086-12
68.4
e086-9
e086-7
68.5
cCD183
cCD193
e086-8
cCD184
68.6
e086-10
68.7
e086-11
68.8
68.9
e086-1
cCD191

Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS



- Mileposts (0.1 mile)
- Centerline
- 300' Corridor
- 0.50 KRA
- All Point Features
- All Area Features
- 300' Corridor Closed Depressions
- Suspect Closed Depressions
- Randolph Caves
- Pocahontas Caves
- Virginia Caves

0 250 500
Feet

CONTOUR MAP 18

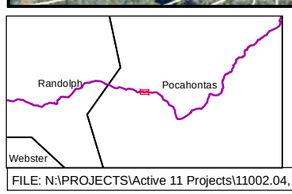
ATLANTIC COAST PIPELINE

11002.04

FILE: N:\PROJECTS\Active 11 Projects\11002.04, Dominion Resources Pipeline - Randolph and Pocahontas Co\Final\GIS Data for Final\reportmap Contour.mxd | REVISED: 02/14/2017 | SCALE: 1:3,000 when printed at 11x17

DRAWN BY: JDV

GeoConcepts Engineering, Inc.



- Mileposts (0.1 mile)
- Centerline
- 300' Corridor
- 0.50 KRA
- All Point Features
- All Area Features
- 300' Corridor Closed Depressions
- Suspect Closed Depressions
- Randolph Caves
- Pocahontas Caves
- Virginia Caves

0 250 500
Feet

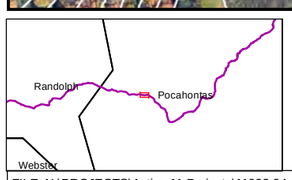
CONTOUR MAP 19
ATLANTIC COAST PIPELINE
11002.04

FILE: N:\PROJECTS\Active 11 Projects\11002.04, Dominion Resources Pipeline - Randolph and Pocahontas Co\Final\GIS Data for Final\reportmap Contour.mxd | REVISED: 02/14/2017 | SCALE: 1:3,000 when printed at 11x17 DRAWN BY: JDV

GeoConcepts Engineering, Inc.

69.4
E023-2
E023-3
E023-3
E023-7
E023-6
69.5
Hi-Up Holes
cCD190
cCD189
69.6
E023-1
E023-1
69.7
E023-5
69.8

Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the



- Mileposts (0.1 mile)
- Centerline
- 300' Corridor
- 0.50 KRA
- All Point Features
- All Area Features
- 300' Corridor Closed Depressions
- Suspect Closed Depressions
- Randolph Caves
- Pocahontas Caves
- Virginia Caves

0 250 500
Feet

CONTOUR MAP 20

ATLANTIC COAST PIPELINE

11002.04

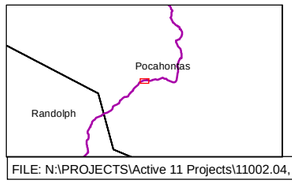
FILE: N:\PROJECTS\Active 11 Projects\11002.04, Dominion Resources Pipeline - Randolph and Pocahontas Co\Final\GIS Data for Final\reportmap Contour.mxd | REVISED: 02/14/2017 | SCALE: 1:3,000 when printed at 11x17

DRAWN BY: JDV

GeoConcepts Engineering, Inc.

69.9
70
70.1
70.2
70.3

Source: Esri, DigitalGlobe, GeoEye,



- Mileposts (0.1 mile)
- Centerline
- 300' Corridor
- 0.50 KRA
- All Point Features
- All Area Features
- 300' Corridor Closed Depressions
- Suspect Closed Depressions
- Randolph Caves
- Pocahontas Caves
- Virginia Caves

N

0 250 500
Feet

CONTOUR MAP 21

ATLANTIC COAST PIPELINE

11002.04

FILE: N:\PROJECTS\Active 11 Projects\11002.04, Dominion Resources Pipeline - Randolph and Pocahontas Co\Final\GIS Data for Final\reportmap Contour.mxd | REVISED: 02/14/2017 | SCALE: 1:3,000 when printed at 11x17

DRAWN BY: JDV

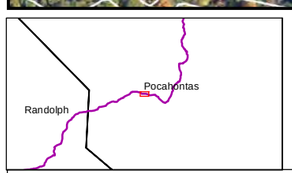
GeoConcepts Engineering, Inc.

CD188

C013-1
C013-2
C013-3
C013-4

70.4
70.5
70.6
70.7
70.8

Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics



- Mileposts (0.1 mile)
- Centerline
- 300' Corridor
- 0.50 KRA
- All Point Features
- All Area Features
- 300' Corridor Closed Depressions
- Suspect Closed Depressions
- Randolph Caves
- Pocahontas Caves
- Virginia Caves

0 250 500
Feet

CONTOUR MAP 22

ATLANTIC COAST PIPELINE

11002.04

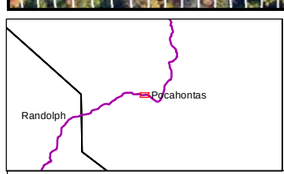
FILE: N:\PROJECTS\Active 11 Projects\11002.04, Dominion Resources Pipeline - Randolph and Pocahontas Co\Final\GIS Data for Final\reportmap Contour.mxd | REVISED: 02/14/2017 | SCALE: 1:3,000 when printed at 11x17

DRAWN BY: JDV

GeoConcepts Engineering, Inc.

70.8
70.9
71
71.1
71.2
71.3
cCD256
cCD26

Source: Esri, DigitalGlobe, GeoEye, Earthstar Geogr



- Mileposts (0.1 mile)
- Centerline
- 300' Corridor
- 0.50 KRA
- All Point Features
- All Area Features
- 300' Corridor Closed Depressions
- Suspect Closed Depressions
- Randolph Caves
- Pocahontas Caves
- Virginia Caves

0 250 500
Feet

CONTOUR MAP 23

ATLANTIC COAST PIPELINE

11002.04

FILE: N:\PROJECTS\Active 11 Projects\11002.04, Dominion Resources Pipeline - Randolph and Pocahontas Co\Final\GIS Data for Final\reportmap Contour.mxd | REVISED: 02/14/2017 | SCALE: 1:3,000 when printed at 11x17

DRAWN BY: JDV

GeoConcepts Engineering, Inc.

cCD262

cCD254

cCD255

71.3

71.4

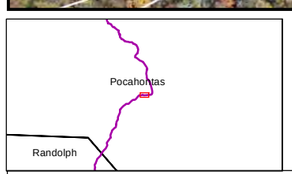
71.5

71.6

71.7

71.8

Source: Esri



- Mileposts (0.1 mile)
- Centerline
- 300' Corridor
- 0.50 KRA
- All Point Features
- All Area Features
- 300' Corridor Closed Depressions
- Suspect Closed Depressions
- Randolph Caves
- Pocahontas Caves
- Virginia Caves

0 250 500
Feet

CONTOUR MAP 24

ATLANTIC COAST PIPELINE

11002.04

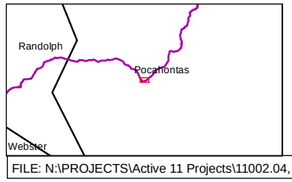
FILE: N:\PROJECTS\Active 11 Projects\11002.04, Dominion Resources Pipeline - Randolph and Pocahontas Co\Final\GIS Data for Final\reportmap Contour.mxd | REVISED: 02/14/2017 | SCALE: 1:3,000 when printed at 11x17

DRAWN BY: JDV

GeoConcepts Engineering, Inc.

71.8
71.9
72
72.1
72.2
72.3
72.4
cCD230
cCD228
cCD229
cCD231
cCD232
cCD226
cCD227
E027-1
E028-6

Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, ...



- Mileposts (0.1 mile)
- Centerline
- 300' Corridor
- 0.50 KRA
- All Point Features
- All Area Features
- 300' Corridor Closed Depressions
- Suspect Closed Depressions
- Randolph Caves
- Pocahontas Caves
- Virginia Caves

0 250 500
Feet

CONTOUR MAP 25

ATLANTIC COAST PIPELINE

11002.04

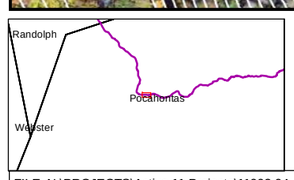
FILE: N:\PROJECTS\Active 11 Projects\11002.04, Dominion Resources Pipeline - Randolph and Pocahontas Co\Final\GIS Data for Final\reportmap Contour.mxd | REVISED: 02/14/2017 | SCALE: 1:3,000 when printed at 11x17

DRAWN BY: JDV

GeoConcepts Engineering, Inc.

72.4
72.5
72.6
72.7
72.8
E028-5
E028-5
E028-4
E028-4
cCD171
E028-3
E028-8
E028-1
Tappa Trap
cCD170

Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community



- Mileposts (0.1 mile)
- Centerline
- 300' Corridor
- 0.50 KRA
- All Point Features
- All Area Features
- 300' Corridor Closed Depressions
- Suspect Closed Depressions
- Randolph Caves
- Pocahontas Caves
- Virginia Caves

0 250 500
Feet

CONTOUR MAP 26

ATLANTIC COAST PIPELINE

11002.04

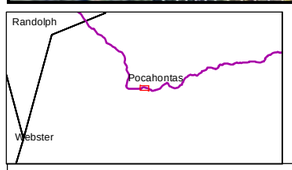
FILE: N:\PROJECTS\Active 11 Projects\11002.04, Dominion Resources Pipeline - Randolph and Pocahontas Co\Final\GIS Data for Final\reportmap Contour.mxd | REVISED: 02/14/2017 | SCALE: 1:3,000 when printed at 11x17

DRAWN BY: JDV

GeoConcepts Engineering, Inc.

73
73.1
73.2
73.3
E028-2
E028-2
72.9
cCD170

Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community



- Mileposts (0.1 mile)
- Centerline
- 300' Corridor
- 0.50 KRA
- All Point Features
- All Area Features
- 300' Corridor Closed Depressions
- Suspect Closed Depressions
- Randolph Caves
- Pocahontas Caves
- Virginia Caves

0 250 500
Feet

CONTOUR MAP 27

ATLANTIC COAST PIPELINE

11002.04

FILE: N:\PROJECTS\Active 11 Projects\11002.04, Dominion Resources Pipeline - Randolph and Pocahontas Co\Final\GIS Data for Final\reportmap Contour.mxd | REVISED: 02/14/2017 | SCALE: 1:3,000 when printed at 11x17

DRAWN BY: JDV

GeoConcepts Engineering, Inc.

73.4

73.5

73.6

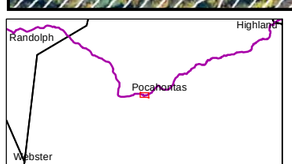
73.7

73.8

73.9

cCD258

Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the



Mileposts (0.1 mile)
Centerline
300' Corridor
0.50 KRA
All Point Features
All Area Features
300' Corridor Closed Depressions
Suspect Closed Depressions
Randolph Caves
Pocahontas Caves
Virginia Caves

0 250 500
Feet

CONTOUR MAP 28

ATLANTIC COAST PIPELINE

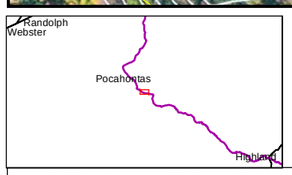
11002.04

FILE: N:\PROJECTS\Active 11 Projects\11002.04, Dominion Resources Pipeline - Randolph and Pocahontas Co\Final\GIS Data for Final\reportmap Contour.mxd | REVISED: 02/14/2017 | SCALE: 1:3,000 when printed at 11x17

DRAWN BY: JDV

GeoConcepts Engineering, Inc.

73.9
74
74.1
74.2
74.3
E031-6
E030-9
E031-5
E030-8
E031-2
E030-6
e030-6
Skunk Cave
Cecil Mallons Cave



- Mileposts (0.1 mile)
- Centerline
- 300' Corridor
- 0.50 KRA
- All Point Features
- All Area Features
- 300' Corridor Closed Depressions
- Suspect Closed Depressions
- Randolph Caves
- Pocahontas Caves
- Virginia Caves

0 250 500
Feet

CONTOUR MAP 29

ATLANTIC COAST PIPELINE

11002.04

FILE: N:\PROJECTS\Active 11 Projects\11002.04, Dominion Resources Pipeline - Randolph and Pocahontas Co\Final\GIS Data for Final\reportmap Contour.mxd | REVISED: 02/14/2017 | SCALE: 1:3,000 when printed at 11x17

DRAWN BY: JDV

GeoConcepts Engineering, Inc.

74.4
74.5
74.6
74.7
74.8
cCD168
E032-2
E030-2
E030-3
E032-4
cCD169
E030-4
E030-5
E031-4
E031-2
E030-6
e030-6
e033-1
E033-1
E033-2
e033-2
cCD167
E033-3
e033-3
cCD166

Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS

Randolph
Highland
Pocahontas
Webster

Mileposts (0.1 mile)
Centerline
300' Corridor
0.50 KRA
All Point Features
All Area Features
300' Corridor Closed Depressions
Suspect Closed Depressions
Randolph Caves
Pocahontas Caves
Virginia Caves

0 250 500
Feet

CONTOUR MAP 30

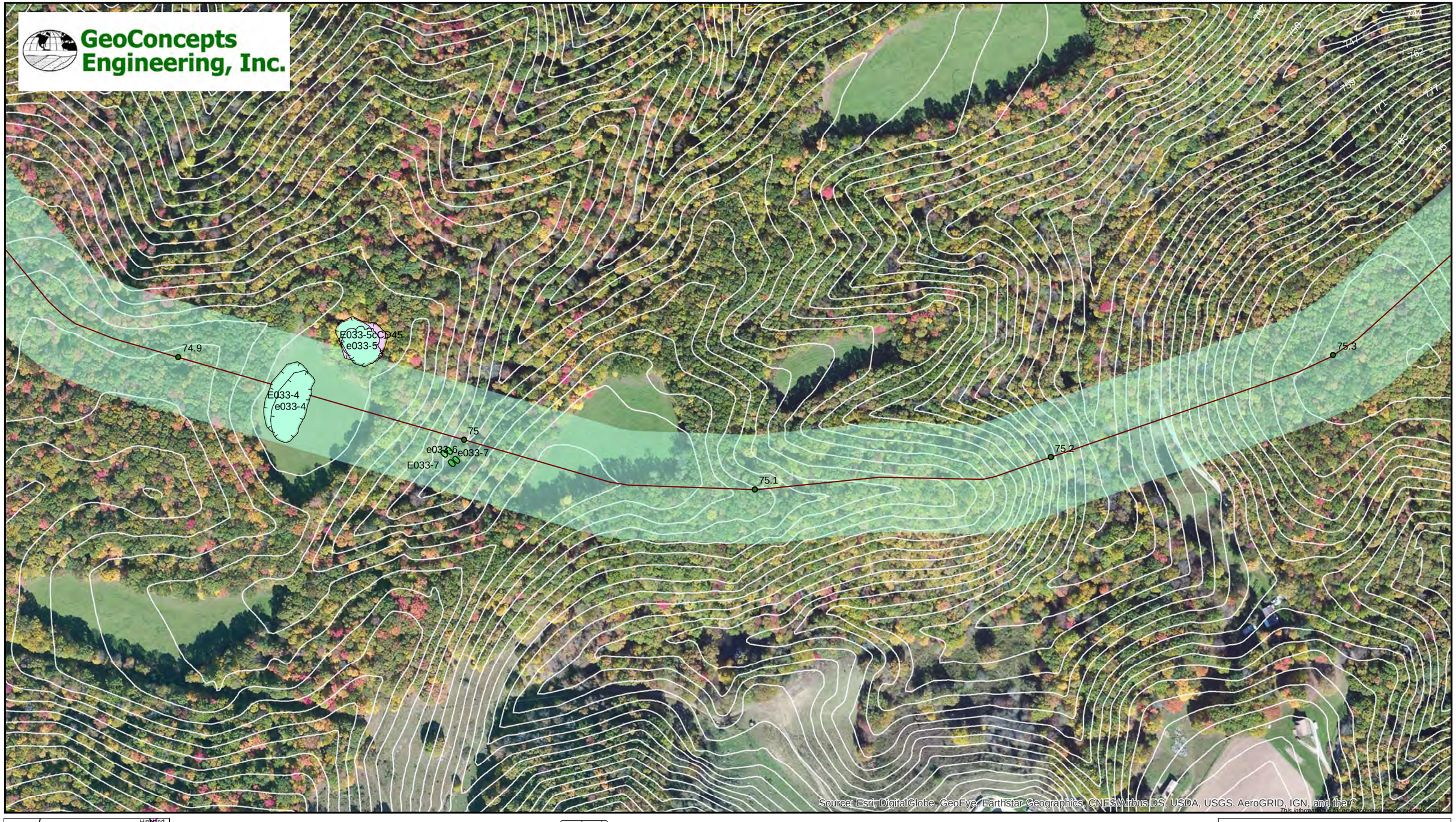
ATLANTIC COAST PIPELINE

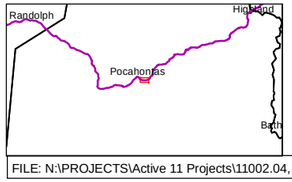
11002.04

FILE: N:\PROJECTS\Active 11 Projects\11002.04, Dominion Resources Pipeline - Randolph and Pocahontas Co\Final\GIS Data for Final\reportmap Contour.mxd | REVISED: 02/14/2017 | SCALE: 1:3,000 when printed at 11x17

DRAWN BY: JDV

GeoConcepts Engineering, Inc.





- Mileposts (0.1 mile)
- Centerline
- 300' Corridor
- 0.50 KRA
- All Point Features
- All Area Features
- 300' Corridor Closed Depressions
- Suspect Closed Depressions
- Randolph Caves
- Pocahontas Caves
- Virginia Caves

0 250 500
Feet

CONTOUR MAP 31

ATLANTIC COAST PIPELINE

11002.04

FILE: N:\PROJECTS\Active 11 Projects\11002.04, Dominion Resources Pipeline - Randolph and Pocahontas Co\Final\GIS Data for Final\reportmap Contour.mxd | REVISED: 02/14/2017 | SCALE: 1:3,000 when printed at 11x17

DRAWN BY: JDV

GeoConcepts Engineering, Inc.

75.3
75.4
75.5
75.6
75.7
75.8
cCD44

- Mileposts (0.1 mile)
- Centerline
- 300' Corridor
- 0.50 KRA
- All Point Features
- All Area Features
- 300' Corridor Closed Depressions
- Suspect Closed Depressions
- Randolph Caves
- Pocahontas Caves
- Virginia Caves

0 250 500
Feet

CONTOUR MAP 32

ATLANTIC COAST PIPELINE

11002.04

FILE: N:\PROJECTS\Active 11 Projects\11002.04, Dominion Resources Pipeline - Randolph and Pocahontas Co\Final\GIS Data for Final\reportmap Contour.mxd | REVISED: 02/14/2017 | SCALE: 1:3,000 when printed at 11x17

DRAWN BY: JDV

This information is for environmental review purposes only.

GeoConcepts Engineering, Inc.

76

75.9

76.1

75.8

76.2

E037-1

E036-1

Mileposts (0.1 mile)
Centerline
300' Corridor
0.50 KRA
All Point Features
All Area Features
300' Corridor Closed Depressions
Suspect Closed Depressions
Randolph Caves
Pocahontas Caves
Virginia Caves

0 250 500
Feet

CONTOUR MAP 33
ATLANTIC COAST PIPELINE
11002.04

FILE: N:\PROJECTS\Active 11 Projects\11002.04, Dominion Resources Pipeline - Randolph and Pocahontas Co\Final\GIS Data for Final\reportmap Contour.mxd | REVISED: 02/14/2017 | SCALE: 1:3,000 when printed at 11x17

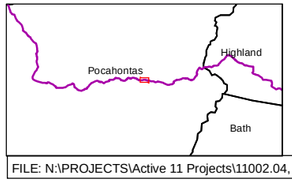
DRAWN BY: JDV

GeoConcepts Engineering, Inc.

79.3 E053-2 79.4 E053-3 E051-1 79.5 79.6 79.7 E051-2 79.8

cCD42 cCD43

774 777 780 783 786 789 792 795 798 801 804 807 810 813 816 819 822 825 828 831 834 837 840 843 846 849 852 855 858 861 864 867 870 873 876 879 882 885



- Mileposts (0.1 mile)
- Centerline
- 300' Corridor
- 0.50 KRA
- All Point Features
- All Area Features
- 300' Corridor Closed Depressions
- Suspect Closed Depressions
- Randolph Caves
- Pocahontas Caves
- Virginia Caves

0 250 500
Feet

CONTOUR MAP 34

ATLANTIC COAST PIPELINE

11002.04

FILE: N:\PROJECTS\Active 11 Projects\11002.04, Dominion Resources Pipeline - Randolph and Pocahontas Co\Final\GIS Data for Final\reportmap Contour.mxd | REVISED: 02/14/2017 | SCALE: 1:3,000 when printed at 11x17

DRAWN BY: JDV

Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the

GeoConcepts Engineering, Inc.

cCD41

cCD40

79.8

79.9

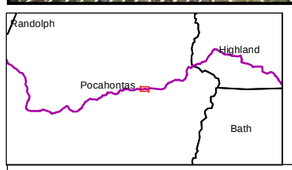
80

80.1

80.2

EOS1-2

Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and



- Mileposts (0.1 mile)
- Centerline
- 300' Corridor
- 0.50 KRA
- All Point Features
- All Area Features
- 300' Corridor Closed Depressions
- Suspect Closed Depressions
- Randolph Caves
- Pocahontas Caves
- Virginia Caves

0 250 500
Feet

CONTOUR MAP 35

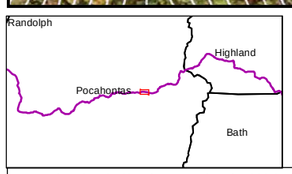
ATLANTIC COAST PIPELINE

11002.04

FILE: N:\PROJECTS\Active 11 Projects\11002.04, Dominion Resources Pipeline - Randolph and Pocahontas Co\Final\GIS Data for Final\reportmap Contour.mxd | REVISED: 02/14/2017 | SCALE: 1:3,000 when printed at 11x17

DRAWN BY: JDV

GeoConcepts Engineering, Inc.



- Mileposts (0.1 mile)
- Centerline
- 300' Corridor
- 0.50 KRA
- All Point Features
- All Area Features
- 300' Corridor Closed Depressions
- Suspect Closed Depressions
- Randolph Caves
- Pocahontas Caves
- Virginia Caves

0 250 500
Feet

CONTOUR MAP 36

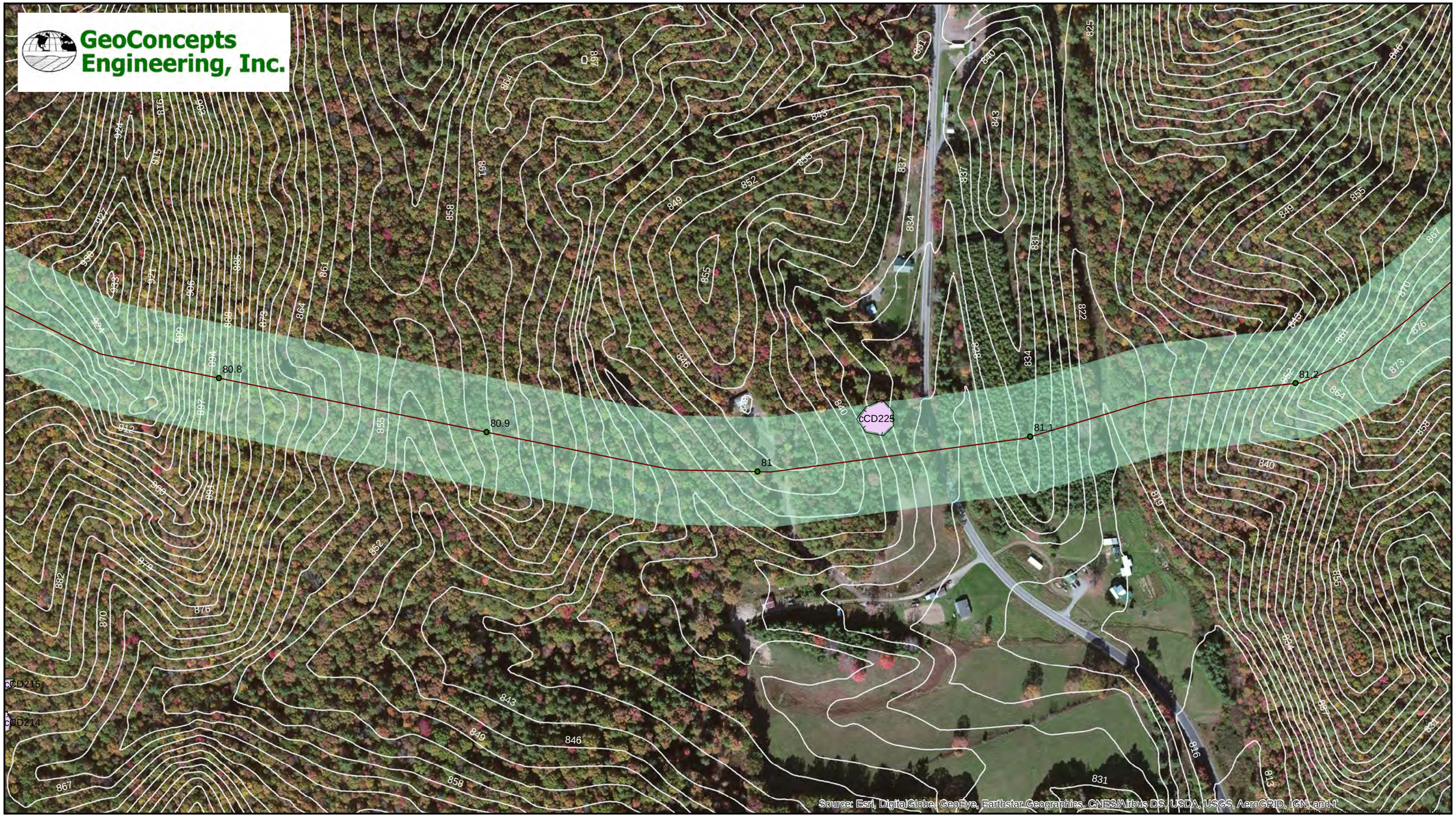
ATLANTIC COAST PIPELINE

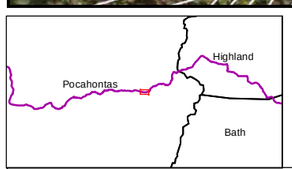
11002.04

FILE: N:\PROJECTS\Active 11 Projects\11002.04, Dominion Resources Pipeline - Randolph and Pocahontas Co\Final\GIS Data for Final\reportmap Contour.mxd | REVISED: 02/14/2017 | SCALE: 1:3,000 when printed at 11x17

DRAWN BY: JDV

GeoConcepts Engineering, Inc.





- Mileposts (0.1 mile)
- Centerline
- 300' Corridor
- 0.50 KRA
- All Point Features
- All Area Features
- 300' Corridor Closed Depressions
- Suspect Closed Depressions
- Randolph Caves
- Pocahontas Caves
- Virginia Caves

0 250 500
Feet

CONTOUR MAP 37

ATLANTIC COAST PIPELINE

11002.04

FILE: N:\PROJECTS\Active 11 Projects\11002.04, Dominion Resources Pipeline - Randolph and Pocahontas Co\Final\GIS Data for Final\reportmap Contour.mxd | REVISED: 02/14/2017 | SCALE: 1:3,000 when printed at 11x17

DRAWN BY: JDV

GeoConcepts Engineering, Inc.

Mileposts (0.1 mile)
Centerline
300' Corridor
0.50 KRA
All Point Features
All Area Features
300' Corridor Closed Depressions
Suspect Closed Depressions
Randolph Caves
Pocahontas Caves
Virginia Caves

0 250 500
Feet

CONTOUR MAP 38

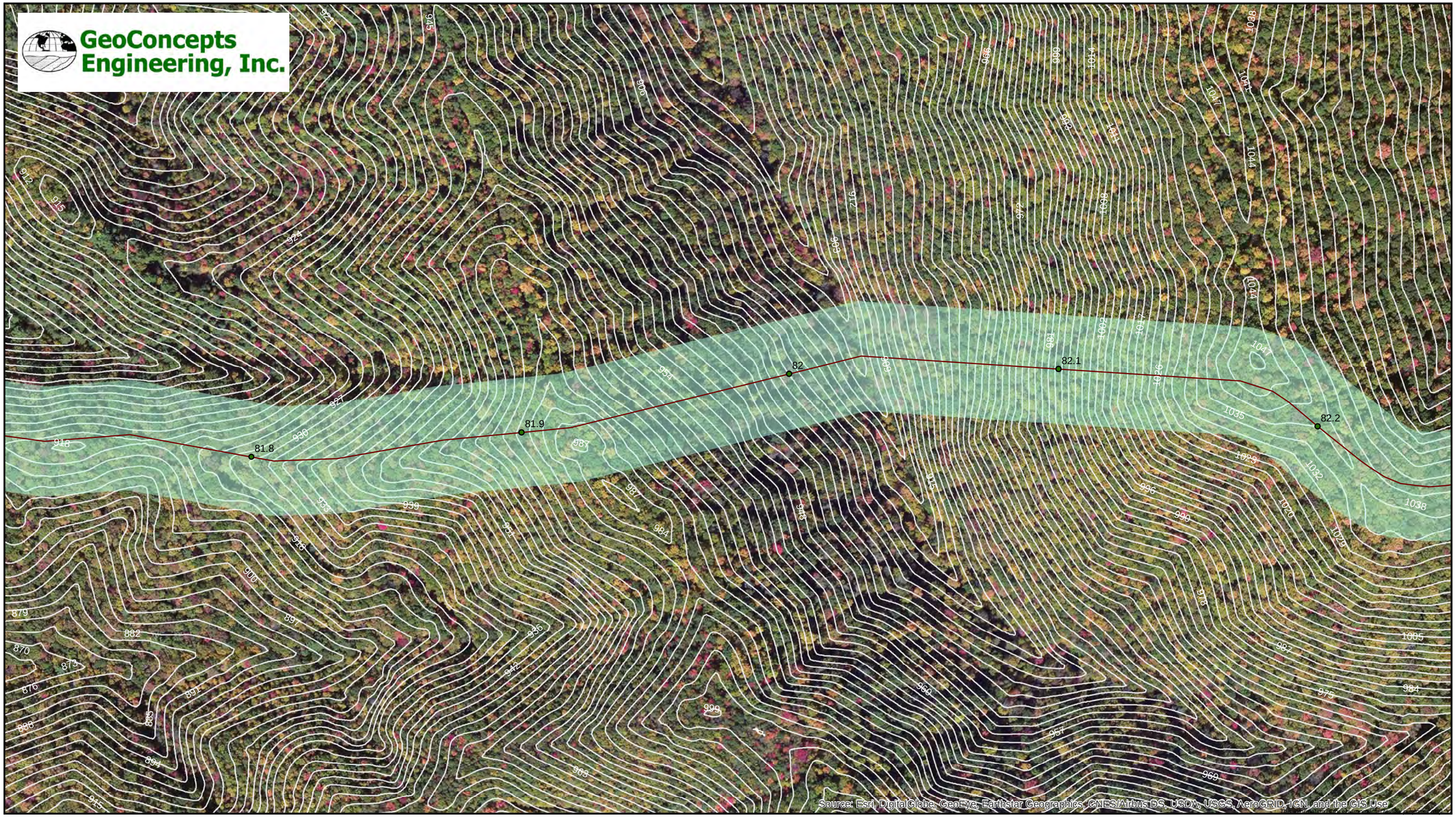
ATLANTIC COAST PIPELINE

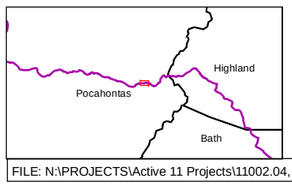
11002.04

FILE: N:\PROJECTS\Active 11 Projects\11002.04, Dominion Resources Pipeline - Randolph and Pocahontas Co\Final\GIS Data for Final\reportmap Contour.mxd | REVISED: 02/14/2017 | SCALE: 1:3,000 when printed at 11x17

DRAWN BY: JDV

GeoConcepts Engineering, Inc.





- Mileposts (0.1 mile)
- Centerline
- 300' Corridor
- 0.50 KRA
- All Point Features
- All Area Features
- 300' Corridor Closed Depressions
- Suspect Closed Depressions
- Randolph Caves
- Pocahontas Caves
- Virginia Caves

0 250 500
Feet

CONTOUR MAP 39

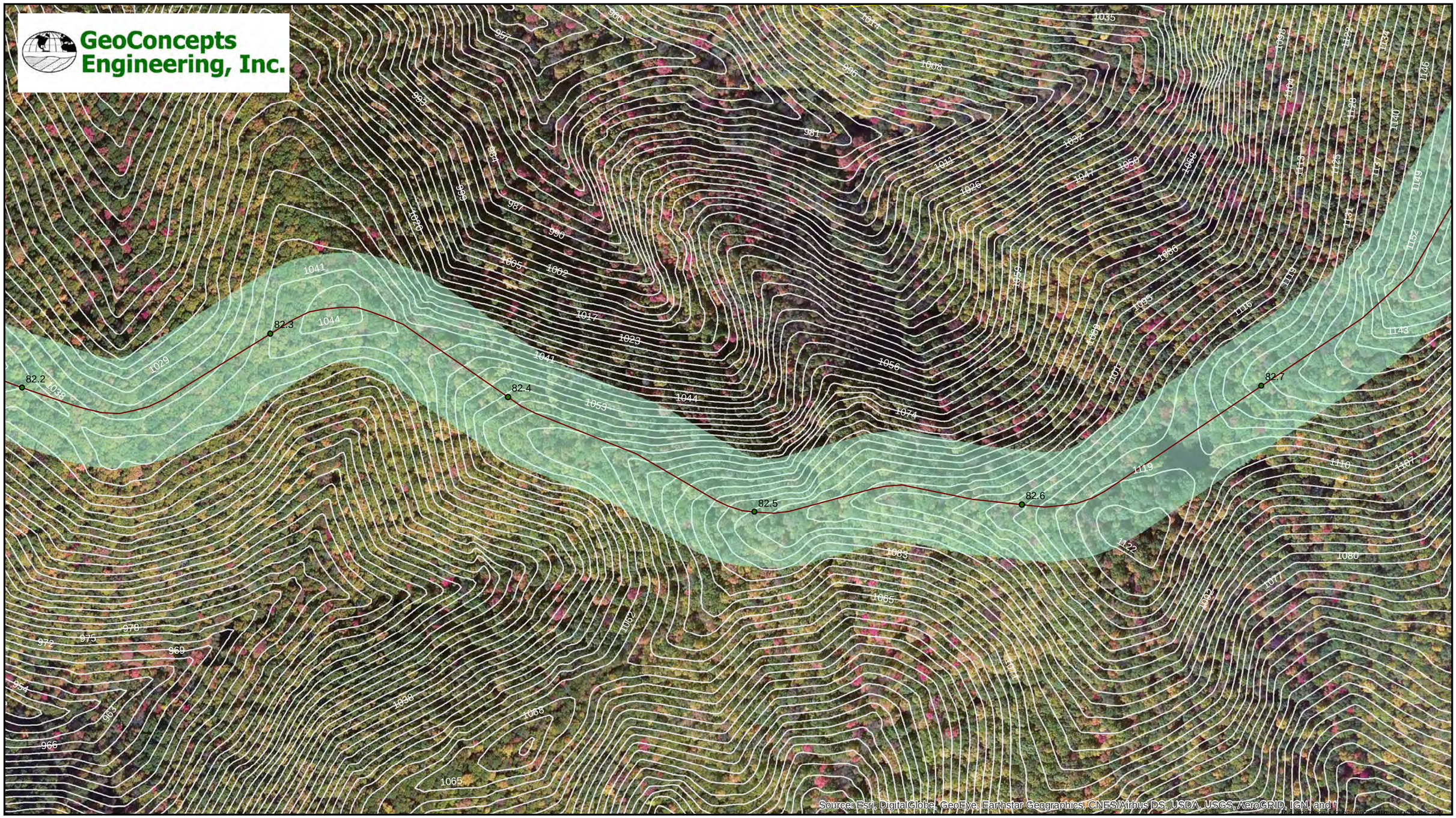
ATLANTIC COAST PIPELINE

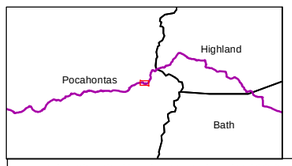
11002.04

FILE: N:\PROJECTS\Active 11 Projects\11002.04, Dominion Resources Pipeline - Randolph and Pocahontas Co\Final\GIS Data for Final\reportmap Contour.mxd | REVISED: 02/14/2017 | SCALE: 1:3,000 when printed at 11x17

DRAWN BY: JDV

GeoConcepts Engineering, Inc.





- Mileposts (0.1 mile)
- Centerline
- 300' Corridor
- 0.50 KRA
- All Point Features
- All Area Features
- 300' Corridor Closed Depressions
- Suspect Closed Depressions
- Randolph Caves
- Pocahontas Caves
- Virginia Caves

0 250 500
Feet

CONTOUR MAP 40

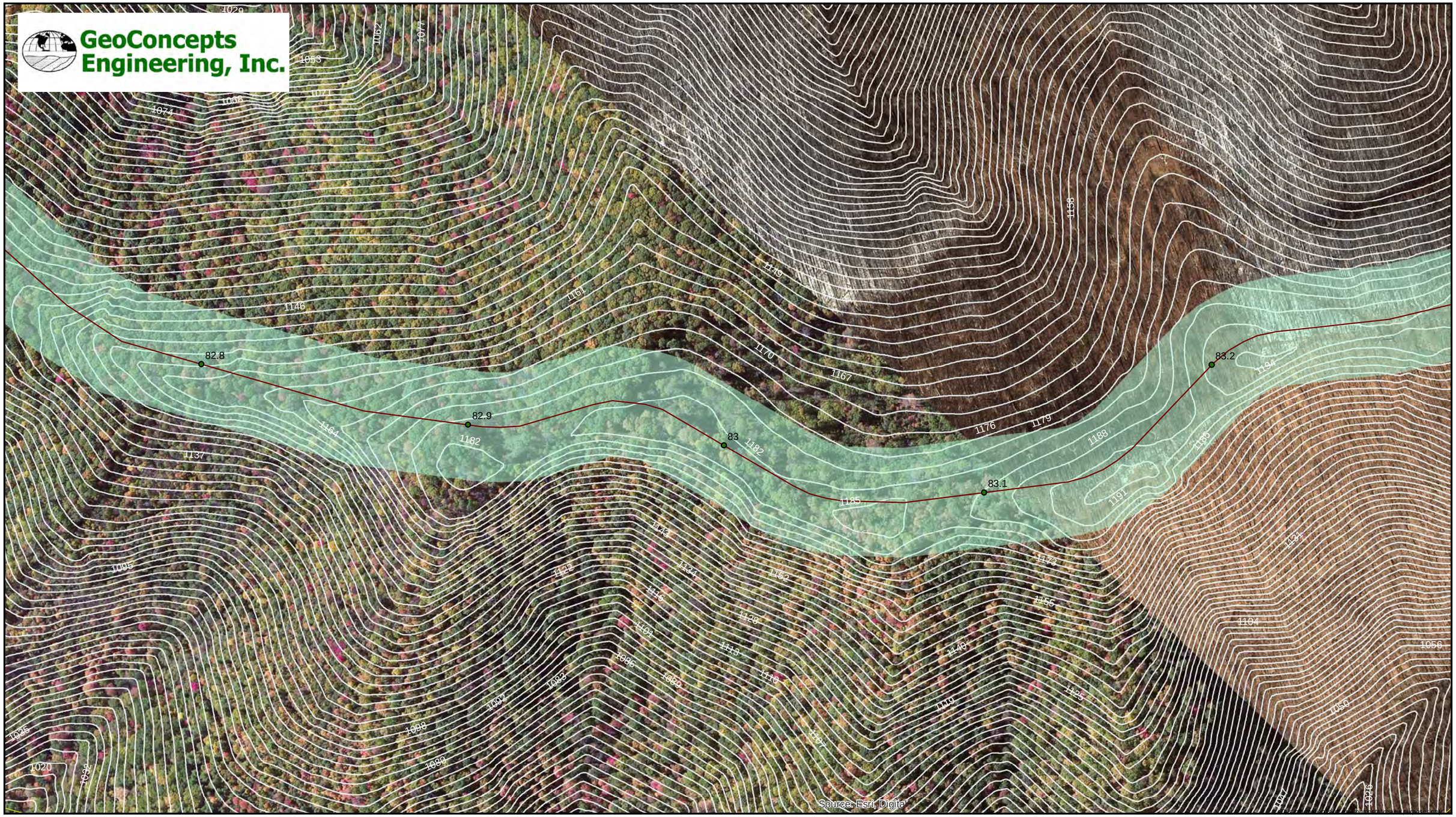
ATLANTIC COAST PIPELINE

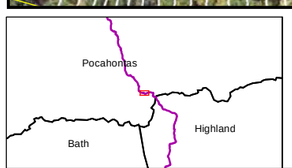
11002.04

FILE: N:\PROJECTS\Active 11 Projects\11002.04, Dominion Resources Pipeline - Randolph and Pocahontas Co\Final\GIS Data for Final\reportmap Contour.mxd | REVISED: 02/14/2017 | SCALE: 1:3,000 when printed at 11x17

DRAWN BY: JDV

GeoConcepts Engineering, Inc.





- Mileposts (0.1 mile)
- Centerline
- 300' Corridor
- 0.50 KRA
- All Point Features
- All Area Features
- 300' Corridor Closed Depressions
- Suspect Closed Depressions
- Randolph Caves
- Pocahontas Caves
- Virginia Caves

0 250 500
Feet

CONTOUR MAP 41

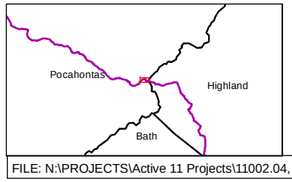
ATLANTIC COAST PIPELINE

11002.04

FILE: N:\PROJECTS\Active 11 Projects\11002.04, Dominion Resources Pipeline - Randolph and Pocahontas Co\Final\GIS Data for Final\reportmap Contour.mxd | REVISED: 02/14/2017 | SCALE: 1:3,000 when printed at 11x17

DRAWN BY: JDV

GeoConcepts Engineering, Inc.



- Mileposts (0.1 mile)
- Centerline
- 300' Corridor
- 0.50 KRA
- All Point Features
- All Area Features
- 300' Corridor Closed Depressions
- Suspect Closed Depressions
- Randolph Caves
- Pocahontas Caves
- Virginia Caves

0 250 500
Feet

CONTOUR MAP 42

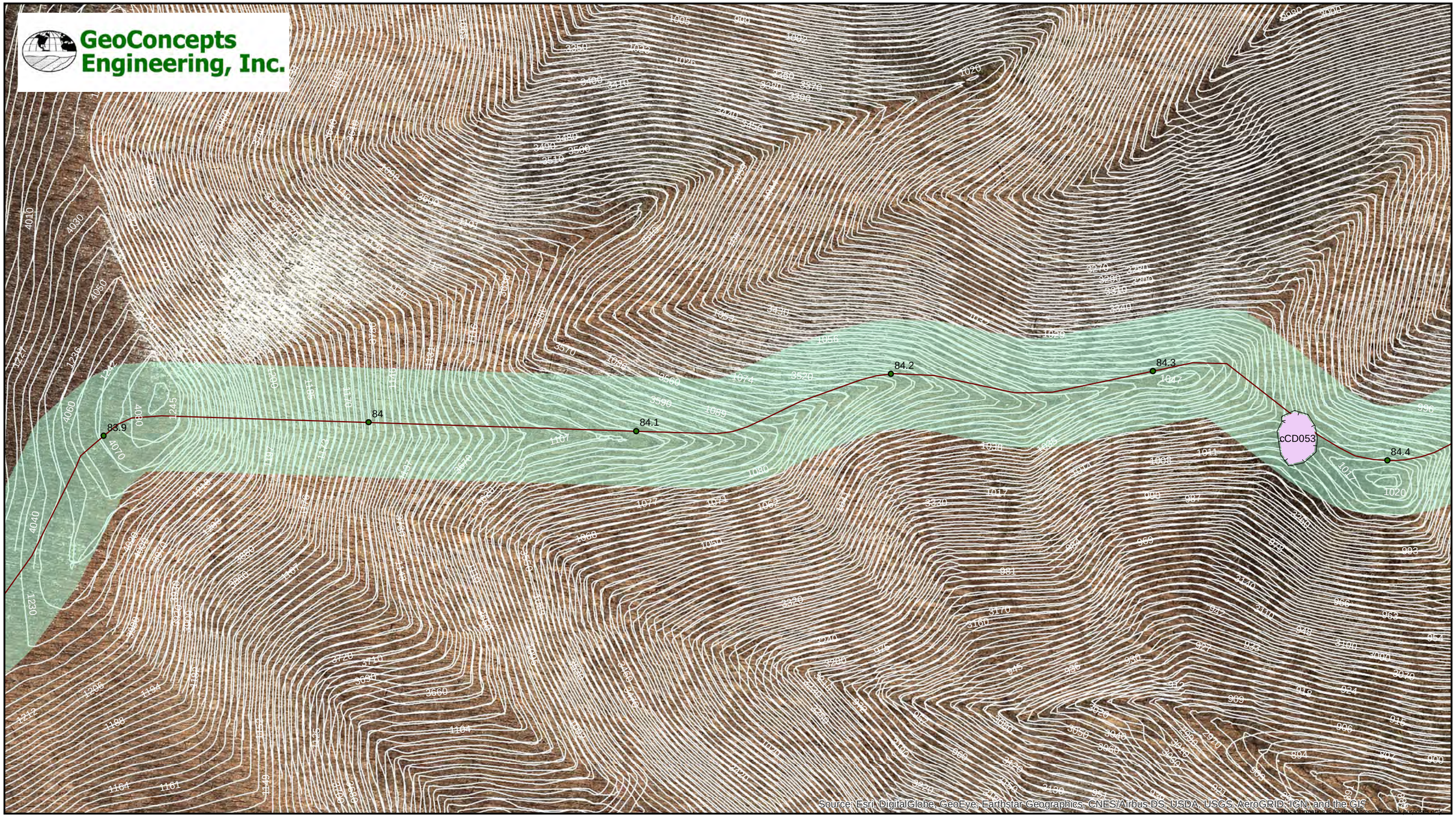
ATLANTIC COAST PIPELINE

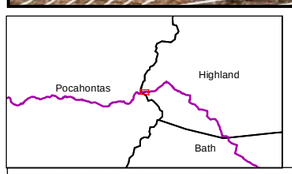
11002.04

FILE: N:\PROJECTS\Active 11 Projects\11002.04, Dominion Resources Pipeline - Randolph and Pocahontas Co\Final\GIS Data for Final\reportmap Contour.mxd | REVISED: 02/14/2017 | SCALE: 1:3,000 when printed at 11x17

DRAWN BY: JDV

GeoConcepts Engineering, Inc.





- Mileposts (0.1 mile)
- Centerline
- 300' Corridor
- 0.50 KRA
- All Point Features
- All Area Features
- 300' Corridor Closed Depressions
- Suspect Closed Depressions
- Randolph Caves
- Pocahontas Caves
- Virginia Caves

0 250 500
Feet

CONTOUR MAP 43

ATLANTIC COAST PIPELINE

11002.04

FILE: N:\PROJECTS\Active 11 Projects\11002.04, Dominion Resources Pipeline - Randolph and Pocahontas Co\Final\GIS Data for Final\reportmap Contour.mxd | REVISED: 02/14/2017 | SCALE: 1:3,000 when printed at 11x17

DRAWN BY: JDV

GeoConcepts Engineering, Inc.

84.4

84.5

84.6

84.7

84.8

84.9

cCD053

cCD054

Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Comm

Mileposts (0.1 mile)
Centerline
300' Corridor
0.50 KRA
All Point Features
All Area Features
300' Corridor Closed Depressions
Suspect Closed Depressions
Randolph Caves
Pocahontas Caves
Virginia Caves

0 250 500
Feet

CONTOUR MAP 44

ATLANTIC COAST PIPELINE

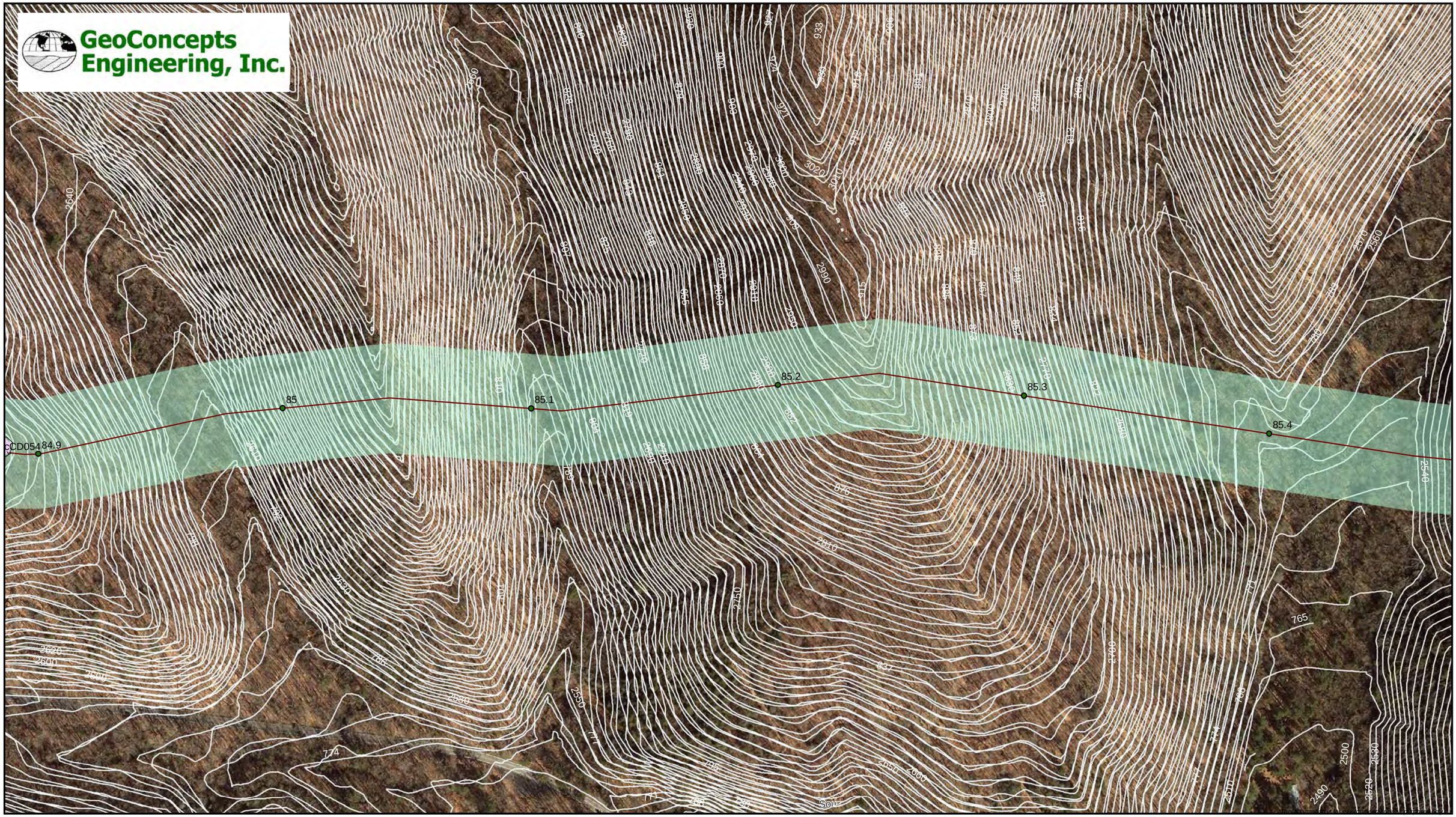
11002.04

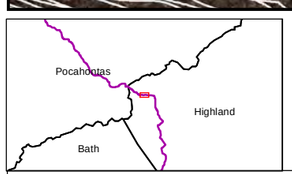
FILE: N:\PROJECTS\Active 11 Projects\11002.04, Dominion Resources Pipeline - Randolph and Pocahontas Co\Final\GIS Data for Final\reportmap Contour.mxd | REVISED: 02/14/2017 | SCALE: 1:3,000 when printed at 11x17

DRAWN BY: JDV

GeoConcepts Engineering, Inc.

85 85.1 85.2 85.3 85.4 CD054 84.9





- Mileposts (0.1 mile)
- Centerline
- 300' Corridor
- 0.50 KRA
- All Point Features
- All Area Features
- 300' Corridor Closed Depressions
- Suspect Closed Depressions
- Randolph Caves
- Pocahontas Caves
- Virginia Caves

0 250 500
Feet

CONTOUR MAP 45

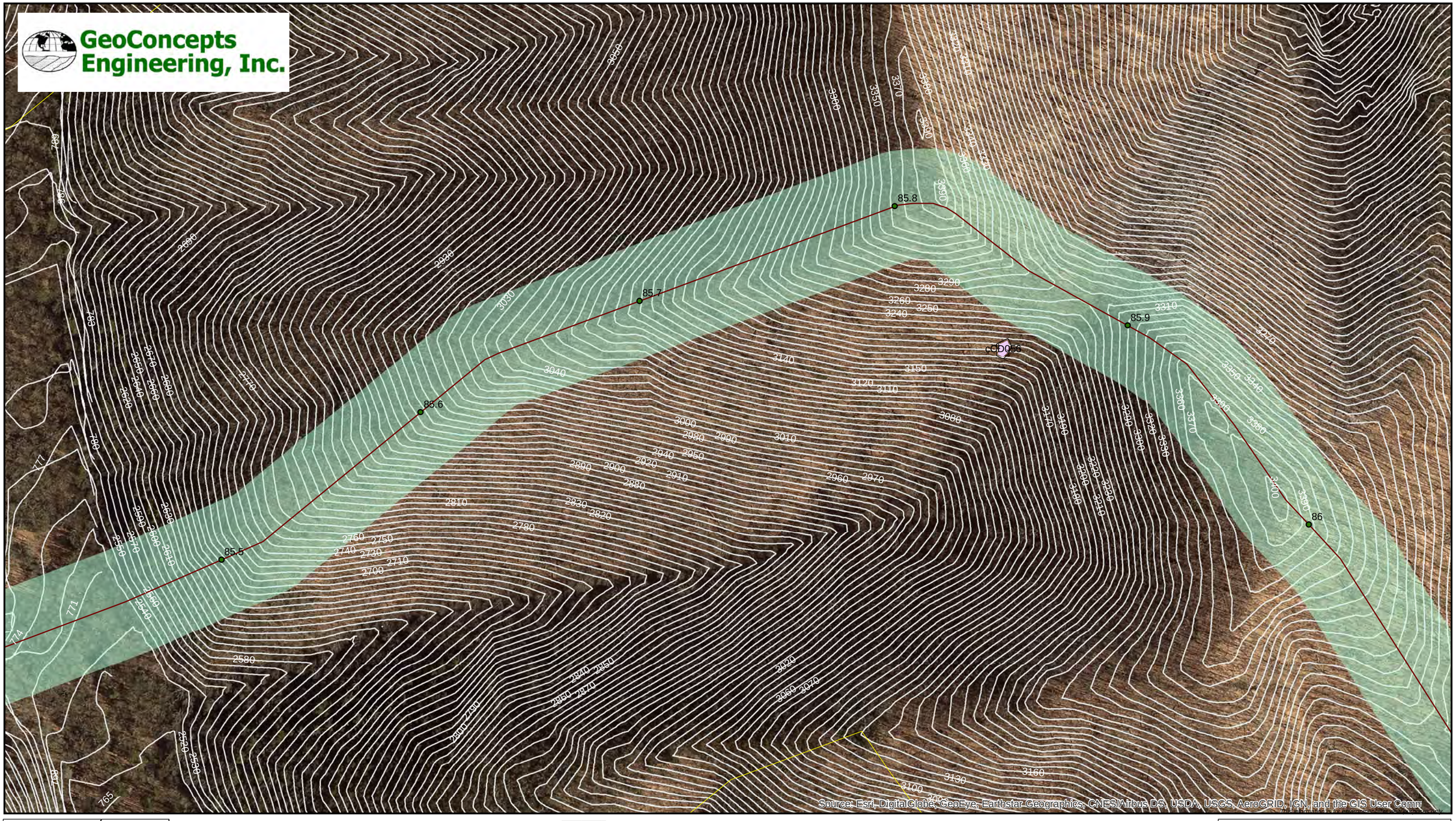
ATLANTIC COAST PIPELINE

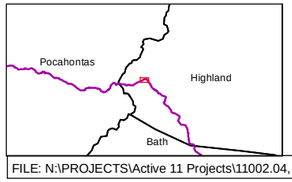
11002.04

FILE: N:\PROJECTS\Active 11 Projects\11002.04, Dominion Resources Pipeline - Randolph and Pocahontas Co\Final\GIS Data for Final\reportmap Contour.mxd | REVISED: 02/14/2017 | SCALE: 1:3,000 when printed at 11x17

DRAWN BY: JDV

GeoConcepts Engineering, Inc.





- Mileposts (0.1 mile)
- Centerline
- 300' Corridor
- 0.50 KRA
- All Point Features
- All Area Features
- 300' Corridor Closed Depressions
- Suspect Closed Depressions
- Randolph Caves
- Pocahontas Caves
- Virginia Caves

0 250 500
Feet

CONTOUR MAP 46

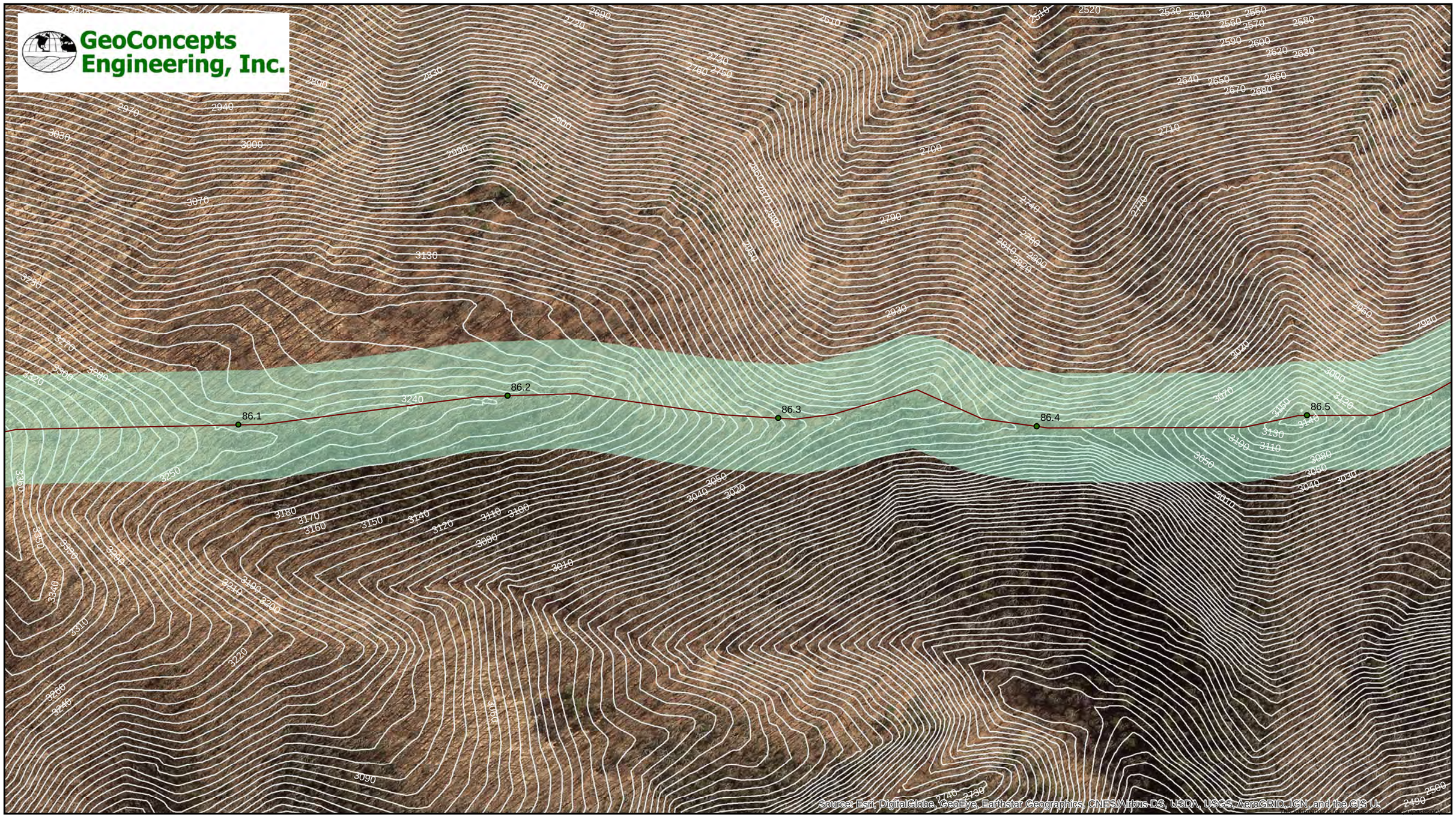
ATLANTIC COAST PIPELINE

11002.04

FILE: N:\PROJECTS\Active 11 Projects\11002.04, Dominion Resources Pipeline - Randolph and Pocahontas Co\Final\GIS Data for Final\reportmap Contour.mxd | REVISED: 02/14/2017 | SCALE: 1:3,000 when printed at 11x17

DRAWN BY: JDV

GeoConcepts Engineering, Inc.



- Mileposts (0.1 mile)
- Centerline
- 300' Corridor
- 0.50 KRA
- All Point Features
- All Area Features
- 300' Corridor Closed Depressions
- Suspect Closed Depressions
- Randolph Caves
- Pocahontas Caves
- Virginia Caves

0 250 500
Feet

CONTOUR MAP 47
ATLANTIC COAST PIPELINE
11002.04

FILE: N:\PROJECTS\Active 11 Projects\11002.04, Dominion Resources Pipeline - Randolph and Pocahontas Co\Final\GIS Data for Final\reportmap Contour.mxd | REVISED: 02/14/2017 | SCALE: 1:3,000 when printed at 11x17

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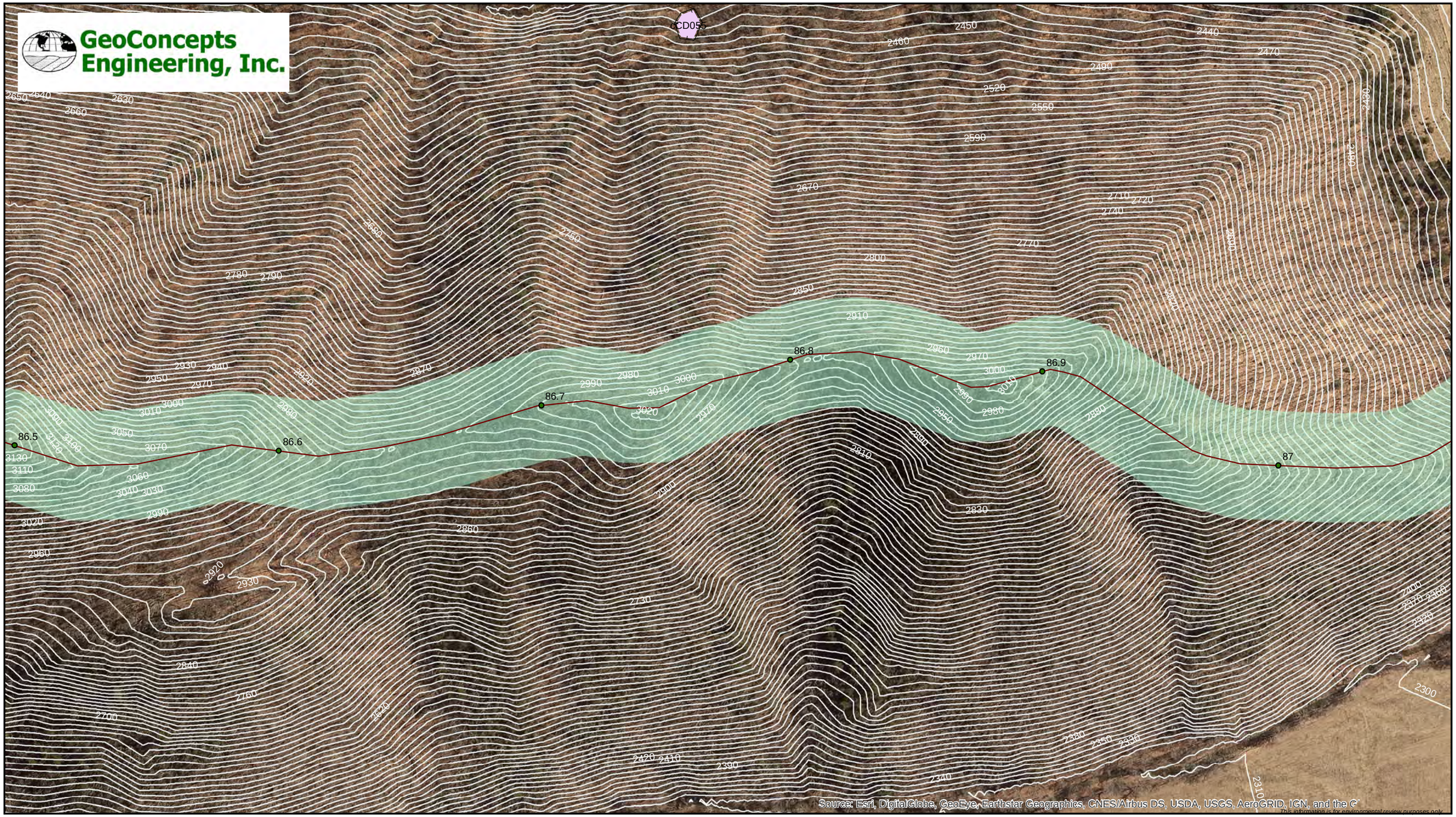
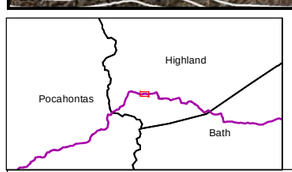
GeoConcepts Engineering, Inc.





- Mileposts (0.1 mile)
- Centerline
- 300' Corridor
- 0.50 KRA
- All Point Features
- All Area Features
- 300' Corridor Closed Depressions
- Suspect Closed Depressions
- Randolph Caves
- Pocahontas Caves
- Virginia Caves

0 250 500
Feet

CONTOUR MAP 48

ATLANTIC COAST PIPELINE

11002.04

FILE: N:\PROJECTS\Active 11 Projects\11002.04, Dominion Resources Pipeline - Randolph and Pocahontas Co\Final\GIS Data for Final\reportmap Contour.mxd | REVISED: 02/14/2017 | SCALE: 1:3,000 when printed at 11x17

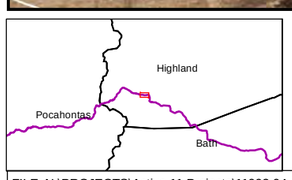
DRAWN BY: JDV

GeoConcepts Engineering, Inc.

87.1 87.2 87.3 87.4 87.5 87.6

cCD052

Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and t



- Mileposts (0.1 mile)
- Centerline
- 300' Corridor
- 0.50 KRA
- All Point Features
- All Area Features
- 300' Corridor Closed Depressions
- Suspect Closed Depressions
- Randolph Caves
- Pocahontas Caves
- Virginia Caves

0 250 500
Feet

CONTOUR MAP 49

ATLANTIC COAST PIPELINE

11002.04

FILE: N:\PROJECTS\Active 11 Projects\11002.04, Dominion Resources Pipeline - Randolph and Pocahontas Co\Final\GIS Data for Final\reportmap Contour.mxd | REVISED: 02/14/2017 | SCALE: 1:3,000 when printed at 11x17

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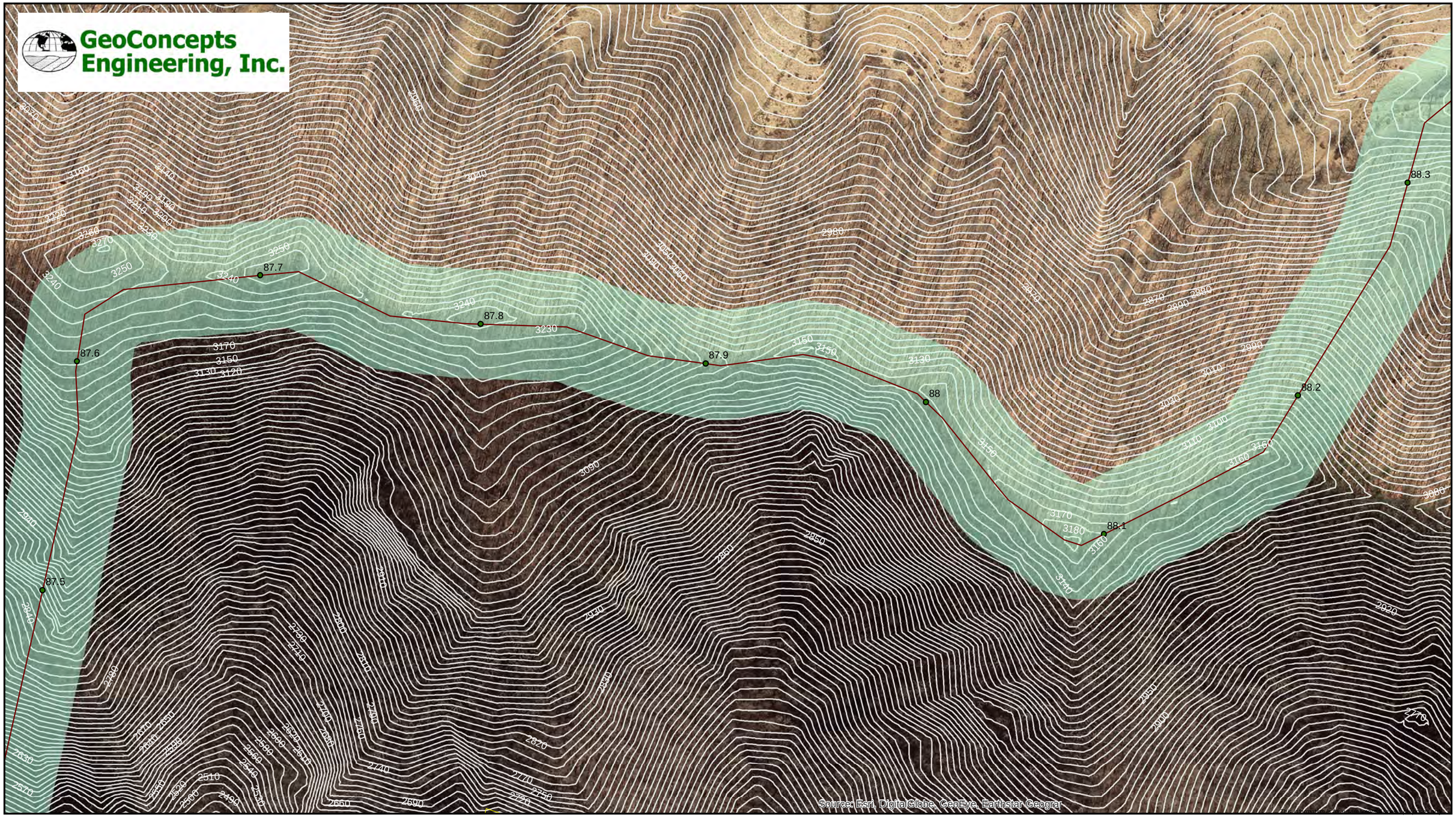
GeoConcepts Engineering, Inc.



- Mileposts (0.1 mile)
- Centerline
- 300' Corridor
- 0.50 KRA
- All Point Features
- All Area Features
- 300' Corridor Closed Depressions
- Suspect Closed Depressions
- Randolph Caves
- Pocahontas Caves
- Virginia Caves

N

0 250 500
Feet

CONTOUR MAP 50

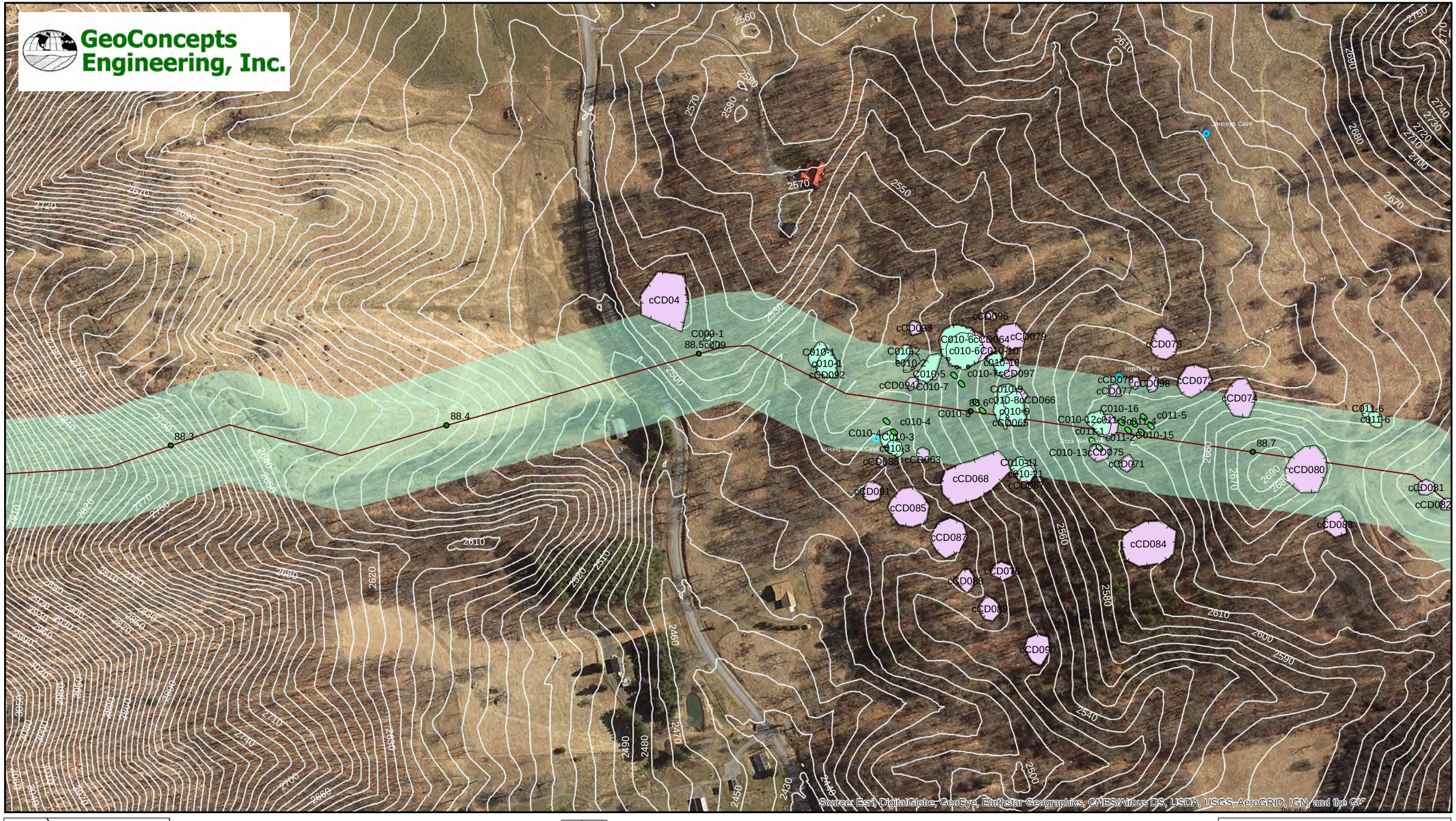
ATLANTIC COAST PIPELINE

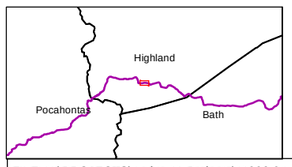
11002.04

FILE: N:\PROJECTS\Active 11 Projects\11002.04, Dominion Resources Pipeline - Randolph and Pocahontas Co\Final\GIS Data for Final\reportmap Contour.mxd | REVISED: 02/14/2017 | SCALE: 1:3,000 when printed at 11x17

DRAWN BY: JDV

GeoConcepts Engineering, Inc.





- Mileposts (0.1 mile)
- Centerline
- 300' Corridor
- 0.50 KRA
- All Point Features
- All Area Features
- 300' Corridor Closed Depressions
- Suspect Closed Depressions
- Randolph Caves
- Pocahontas Caves
- Virginia Caves

0 250 500
Feet

CONTOUR MAP 51

ATLANTIC COAST PIPELINE

11002.04

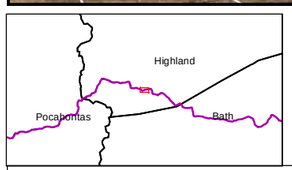
FILE: N:\PROJECTS\Active 11 Projects\11002.04, Dominion Resources Pipeline - Randolph and Pocahontas Co\Final\GIS Data for Final\reportmap Contour.mxd | REVISED: 02/14/2017 | SCALE: 1:3,000 when printed at 11x17

DRAWN BY: JDV

GeoConcepts Engineering, Inc.

C011-6
c011-6
cCD080
cCD081
cCD082
cCD083
88.8
89
89.1
89.2
C011-2
c023-2
c023-1
C011-1
88.9

Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the



- Mileposts (0.1 mile)
- Centerline
- 300' Corridor
- 0.50 KRA
- All Point Features
- All Area Features
- 300' Corridor Closed Depressions
- Suspect Closed Depressions
- Randolph Caves
- Pocahontas Caves
- Virginia Caves

0 250 500
Feet

CONTOUR MAP 52

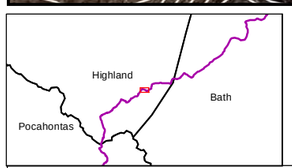
ATLANTIC COAST PIPELINE

11002.04

FILE: N:\PROJECTS\Active 11 Projects\11002.04, Dominion Resources Pipeline - Randolph and Pocahontas Co\Final\GIS Data for Final\reportmap Contour.mxd | REVISED: 02/14/2017 | SCALE: 1:3,000 when printed at 11x17

DRAWN BY: JDV

GeoConcepts Engineering, Inc.



- Mileposts (0.1 mile)
- Centerline
- 300' Corridor
- 0.50 KRA
- All Point Features
- All Area Features
- 300' Corridor Closed Depressions
- Suspect Closed Depressions
- Randolph Caves
- Pocahontas Caves
- Virginia Caves

0 250 500
Feet

CONTOUR MAP 53

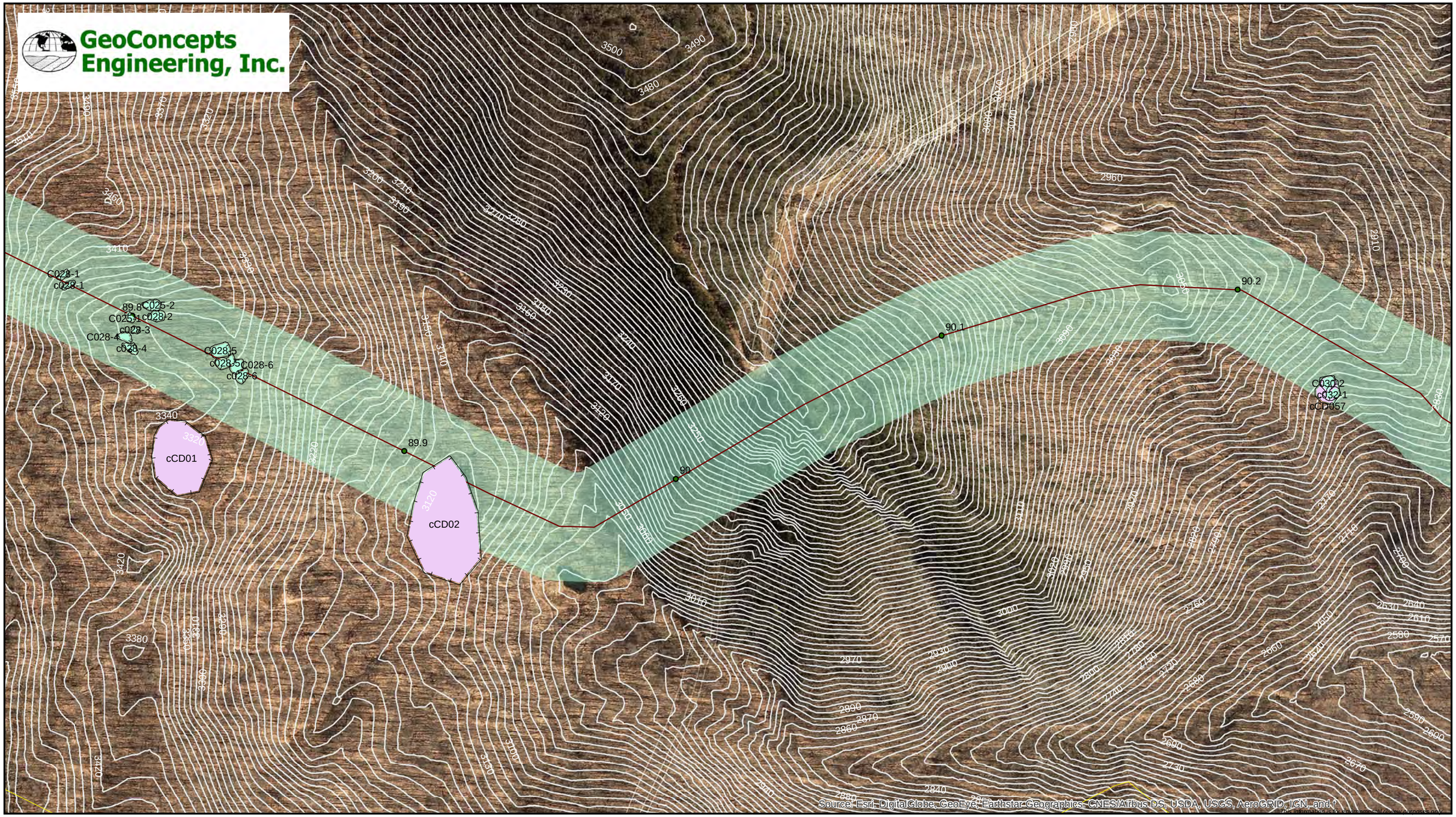
ATLANTIC COAST PIPELINE

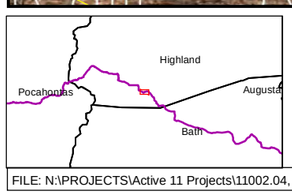
11002.04

FILE: N:\PROJECTS\Active 11 Projects\11002.04, Dominion Resources Pipeline - Randolph and Pocahontas Co\Final\GIS Data for Final\reportmap Contour.mxd | REVISED: 02/14/2017 | SCALE: 1:3,000 when printed at 11x17

DRAWN BY: JDV

GeoConcepts Engineering, Inc.





- Mileposts (0.1 mile)
- Centerline
- 300' Corridor
- 0.50 KRA
- All Point Features
- All Area Features
- 300' Corridor Closed Depressions
- Suspect Closed Depressions
- Randolph Caves
- Pocahontas Caves
- Virginia Caves

0 250 500
Feet

CONTOUR MAP 54

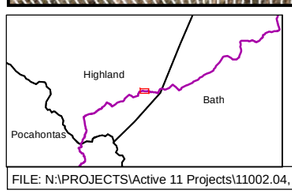
ATLANTIC COAST PIPELINE

11002.04

FILE: N:\PROJECTS\Active 11 Projects\11002.04, Dominion Resources Pipeline - Randolph and Pocahontas Co\Final\GIS Data for Final\reportmap Contour.mxd | REVISED: 02/14/2017 | SCALE: 1:3,000 when printed at 11x17

DRAWN BY: JDV

GeoConcepts Engineering, Inc.



- Mileposts (0.1 mile)
- Centerline
- 300' Corridor
- 0.50 KRA
- All Point Features
- All Area Features
- 300' Corridor Closed Depressions
- Suspect Closed Depressions
- Randolph Caves
- Pocahontas Caves
- Virginia Caves

0 250 500
Feet

CONTOUR MAP 55

ATLANTIC COAST PIPELINE

11002.04

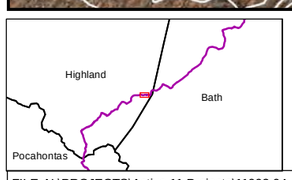
FILE: N:\PROJECTS\Active 11 Projects\11002.04, Dominion Resources Pipeline - Randolph and Pocahontas Co\Final\GIS Data for Final\reportmap Contour.mxd | REVISED: 02/14/2017 | SCALE: 1:3,000 when printed at 11x17

DRAWN BY: JDV

GeoConcepts Engineering, Inc.

90.7
90.8
90.9
91
91.1
cCD121
cCD122
cCD123

Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbu



- Mileposts (0.1 mile)
- Centerline
- 300' Corridor
- 0.50 KRA
- All Point Features
- All Area Features
- 300' Corridor Closed Depressions
- Suspect Closed Depressions
- Randolph Caves
- Pocahontas Caves
- Virginia Caves

0 250 500
Feet

CONTOUR MAP 56

ATLANTIC COAST PIPELINE

11002.04

FILE: N:\PROJECTS\Active 11 Projects\11002.04, Dominion Resources Pipeline - Randolph and Pocahontas Co\Final\GIS Data for Final\reportmap Contour.mxd | REVISED: 02/14/2017 | SCALE: 1:3,000 when printed at 11x17

DRAWN BY: JDV

GeoConcepts Engineering, Inc.

cCD123

91.2

91.3

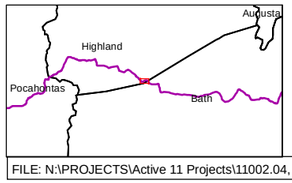
91.4

91.5

91.6

91.7

Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the



- Mileposts (0.1 mile)
- Centerline
- 300' Corridor
- 0.50 KRA
- All Point Features
- All Area Features
- 300' Corridor Closed Depressions
- Suspect Closed Depressions
- Randolph Caves
- Pocahontas Caves
- Virginia Caves

0 250 500
Feet

CONTOUR MAP 57

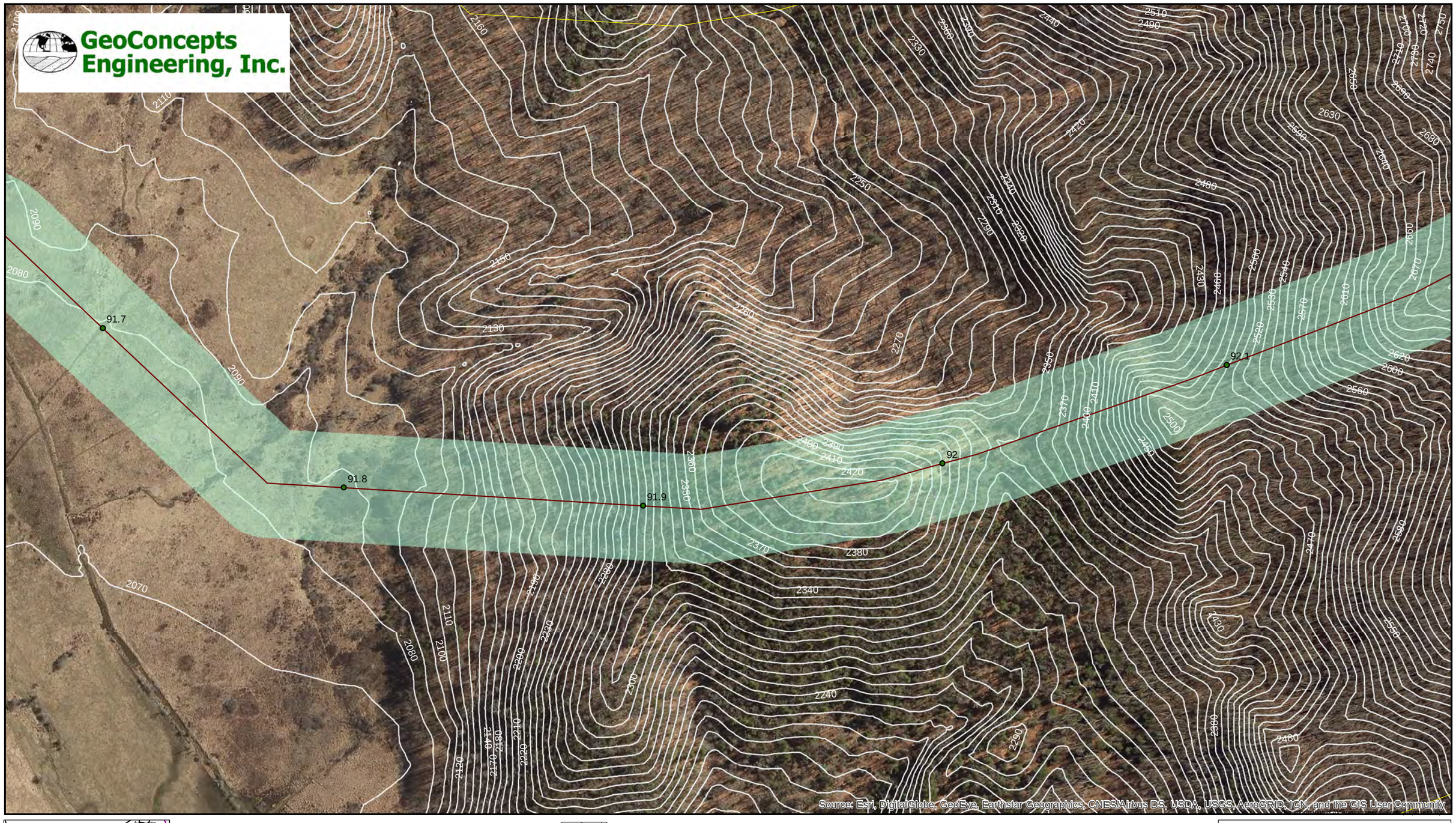
ATLANTIC COAST PIPELINE

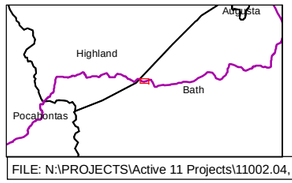
11002.04

FILE: N:\PROJECTS\Active 11 Projects\11002.04, Dominion Resources Pipeline - Randolph and Pocahontas Co\Final\GIS Data for Final\reportmap Contour.mxd | REVISED: 02/14/2017 | SCALE: 1:3,000 when printed at 11x17

DRAWN BY: JDV

GeoConcepts Engineering, Inc.





- Mileposts (0.1 mile)
- Centerline
- 300' Corridor
- 0.50 KRA
- All Point Features
- All Area Features
- 300' Corridor Closed Depressions
- Suspect Closed Depressions
- Randolph Caves
- Pocahontas Caves
- Virginia Caves

0 250 500
Feet

CONTOUR MAP 58

ATLANTIC COAST PIPELINE

11002.04

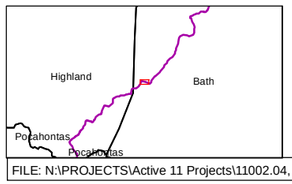
FILE: N:\PROJECTS\Active 11 Projects\11002.04, Dominion Resources Pipeline - Randolph and Pocahontas Co\Final\GIS Data for Final\reportmap Contour.mxd | REVISED: 02/14/2017 | SCALE: 1:3,000 when printed at 11x17

DRAWN BY: JDV

GeoConcepts Engineering, Inc.

92.1 92.2 92.3 92.4 92.5 92.6 92.7

Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographic



Mileposts (0.1 mile)
Centerline
300' Corridor
0.50 KRA
All Point Features
All Area Features
300' Corridor Closed Depressions
Suspect Closed Depressions
Randolph Caves
Pocahontas Caves
Virginia Caves

0 250 500
Feet

CONTOUR MAP 59

ATLANTIC COAST PIPELINE

11002.04

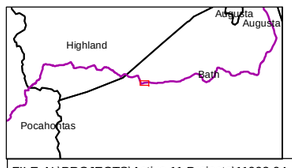
FILE: N:\PROJECTS\Active 11 Projects\11002.04, Dominion Resources Pipeline - Randolph and Pocahontas Co\Final\GIS Data for Final\reportmap Contour.mxd | REVISED: 02/14/2017 | SCALE: 1:3,000 when printed at 11x17

DRAWN BY: JDV

GeoConcepts Engineering, Inc.

cCD118
cCD119
cCD120
92.7
92.8
92.9
93
93.1
93.2

Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User C



- Mileposts (0.1 mile)
- Centerline
- 300' Corridor
- 0.50 KRA
- All Point Features
- All Area Features
- 300' Corridor Closed Depressions
- Suspect Closed Depressions
- Randolph Caves
- Pocahontas Caves
- Virginia Caves

0 250 500
Feet

CONTOUR MAP 60

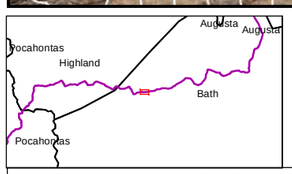
ATLANTIC COAST PIPELINE

11002.04

FILE: N:\PROJECTS\Active 11 Projects\11002.04, Dominion Resources Pipeline - Randolph and Pocahontas Co\Final\GIS Data for Final\reportmap Contour.mxd | REVISED: 02/14/2017 | SCALE: 1:3,000 when printed at 11x17

DRAWN BY: JDV

GeoConcepts Engineering, Inc.



- Mileposts (0.1 mile)
- Centerline
- 300' Corridor
- 0.50 KRA
- All Point Features
- All Area Features
- 300' Corridor Closed Depressions
- Suspect Closed Depressions
- Randolph Caves
- Pocahontas Caves
- Virginia Caves

0 250 500
Feet

CONTOUR MAP 61

ATLANTIC COAST PIPELINE

11002.04

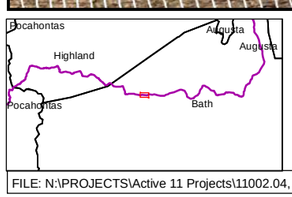
FILE: N:\PROJECTS\Active 11 Projects\11002.04, Dominion Resources Pipeline - Randolph and Pocahontas Co\Final\GIS Data for Final\reportmap Contour.mxd | REVISED: 02/14/2017 | SCALE: 1:3,000 when printed at 11x17

DRAWN BY: JDV

GeoConcepts Engineering, Inc.

93.8
93.9
94
94.1
94.2
93.7

Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS



- Mileposts (0.1 mile)
- Centerline
- 300' Corridor
- 0.50 KRA
- All Point Features
- All Area Features
- 300' Corridor Closed Depressions
- Suspect Closed Depressions
- Randolph Caves
- Pocahontas Caves
- Virginia Caves

0 250 500
Feet

CONTOUR MAP 62

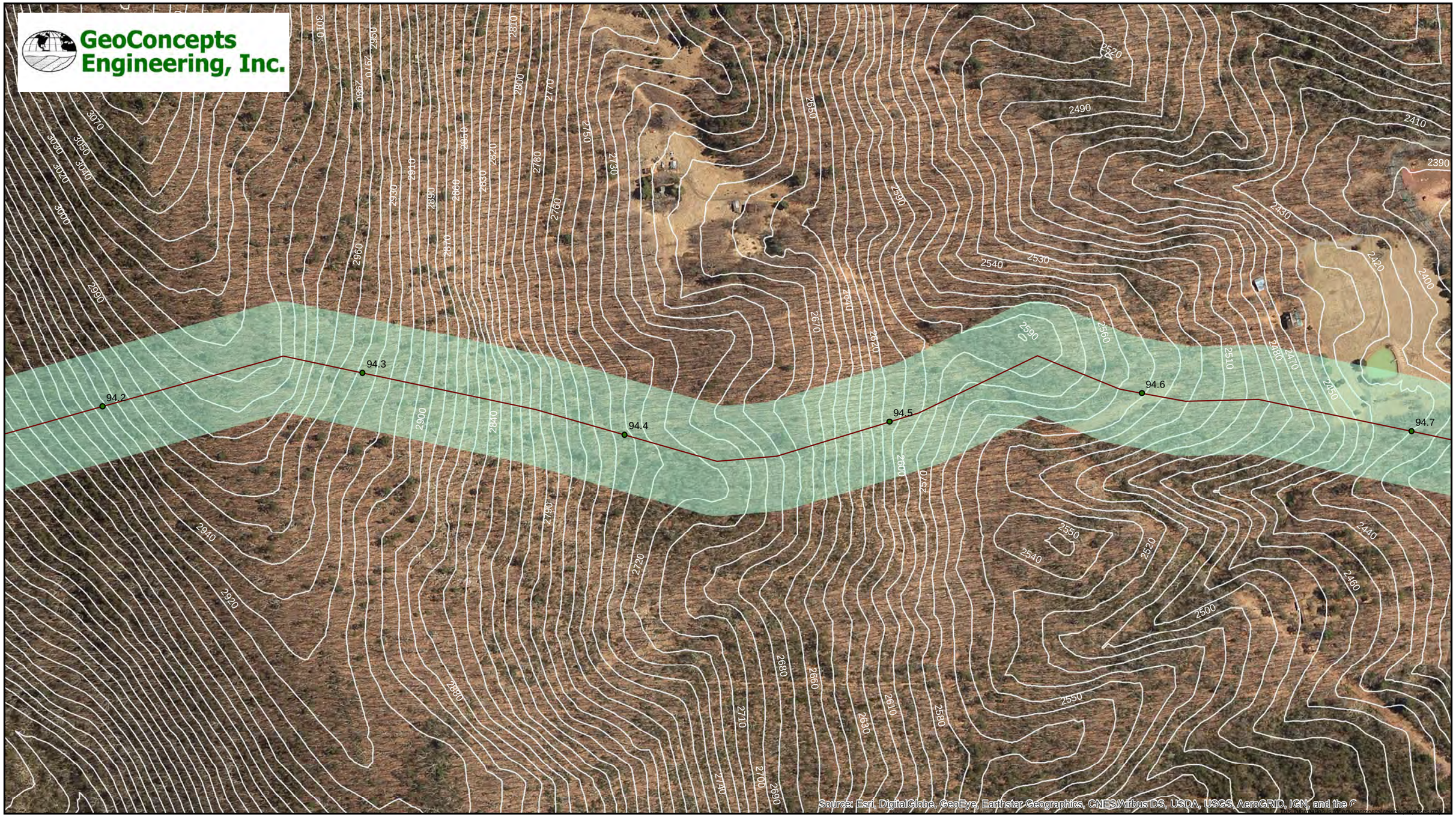
ATLANTIC COAST PIPELINE

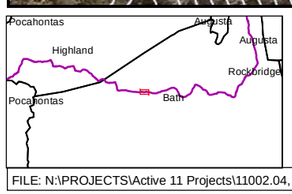
11002.04

FILE: N:\PROJECTS\Active 11 Projects\11002.04, Dominion Resources Pipeline - Randolph and Pocahontas Co\Final\GIS Data for Final\reportmap Contour.mxd | REVISED: 02/14/2017 | SCALE: 1:3,000 when printed at 11x17

DRAWN BY: JDV

GeoConcepts Engineering, Inc.





- Mileposts (0.1 mile)
- Centerline
- 300' Corridor
- 0.50 KRA
- All Point Features
- All Area Features
- 300' Corridor Closed Depressions
- Suspect Closed Depressions
- Randolph Caves
- Pocahontas Caves
- Virginia Caves

0 250 500
Feet

CONTOUR MAP 63

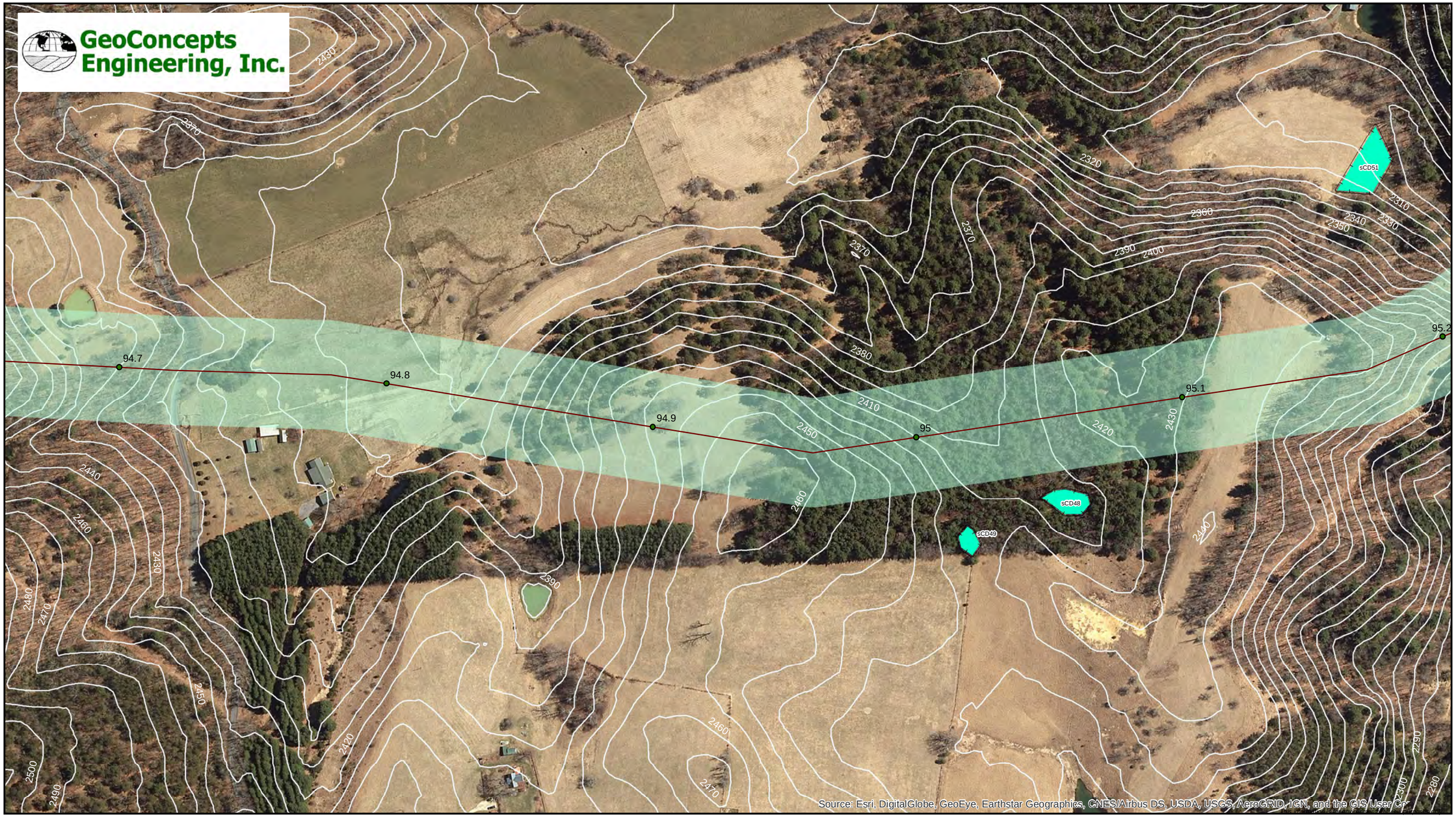
ATLANTIC COAST PIPELINE

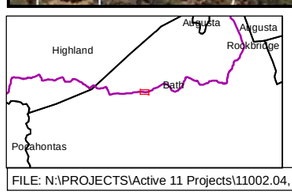
11002.04

FILE: N:\PROJECTS\Active 11 Projects\11002.04, Dominion Resources Pipeline - Randolph and Pocahontas Co\Final\GIS Data for Final\reportmap Contour.mxd | REVISED: 02/14/2017 | SCALE: 1:3,000 when printed at 11x17

DRAWN BY: JDV

GeoConcepts Engineering, Inc.





- Mileposts (0.1 mile)
- Centerline
- 300' Corridor
- 0.50 KRA
- All Point Features
- All Area Features
- 300' Corridor Closed Depressions
- Suspect Closed Depressions
- Randolph Caves
- Pocahontas Caves
- Virginia Caves

0 250 500
Feet

CONTOUR MAP 64

ATLANTIC COAST PIPELINE

11002.04

FILE: N:\PROJECTS\Active 11 Projects\11002.04, Dominion Resources Pipeline - Randolph and Pocahontas Co\Final\GIS Data for Final\reportmap Contour.mxd | REVISED: 02/14/2017 | SCALE: 1:3,000 when printed at 11x17

DRAWN BY: JDV

GeoConcepts Engineering, Inc.

sCD51

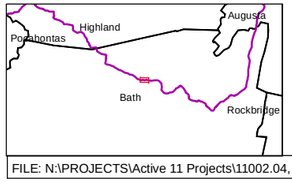
sCD50

36-024-1

95.2 95.3 95.4 95.5 95.6

2430 2420 2330 2300 2280 2320 2440 2350 2340 2310 2290 2270 2260 2250 2240 2380 2360 2370 2400 2410 2450 2460 2470 2480 2490

Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the



- Mileposts (0.1 mile)
- Centerline
- 300' Corridor
- 0.50 KRA
- All Point Features
- All Area Features
- 300' Corridor Closed Depressions
- Suspect Closed Depressions
- Randolph Caves
- Pocahontas Caves
- Virginia Caves

0 250 500
Feet

CONTOUR MAP 65

ATLANTIC COAST PIPELINE

11002.04

FILE: N:\PROJECTS\Active 11 Projects\11002.04, Dominion Resources Pipeline - Randolph and Pocahontas Co\Final\GIS Data for Final\reportmap Contour.mxd | REVISED: 02/14/2017 | SCALE: 1:3,000 when printed at 11x17

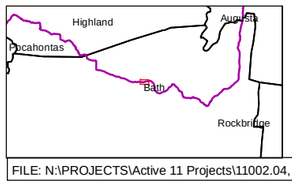
DRAWN BY: JDV

GeoConcepts Engineering, Inc.

95.7 95.8 95.9 96 96.1

cCD139 cCD137 cCD138

Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community



- Mileposts (0.1 mile)
- Centerline
- 300' Corridor
- 0.50 KRA
- All Point Features
- All Area Features
- 300' Corridor Closed Depressions
- Suspect Closed Depressions
- Randolph Caves
- Pocahontas Caves
- Virginia Caves

0 250 500
Feet

CONTOUR MAP 66

ATLANTIC COAST PIPELINE

11002.04

FILE: N:\PROJECTS\Active 11 Projects\11002.04, Dominion Resources Pipeline - Randolph and Pocahontas Co\Final\GIS Data for Final\reportmap Contour.mxd | REVISED: 02/14/2017 | SCALE: 1:3,000 when printed at 11x17

DRAWN BY: JDV

GeoConcepts Engineering, Inc.

cCD03

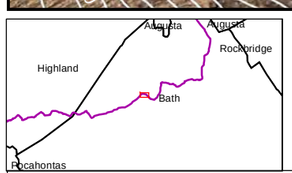
96.2 96.3 96.4 96.5 96.6 96.7

cCD140 cCD143 cCD142 cCD144 cCD141

Bruce's Wild Cave

Jewel Box Cave

Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and th...



- Mileposts (0.1 mile)
- Centerline
- 300' Corridor
- 0.50 KRA
- All Point Features
- All Area Features
- 300' Corridor Closed Depressions
- Suspect Closed Depressions
- Randolph Caves
- Pocahontas Caves
- Virginia Caves

0 250 500
Feet

CONTOUR MAP 67

ATLANTIC COAST PIPELINE

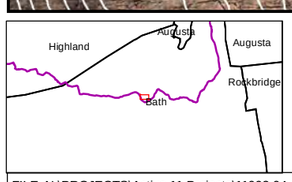
11002.04

FILE: N:\PROJECTS\Active 11 Projects\11002.04, Dominion Resources Pipeline - Randolph and Pocahontas Co\Final\GIS Data for Final\reportmap Contour.mxd | REVISED: 02/14/2017 | SCALE: 1:3,000 when printed at 11x17

DRAWN BY: JDV

GeoConcepts Engineering, Inc.

96.7
96.8
96.9
97
97.1
97.2
cCD142
cCD144
cCD141
cCD145
cCD127
cCD124
cCD128



Mileposts (0.1 mile)
Centerline
300' Corridor
0.50 KRA
All Point Features
All Area Features
300' Corridor Closed Depressions
Suspect Closed Depressions
Randolph Caves
Pocahontas Caves
Virginia Caves

0 250 500
Feet

CONTOUR MAP 68

ATLANTIC COAST PIPELINE

11002.04

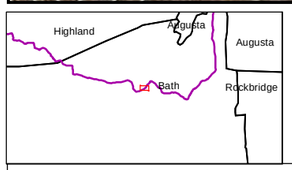
FILE: N:\PROJECTS\Active 11 Projects\11002.04, Dominion Resources Pipeline - Randolph and Pocahontas Co\Final\GIS Data for Final\reportmap Contour.mxd | REVISED: 02/14/2017 | SCALE: 1:3,000 when printed at 11x17

DRAWN BY: JDV

GeoConcepts Engineering, Inc.

97.2
97.3
97.4
97.5
97.6
97.7

Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community



- Mileposts (0.1 mile)
- Centerline
- 300' Corridor
- 0.50 KRA
- All Point Features
- All Area Features
- 300' Corridor Closed Depressions
- Suspect Closed Depressions
- Randolph Caves
- Pocahontas Caves
- Virginia Caves

0 250 500
Feet

CONTOUR MAP 69
ATLANTIC COAST PIPELINE
11002.04

FILE: N:\PROJECTS\Active 11 Projects\11002.04, Dominion Resources Pipeline - Randolph and Pocahontas Co\Final\GIS Data for Final\reportmap Contour.mxd | REVISED: 02/14/2017 | SCALE: 1:3,000 when printed at 11x17

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- Mileposts (0.1 mile)
- Centerline
- 300' Corridor
- 0.50 KRA
- All Point Features
- All Area Features
- 300' Corridor Closed Depressions
- Suspect Closed Depressions
- Randolph Caves
- Pocahontas Caves
- Virginia Caves

0 250 500
Feet

CONTOUR MAP 70

ATLANTIC COAST PIPELINE

11002.04

FILE: N:\PROJECTS\Active 11 Projects\11002.04, Dominion Resources Pipeline - Randolph and Pocahontas Co\Final\GIS Data for Final\reportmap Contour.mxd | REVISED: 02/14/2017 | SCALE: 1:3,000 when printed at 11x17

DRAWN BY: JDV

GeoConcepts Engineering, Inc.

100.9
101
052.5-1
101.1
101.2
101.3

Mileposts (0.1 mile)
Centerline
300' Corridor
0.50 KRA
All Point Features
All Area Features
300' Corridor Closed Depressions
Suspect Closed Depressions
Randolph Caves
Pocahontas Caves
Virginia Caves

0 250 500
Feet

CONTOUR MAP 71

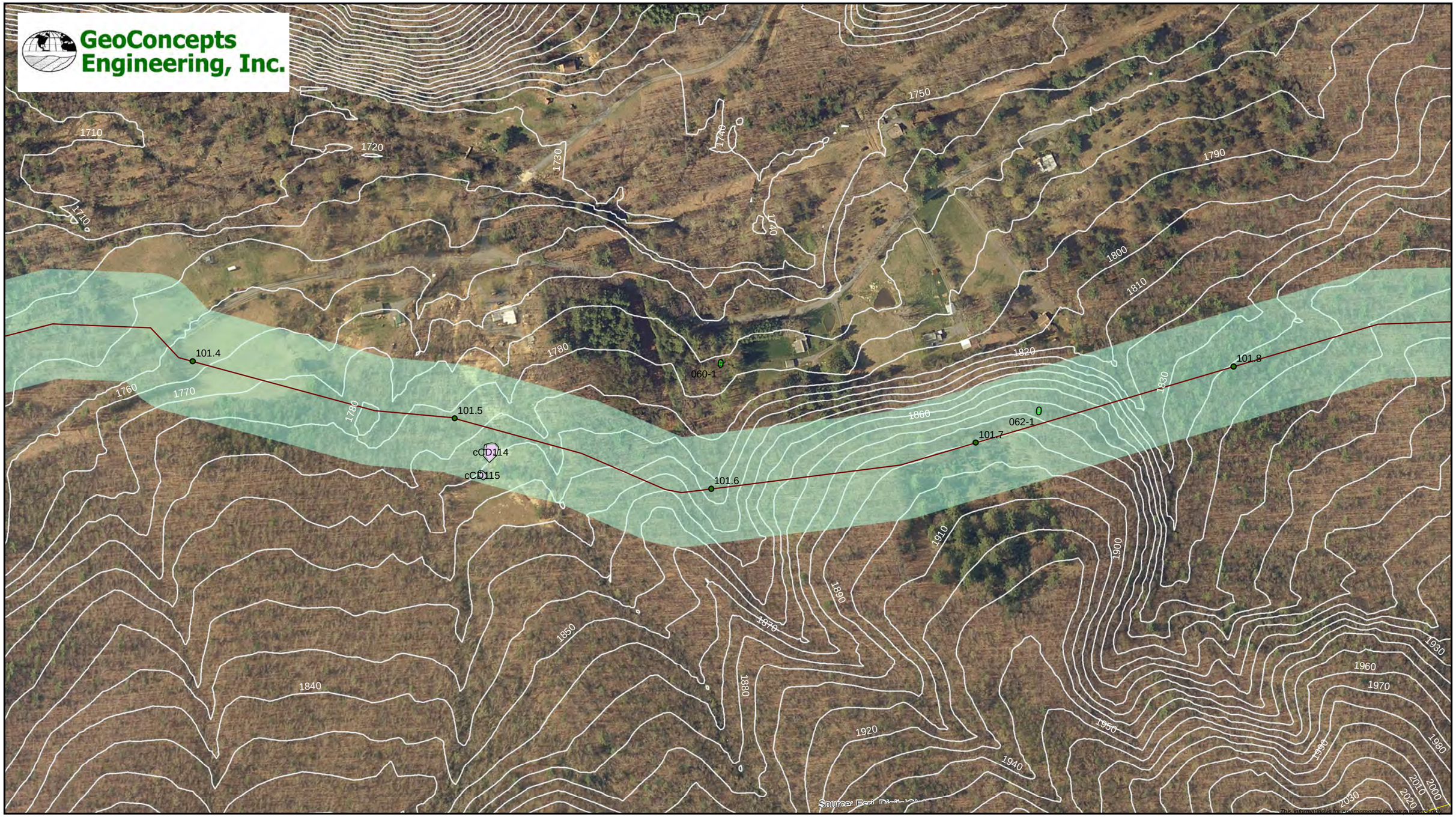
ATLANTIC COAST PIPELINE

11002.04

FILE: N:\PROJECTS\Active 11 Projects\11002.04, Dominion Resources Pipeline - Randolph and Pocahontas Co\Final\GIS Data for Final\reportmap Contour.mxd | REVISED: 02/14/2017 | SCALE: 1:3,000 when printed at 11x17

DRAWN BY: JDV

GeoConcepts Engineering, Inc.



- Mileposts (0.1 mile)
- Centerline
- 300' Corridor
- 0.50 KRA
- All Point Features
- All Area Features
- 300' Corridor Closed Depressions
- Suspect Closed Depressions
- Randolph Caves
- Pocahontas Caves
- Virginia Caves

0 250 500
Feet

CONTOUR MAP 72

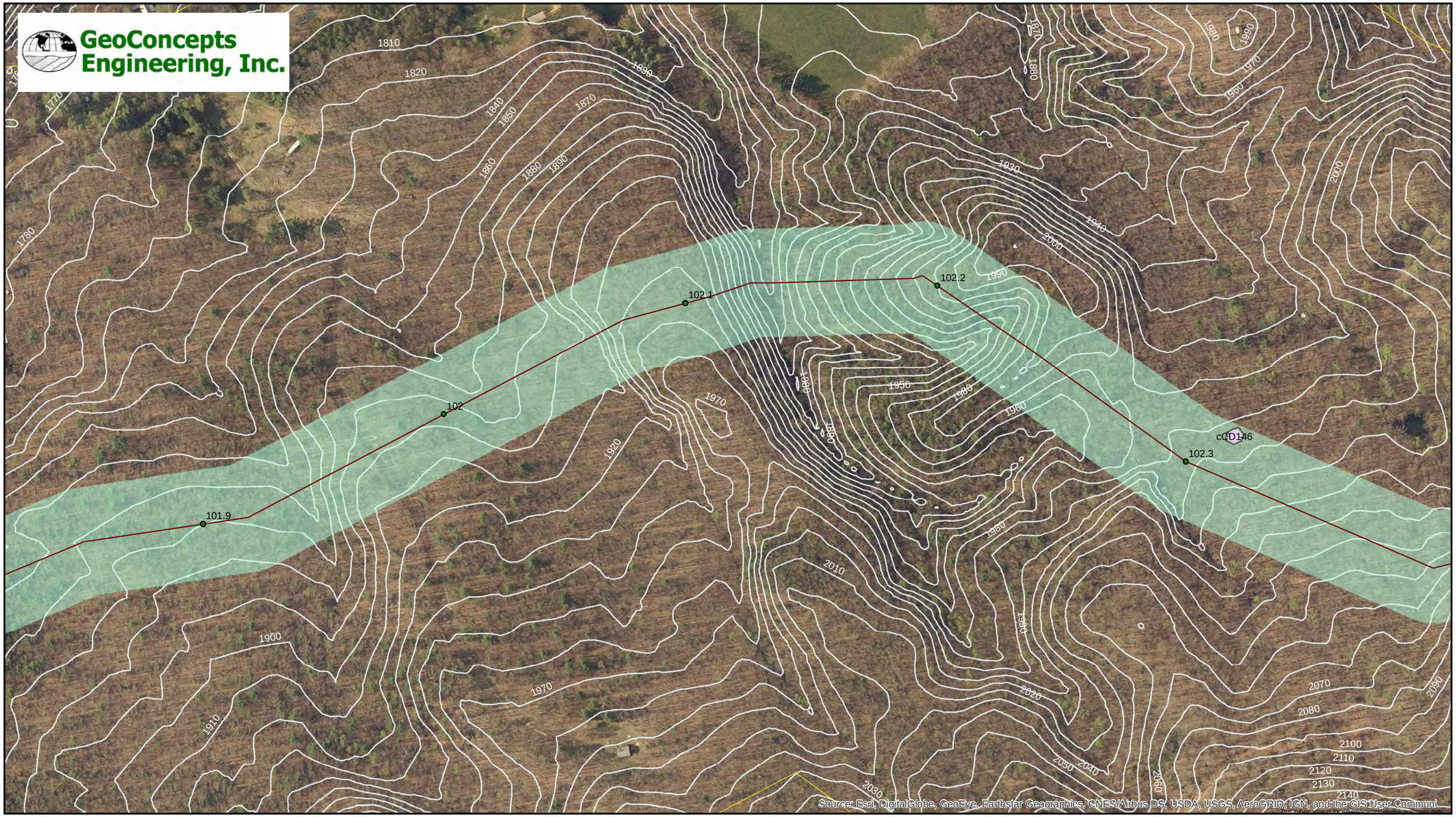
ATLANTIC COAST PIPELINE

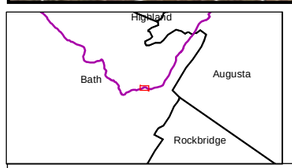
11002.04

FILE: N:\PROJECTS\Active 11 Projects\11002.04, Dominion Resources Pipeline - Randolph and Pocahontas Co\Final\GIS Data for Final\reportmap Contour.mxd | REVISED: 02/14/2017 | SCALE: 1:3,000 when printed at 11x17

DRAWN BY: JDV

GeoConcepts Engineering, Inc.





- Mileposts (0.1 mile)
- Centerline
- 300' Corridor
- 0.50 KRA
- All Point Features
- All Area Features
- 300' Corridor Closed Depressions
- Suspect Closed Depressions
- Randolph Caves
- Pocahontas Caves
- Virginia Caves

0 250 500
Feet

CONTOUR MAP 73

ATLANTIC COAST PIPELINE

11002.04

FILE: N:\PROJECTS\Active 11 Projects\11002.04, Dominion Resources Pipeline - Randolph and Pocahontas Co\Final\GIS Data for Final\reportmap Contour.mxd | REVISED: 02/14/2017 | SCALE: 1:3,000 when printed at 11x17

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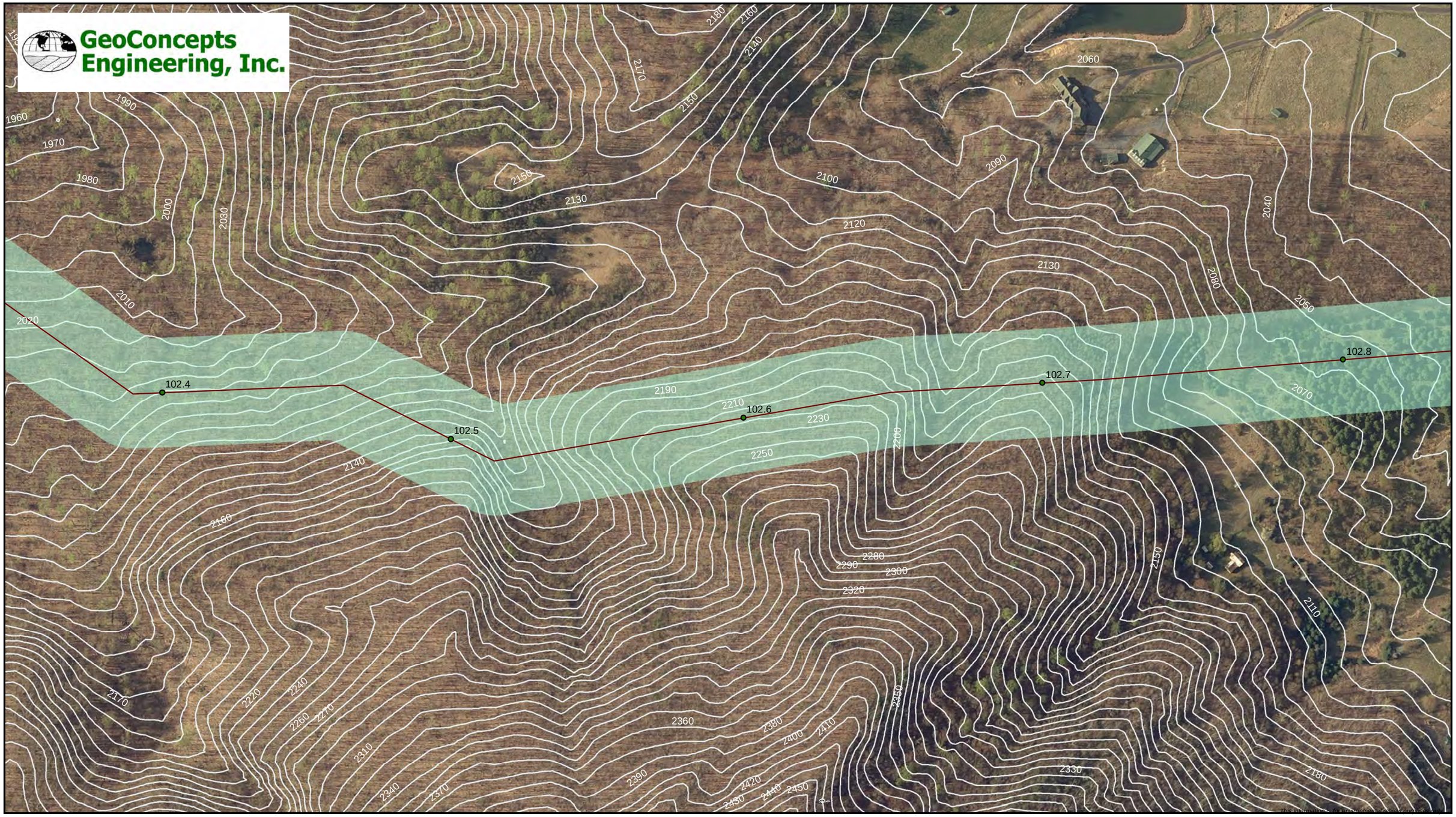
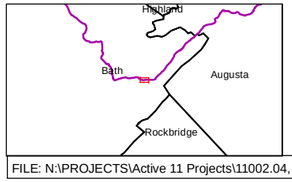
GeoConcepts Engineering, Inc.





- Mileposts (0.1 mile)
- Centerline
- 300' Corridor
- 0.50 KRA
- All Point Features
- All Area Features
- 300' Corridor Closed Depressions
- Suspect Closed Depressions
- Randolph Caves
- Pocahontas Caves
- Virginia Caves

0 250 500
Feet

CONTOUR MAP 74

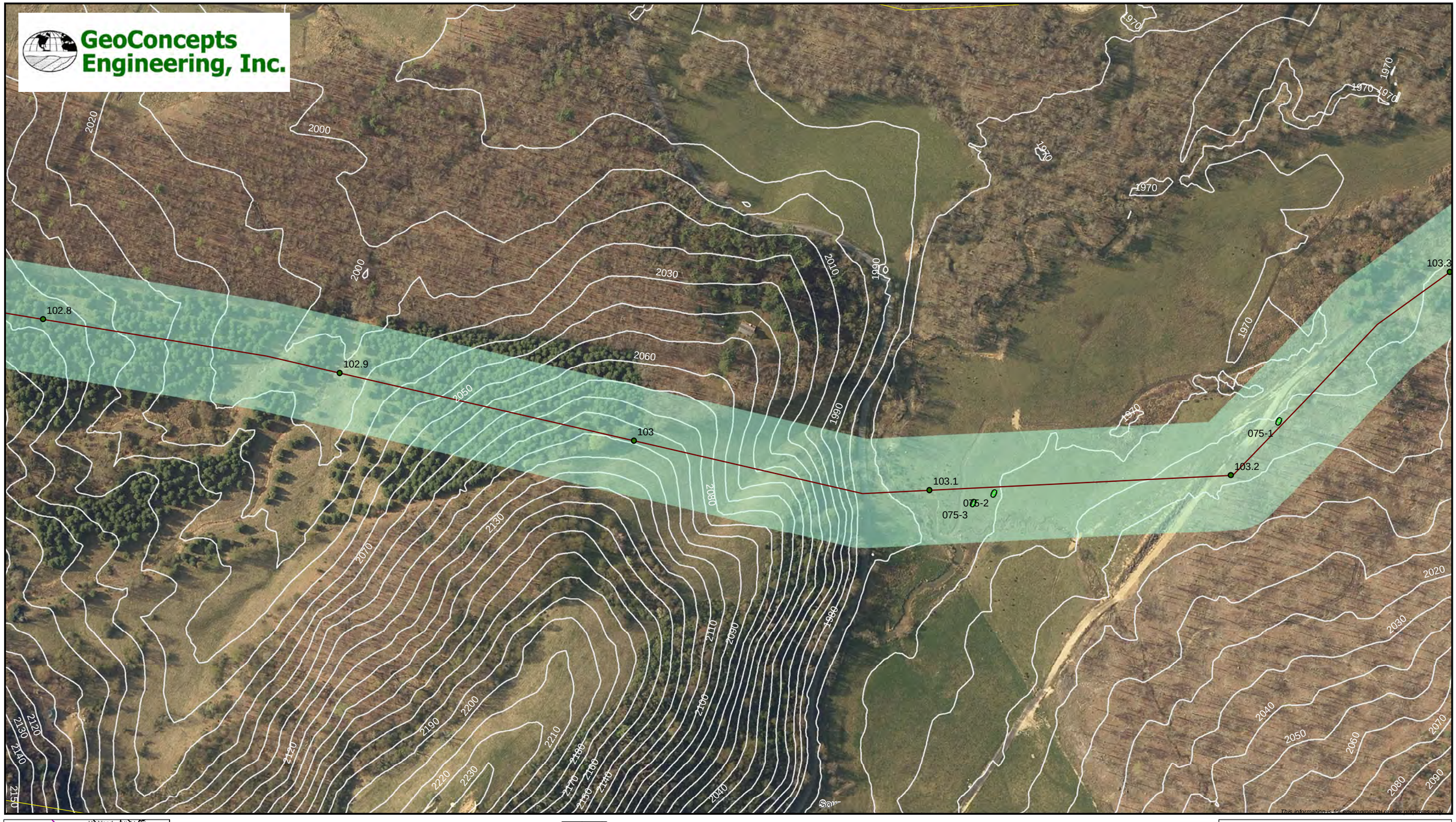
ATLANTIC COAST PIPELINE

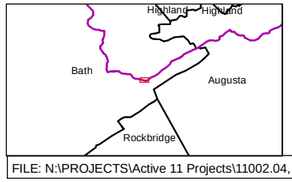
11002.04

FILE: N:\PROJECTS\Active 11 Projects\11002.04, Dominion Resources Pipeline - Randolph and Pocahontas Co\Final\GIS Data for Final\reportmap Contour.mxd | REVISED: 02/14/2017 | SCALE: 1:3,000 when printed at 11x17

DRAWN BY: JDV

GeoConcepts Engineering, Inc.





- Mileposts (0.1 mile)
- Centerline
- 300' Corridor
- 0.50 KRA
- All Point Features
- All Area Features
- 300' Corridor Closed Depressions
- Suspect Closed Depressions
- Randolph Caves
- Pocahontas Caves
- Virginia Caves

0 250 500
Feet

CONTOUR MAP 75

ATLANTIC COAST PIPELINE

11002.04

FILE: N:\PROJECTS\Active 11 Projects\11002.04, Dominion Resources Pipeline - Randolph and Pocahontas Co\Final\GIS Data for Final\reportmap Contour.mxd | REVISED: 02/14/2017 | SCALE: 1:3,000 when printed at 11x17

DRAWN BY: JDV

GeoConcepts Engineering, Inc.

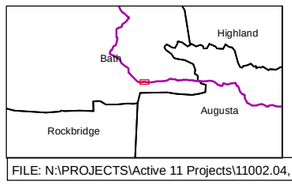
1970 1970 1970 1970 1970 1970 1980 1980 1990 2000 1980 2010 2020 2030 2040 2030 2020 2050 2090 2110 2130 2060 2070 2080 2100 2120 2140 2160 2150 2170 2180 2190 2200

103.3 103.4 103.5 103.6 103.7

077-2 077-1 078-22 078-21 078-09 078-20

Source: Esri, DigitalGlobe, G

This information is for environmental review purposes only.



- Mileposts (0.1 mile)
- Centerline
- 300' Corridor
- 0.50 KRA
- All Point Features
- All Area Features
- 300' Corridor Closed Depressions
- Suspect Closed Depressions
- Randolph Caves
- Pocahontas Caves
- Virginia Caves

0 250 500
Feet

CONTOUR MAP 76

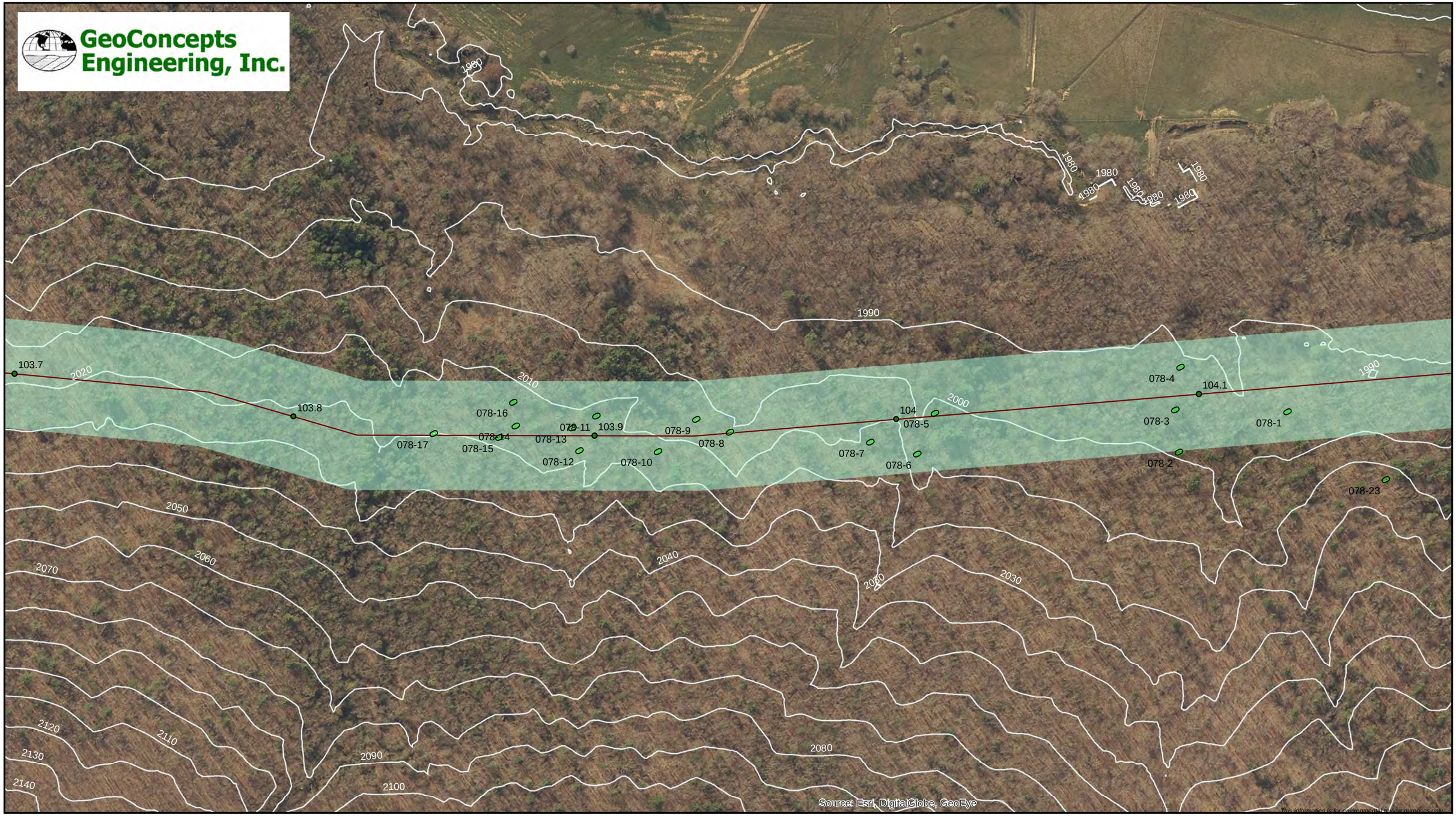
ATLANTIC COAST PIPELINE

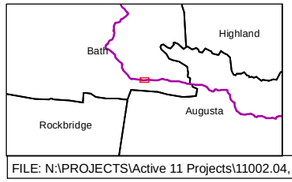
11002.04

FILE: N:\PROJECTS\Active 11 Projects\11002.04, Dominion Resources Pipeline - Randolph and Pocahontas Co\Final\GIS Data for Final\reportmap Contour.mxd | REVISED: 02/14/2017 | SCALE: 1:3,000 when printed at 11x17

DRAWN BY: JDV

GeoConcepts Engineering, Inc.





- Mileposts (0.1 mile)
- Centerline
- 300' Corridor
- 0.50 KRA
- All Point Features
- All Area Features
- 300' Corridor Closed Depressions
- Suspect Closed Depressions
- Randolph Caves
- Pocahontas Caves
- Virginia Caves

0 250 500
Feet

CONTOUR MAP 77

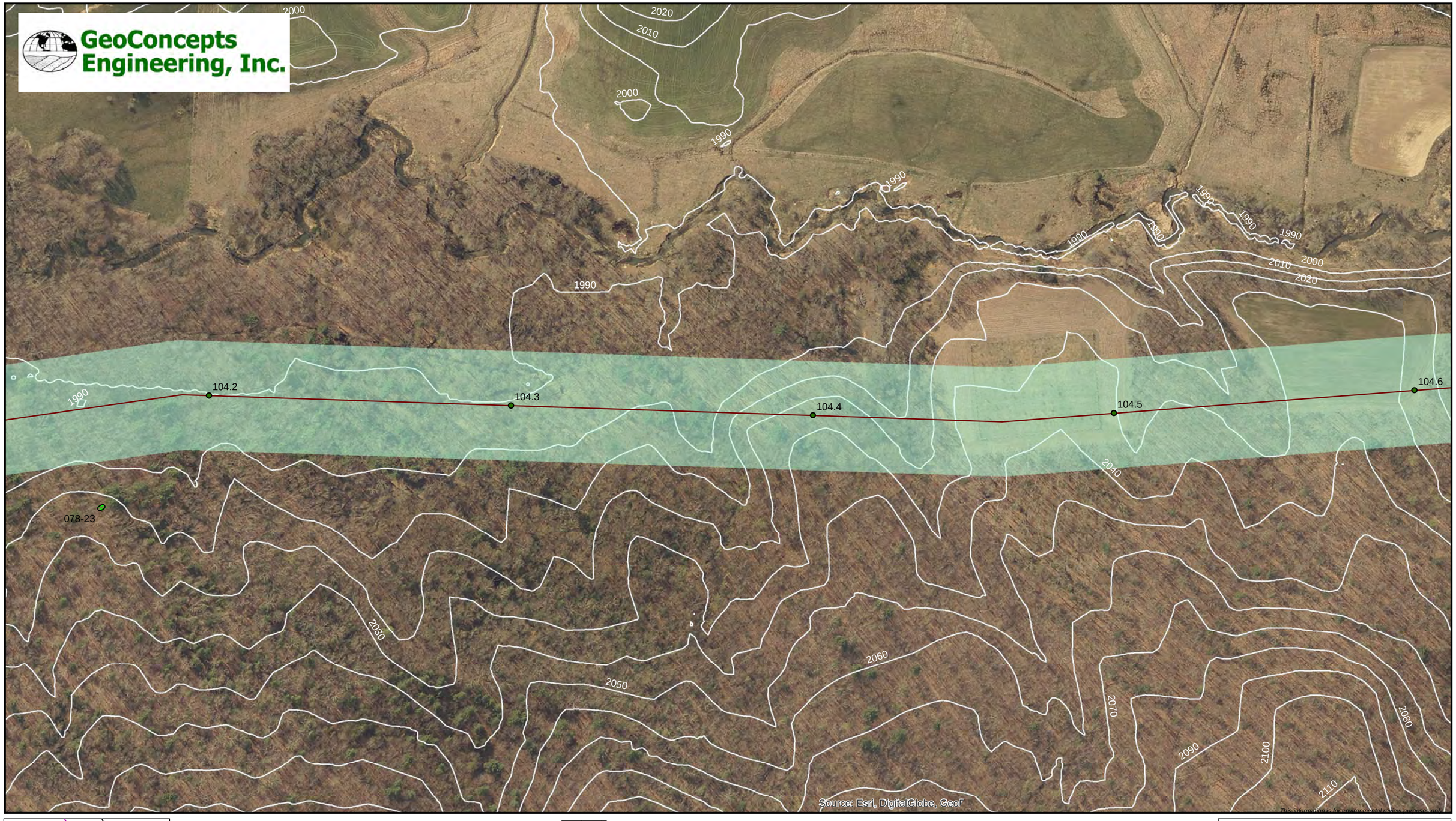
ATLANTIC COAST PIPELINE

11002.04

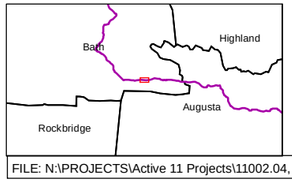
FILE: N:\PROJECTS\Active 11 Projects\11002.04, Dominion Resources Pipeline - Randolph and Pocahontas Co\Final\GIS Data for Final\reportmap Contour.mxd | REVISED: 02/14/2017 | SCALE: 1:3,000 when printed at 11x17

DRAWN BY: JDV

GeoConcepts Engineering, Inc.



This information is for environmental review purposes only.



- Mileposts (0.1 mile)
- Centerline
- 300' Corridor
- 0.50 KRA
- All Point Features
- All Area Features
- 300' Corridor Closed Depressions
- Suspect Closed Depressions
- Randolph Caves
- Pocahontas Caves
- Virginia Caves

0 250 500
Feet

CONTOUR MAP 78

ATLANTIC COAST PIPELINE

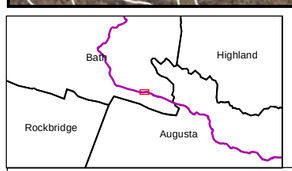
11002.04

FILE: N:\PROJECTS\Active 11 Projects\11002.04, Dominion Resources Pipeline - Randolph and Pocahontas Co\Final\GIS Data for Final\reportmap Contour.mxd | REVISED: 02/14/2017 | SCALE: 1:3,000 when printed at 11x17

DRAWN BY: JDV

GeoConcepts Engineering, Inc.

104.6
104.7
104.8
104.9
105
cCD060
Source: Esri, DigitalGlobe, GeoEye, Earthstar G



- Mileposts (0.1 mile)
- Centerline
- 300' Corridor
- 0.50 KRA
- All Point Features
- All Area Features
- 300' Corridor Closed Depressions
- Suspect Closed Depressions
- Randolph Caves
- Pocahontas Caves
- Virginia Caves

0 250 500
Feet

CONTOUR MAP 79

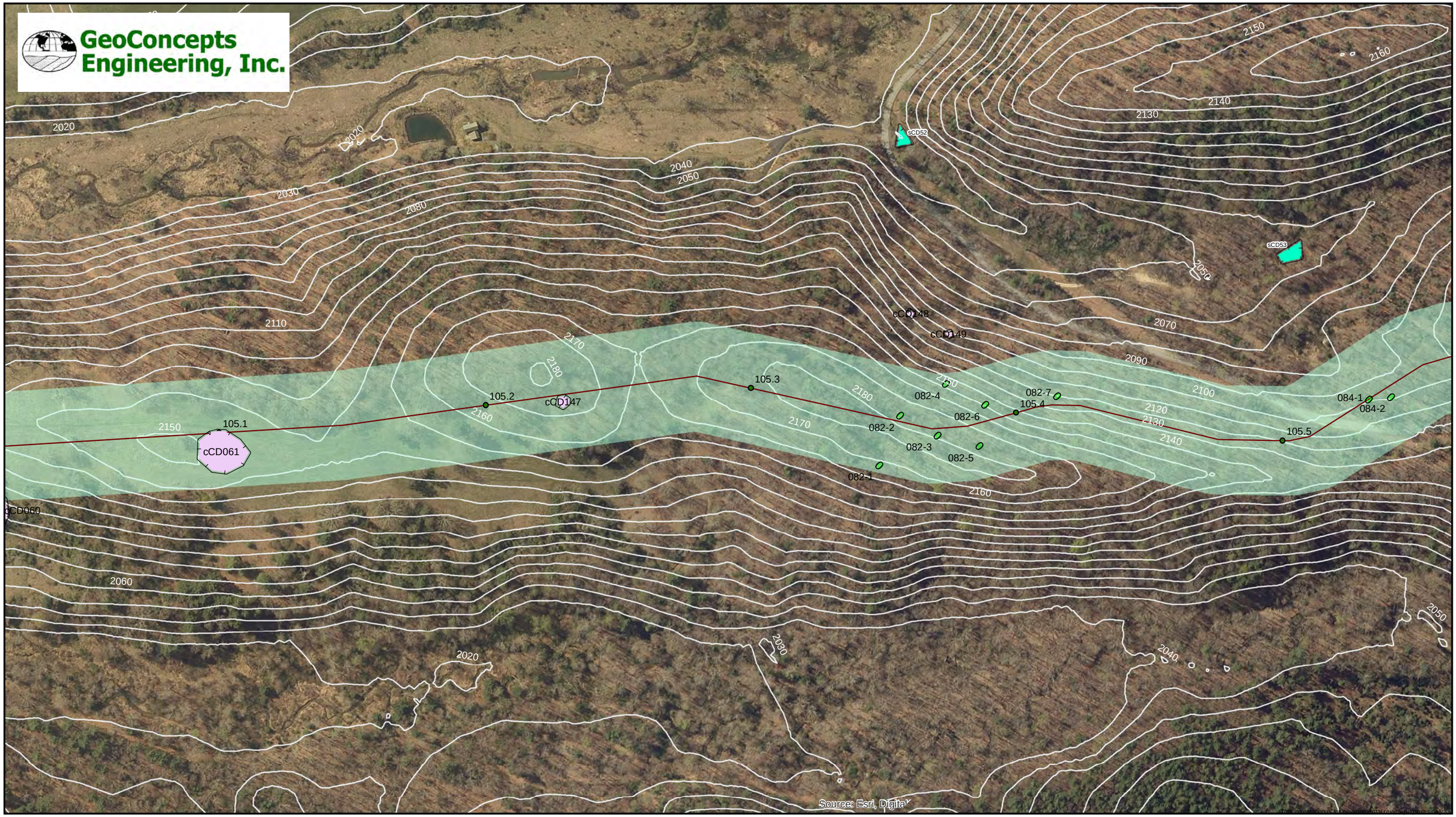
ATLANTIC COAST PIPELINE

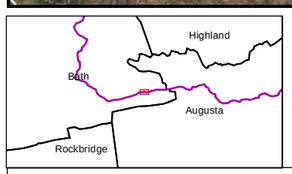
11002.04

FILE: N:\PROJECTS\Active 11 Projects\11002.04, Dominion Resources Pipeline - Randolph and Pocahontas Co\Final\GIS Data for Final\reportmap Contour.mxd | REVISED: 02/14/2017 | SCALE: 1:3,000 when printed at 11x17

DRAWN BY: JDV

GeoConcepts Engineering, Inc.





- Mileposts (0.1 mile)
- Centerline
- 300' Corridor
- 0.50 KRA
- All Point Features
- All Area Features
- 300' Corridor Closed Depressions
- Suspect Closed Depressions
- Randolph Caves
- Pocahontas Caves
- Virginia Caves

0 250 500
Feet

CONTOUR MAP 80

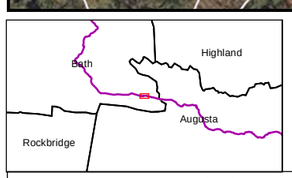
ATLANTIC COAST PIPELINE

11002.04

FILE: N:\PROJECTS\Active 11 Projects\11002.04, Dominion Resources Pipeline - Randolph and Pocahontas Co\Final\GIS Data for Final\reportmap Contour.mxd | REVISED: 02/14/2017 | SCALE: 1:3,000 when printed at 11x17

DRAWN BY: JDV

GeoConcepts Engineering, Inc.



- Mileposts (0.1 mile)
- Centerline
- 300' Corridor
- 0.50 KRA
- All Point Features
- All Area Features
- 300' Corridor Closed Depressions
- Suspect Closed Depressions
- Randolph Caves
- Pocahontas Caves
- Virginia Caves

0 250 500
Feet

CONTOUR MAP 81

ATLANTIC COAST PIPELINE

11002.04

FILE: N:\PROJECTS\Active 11 Projects\11002.04, Dominion Resources Pipeline - Randolph and Pocahontas Co\Final\GIS Data for Final\reportmap Contour.mxd | REVISED: 02/14/2017 | SCALE: 1:3,000 when printed at 11x17

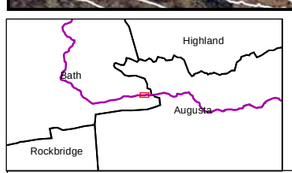
DRAWN BY: JDV

GeoConcepts Engineering, Inc.

106 106.1 106.2 106.3 106.4 106.5

cCD150 cCD151 cCD152 cCD157 sCD54

Source: Esri, DigitalGl



Mileposts (0.1 mile)
Centerline
300' Corridor
0.50 KRA
All Point Features
All Area Features
300' Corridor Closed Depressions
Suspect Closed Depressions
Randolph Caves
Pocahontas Caves
Virginia Caves

0 250 500
Feet

CONTOUR MAP 82

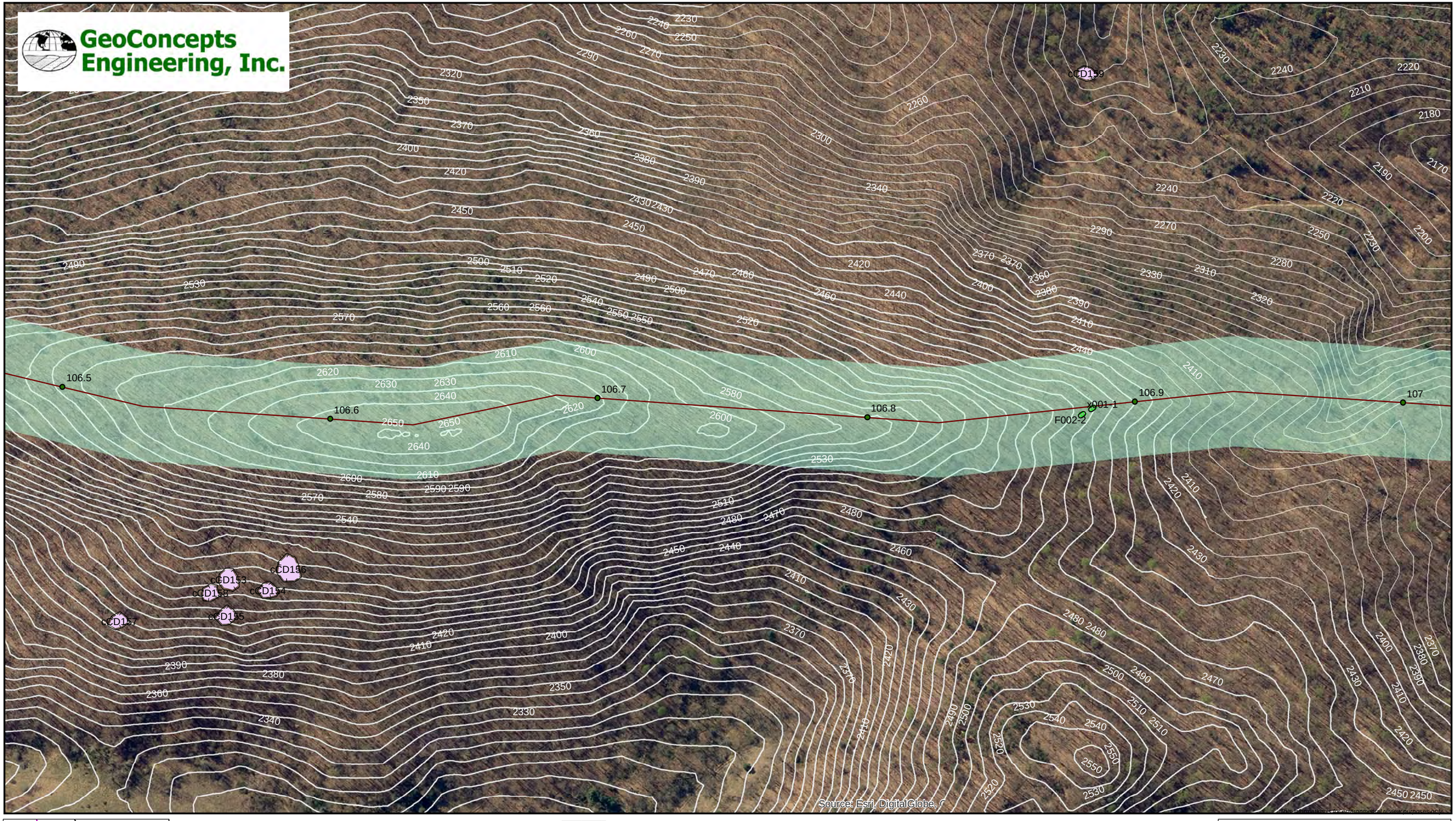
ATLANTIC COAST PIPELINE

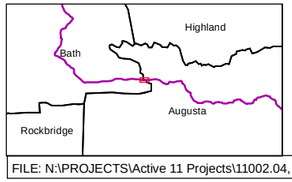
11002.04

FILE: N:\PROJECTS\Active 11 Projects\11002.04, Dominion Resources Pipeline - Randolph and Pocahontas Co\Final\GIS Data for Final\reportmap Contour.mxd | REVISED: 02/14/2017 | SCALE: 1:3,000 when printed at 11x17

DRAWN BY: JDV

GeoConcepts Engineering, Inc.





- Mileposts (0.1 mile)
- Centerline
- 300' Corridor
- 0.50 KRA
- All Point Features
- All Area Features
- 300' Corridor Closed Depressions
- Suspect Closed Depressions
- Randolph Caves
- Pocahontas Caves
- Virginia Caves

0 250 500
Feet

CONTOUR MAP 83

ATLANTIC COAST PIPELINE

11002.04

FILE: N:\PROJECTS\Active 11 Projects\11002.04, Dominion Resources Pipeline - Randolph and Pocahontas Co\Final\GIS Data for Final\reportmap Contour.mxd | REVISED: 02/14/2017 | SCALE: 1:3,000 when printed at 11x17

DRAWN BY: JDV

GeoConcepts Engineering, Inc.

cCD160

cCD161

f002-1

F002-1

107

107.1

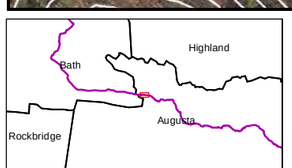
107.2

107.3

107.4

107.5

Source: Esri, DigitalGlobe, GeoEye



- Mileposts (0.1 mile)
- Centerline
- 300' Corridor
- 0.50 KRA
- All Point Features
- All Area Features
- 300' Corridor Closed Depressions
- Suspect Closed Depressions
- Randolph Caves
- Pocahontas Caves
- Virginia Caves

0 250 500
Feet

CONTOUR MAP 84

ATLANTIC COAST PIPELINE

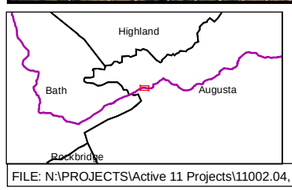
11002.04

FILE: N:\PROJECTS\Active 11 Projects\11002.04, Dominion Resources Pipeline - Randolph and Pocahontas Co\Final\GIS Data for Final\reportmap Contour.mxd | REVISED: 02/14/2017 | SCALE: 1:3,000 when printed at 11x17

DRAWN BY: JDV

GeoConcepts Engineering, Inc.

cCD162
cCD163
cCD164
F012-2
f012-2
f012-1
107.5
107.6
107.7
107.8
107.9



Mileposts (0.1 mile)
Centerline
300' Corridor
0.50 KRA
All Point Features
All Area Features
300' Corridor Closed Depressions
Suspect Closed Depressions
Randolph Caves
Pocahontas Caves
Virginia Caves

0 250 500
Feet

CONTOUR MAP 85

ATLANTIC COAST PIPELINE

11002.04

FILE: N:\PROJECTS\Active 11 Projects\11002.04, Dominion Resources Pipeline - Randolph and Pocahontas Co\Final\GIS Data for Final\reportmap Contour.mxd | REVISED: 02/14/2017 | SCALE: 1:3,000 when printed at 11x17

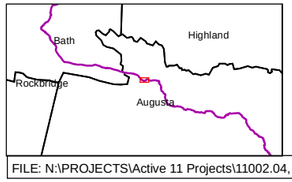
DRAWN BY: JDV

GeoConcepts Engineering, Inc.

cCP164
f012-2
f012-1
F012-2
F012-1
F012-3
f012-3
108
108.1
108.2
108.3
108.4
108.5
1810
1820
1830
1840
1850
1860
1870
1880
1890
1900
1910
1920
1930
1940
1950
1960
1970
1980
1990
2000
2010
2020
2030
2040
2050
2060
2066
2070
2080
2090
2100
2110
2120
2130
2140
2150
2160
2170
2180
2190
2200
2210
2220
2230
2240
2250

Source: Esri, DigitalGlobe, GeoEye, Ear

This information is for environmental review purposes only.



- Mileposts (0.1 mile)
- Centerline
- 300' Corridor
- 0.50 KRA
- All Point Features
- All Area Features
- 300' Corridor Closed Depressions
- Suspect Closed Depressions
- Randolph Caves
- Pocahontas Caves
- Virginia Caves

0 250 500
Feet

CONTOUR MAP 86

ATLANTIC COAST PIPELINE

11002.04

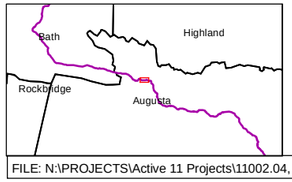
FILE: N:\PROJECTS\Active 11 Projects\11002.04, Dominion Resources Pipeline - Randolph and Pocahontas Co\Final\GIS Data for Final\reportmap Contour.mxd | REVISED: 02/14/2017 | SCALE: 1:3,000 when printed at 11x17

DRAWN BY: JDV

GeoConcepts Engineering, Inc.

108.5 108.6 108.7 108.8 108.9

Source: Esri, DigitalGlobe, GeoEye, Ea



Mileposts (0.1 mile)
Centerline
300' Corridor
0.50 KRA
All Point Features
All Area Features
300' Corridor Closed Depressions
Suspect Closed Depressions
Randolph Caves
Pocahontas Caves
Virginia Caves

0 250 500
Feet

CONTOUR MAP 87

ATLANTIC COAST PIPELINE

11002.04

FILE: N:\PROJECTS\Active 11 Projects\11002.04, Dominion Resources Pipeline - Randolph and Pocahontas Co\Final\GIS Data for Final\reportmap Contour.mxd | REVISED: 02/14/2017 | SCALE: 1:3,000 when printed at 11x17

DRAWN BY: JDV

GeoConcepts Engineering, Inc.

109

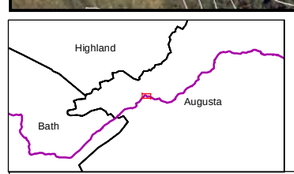
109.1

109.2

109.3

108.9

CCD02



Mileposts (0.1 mile)

Centerline

300' Corridor

0.50 KRA

All Point Features

All Area Features

300' Corridor Closed Depressions

Suspect Closed Depressions

Randolph Caves

Pocahontas Caves

Virginia Caves

0 250 500

Feet

CONTOUR MAP 88

ATLANTIC COAST PIPELINE

11002.04

FILE: N:\PROJECTS\Active 11 Projects\11002.04, Dominion Resources Pipeline - Randolph and Pocahontas Co\Final\GIS Data for Final\reportmap Contour.mxd | REVISED: 02/14/2017 | SCALE: 1:3,000 when printed at 11x17

DRAWN BY: JDV

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GeoConcepts Engineering, Inc.

109.3
109.4
109.5
109.6
109.7
cCD62

Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Commun

- Mileposts (0.1 mile)
- Centerline
- 300' Corridor
- 0.50 KRA
- All Point Features
- All Area Features
- 300' Corridor Closed Depressions
- Suspect Closed Depressions
- Randolph Caves
- Pocahontas Caves
- Virginia Caves

0 250 500
Feet

CONTOUR MAP 89

ATLANTIC COAST PIPELINE

11002.04

FILE: N:\PROJECTS\Active 11 Projects\11002.04, Dominion Resources Pipeline - Randolph and Pocahontas Co\Final\GIS Data for Final\reportmap Contour.mxd | REVISED: 02/14/2017 | SCALE: 1:3,000 when printed at 11x17

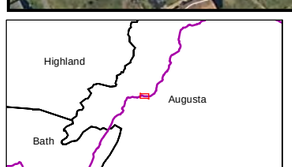
DRAWN BY: JDV

GeoConcepts Engineering, Inc.

109.9
109.8
110
110.1
110.2

Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Co

This information is for environmental review purposes only



Mileposts (0.1 mile)
Centerline
300' Corridor
0.50 KRA
All Point Features
All Area Features
300' Corridor Closed Depressions
Suspect Closed Depressions
Randolph Caves
Pocahontas Caves
Virginia Caves

0 250 500
Feet

CONTOUR MAP 90

ATLANTIC COAST PIPELINE

11002.04

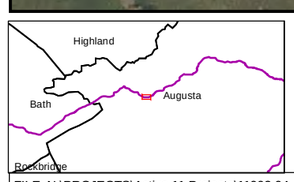
FILE: N:\PROJECTS\Active 11 Projects\11002.04, Dominion Resources Pipeline - Randolph and Pocahontas Co\Final\GIS Data for Final\reportmap Contour.mxd | REVISED: 02/14/2017 | SCALE: 1:3,000 when printed at 11x17

DRAWN BY: JDV

GeoConcepts Engineering, Inc.

1770
1760
1750
1730
1710
1720
1700
1690

110.3
110.4
110.5
110.6
110.7



Mileposts (0.1 mile)
Centerline
300' Corridor
0.50 KRA
All Point Features
All Area Features
300' Corridor Closed Depressions
Suspect Closed Depressions
Randolph Caves
Pocahontas Caves
Virginia Caves

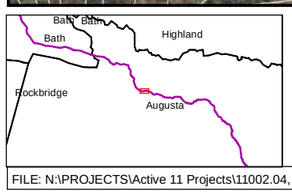
0 250 500
Feet

CONTOUR MAP 91
ATLANTIC COAST PIPELINE
11002.04

FILE: N:\PROJECTS\Active 11 Projects\11002.04, Dominion Resources Pipeline - Randolph and Pocahontas Co\Final\GIS Data for Final\reportmap Contour.mxd | REVISED: 02/14/2017 | SCALE: 1:3,000 when printed at 11x17

DRAWN BY: JDV

GeoConcepts Engineering, Inc.



Mileposts (0.1 mile)
Centerline
300' Corridor
0.50 KRA
All Point Features
All Area Features
300' Corridor Closed Depressions
Suspect Closed Depressions
Randolph Caves
Pocahontas Caves
Virginia Caves

0 250 500
Feet

CONTOUR MAP 92

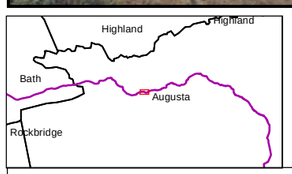
ATLANTIC COAST PIPELINE

11002.04

FILE: N:\PROJECTS\Active 11 Projects\11002.04, Dominion Resources Pipeline - Randolph and Pocahontas Co\Final\GIS Data for Final\reportmap Contour.mxd | REVISED: 02/14/2017 | SCALE: 1:3,000 when printed at 11x17

DRAWN BY: JDV

GeoConcepts Engineering, Inc.



- Mileposts (0.1 mile)
- Centerline
- 300' Corridor
- 0.50 KRA
- All Point Features
- All Area Features
- 300' Corridor Closed Depressions
- Suspect Closed Depressions
- Randolph Caves
- Pocahontas Caves
- Virginia Caves

0 250 500
Feet

CONTOUR MAP 93

ATLANTIC COAST PIPELINE

11002.04

FILE: N:\PROJECTS\Active 11 Projects\11002.04, Dominion Resources Pipeline - Randolph and Pocahontas Co\Final\GIS Data for Final\reportmap Contour.mxd | REVISED: 02/14/2017 | SCALE: 1:3,000 when printed at 11x17

DRAWN BY: JDV

GeoConcepts Engineering, Inc.

1810 1800 1790 1770 1740 1740 1740 1740 1730 1760 1850 1860 1880 1840 1870 1750

cCD113

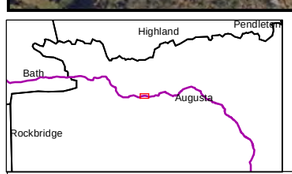
111.9 112 112.1 111.8 111.7

cCD112

1740 1740 1740 1750 1750

Source: Esri, DigitalGlobe

This information is for environmental review purposes only.



- Mileposts (0.1 mile)
- Centerline
- 300' Corridor
- 0.50 KRA
- All Point Features
- All Area Features
- 300' Corridor Closed Depressions
- Suspect Closed Depressions
- Randolph Caves
- Pocahontas Caves
- Virginia Caves

0 250 500
Feet

CONTOUR MAP 94

ATLANTIC COAST PIPELINE

11002.04

FILE: N:\PROJECTS\Active 11 Projects\11002.04, Dominion Resources Pipeline - Randolph and Pocahontas Co\Final\GIS Data for Final\reportmap Contour.mxd | REVISED: 02/14/2017 | SCALE: 1:3,000 when printed at 11x17

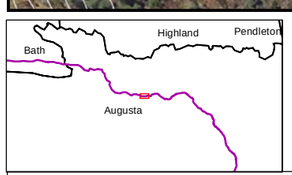
DRAWN BY: JDV

GeoConcepts Engineering, Inc.

cCD112
cCD101
cCD102
cCD103
112.2
112.3
112.4
112.5
112.6
1760
1770
1780
1790
1800
1810
1820
1830
1840
1850
1860
1870
1880
1890
1900
1910
1920
1930
1940
1950
1960
1970
1980
1990
2000

Source: Esri, DigitalGlobe, GeoEy

This information is for environmental review purposes only



- Mileposts (0.1 mile)
- Centerline
- 300' Corridor
- 0.50 KRA
- All Point Features
- All Area Features
- 300' Corridor Closed Depressions
- Suspect Closed Depressions
- Randolph Caves
- Pocahontas Caves
- Virginia Caves

0 250 500
Feet

CONTOUR MAP 95

ATLANTIC COAST PIPELINE

11002.04

FILE: N:\PROJECTS\Active 11 Projects\11002.04, Dominion Resources Pipeline - Randolph and Pocahontas Co\Final\GIS Data for Final\reportmap Contour.mxd | REVISED: 02/14/2017 | SCALE: 1:3,000 when printed at 11x17

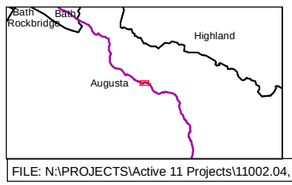
DRAWN BY: JDV

GeoConcepts Engineering, Inc.

cCD102
112.6
cCD103
112.7
cCD106
cCD107
cCD105
cCD104
112.8
112.9
113
113.1
cCD108

1840 1850 1860 1870 1880 1900 1910 1920 1930 1940 1950 1960 1970 1980 1990 2000 2010 2020 2030 2040 2050

Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CI



- Mileposts (0.1 mile)
- Centerline
- 300' Corridor
- 0.50 KRA
- All Point Features
- All Area Features
- 300' Corridor Closed Depressions
- Suspect Closed Depressions
- Randolph Caves
- Pocahontas Caves
- Virginia Caves

0 250 500
Feet

CONTOUR MAP 96

ATLANTIC COAST PIPELINE

11002.04

FILE: N:\PROJECTS\Active 11 Projects\11002.04, Dominion Resources Pipeline - Randolph and Pocahontas Co\Final\GIS Data for Final\reportmap Contour.mxd | REVISED: 02/14/2017 | SCALE: 1:3,000 when printed at 11x17

DRAWN BY: JDV

GeoConcepts Engineering, Inc.

113.1
113.2
113.3
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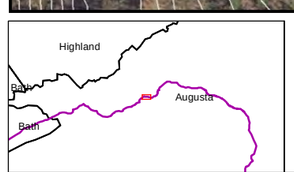
Source:

This information is for environmental review purposes only.



- Mileposts (0.1 mile)
- Centerline
- 300' Corridor
- 0.50 KRA
- All Point Features
- All Area Features
- 300' Corridor Closed Depressions
- Suspect Closed Depressions
- Randolph Caves
- Pocahontas Caves
- Virginia Caves

0 250 500
Feet

CONTOUR MAP 97

ATLANTIC COAST PIPELINE

11002.04

FILE: N:\PROJECTS\Active 11 Projects\11002.04, Dominion Resources Pipeline - Randolph and Pocahontas Co\Final\GIS Data for Final\reportmap Contour.mxd | REVISED: 02/14/2017 | SCALE: 1:3,000 when printed at 11x17

DRAWN BY: JDV

GeoConcepts Engineering, Inc.

- Mileposts (0.1 mile)
- Centerline
- 300' Corridor
- 0.50 KRA
- All Point Features
- All Area Features
- 300' Corridor Closed Depressions
- Suspect Closed Depressions
- Randolph Caves
- Pocahontas Caves
- Virginia Caves

0 250 500
Feet

CONTOUR MAP 98

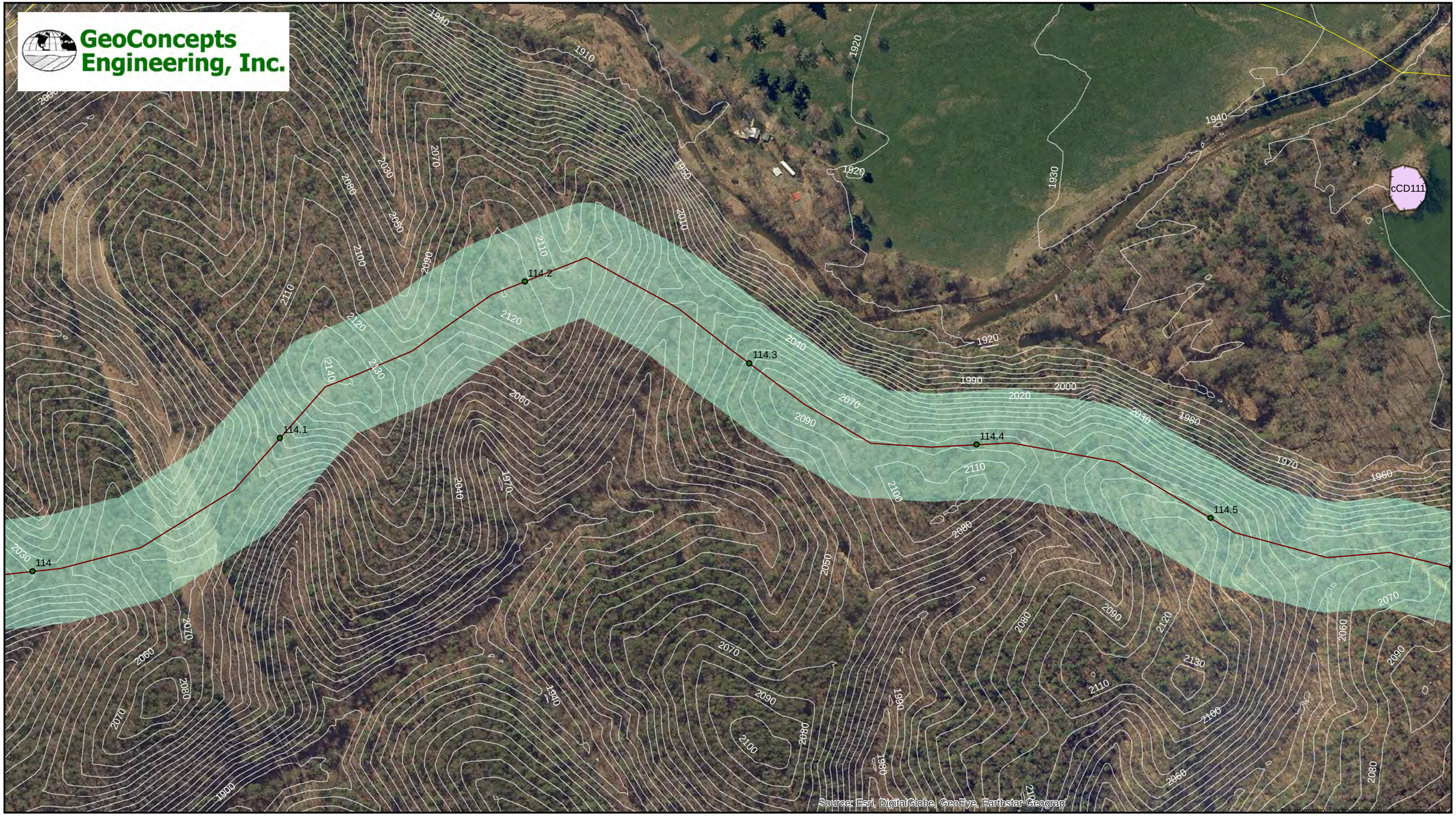
ATLANTIC COAST PIPELINE

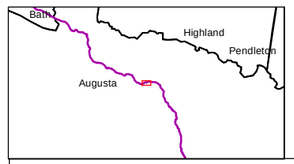
11002.04

FILE: N:\PROJECTS\Active 11 Projects\11002.04, Dominion Resources Pipeline - Randolph and Pocahontas Co\Final\GIS Data for Final\reportmap Contour.mxd | REVISED: 02/14/2017 | SCALE: 1:3,000 when printed at 11x17

DRAWN BY: JDV

GeoConcepts Engineering, Inc.





- Mileposts (0.1 mile)
- Centerline
- 300' Corridor
- 0.50 KRA
- All Point Features
- All Area Features
- 300' Corridor Closed Depressions
- Suspect Closed Depressions
- Randolph Caves
- Pocahontas Caves
- Virginia Caves

N

0 250 500

Feet

CONTOUR MAP 99

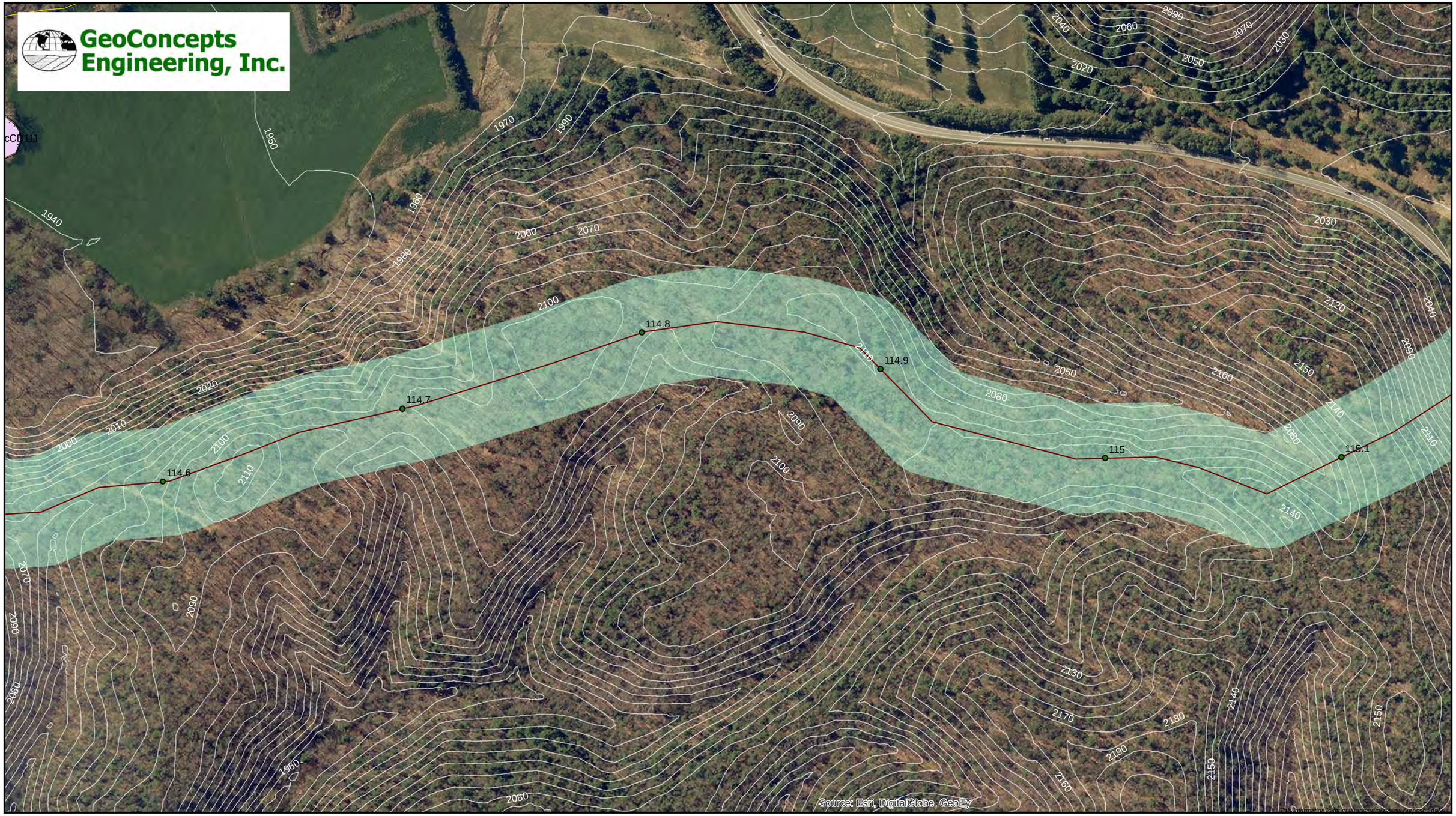
ATLANTIC COAST PIPELINE

11002.04

FILE: N:\PROJECTS\Active 11 Projects\11002.04, Dominion Resources Pipeline - Randolph and Pocahontas Co\Final\GIS Data for Final\reportmap Contour.mxd | REVISED: 02/14/2017 | SCALE: 1:3,000 when printed at 11x17

DRAWN BY: JDV

GeoConcepts Engineering, Inc.



- Mileposts (0.1 mile)
- Centerline
- 300' Corridor
- 0.50 KRA
- All Point Features
- All Area Features
- 300' Corridor Closed Depressions
- Suspect Closed Depressions
- Randolph Caves
- Pocahontas Caves
- Virginia Caves

0 250 500
Feet

CONTOUR MAP 100

ATLANTIC COAST PIPELINE

11002.04

FILE: N:\PROJECTS\Active 11 Projects\11002.04, Dominion Resources Pipeline - Randolph and Pocahontas Co\Final\GIS Data for Final\reportmap Contour.mxd | REVISED: 02/14/2017 | SCALE: 1:3,000 when printed at 11x17

DRAWN BY: JDV

GeoConcepts Engineering, Inc.

115.1
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115.6
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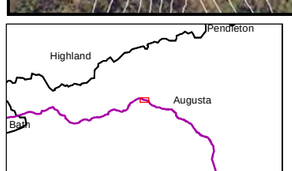
Source: Esri, D



Mileposts (0.1 mile)
Centerline
300' Corridor
0.50 KRA
All Point Features
All Area Features
300' Corridor Closed Depressions
Suspect Closed Depressions
Randolph Caves
Pocahontas Caves
Virginia Caves

0 250 500
Feet

CONTOUR MAP 101

ATLANTIC COAST PIPELINE

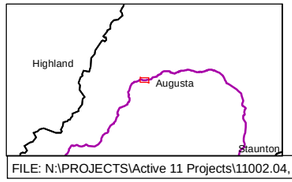
11002.04

FILE: N:\PROJECTS\Active 11 Projects\11002.04, Dominion Resources Pipeline - Randolph and Pocahontas Co\Final\GIS Data for Final\reportmap Contour.mxd | REVISED: 02/14/2017 | SCALE: 1:3,000 when printed at 11x17

DRAWN BY: JDV

GeoConcepts Engineering, Inc.

115.8 115.9 116 116.1 116.2 116.3 116.4 116.5



Mileposts (0.1 mile)
Centerline
300' Corridor
0.50 KRA
All Point Features
All Area Features
300' Corridor Closed Depressions
Suspect Closed Depressions
Randolph Caves
Pocahontas Caves
Virginia Caves

0 250 500
Feet

CONTOUR MAP 102

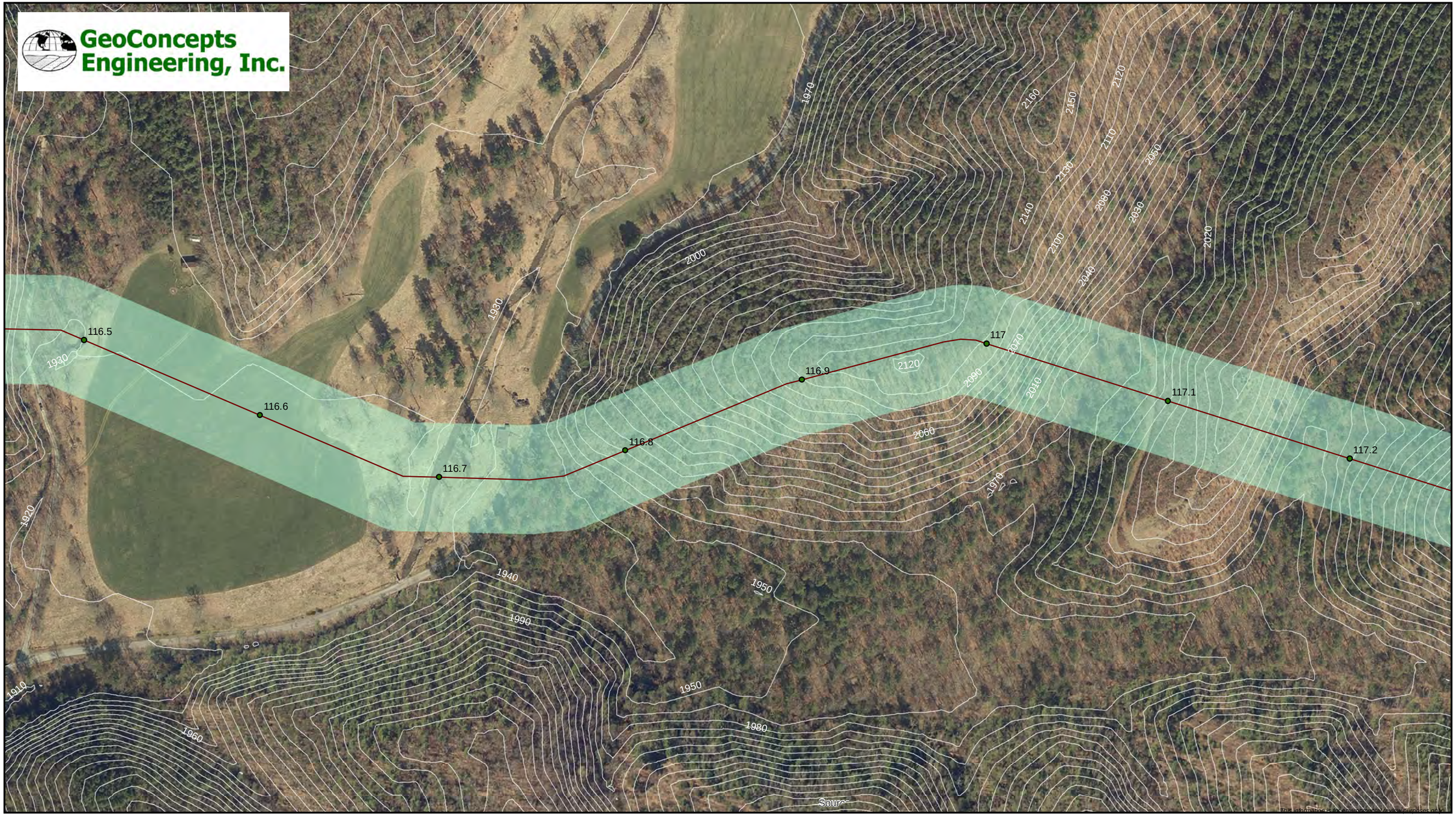
ATLANTIC COAST PIPELINE

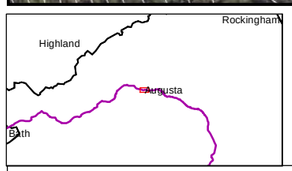
11002.04

Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

FILE: N:\PROJECTS\Active 11 Projects\11002.04, Dominion Resources Pipeline - Randolph and Pocahontas Co\Final\GIS Data for Final\reportmap Contour.mxd | REVISED: 02/14/2017 | SCALE: 1:3,000 when printed at 11x17 DRAWN BY: JDV

GeoConcepts Engineering, Inc.





Mileposts (0.1 mile)
Centerline
300' Corridor
0.50 KRA
All Point Features
All Area Features
300' Corridor Closed Depressions
Suspect Closed Depressions
Randolph Caves
Pocahontas Caves
Virginia Caves

0 250 500
Feet

CONTOUR MAP 103

ATLANTIC COAST PIPELINE

11002.04

FILE: N:\PROJECTS\Active 11 Projects\11002.04, Dominion Resources Pipeline - Randolph and Pocahontas Co\Final\GIS Data for Final\reportmap Contour.mxd | REVISED: 02/14/2017 | SCALE: 1:3,000 when printed at 11x17

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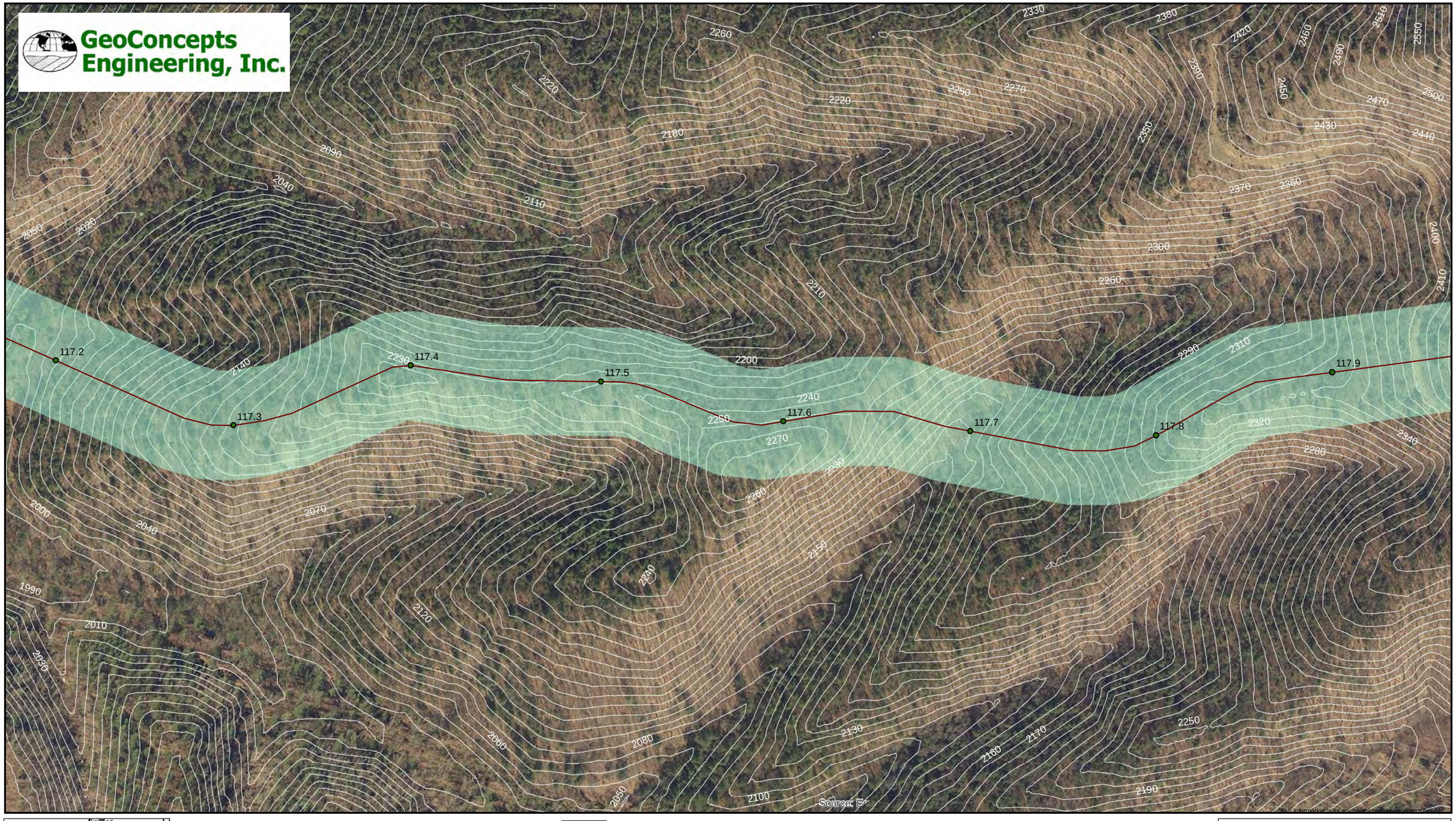
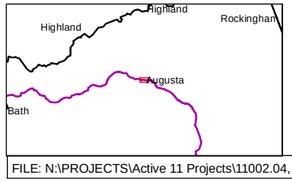
GeoConcepts Engineering, Inc.





- Mileposts (0.1 mile)
- Centerline
- 300' Corridor
- 0.50 KRA
- All Point Features
- All Area Features
- 300' Corridor Closed Depressions
- Suspect Closed Depressions
- Randolph Caves
- Pocahontas Caves
- Virginia Caves

0 250 500
Feet

CONTOUR MAP 104

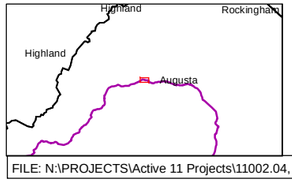
ATLANTIC COAST PIPELINE

11002.04

FILE: N:\PROJECTS\Active 11 Projects\11002.04, Dominion Resources Pipeline - Randolph and Pocahontas Co\Final\GIS Data for Final\reportmap Contour.mxd | REVISED: 02/14/2017 | SCALE: 1:3,000 when printed at 11x17

DRAWN BY: JDV

GeoConcepts Engineering, Inc.



- Mileposts (0.1 mile)
- Centerline
- 300' Corridor
- 0.50 KRA
- All Point Features
- All Area Features
- 300' Corridor Closed Depressions
- Suspect Closed Depressions
- Randolph Caves
- Pocahontas Caves
- Virginia Caves

0 250 500
Feet

CONTOUR MAP 105

ATLANTIC COAST PIPELINE

11002.04

FILE: N:\PROJECTS\Active 11 Projects\11002.04, Dominion Resources Pipeline - Randolph and Pocahontas Co\Final\GIS Data for Final\reportmap Contour.mxd | REVISED: 02/14/2017 | SCALE: 1:3,000 when printed at 11x17

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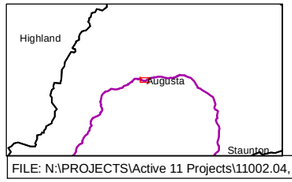
GeoConcepts Engineering, Inc.



- Mileposts (0.1 mile)
- Centerline
- 300' Corridor
- 0.50 KRA
- All Point Features
- All Area Features
- 300' Corridor Closed Depressions
- Suspect Closed Depressions
- Randolph Caves
- Pocahontas Caves
- Virginia Caves

0 250 500
Feet

CONTOUR MAP 106

ATLANTIC COAST PIPELINE

11002.04

FILE: N:\PROJECTS\Active 11 Projects\11002.04, Dominion Resources Pipeline - Randolph and Pocahontas Co\Final\GIS Data for Final\reportmap Contour.mxd | REVISED: 02/14/2017 | SCALE: 1:3,000 when printed at 11x17

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- Mileposts (0.1 mile)
- Centerline
- 300' Corridor
- 0.50 KRA
- All Point Features
- All Area Features
- 300' Corridor Closed Depressions
- Suspect Closed Depressions
- Randolph Caves
- Pocahontas Caves
- Virginia Caves

0 250 500
Feet

CONTOUR MAP 107

ATLANTIC COAST PIPELINE

11002.04

FILE: N:\PROJECTS\Active 11 Projects\11002.04, Dominion Resources Pipeline - Randolph and Pocahontas Co\Final\GIS Data for Final\reportmap Contour.mxd | REVISED: 02/14/2017 | SCALE: 1:3,000 when printed at 11x17

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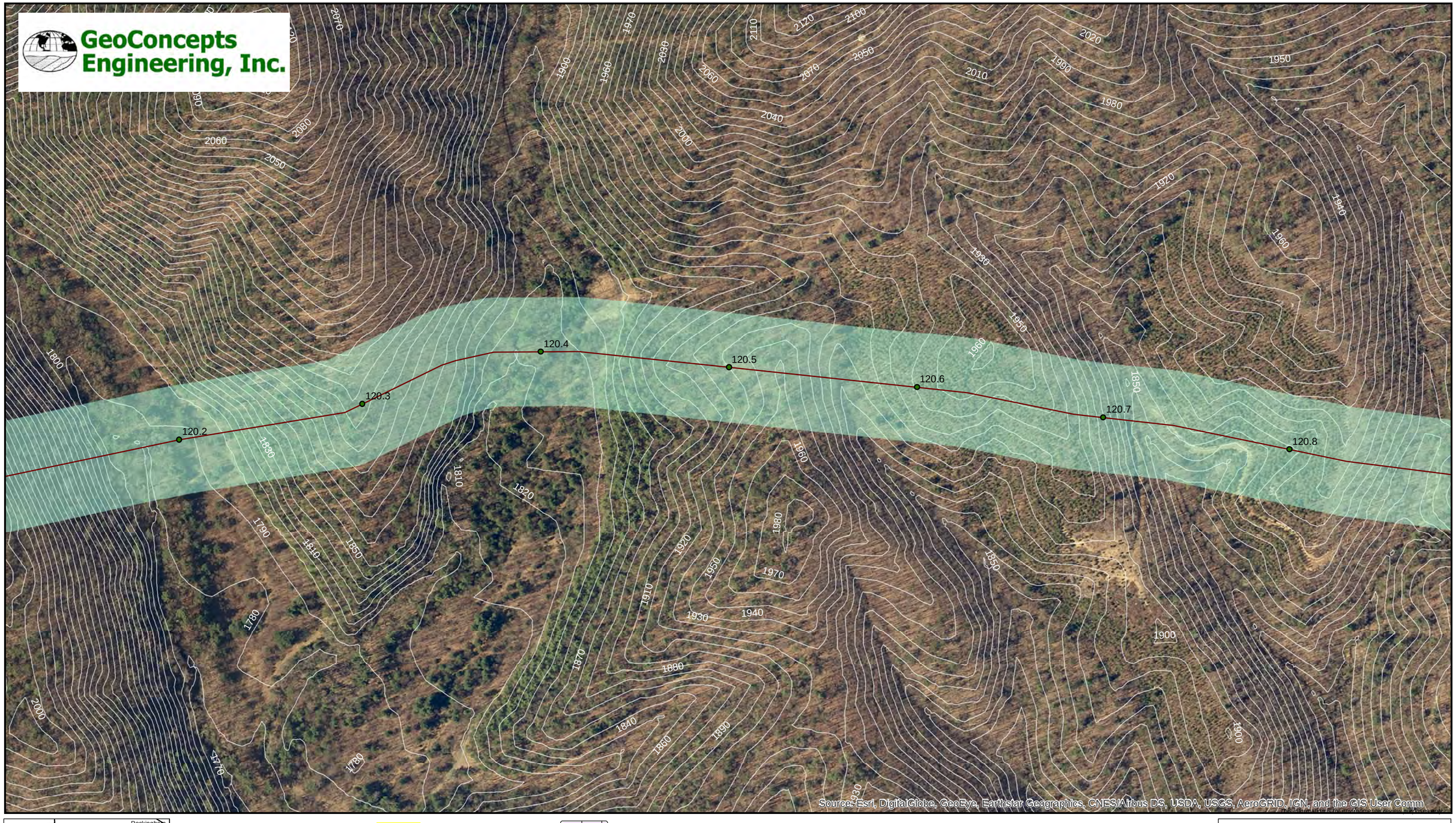
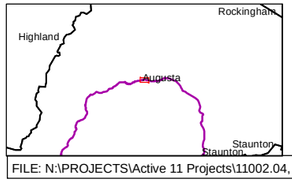
GeoConcepts Engineering, Inc.





- Mileposts (0.1 mile)
- Centerline
- 300' Corridor
- 0.50 KRA
- All Point Features
- All Area Features
- 300' Corridor Closed Depressions
- Suspect Closed Depressions
- Randolph Caves
- Pocahontas Caves
- Virginia Caves

0 250 500
Feet

CONTOUR MAP 108

ATLANTIC COAST PIPELINE

11002.04

FILE: N:\PROJECTS\Active 11 Projects\11002.04, Dominion Resources Pipeline - Randolph and Pocahontas Co\Final\GIS Data for Final\reportmap Contour.mxd | REVISED: 02/14/2017 | SCALE: 1:3,000 when printed at 11x17

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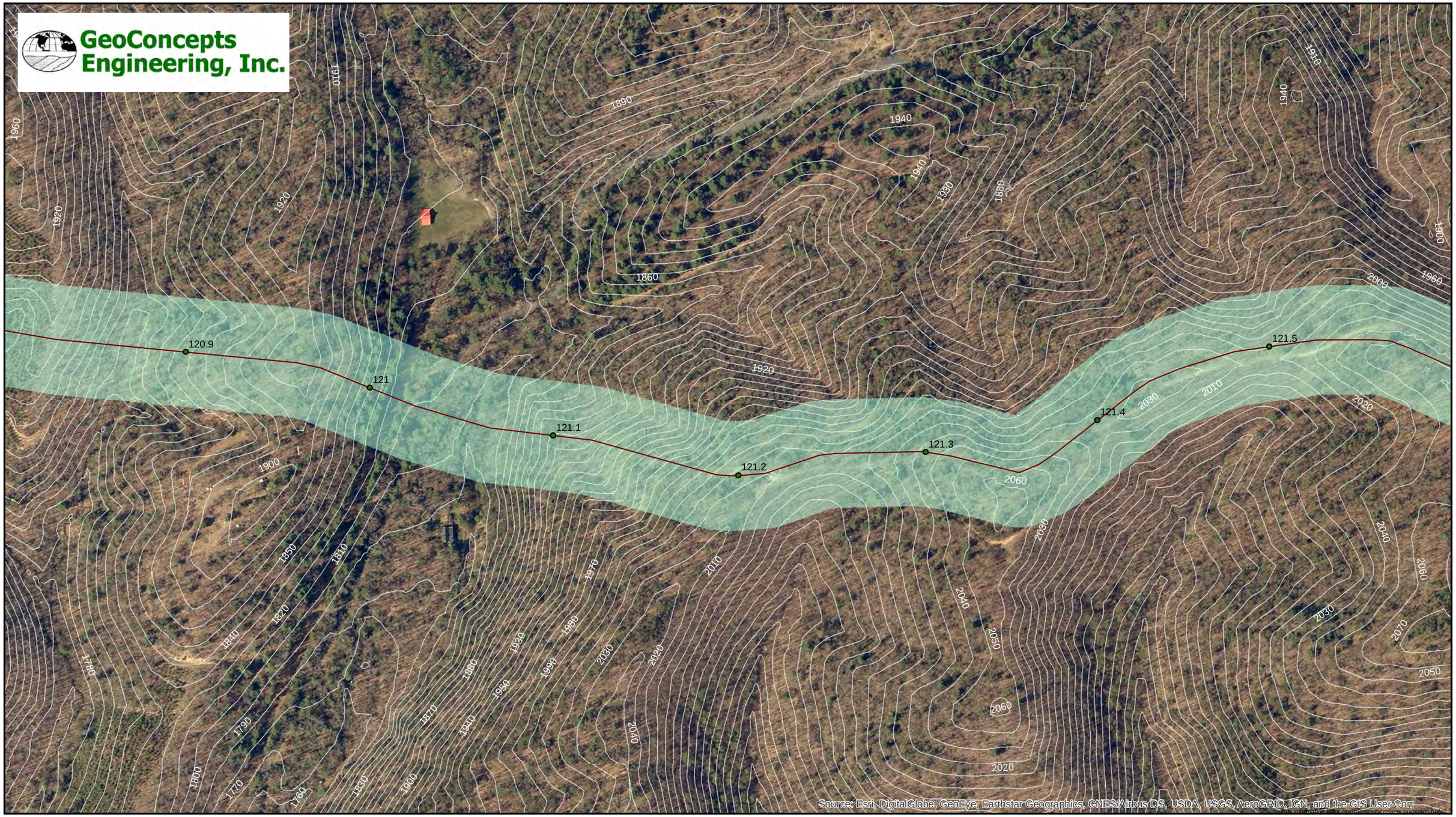
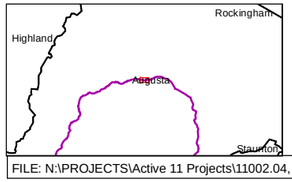
GeoConcepts Engineering, Inc.





- Mileposts (0.1 mile)
- Centerline
- 300' Corridor
- 0.50 KRA
- All Point Features
- All Area Features
- 300' Corridor Closed Depressions
- Suspect Closed Depressions
- Randolph Caves
- Pocahontas Caves
- Virginia Caves

0 250 500
Feet

CONTOUR MAP 109

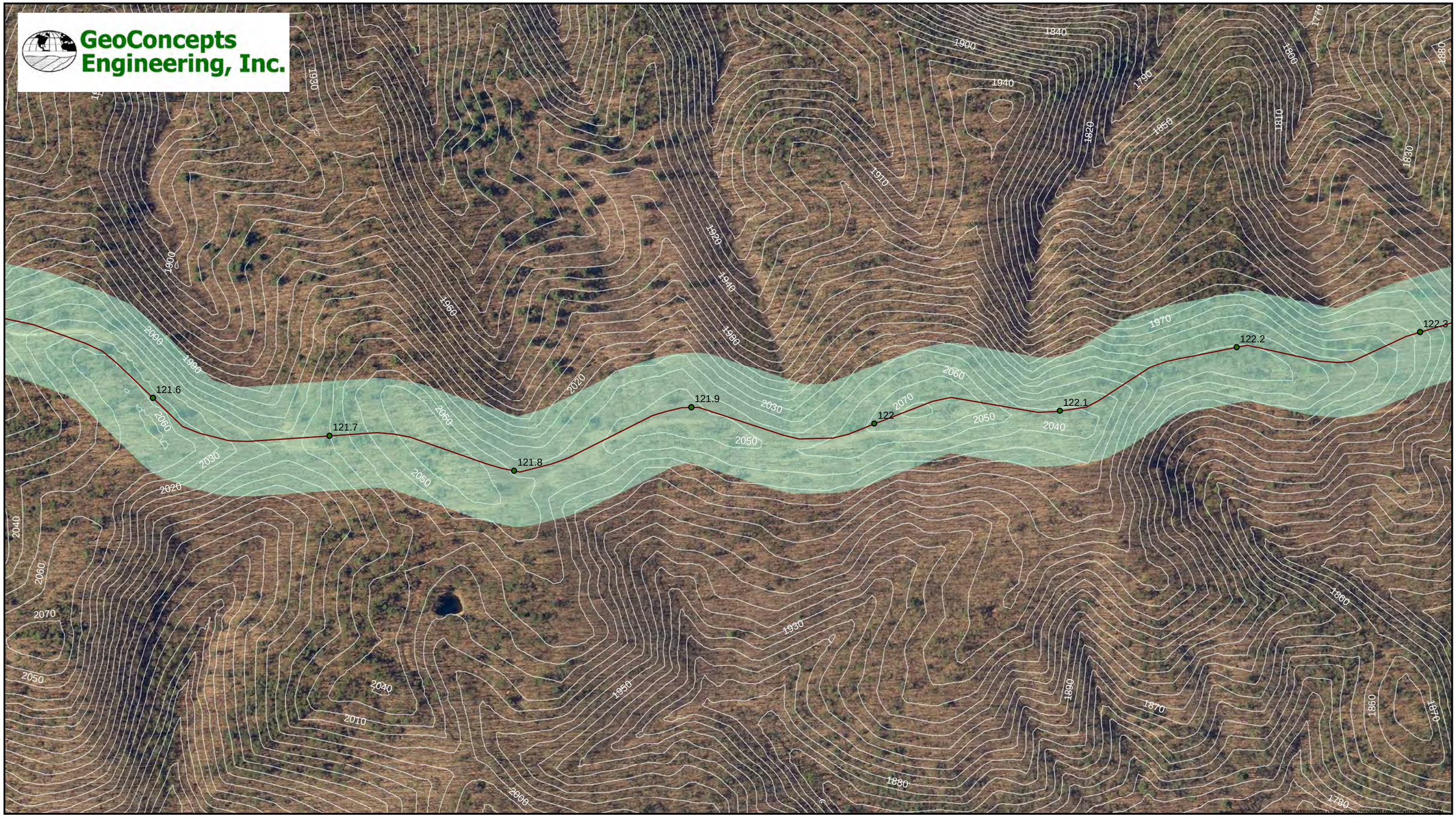
ATLANTIC COAST PIPELINE

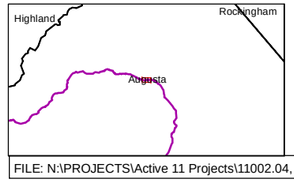
11002.04

FILE: N:\PROJECTS\Active 11 Projects\11002.04, Dominion Resources Pipeline - Randolph and Pocahontas Co\Final\GIS Data for Final\reportmap Contour.mxd | REVISED: 02/14/2017 | SCALE: 1:3,000 when printed at 11x17

DRAWN BY: JDV

GeoConcepts Engineering, Inc.





- Mileposts (0.1 mile)
- Centerline
- 300' Corridor
- 0.50 KRA
- All Point Features
- All Area Features
- 300' Corridor Closed Depressions
- Suspect Closed Depressions
- Randolph Caves
- Pocahontas Caves
- Virginia Caves

0 250 500
Feet

CONTOUR MAP 110

ATLANTIC COAST PIPELINE

11002.04

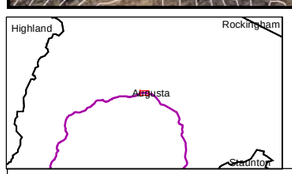
FILE: N:\PROJECTS\Active 11 Projects\11002.04, Dominion Resources Pipeline - Randolph and Pocahontas Co\Final\GIS Data for Final\reportmap Contour.mxd | REVISED: 02/14/2017 | SCALE: 1:3,000 when printed at 11x17

DRAWN BY: JDV

GeoConcepts Engineering, Inc.

122.3 122.4 122.5 122.6 122.7 122.8 122.9 123

Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User C



- Mileposts (0.1 mile)
- Centerline
- 300' Corridor
- 0.50 KRA
- All Point Features
- All Area Features
- 300' Corridor Closed Depressions
- Suspect Closed Depressions
- Randolph Caves
- Pocahontas Caves
- Virginia Caves

0 250 500
Feet

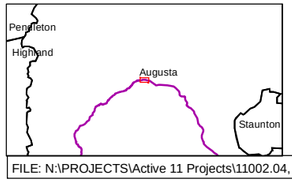
CONTOUR MAP 111
ATLANTIC COAST PIPELINE
11002.04

FILE: N:\PROJECTS\Active 11 Projects\11002.04, Dominion Resources Pipeline - Randolph and Pocahontas Co\Final\GIS Data for Final\reportmap Contour.mxd | REVISED: 02/14/2017 | SCALE: 1:3,000 when printed at 11x17

DRAWN BY: JDV

GeoConcepts Engineering, Inc.

123 123.1 123.2 123.3 123.4 123.5 123.6 123.7



- Mileposts (0.1 mile)
- Centerline
- 300' Corridor
- 0.50 KRA
- All Point Features
- All Area Features
- 300' Corridor Closed Depressions
- Suspect Closed Depressions
- Randolph Caves
- Pocahontas Caves
- Virginia Caves

0 250 500
Feet

Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

CONTOUR MAP 112

ATLANTIC COAST PIPELINE

11002.04

FILE: N:\PROJECTS\Active 11 Projects\11002.04, Dominion Resources Pipeline - Randolph and Pocahontas Co\Final\GIS Data for Final\reportmap Contour.mxd | REVISED: 02/14/2017 | SCALE: 1:3,000 when printed at 11x17

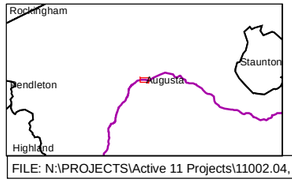
DRAWN BY: JDV

GeoConcepts Engineering, Inc.

123.7 123.8 123.9 124 124.1 AO19-1 124.2 124.3 124.4

1690 1670 1650 1620 1610 1580 1570 1560 1550 1590 1630 1600 1680 1660 1700 1710 1720 1730 1640

Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User C



- Mileposts (0.1 mile)
- Centerline
- 300' Corridor
- 0.50 KRA
- All Point Features
- All Area Features
- 300' Corridor Closed Depressions
- Suspect Closed Depressions
- Randolph Caves
- Pocahontas Caves
- Virginia Caves

0 250 500
Feet

CONTOUR MAP 113

ATLANTIC COAST PIPELINE

11002.04

FILE: N:\PROJECTS\Active 11 Projects\11002.04, Dominion Resources Pipeline - Randolph and Pocahontas Co\Final\GIS Data for Final\reportmap Contour.mxd | REVISED: 02/14/2017 | SCALE: 1:3,000 when printed at 11x17

DRAWN BY: JDV

GeoConcepts Engineering, Inc.

124.4 124.5 124.6 124.7 124.8 124.9 125 125.1

1590 1560 1530 1550 1520 1570 1600 1580 1540 1650 1630 1620 1610 1640

Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and

- Mileposts (0.1 mile)
- Centerline
- 300' Corridor
- 0.50 KRA
- All Point Features
- All Area Features
- 300' Corridor Closed Depressions
- Suspect Closed Depressions
- Randolph Caves
- Pocahontas Caves
- Virginia Caves

0 250 500
Feet

CONTOUR MAP 114

ATLANTIC COAST PIPELINE

11002.04

FILE: N:\PROJECTS\Active 11 Projects\11002.04, Dominion Resources Pipeline - Randolph and Pocahontas Co\Final\GIS Data for Final\reportmap Contour.mxd | REVISED: 02/14/2017 | SCALE: 1:3,000 when printed at 11x17

DRAWN BY: JDV

GeoConcepts Engineering, Inc.

1520 1510 1530 1540 1550 1560 1570 1610 1590 1620 1630 1600 1580

sCD26 sCD28 sCD29 sCD30 sCD27 sCD25 sCD24 sCD33 sCD23 sCD13 A029-1S A029-2

125.1 125.2 125.3 125.4 125.5 125.6 125.7 125.8

Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and "

Pendleton
Highland
Augusta
Highland
Highland
Highland
Staunton
Highland
Staunton

- Mileposts (0.1 mile)
- Centerline
- 300' Corridor
- 0.50 KRA
- All Point Features
- All Area Features
- 300' Corridor Closed Depressions
- Suspect Closed Depressions
- Randolph Caves
- Pocahontas Caves
- Virginia Caves

0 250 500
Feet

CONTOUR MAP 115

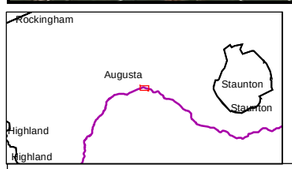
ATLANTIC COAST PIPELINE

11002.04

FILE: N:\PROJECTS\Active 11 Projects\11002.04, Dominion Resources Pipeline - Randolph and Pocahontas Co\Final\GIS Data for Final\reportmap Contour.mxd | REVISED: 02/14/2017 | SCALE: 1:3,000 when printed at 11x17

DRAWN BY: JDV

GeoConcepts Engineering, Inc.



- Mileposts (0.1 mile)
- Centerline
- 300' Corridor
- 0.50 KRA
- All Point Features
- All Area Features
- 300' Corridor Closed Depressions
- Suspect Closed Depressions
- Randolph Caves
- Pocahontas Caves
- Virginia Caves

0 250 500
Feet

CONTOUR MAP 116

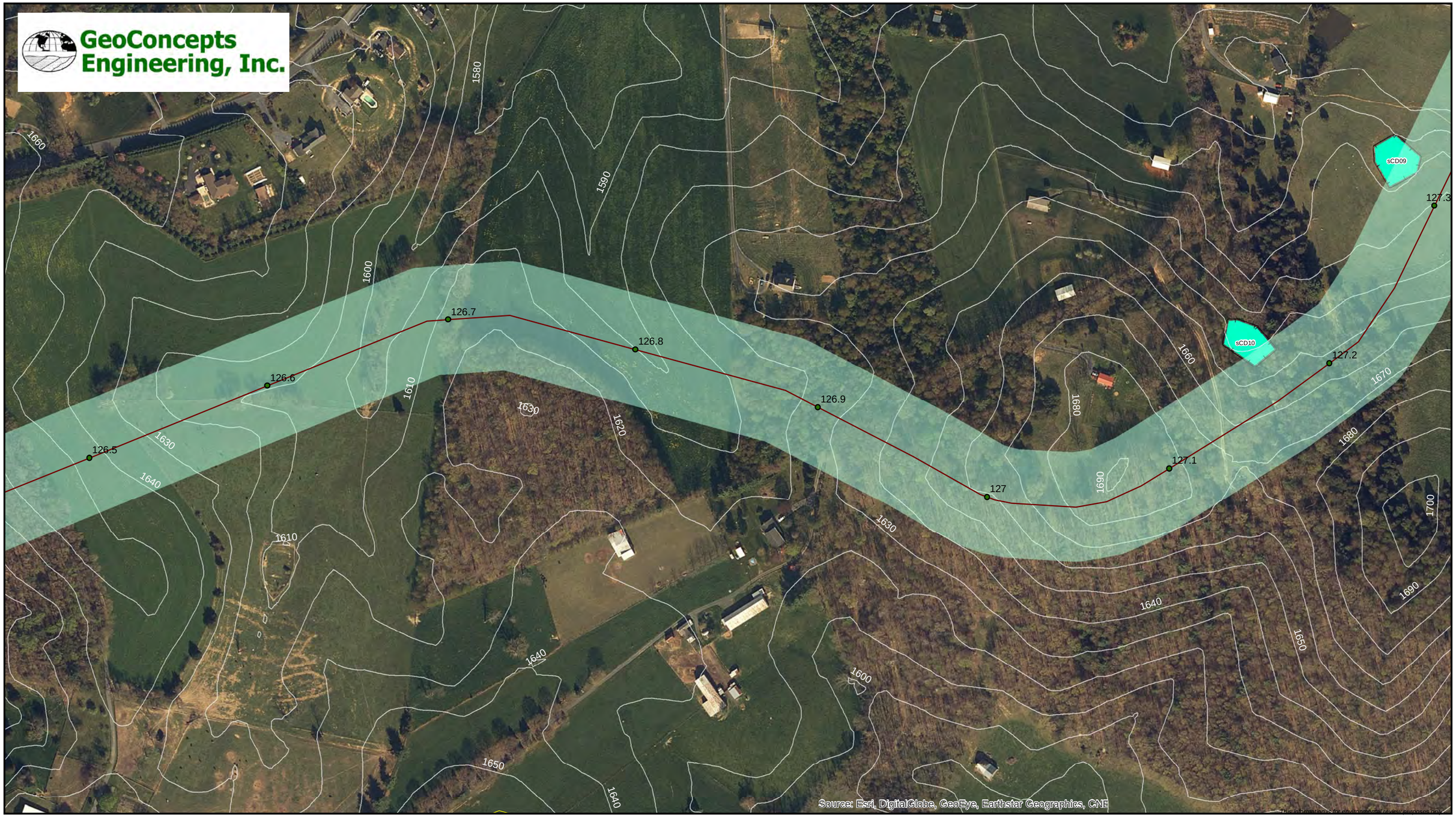
ATLANTIC COAST PIPELINE

11002.04

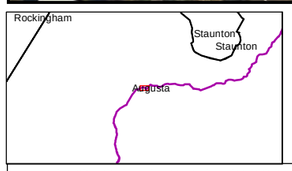
FILE: N:\PROJECTS\Active 11 Projects\11002.04, Dominion Resources Pipeline - Randolph and Pocahontas Co\Final\GIS Data for Final\reportmap Contour.mxd | REVISED: 02/14/2017 | SCALE: 1:3,000 when printed at 11x17

DRAWN BY: JDV

GeoConcepts Engineering, Inc.



Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNE



- Mileposts (0.1 mile)
- Centerline
- 300' Corridor
- 0.50 KRA
- All Point Features
- All Area Features
- 300' Corridor Closed Depressions
- Suspect Closed Depressions
- Randolph Caves
- Pocahontas Caves
- Virginia Caves

0 250 500
Feet

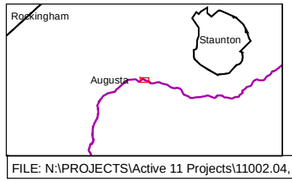
CONTOUR MAP 117
ATLANTIC COAST PIPELINE
11002.04

FILE: N:\PROJECTS\Active 11 Projects\11002.04, Dominion Resources Pipeline - Randolph and Pocahontas Co\Final\GIS Data for Final\reportmap Contour.mxd | REVISED: 02/14/2017 | SCALE: 1:3,000 when printed at 11x17 DRAWN BY: JDV

GeoConcepts Engineering, Inc.

127.2
127.3
127.4
127.5
127.6
127.7
127.8
127.9
128
A057-1
A057-2
sCD09
sCD11

Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS



- Mileposts (0.1 mile)
- Centerline
- 300' Corridor
- 0.50 KRA
- All Point Features
- All Area Features
- 300' Corridor Closed Depressions
- Suspect Closed Depressions
- Randolph Caves
- Pocahontas Caves
- Virginia Caves

0 250 500
Feet

CONTOUR MAP 118

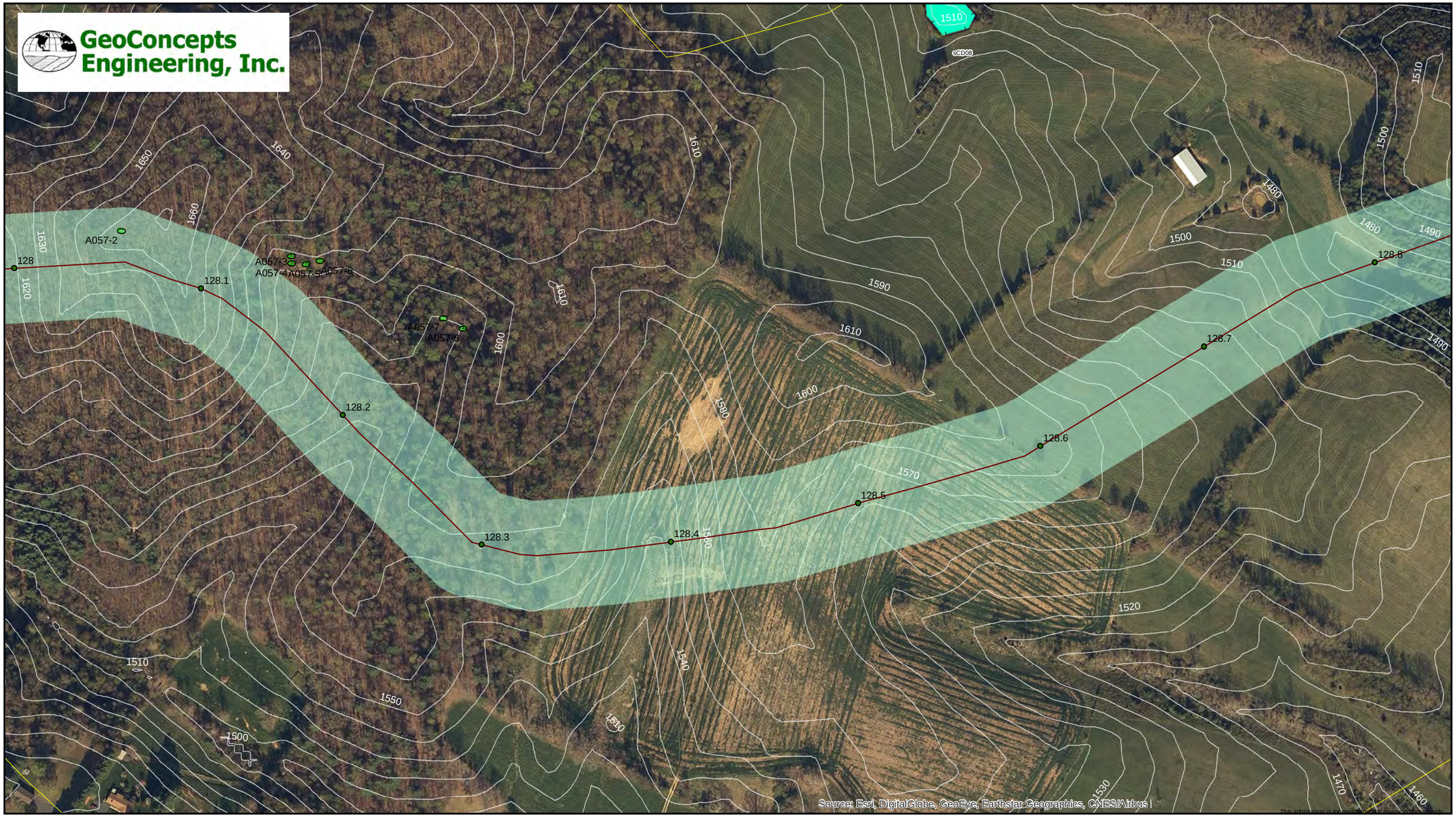
ATLANTIC COAST PIPELINE

11002.04

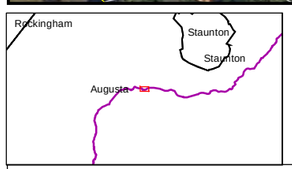
FILE: N:\PROJECTS\Active 11 Projects\11002.04, Dominion Resources Pipeline - Randolph and Pocahontas Co\Final\GIS Data for Final\reportmap Contour.mxd | REVISED: 02/14/2017 | SCALE: 1:3,000 when printed at 11x17

DRAWN BY: JDV

GeoConcepts Engineering, Inc.



This information is for environmental planning purposes only.



- Mileposts (0.1 mile)
- Centerline
- 300' Corridor
- 0.50 KRA
- All Point Features
- All Area Features
- 300' Corridor Closed Depressions
- Suspect Closed Depressions
- Randolph Caves
- Pocahontas Caves
- Virginia Caves

0 250 500
Feet

CONTOUR MAP 119

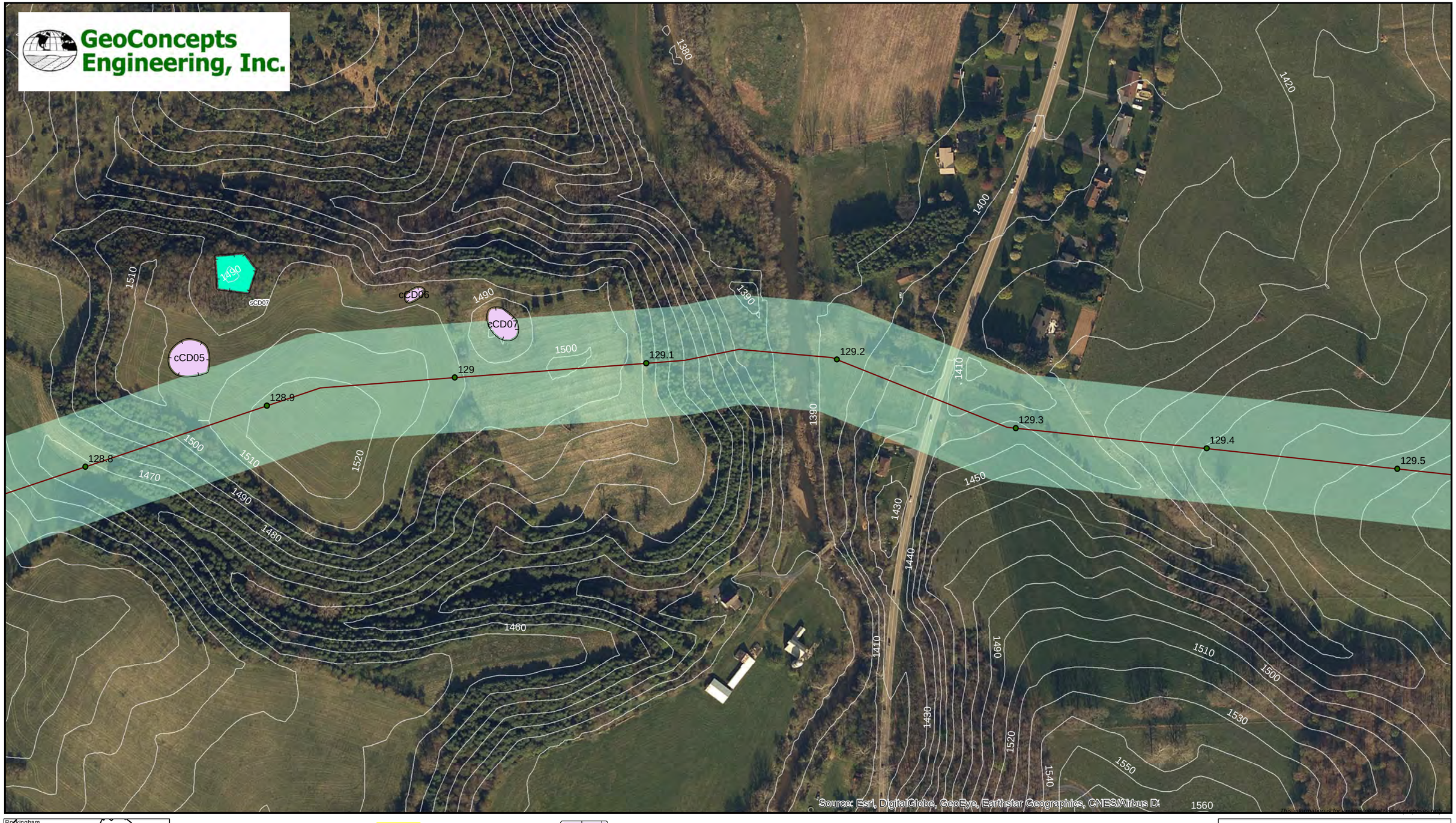
ATLANTIC COAST PIPELINE

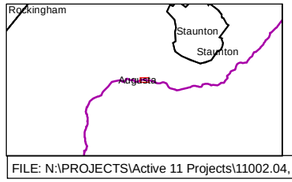
11002.04

FILE: N:\PROJECTS\Active 11 Projects\11002.04, Dominion Resources Pipeline - Randolph and Pocahontas Co\Final\GIS Data for Final\reportmap Contour.mxd | REVISED: 02/14/2017 | SCALE: 1:3,000 when printed at 11x17

DRAWN BY: JDV

GeoConcepts Engineering, Inc.





- Mileposts (0.1 mile)
- Centerline
- 300' Corridor
- 0.50 KRA
- All Point Features
- All Area Features
- 300' Corridor Closed Depressions
- Suspect Closed Depressions
- Randolph Caves
- Pocahontas Caves
- Virginia Caves

0 250 500
Feet

CONTOUR MAP 120

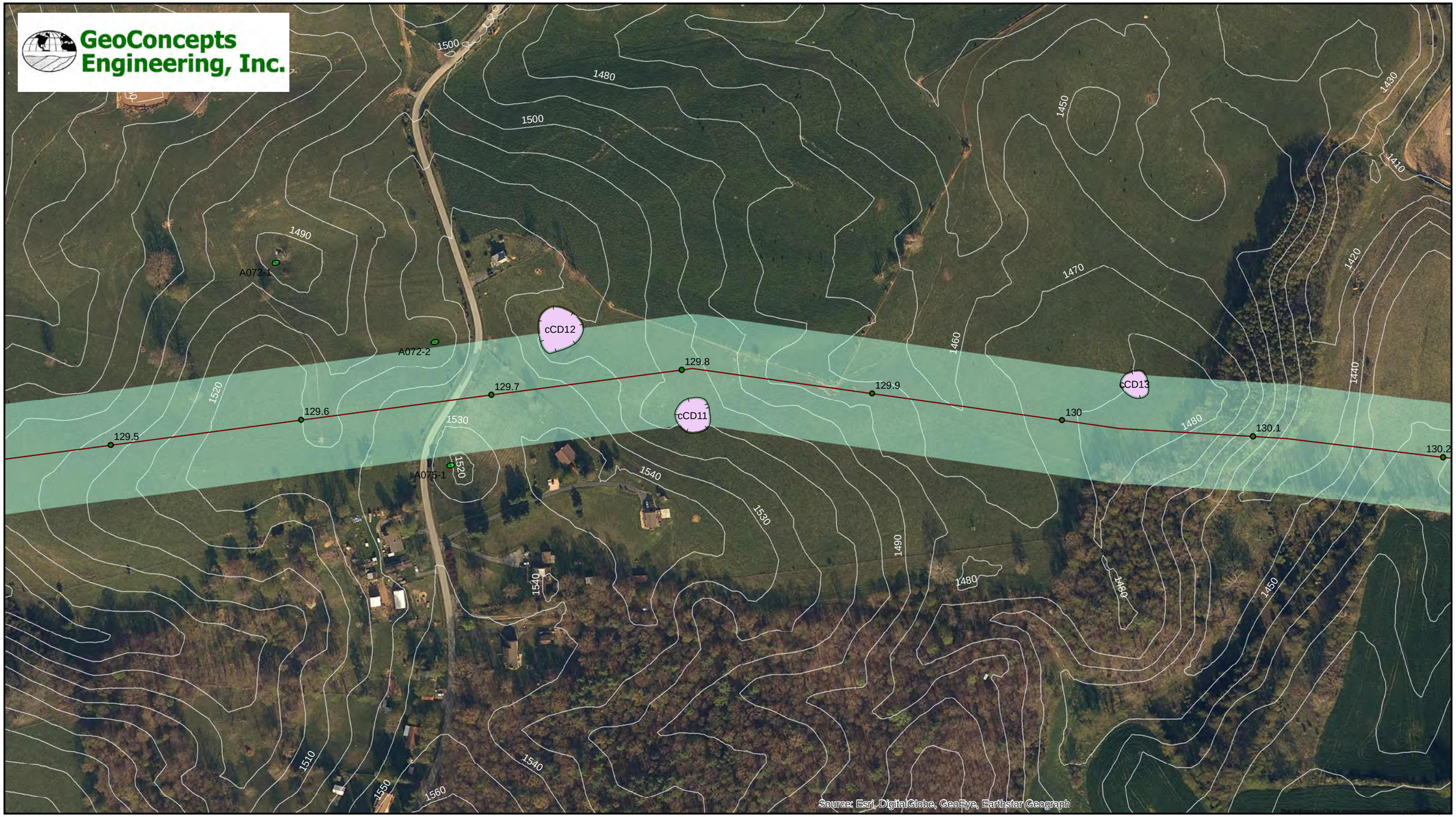
ATLANTIC COAST PIPELINE

11002.04

FILE: N:\PROJECTS\Active 11 Projects\11002.04, Dominion Resources Pipeline - Randolph and Pocahontas Co\Final\GIS Data for Final\reportmap Contour.mxd | REVISED: 02/14/2017 | SCALE: 1:3,000 when printed at 11x17

DRAWN BY: JDV

GeoConcepts Engineering, Inc.



- Mileposts (0.1 mile)
- Centerline
- 300' Corridor
- 0.50 KRA
- All Point Features
- All Area Features
- 300' Corridor Closed Depressions
- Suspect Closed Depressions
- Randolph Caves
- Pocahontas Caves
- Virginia Caves

0 250 500
Feet

CONTOUR MAP 121

ATLANTIC COAST PIPELINE

11002.04

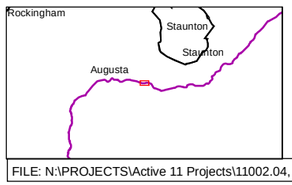
FILE: N:\PROJECTS\Active 11 Projects\11002.04, Dominion Resources Pipeline - Randolph and Pocahontas Co\Final\GIS Data for Final\reportmap Contour.mxd | REVISED: 02/14/2017 | SCALE: 1:3,000 when printed at 11x17

DRAWN BY: JDV

GeoConcepts Engineering, Inc.

130.2
130.3
130.4
130.5
130.6
AO83-1
130.7
130.8
cCD14
A083-1
A082-1

Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS



Mileposts (0.1 mile)
Centerline
300' Corridor
0.50 KRA
All Point Features
All Area Features
300' Corridor Closed Depressions
Suspect Closed Depressions
Randolph Caves
Pocahontas Caves
Virginia Caves

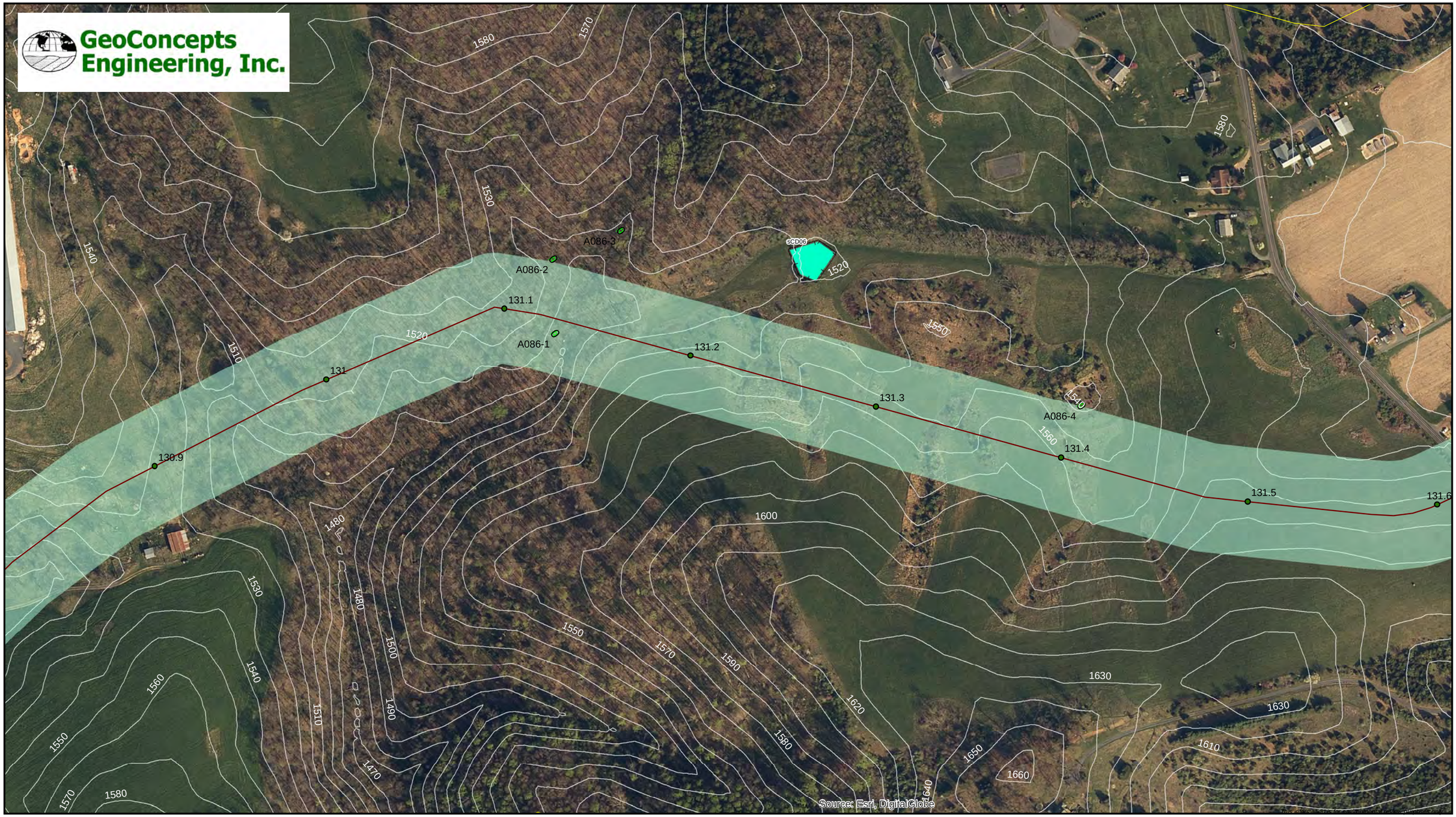
0 250 500
Feet

CONTOUR MAP 122
ATLANTIC COAST PIPELINE
11002.04

FILE: N:\PROJECTS\Active 11 Projects\11002.04, Dominion Resources Pipeline - Randolph and Pocahontas Co\Final\GIS Data for Final\reportmap Contour.mxd | REVISED: 02/14/2017 | SCALE: 1:3,000 when printed at 11x17

DRAWN BY: JDV

GeoConcepts Engineering, Inc.



- Mileposts (0.1 mile)
- Centerline
- 300' Corridor
- 0.50 KRA
- All Point Features
- All Area Features
- 300' Corridor Closed Depressions
- Suspect Closed Depressions
- Randolph Caves
- Pocahontas Caves
- Virginia Caves

0 250 500
Feet

CONTOUR MAP 123

ATLANTIC COAST PIPELINE

11002.04

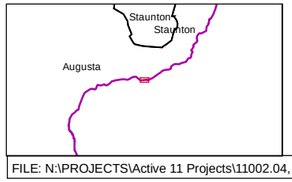
FILE: N:\PROJECTS\Active 11 Projects\11002.04, Dominion Resources Pipeline - Randolph and Pocahontas Co\Final\GIS Data for Final\reportmap Contour.mxd | REVISED: 02/14/2017 | SCALE: 1:3,000 when printed at 11x17

DRAWN BY: JDV

GeoConcepts Engineering, Inc.

131.6 131.7 131.8 A092-1 131.9 132 132.1 A096-1 132.2

Source: Esri, DigitalGlobe, GeoEye, Earthstar Ge



- Mileposts (0.1 mile)
- Centerline
- 300' Corridor
- 0.50 KRA
- All Point Features
- All Area Features
- 300' Corridor Closed Depressions
- Suspect Closed Depressions
- Randolph Caves
- Pocahontas Caves
- Virginia Caves

0 250 500
Feet

CONTOUR MAP 124

ATLANTIC COAST PIPELINE

11002.04

FILE: N:\PROJECTS\Active 11 Projects\11002.04, Dominion Resources Pipeline - Randolph and Pocahontas Co\Final\GIS Data for Final\reportmap Contour.mxd | REVISED: 02/14/2017 | SCALE: 1:3,000 when printed at 11x17

DRAWN BY: JDV

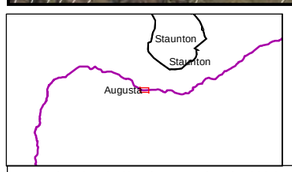
GeoConcepts Engineering, Inc.

132.3 132.4 132.5 132.6 132.7 132.8 132.9

A096-2 A096-3 A096-4 A096-5 A096-6 A096-7 A096-8

RCD1

Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGR...



- Mileposts (0.1 mile)
- Centerline
- 300' Corridor
- 0.50 KRA
- All Point Features
- All Area Features
- 300' Corridor Closed Depressions
- Suspect Closed Depressions
- Randolph Caves
- Pocahontas Caves
- Virginia Caves

0 250 500
Feet

CONTOUR MAP 125

ATLANTIC COAST PIPELINE

11002.04

FILE: N:\PROJECTS\Active 11 Projects\11002.04, Dominion Resources Pipeline - Randolph and Pocahontas Co\Final\GIS Data for Final\reportmap Contour.mxd | REVISED: 02/14/2017 | SCALE: 1:3,000 when printed at 11x17

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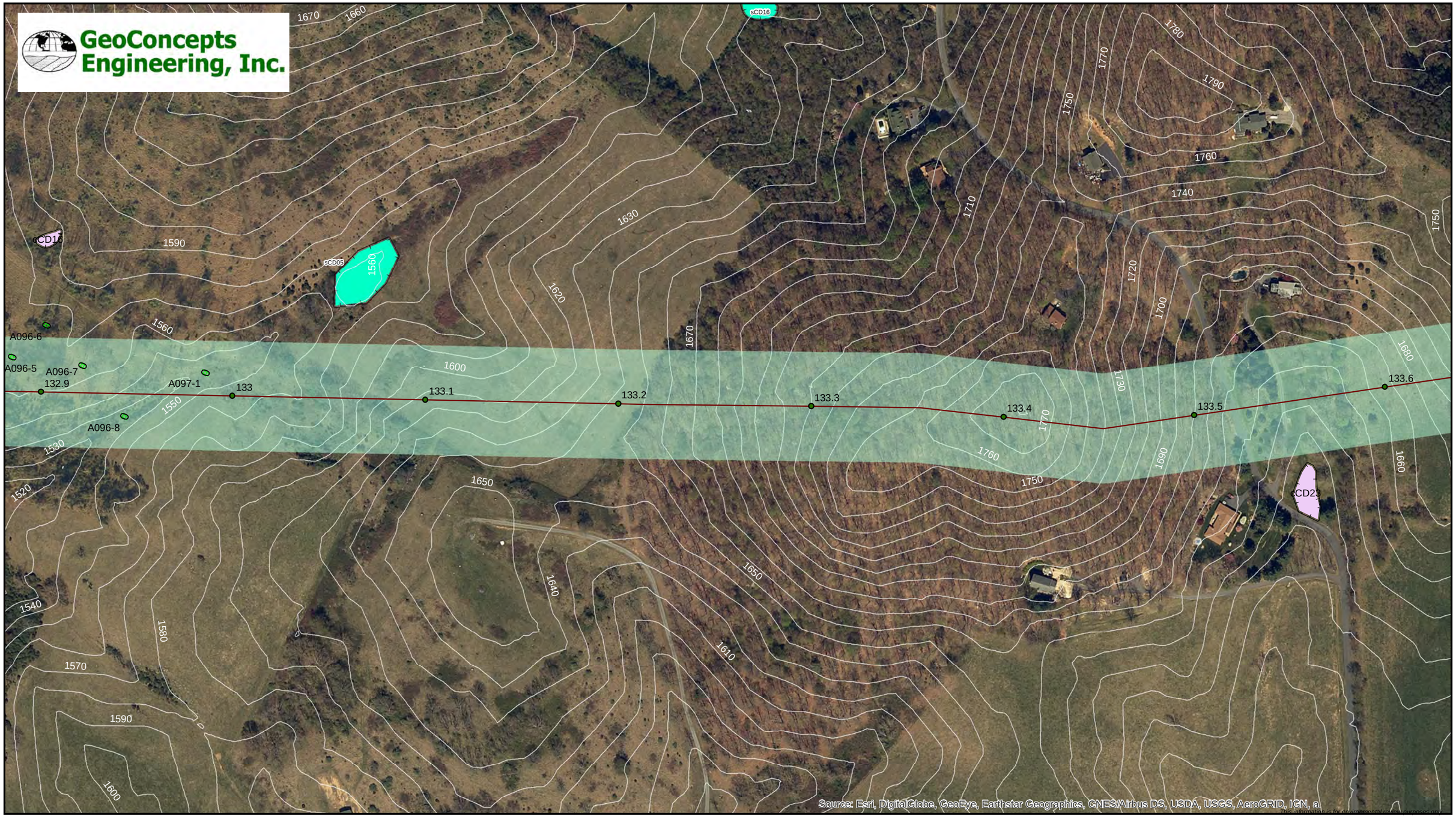
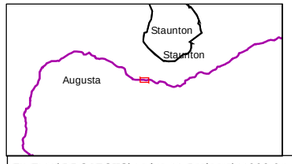
GeoConcepts Engineering, Inc.





- Mileposts (0.1 mile)
- Centerline
- 300' Corridor
- 0.50 KRA
- All Point Features
- All Area Features
- 300' Corridor Closed Depressions
- Suspect Closed Depressions
- Randolph Caves
- Pocahontas Caves
- Virginia Caves

0 250 500
Feet

CONTOUR MAP 126

ATLANTIC COAST PIPELINE

11002.04

FILE: N:\PROJECTS\Active 11 Projects\11002.04, Dominion Resources Pipeline - Randolph and Pocahontas Co\Final\GIS Data for Final\reportmap Contour.mxd | REVISED: 02/14/2017 | SCALE: 1:3,000 when printed at 11x17

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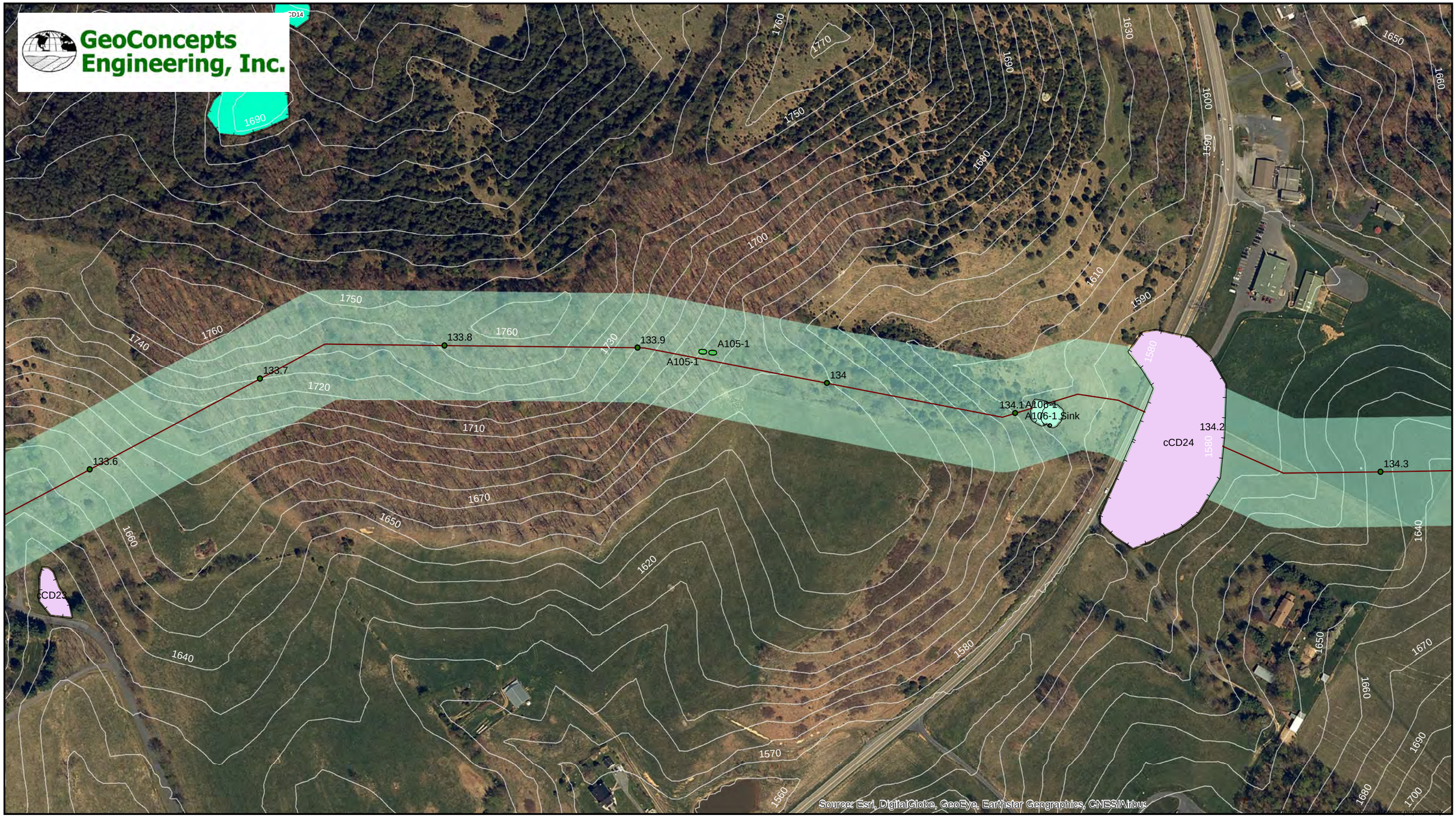
GeoConcepts Engineering, Inc.



- Mileposts (0.1 mile)
- Centerline
- 300' Corridor
- 0.50 KRA
- All Point Features
- All Area Features
- 300' Corridor Closed Depressions
- Suspect Closed Depressions
- Randolph Caves
- Pocahontas Caves
- Virginia Caves

0 250 500
Feet

CONTOUR MAP 127

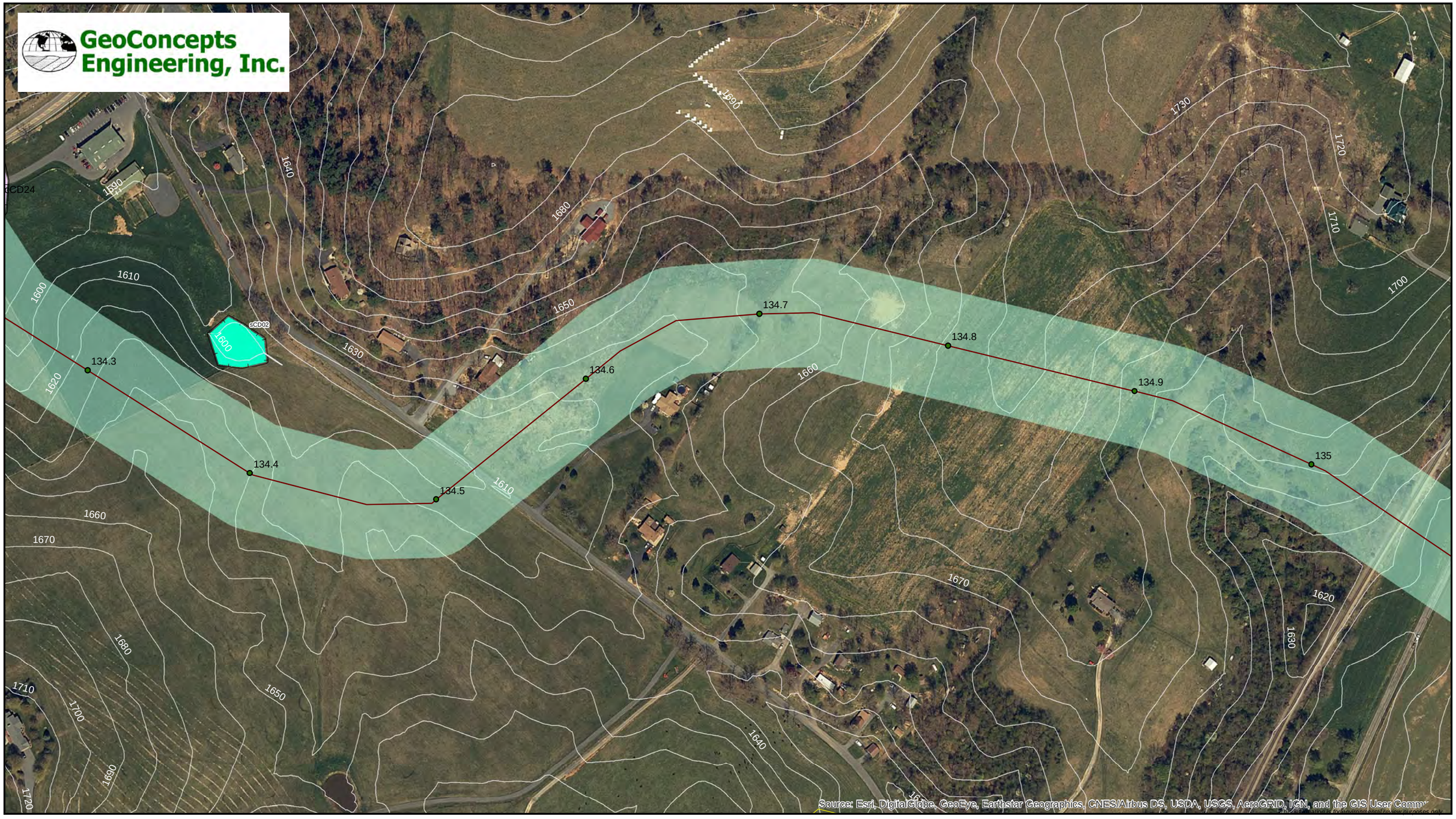
ATLANTIC COAST PIPELINE

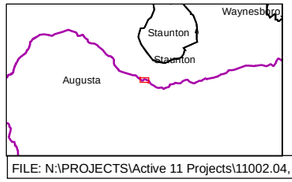
11002.04

FILE: N:\PROJECTS\Active 11 Projects\11002.04, Dominion Resources Pipeline - Randolph and Pocahontas Co\Final\GIS Data for Final\reportmap Contour.mxd | REVISED: 02/14/2017 | SCALE: 1:3,000 when printed at 11x17

DRAWN BY: JDV

GeoConcepts Engineering, Inc.





Mileposts (0.1 mile)
Centerline
300' Corridor
0.50 KRA
All Point Features
All Area Features
300' Corridor Closed Depressions
Suspect Closed Depressions
Randolph Caves
Pocahontas Caves
Virginia Caves

0 250 500
Feet

CONTOUR MAP 128

ATLANTIC COAST PIPELINE

11002.04

FILE: N:\PROJECTS\Active 11 Projects\11002.04, Dominion Resources Pipeline - Randolph and Pocahontas Co\Final\GIS Data for Final\reportmap Contour.mxd | REVISED: 02/14/2017 | SCALE: 1:3,000 when printed at 11x17

DRAWN BY: JDV

GeoConcepts Engineering, Inc.

135 135.1 135.2 135.3 135.4 135.5 135.6

sCD19 sCD20

Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, C

This information is for environmental review purposes only

Mileposts (0.1 mile)
Centerline
300' Corridor
0.50 KRA
All Point Features
All Area Features
300' Corridor Closed Depressions
Suspect Closed Depressions
Randolph Caves
Pocahontas Caves
Virginia Caves

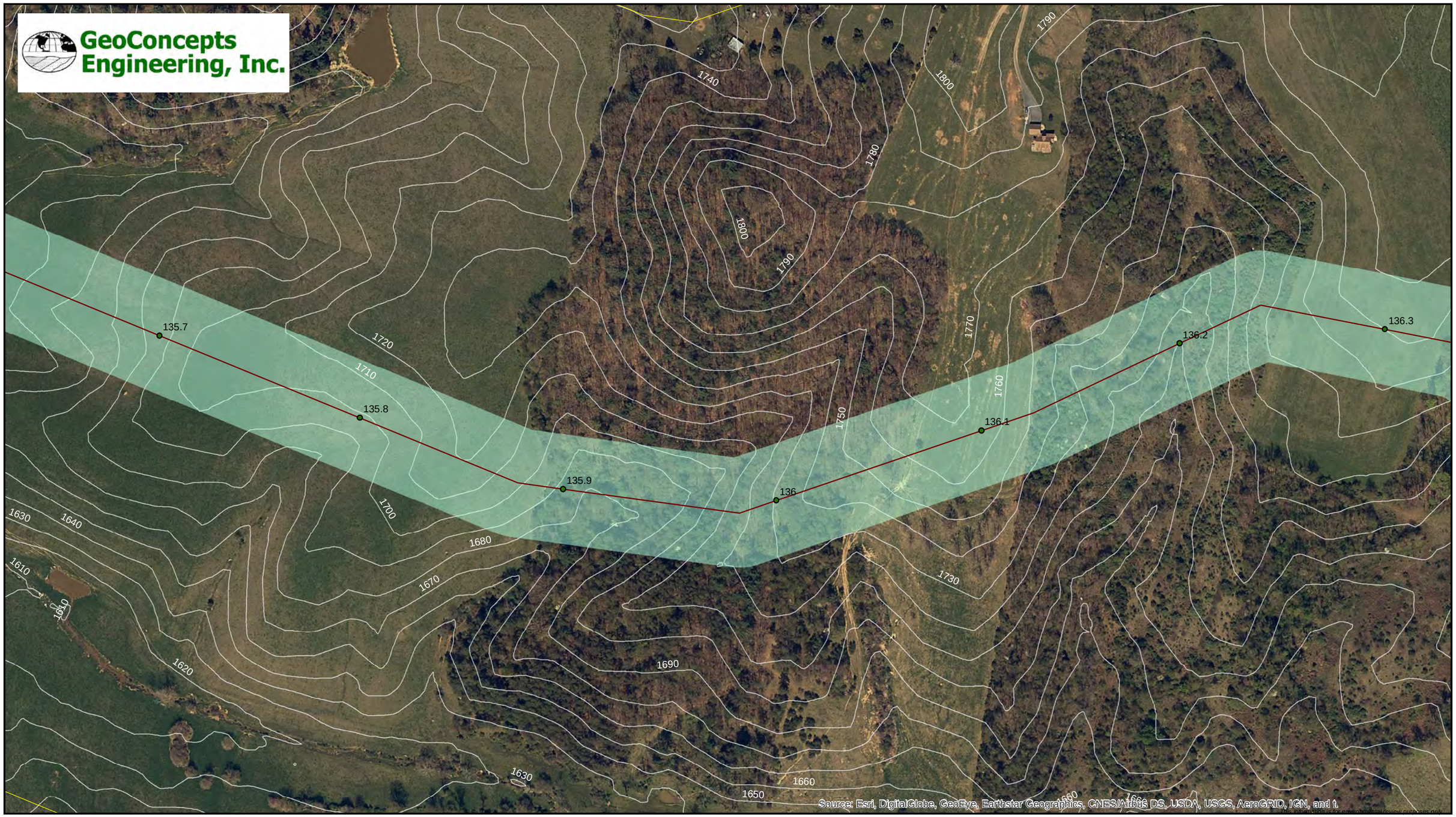
0 250 500
Feet

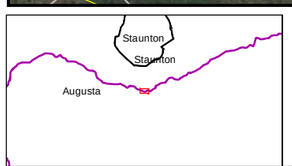
CONTOUR MAP 129
ATLANTIC COAST PIPELINE
11002.04

FILE: N:\PROJECTS\Active 11 Projects\11002.04, Dominion Resources Pipeline - Randolph and Pocahontas Co\Final\GIS Data for Final\reportmap Contour.mxd | REVISED: 02/14/2017 | SCALE: 1:3,000 when printed at 11x17

DRAWN BY: JDV

GeoConcepts Engineering, Inc.





- Mileposts (0.1 mile)
- Centerline
- 300' Corridor
- 0.50 KRA
- All Point Features
- All Area Features
- 300' Corridor Closed Depressions
- Suspect Closed Depressions
- Randolph Caves
- Pocahontas Caves
- Virginia Caves

0 250 500
Feet

CONTOUR MAP 130

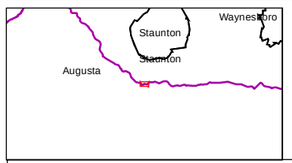
ATLANTIC COAST PIPELINE

11002.04

FILE: N:\PROJECTS\Active 11 Projects\11002.04, Dominion Resources Pipeline - Randolph and Pocahontas Co\Final\GIS Data for Final\reportmap Contour.mxd | REVISED: 02/14/2017 | SCALE: 1:3,000 when printed at 11x17

DRAWN BY: JDV

GeoConcepts Engineering, Inc.



- Mileposts (0.1 mile)
- Centerline
- 300' Corridor
- 0.50 KRA
- All Point Features
- All Area Features
- 300' Corridor Closed Depressions
- Suspect Closed Depressions
- Randolph Caves
- Pocahontas Caves
- Virginia Caves

0 250 500
Feet

CONTOUR MAP 131

ATLANTIC COAST PIPELINE

11002.04

FILE: N:\PROJECTS\Active 11 Projects\11002.04, Dominion Resources Pipeline - Randolph and Pocahontas Co\Final\GIS Data for Final\reportmap Contour.mxd | REVISED: 02/14/2017 | SCALE: 1:3,000 when printed at 11x17

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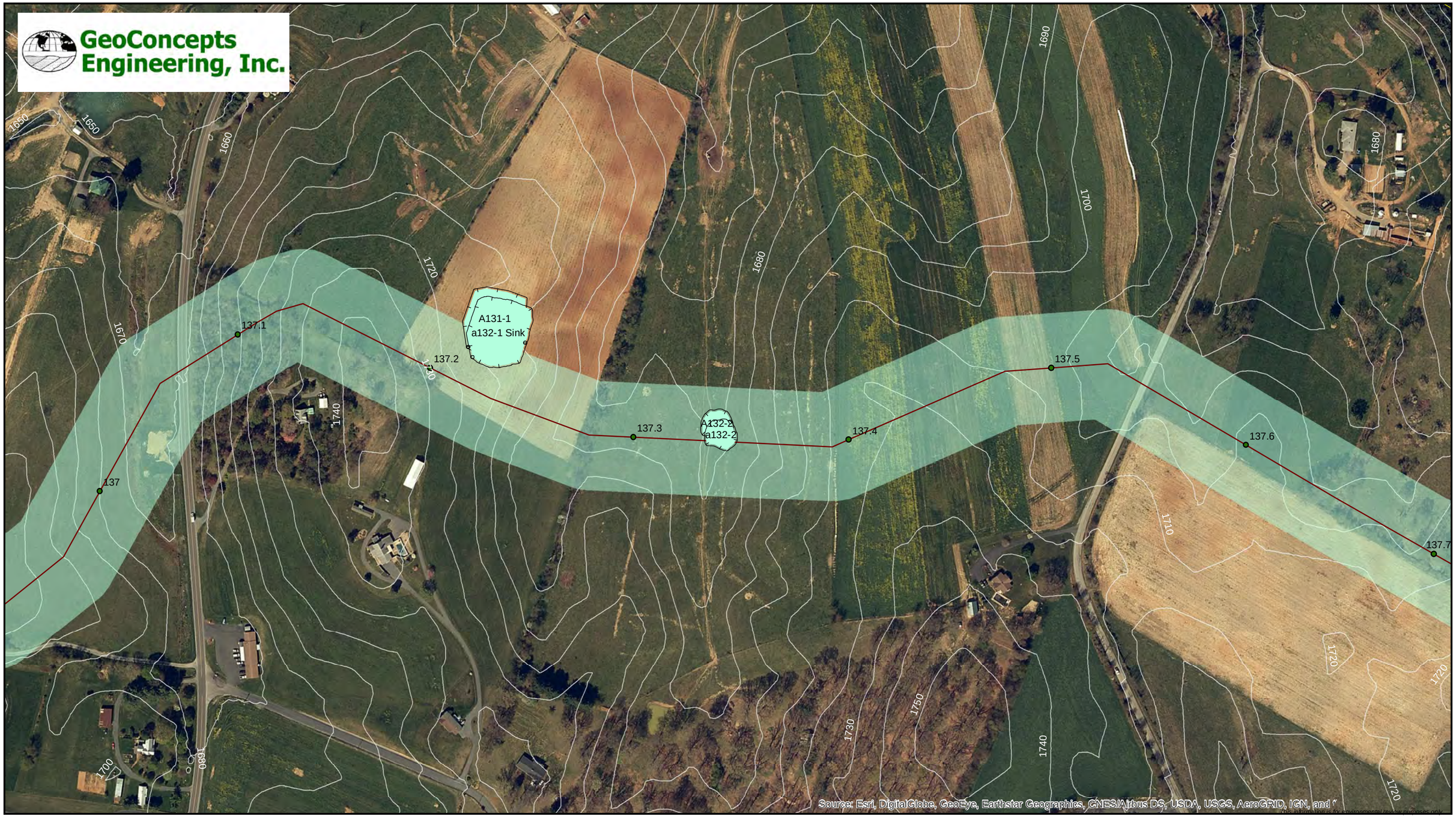
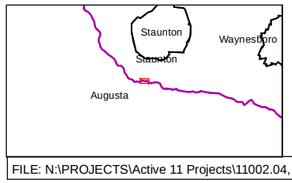
GeoConcepts Engineering, Inc.





- Mileposts (0.1 mile)
- Centerline
- 300' Corridor
- 0.50 KRA
- All Point Features
- All Area Features
- 300' Corridor Closed Depressions
- Suspect Closed Depressions
- Randolph Caves
- Pocahontas Caves
- Virginia Caves

0 250 500
Feet

CONTOUR MAP 132

ATLANTIC COAST PIPELINE

11002.04

FILE: N:\PROJECTS\Active 11 Projects\11002.04, Dominion Resources Pipeline - Randolph and Pocahontas Co\Final\GIS Data for Final\reportmap Contour.mxd | REVISED: 02/14/2017 | SCALE: 1:3,000 when printed at 11x17

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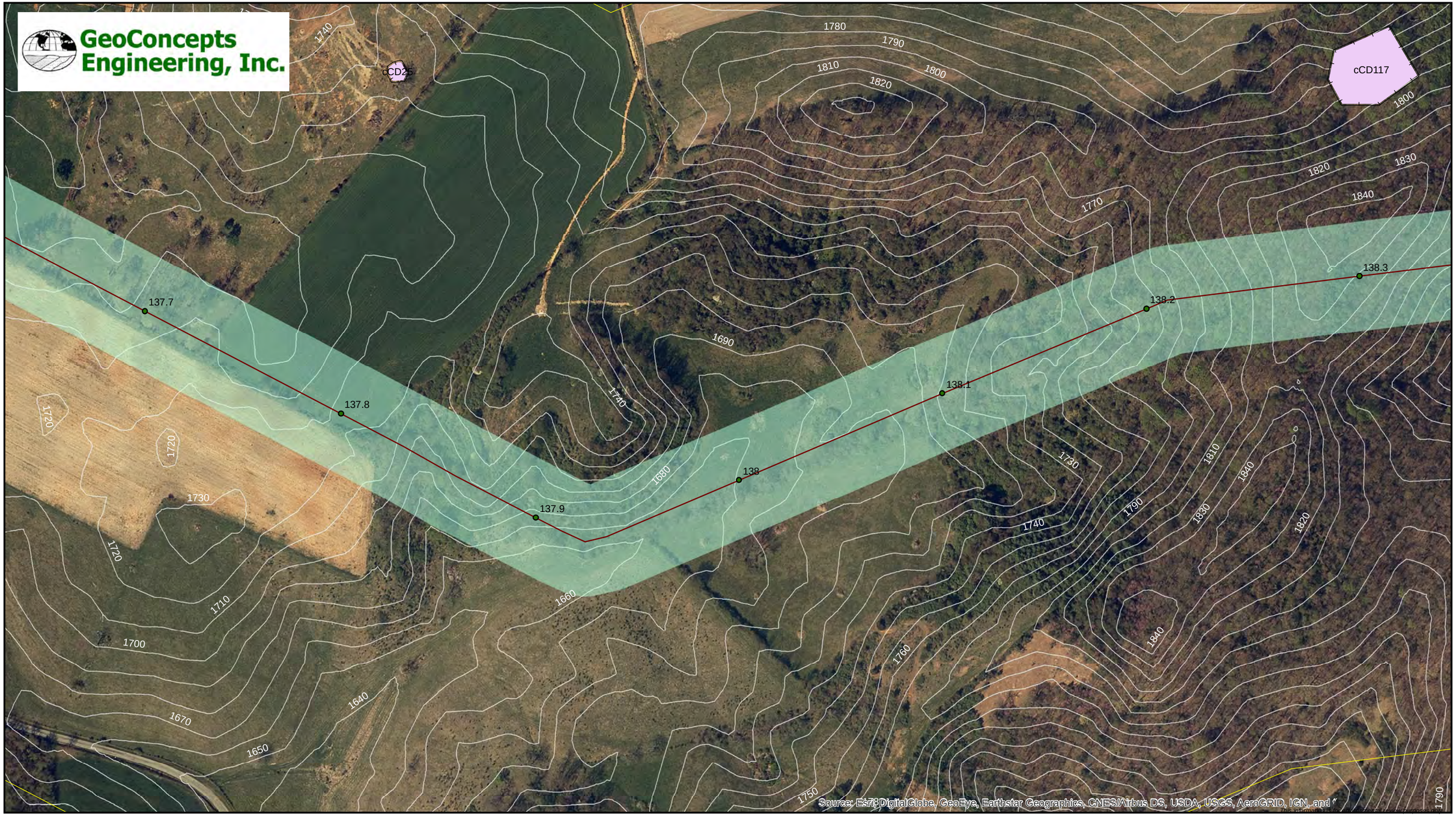
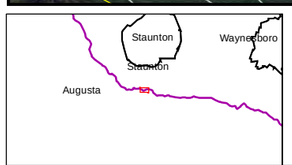
GeoConcepts Engineering, Inc.





Mileposts (0.1 mile)
Centerline
300' Corridor
0.50 KRA
All Point Features
All Area Features
300' Corridor Closed Depressions
Suspect Closed Depressions
Randolph Caves
Pocahontas Caves
Virginia Caves

0 250 500
Feet

CONTOUR MAP 133

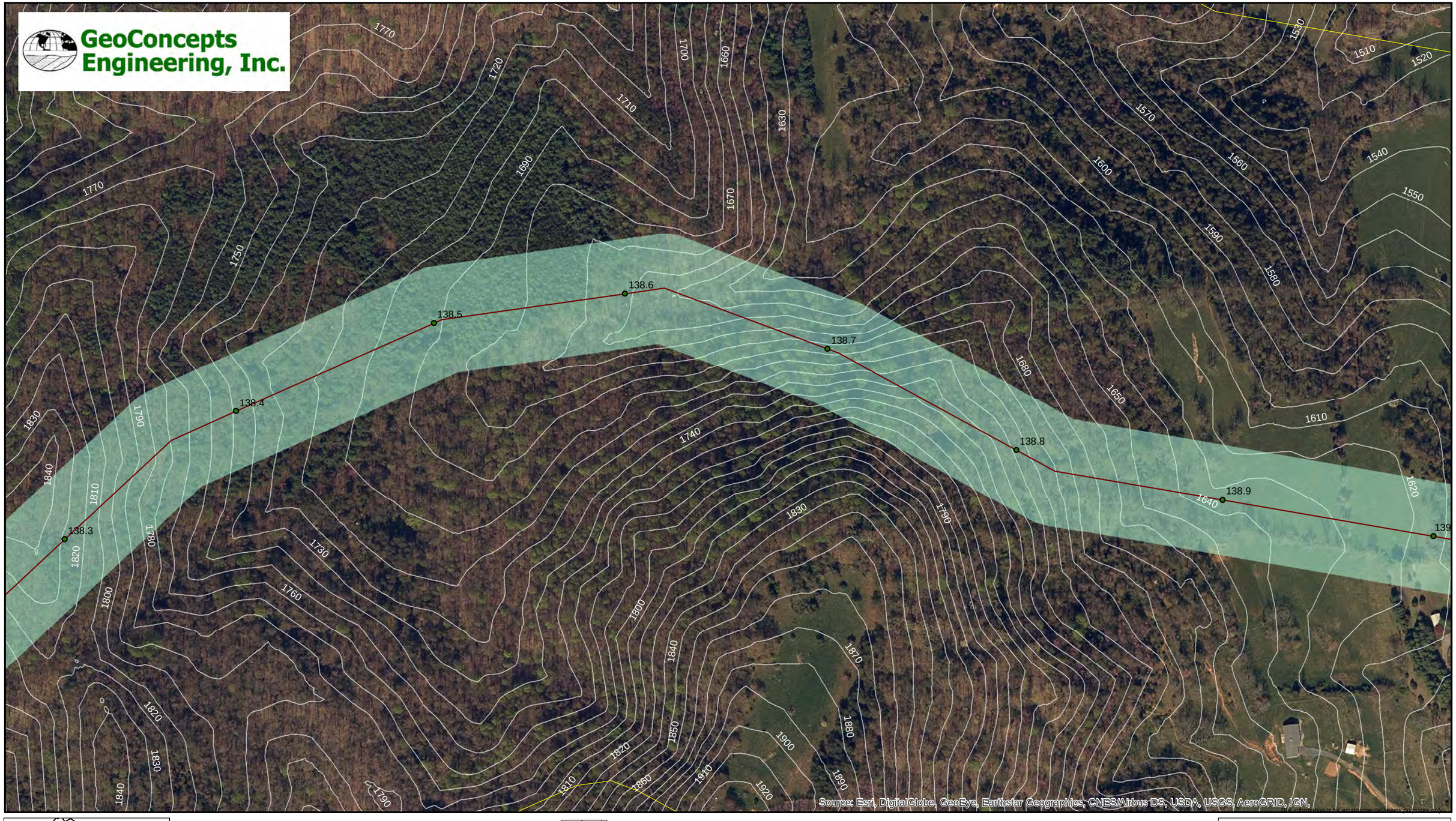
ATLANTIC COAST PIPELINE

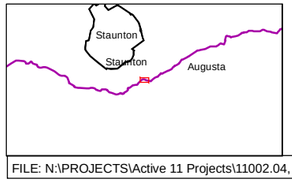
11002.04

FILE: N:\PROJECTS\Active 11 Projects\11002.04, Dominion Resources Pipeline - Randolph and Pocahontas Co\Final\GIS Data for Final\reportmap Contour.mxd | REVISED: 02/14/2017 | SCALE: 1:3,000 when printed at 11x17

DRAWN BY: JDV

GeoConcepts Engineering, Inc.





- Mileposts (0.1 mile)
- Centerline
- 300' Corridor
- 0.50 KRA
- All Point Features
- All Area Features
- 300' Corridor Closed Depressions
- Suspect Closed Depressions
- Randolph Caves
- Pocahontas Caves
- Virginia Caves

0 250 500
Feet

CONTOUR MAP 134

ATLANTIC COAST PIPELINE

11002.04

FILE: N:\PROJECTS\Active 11 Projects\11002.04, Dominion Resources Pipeline - Randolph and Pocahontas Co\Final\GIS Data for Final\reportmap Contour.mxd | REVISED: 02/14/2017 | SCALE: 1:3,000 when printed at 11x17

DRAWN BY: JDV

GeoConcepts Engineering, Inc.

139
139.1
a138-1 sink
a138-2 springs and swallet
a138-3 sink
139.2
139.3
139.4
139.5
139.6

Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the

Mileposts (0.1 mile)
Centerline
300' Corridor
0.50 KRA
All Point Features
All Area Features
300' Corridor Closed Depressions
Suspect Closed Depressions
Randolph Caves
Pocahontas Caves
Virginia Caves

0 250 500
Feet

CONTOUR MAP 135
ATLANTIC COAST PIPELINE
11002.04

FILE: N:\PROJECTS\Active 11 Projects\11002.04, Dominion Resources Pipeline - Randolph and Pocahontas Co\Final\GIS Data for Final\reportmap Contour.mxd | REVISED: 02/14/2017 | SCALE: 1:3,000 when printed at 11x17

DRAWN BY: JDV

GeoConcepts Engineering, Inc.

Cochran Spring Cave
Cochrans Cave No. 3
A142-1
A142-2
A142-3
A142-4
A142-5
A142-6
A140-1
A140-2
A140-4
A146-1
139.6
139.7
139.8
139.9
140
140.1
140.2
140.3
cCD100
sCD22
Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and *

Staunton
Waynesboro
Augusta

Mileposts (0.1 mile)
Centerline
300' Corridor
0.50 KRA
All Point Features
All Area Features
300' Corridor Closed Depressions
Suspect Closed Depressions
Randolph Caves
Pocahontas Caves
Virginia Caves

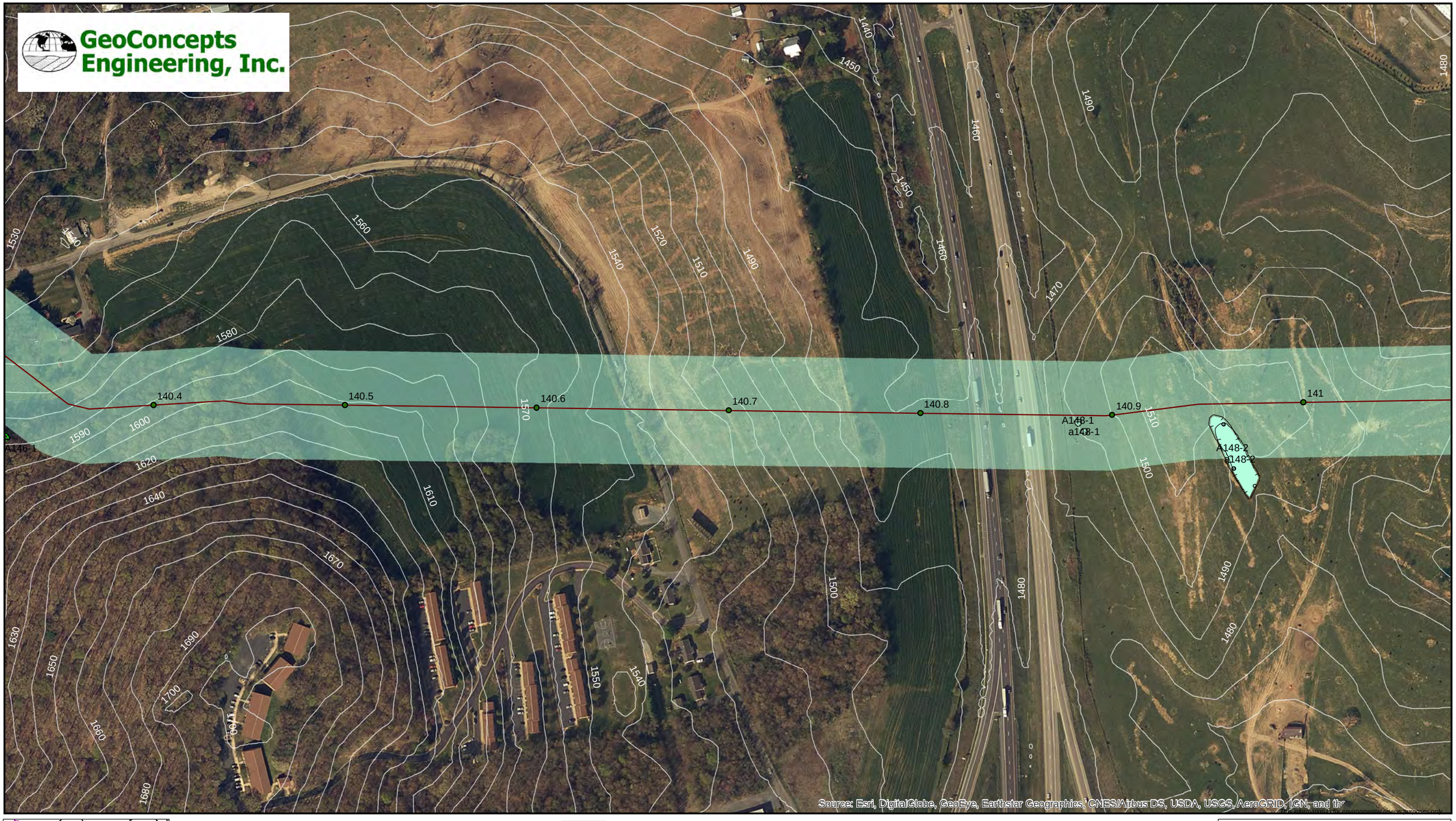
0 250 500
Feet

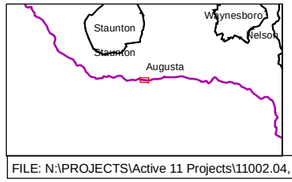
CONTOUR MAP 136
ATLANTIC COAST PIPELINE
11002.04

FILE: N:\PROJECTS\Active 11 Projects\11002.04, Dominion Resources Pipeline - Randolph and Pocahontas Co\Final\GIS Data for Final\reportmap Contour.mxd | REVISED: 02/14/2017 | SCALE: 1:3,000 when printed at 11x17

DRAWN BY: JDV

GeoConcepts Engineering, Inc.





- Mileposts (0.1 mile)
- Centerline
- 300' Corridor
- 0.50 KRA
- All Point Features
- All Area Features
- 300' Corridor Closed Depressions
- Suspect Closed Depressions
- Randolph Caves
- Pocahontas Caves
- Virginia Caves

0 250 500
Feet

CONTOUR MAP 137

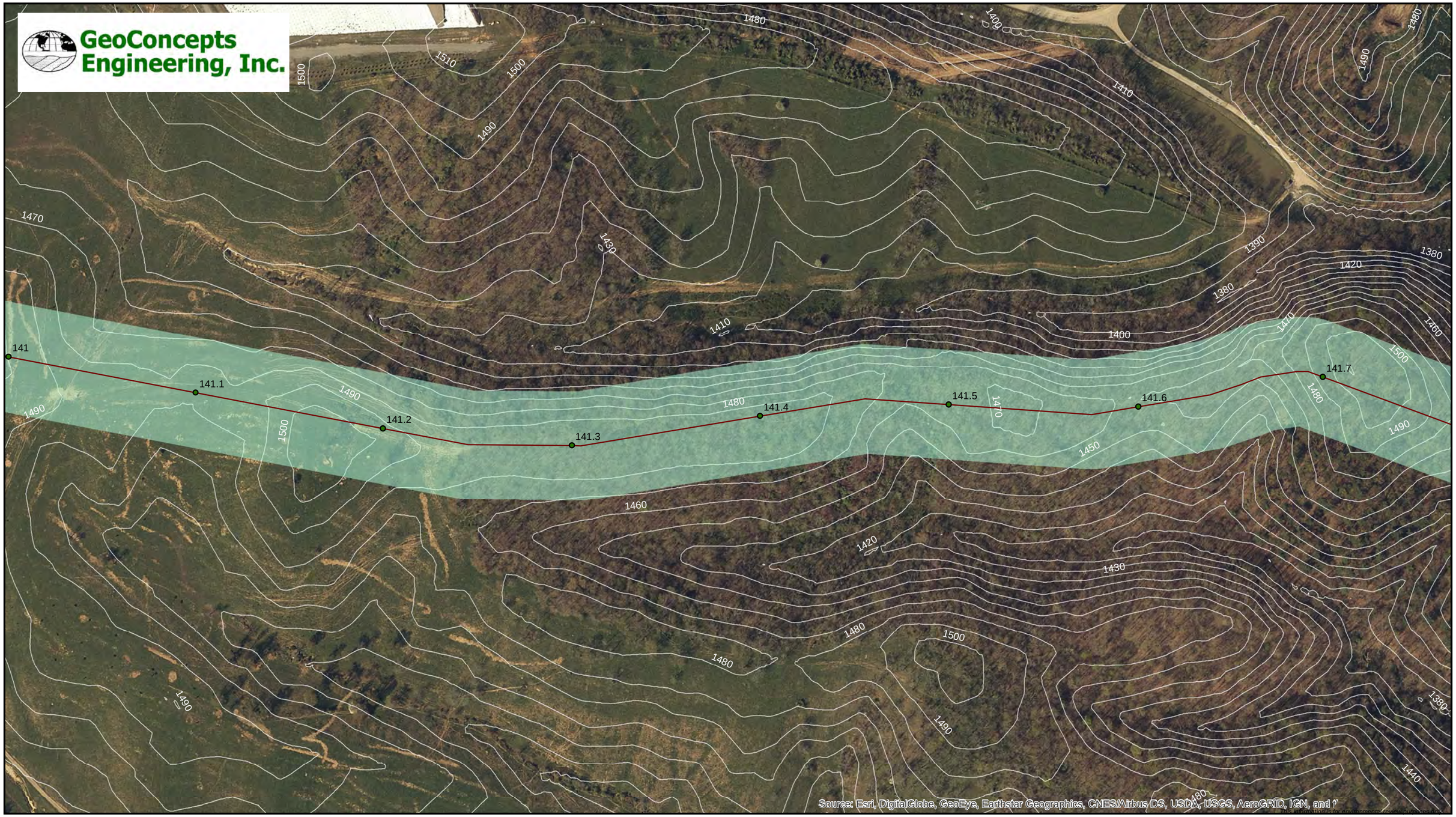
ATLANTIC COAST PIPELINE

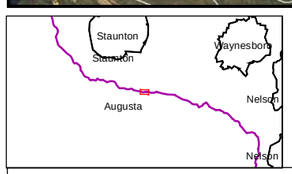
11002.04

FILE: N:\PROJECTS\Active 11 Projects\11002.04, Dominion Resources Pipeline - Randolph and Pocahontas Co\Final\GIS Data for Final\reportmap Contour.mxd | REVISED: 02/14/2017 | SCALE: 1:3,000 when printed at 11x17

DRAWN BY: JDV

GeoConcepts Engineering, Inc.





- Mileposts (0.1 mile)
- Centerline
- 300' Corridor
- 0.50 KRA
- All Point Features
- All Area Features
- 300' Corridor Closed Depressions
- Suspect Closed Depressions
- Randolph Caves
- Pocahontas Caves
- Virginia Caves

0 250 500
Feet

CONTOUR MAP 138

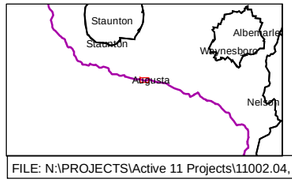
ATLANTIC COAST PIPELINE

11002.04

FILE: N:\PROJECTS\Active 11 Projects\11002.04, Dominion Resources Pipeline - Randolph and Pocahontas Co\Final\GIS Data for Final\reportmap Contour.mxd | REVISED: 02/14/2017 | SCALE: 1:3,000 when printed at 11x17

DRAWN BY: JDV

GeoConcepts Engineering, Inc.



- Mileposts (0.1 mile)
- Centerline
- 300' Corridor
- 0.50 KRA
- All Point Features
- All Area Features
- 300' Corridor Closed Depressions
- Suspect Closed Depressions
- Randolph Caves
- Pocahontas Caves
- Virginia Caves

0 250 500
Feet

CONTOUR MAP 139

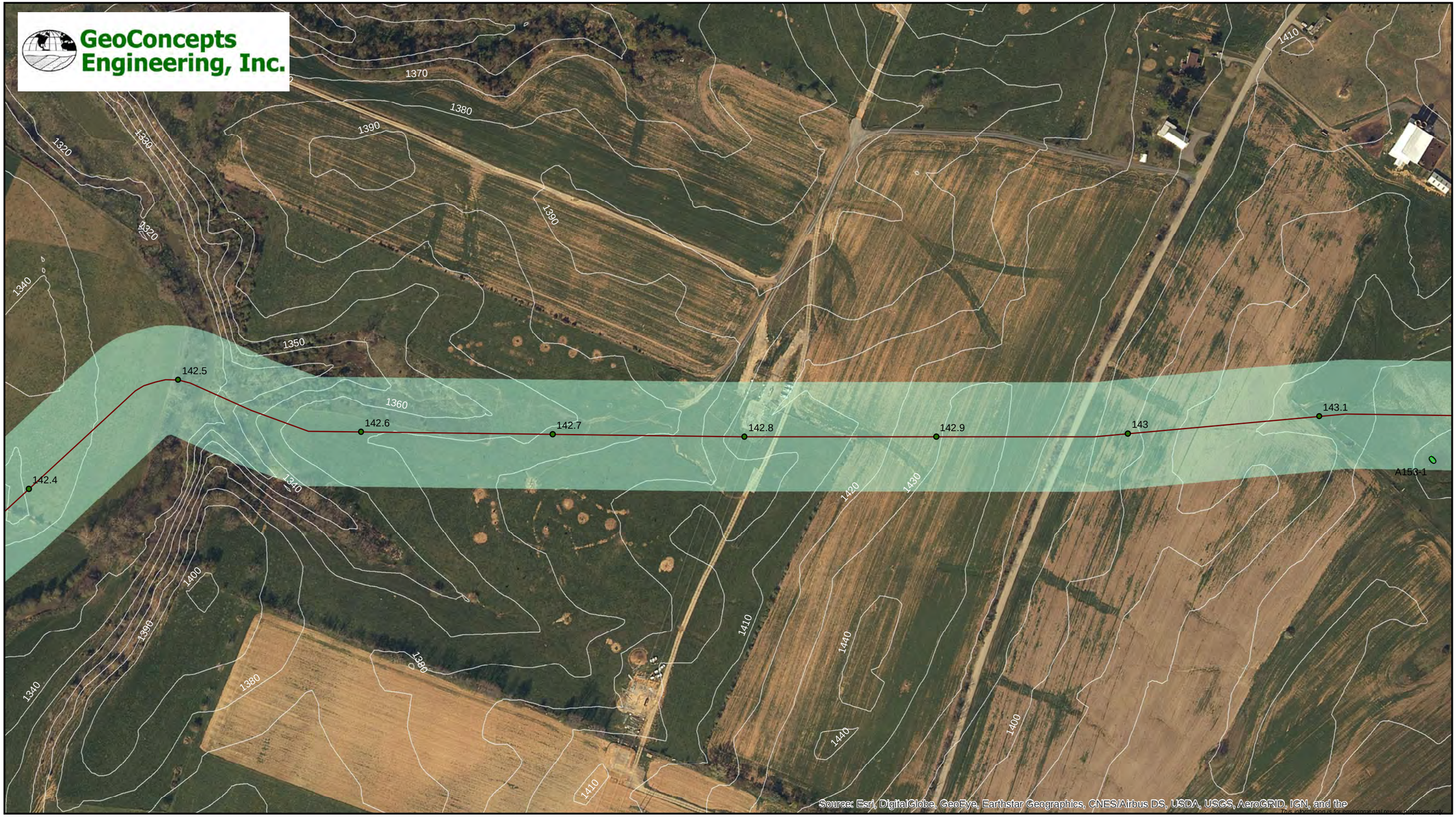
ATLANTIC COAST PIPELINE

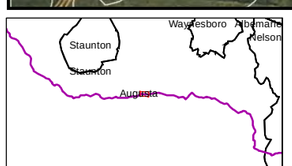
11002.04

FILE: N:\PROJECTS\Active 11 Projects\11002.04, Dominion Resources Pipeline - Randolph and Pocahontas Co\Final\GIS Data for Final\reportmap Contour.mxd | REVISED: 02/14/2017 | SCALE: 1:3,000 when printed at 11x17

DRAWN BY: JDV

GeoConcepts Engineering, Inc.





- Mileposts (0.1 mile)
- Centerline
- 300' Corridor
- 0.50 KRA
- All Point Features
- All Area Features
- 300' Corridor Closed Depressions
- Suspect Closed Depressions
- Randolph Caves
- Pocahontas Caves
- Virginia Caves

0 250 500
Feet

CONTOUR MAP 140

ATLANTIC COAST PIPELINE

11002.04

FILE: N:\PROJECTS\Active 11 Projects\11002.04, Dominion Resources Pipeline - Randolph and Pocahontas Co\Final\GIS Data for Final\reportmap Contour.mxd | REVISED: 02/14/2017 | SCALE: 1:3,000 when printed at 11x17

DRAWN BY: JDV

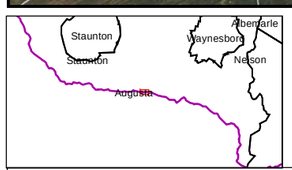
GeoConcepts Engineering, Inc.

143.1 143.2 143.3 143.4 143.5 143.6 143.7 143.8

A153-1

1400 1390 1350 1370 1380 1400 1390 1390 1360 1380 1390

Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and "



- Mileposts (0.1 mile)
- Centerline
- 300' Corridor
- 0.50 KRA
- All Point Features
- All Area Features
- 300' Corridor Closed Depressions
- Suspect Closed Depressions
- Randolph Caves
- Pocahontas Caves
- Virginia Caves

0 250 500
Feet

CONTOUR MAP 141

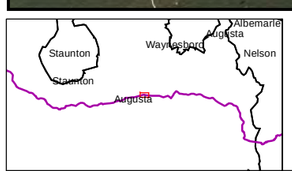
ATLANTIC COAST PIPELINE

11002.04

FILE: N:\PROJECTS\Active 11 Projects\11002.04, Dominion Resources Pipeline - Randolph and Pocahontas Co\Final\GIS Data for Final\reportmap Contour.mxd | REVISED: 02/14/2017 | SCALE: 1:3,000 when printed at 11x17

DRAWN BY: JDV

GeoConcepts Engineering, Inc.



Mileposts (0.1 mile)
Centerline
300' Corridor
0.50 KRA
All Point Features
All Area Features
300' Corridor Closed Depressions
Suspect Closed Depressions
Randolph Caves
Pocahontas Caves
Virginia Caves

0 250 500
Feet

CONTOUR MAP 142

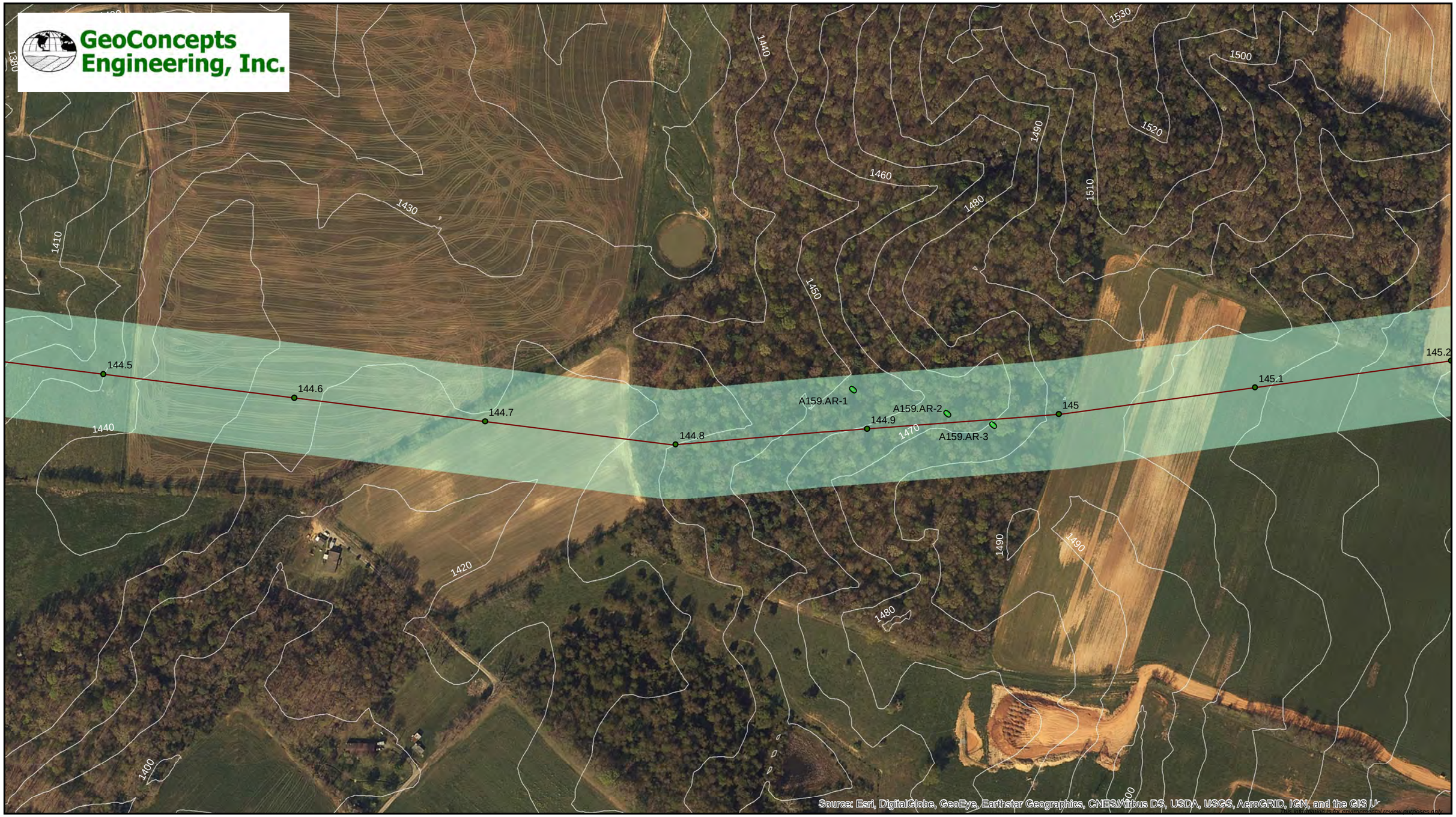
ATLANTIC COAST PIPELINE

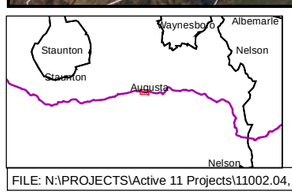
11002.04

FILE: N:\PROJECTS\Active 11 Projects\11002.04, Dominion Resources Pipeline - Randolph and Pocahontas Co\Final\GIS Data for Final\reportmap Contour.mxd | REVISED: 02/14/2017 | SCALE: 1:3,000 when printed at 11x17

DRAWN BY: JDV

GeoConcepts Engineering, Inc.





- Mileposts (0.1 mile)
- Centerline
- 300' Corridor
- 0.50 KRA
- All Point Features
- All Area Features
- 300' Corridor Closed Depressions
- Suspect Closed Depressions
- Randolph Caves
- Pocahontas Caves
- Virginia Caves

0 250 500
Feet

CONTOUR MAP 143

ATLANTIC COAST PIPELINE

11002.04

FILE: N:\PROJECTS\Active 11 Projects\11002.04, Dominion Resources Pipeline - Randolph and Pocahontas Co\Final\GIS Data for Final\reportmap Contour.mxd | REVISED: 02/14/2017 | SCALE: 1:3,000 when printed at 11x17

DRAWN BY: JDV

GeoConcepts Engineering, Inc.

1490 1470 1480 1460 1460 1440 1440 1440 1430 1420 1430 1430 1450 1430 1420 1430 1430 1440 1440 1430 1410 1430

145.2 145.3 145.4 145.5 145.6 145.7 145.8

A162-1
a162-1 filled sink

A162-2
a162-2

A162-3
a162-3

Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Commu

- Mileposts (0.1 mile)
- Centerline
- 300' Corridor
- 0.50 KRA
- All Point Features
- All Area Features
- 300' Corridor Closed Depressions
- Suspect Closed Depressions
- Randolph Caves
- Pocahontas Caves
- Virginia Caves

0 250 500
Feet

CONTOUR MAP 144

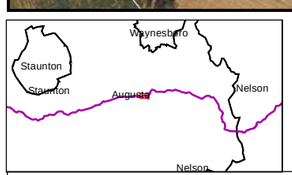
ATLANTIC COAST PIPELINE

11002.04

FILE: N:\PROJECTS\Active 11 Projects\11002.04, Dominion Resources Pipeline - Randolph and Pocahontas Co\Final\GIS Data for Final\reportmap Contour.mxd | REVISED: 02/14/2017 | SCALE: 1:3,000 when printed at 11x17

DRAWN BY: JDV

GeoConcepts Engineering, Inc.



- Mileposts (0.1 mile)
- Centerline
- 300' Corridor
- 0.50 KRA
- All Point Features
- All Area Features
- 300' Corridor Closed Depressions
- Suspect Closed Depressions
- Randolph Caves
- Pocahontas Caves
- Virginia Caves

0 250 500
Feet

CONTOUR MAP 145
ATLANTIC COAST PIPELINE
11002.04

FILE: N:\PROJECTS\Active 11 Projects\11002.04, Dominion Resources Pipeline - Randolph and Pocahontas Co\Final\GIS Data for Final\reportmap Contour.mxd | REVISED: 02/14/2017 | SCALE: 1:3,000 when printed at 11x17

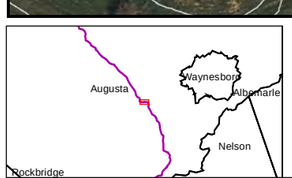
DRAWN BY: JDV

GeoConcepts Engineering, Inc.

D006-1

1420 1410 1410 1410 1420 1410 1420 1390 1400 1400 1430 1390 1430 1400 1390 1380 1380 1400 1380 1370

146.6 146.7 146.8 146.9 147 147.1 147.2 147.3 147.4



Mileposts (0.1 mile)
Centerline
300' Corridor
0.50 KRA
All Point Features
All Area Features
300' Corridor Closed Depressions
Suspect Closed Depressions
Randolph Caves
Pocahontas Caves
Virginia Caves

0 250 500
Feet

CONTOUR MAP 146
ATLANTIC COAST PIPELINE
11002.04

FILE: N:\PROJECTS\Active 11 Projects\11002.04, Dominion Resources Pipeline - Randolph and Pocahontas Co\Final\GIS Data for Final\reportmap Contour.mxd | REVISED: 02/14/2017 | SCALE: 1:3,000 when printed at 11x17

DRAWN BY: JDV

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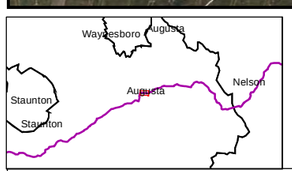
GeoConcepts Engineering, Inc.



- Mileposts (0.1 mile)
- Centerline
- 300' Corridor
- 0.50 KRA
- All Point Features
- All Area Features
- 300' Corridor Closed Depressions
- Suspect Closed Depressions
- Randolph Caves
- Pocahontas Caves
- Virginia Caves

0 250 500
Feet

CONTOUR MAP 147

ATLANTIC COAST PIPELINE

11002.04

FILE: N:\PROJECTS\Active 11 Projects\11002.04, Dominion Resources Pipeline - Randolph and Pocahontas Co\Final\GIS Data for Final\reportmap Contour.mxd | REVISED: 02/14/2017 | SCALE: 1:3,000 when printed at 11x17

DRAWN BY: JDV

GeoConcepts Engineering, Inc.

sCD39
sCD38
1360
1360
1360
1360
1420
1400
148.2
148.3
148.4
148.5
148.6
possible psuedokarst a002
a002 2-2 small depression
A002-2
148.7
148.8
A003-1
a003-1 throat possible animal
149
149.1
1410
1420
1430
1400
1390
1370
1380
a002-3 spring
A002-3
Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the
This information is for environmental review purposes only.

Staunton
Waynesboro
Albemarle
Nelson
Augusta

- Mileposts (0.1 mile)
- Centerline
- 300' Corridor
- 0.50 KRA
- All Point Features
- All Area Features
- 300' Corridor Closed Depressions
- Suspect Closed Depressions
- Randolph Caves
- Pocahontas Caves
- Virginia Caves

0 250 500
Feet

CONTOUR MAP 148
ATLANTIC COAST PIPELINE
11002.04

FILE: N:\PROJECTS\Active 11 Projects\11002.04, Dominion Resources Pipeline - Randolph and Pocahontas Co\Final\GIS Data for Final\reportmap Contour.mxd | REVISED: 02/14/2017 | SCALE: 1:3,000 when printed at 11x17

DRAWN BY: JDV

GeoConcepts Engineering, Inc.

149.1 149.2 149.3 149.4 149.5 149.6 149.7 149.8 149.9 150

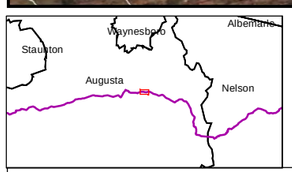
A003-3 a003-3 small sink

A003-2 a003-2 series of 3 small sinks

cCD31 cCD32 cCD33 sCD41

1400 1410 1420 1430 1440 1450 1460 1470

Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User C



- Mileposts (0.1 mile)
- Centerline
- 300' Corridor
- 0.50 KRA
- All Point Features
- All Area Features
- 300' Corridor Closed Depressions
- Suspect Closed Depressions
- Randolph Caves
- Pocahontas Caves
- Virginia Caves

0 250 500
Feet

CONTOUR MAP 149

ATLANTIC COAST PIPELINE

11002.04

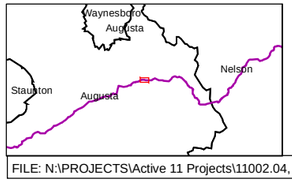
FILE: N:\PROJECTS\Active 11 Projects\11002.04, Dominion Resources Pipeline - Randolph and Pocahontas Co\Final\GIS Data for Final\reportmap Contour.mxd | REVISED: 02/14/2017 | SCALE: 1:3,000 when printed at 11x17

DRAWN BY: JDV

GeoConcepts Engineering, Inc.

1470
1500
1490
1480
1460
1430
1440
1450
150
150.1
150.2
150.3
150.4
150.5
150.6
150.7
150.8
150.9
A032-1
a032 probably man made sink
sCD42

Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID,



Mileposts (0.1 mile)
Centerline
300' Corridor
0.50 KRA
All Point Features
All Area Features
300' Corridor Closed Depressions
Suspect Closed Depressions
Randolph Caves
Pocahontas Caves
Virginia Caves

0 250 500
Feet

CONTOUR MAP 150
ATLANTIC COAST PIPELINE
11002.04

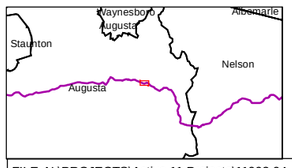
FILE: N:\PROJECTS\Active 11 Projects\11002.04, Dominion Resources Pipeline - Randolph and Pocahontas Co\Final\GIS Data for Final\reportmap Contour.mxd | REVISED: 02/14/2017 | SCALE: 1:3,000 when printed at 11x17

DRAWN BY: JDV

GeoConcepts Engineering, Inc.

150.9
151
151.1
151.2
151.3
151.4
151.5
151.6
151.7
151.8
151.9
cCD34
sCD42
A033-1
a033 small sink
A033-2
a033-2 large steep oblong sink
a033-2 small sink 3
a-033-03
A033-3
1450
1460
1470
1480
1490
1500
1510
1520
1530
1540
1550

Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User



Mileposts (0.1 mile)
Centerline
300' Corridor
0.50 KRA
All Point Features
All Area Features
300' Corridor Closed Depressions
Suspect Closed Depressions
Randolph Caves
Pocahontas Caves
Virginia Caves

0 250 500
Feet

CONTOUR MAP 151

ATLANTIC COAST PIPELINE

11002.04

FILE: N:\PROJECTS\Active 11 Projects\11002.04, Dominion Resources Pipeline - Randolph and Pocahontas Co\Final\GIS Data for Final\reportmap Contour.mxd | REVISED: 02/14/2017 | SCALE: 1:3,000 when printed at 11x17

DRAWN BY: JDV

GeoConcepts Engineering, Inc.

cCD099

sCD43

E032-1

E026-1

e-020-01 oblong sink

151.8 151.9 152 152.1 152.2 152.3 152.4 152.5 152.6

1550 1540 1530 1520 1510 1500 1490 1560

Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS,

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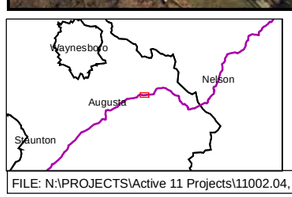


- Mileposts (0.1 mile)
- Centerline
- 300' Corridor
- 0.50 KRA
- All Point Features
- All Area Features
- 300' Corridor Closed Depressions
- Suspect Closed Depressions
- Randolph Caves
- Pocahontas Caves
- Virginia Caves

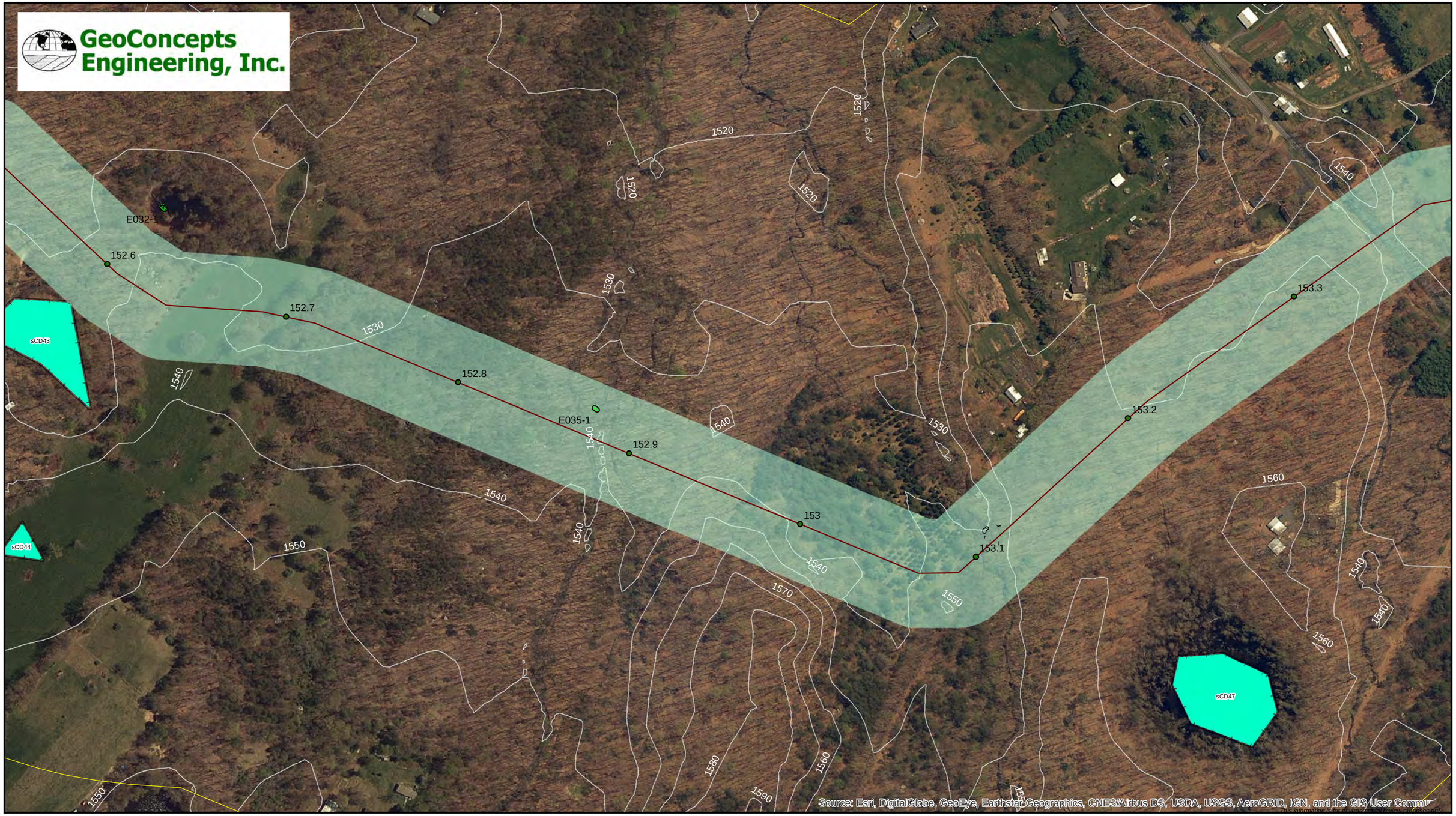
0 250 500
Feet

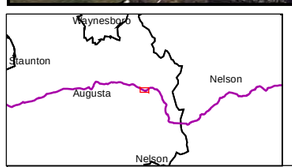
CONTOUR MAP 152
ATLANTIC COAST PIPELINE
11002.04

FILE: N:\PROJECTS\Active 11 Projects\11002.04, Dominion Resources Pipeline - Randolph and Pocahontas Co\Final\GIS Data for Final\reportmap Contour.mxd | REVISED: 02/14/2017 | SCALE: 1:3,000 when printed at 11x17

DRAWN BY: JDV

GeoConcepts Engineering, Inc.





- Mileposts (0.1 mile)
- Centerline
- 300' Corridor
- 0.50 KRA
- All Point Features
- All Area Features
- 300' Corridor Closed Depressions
- Suspect Closed Depressions
- Randolph Caves
- Pocahontas Caves
- Virginia Caves

0 250 500
Feet

CONTOUR MAP 153

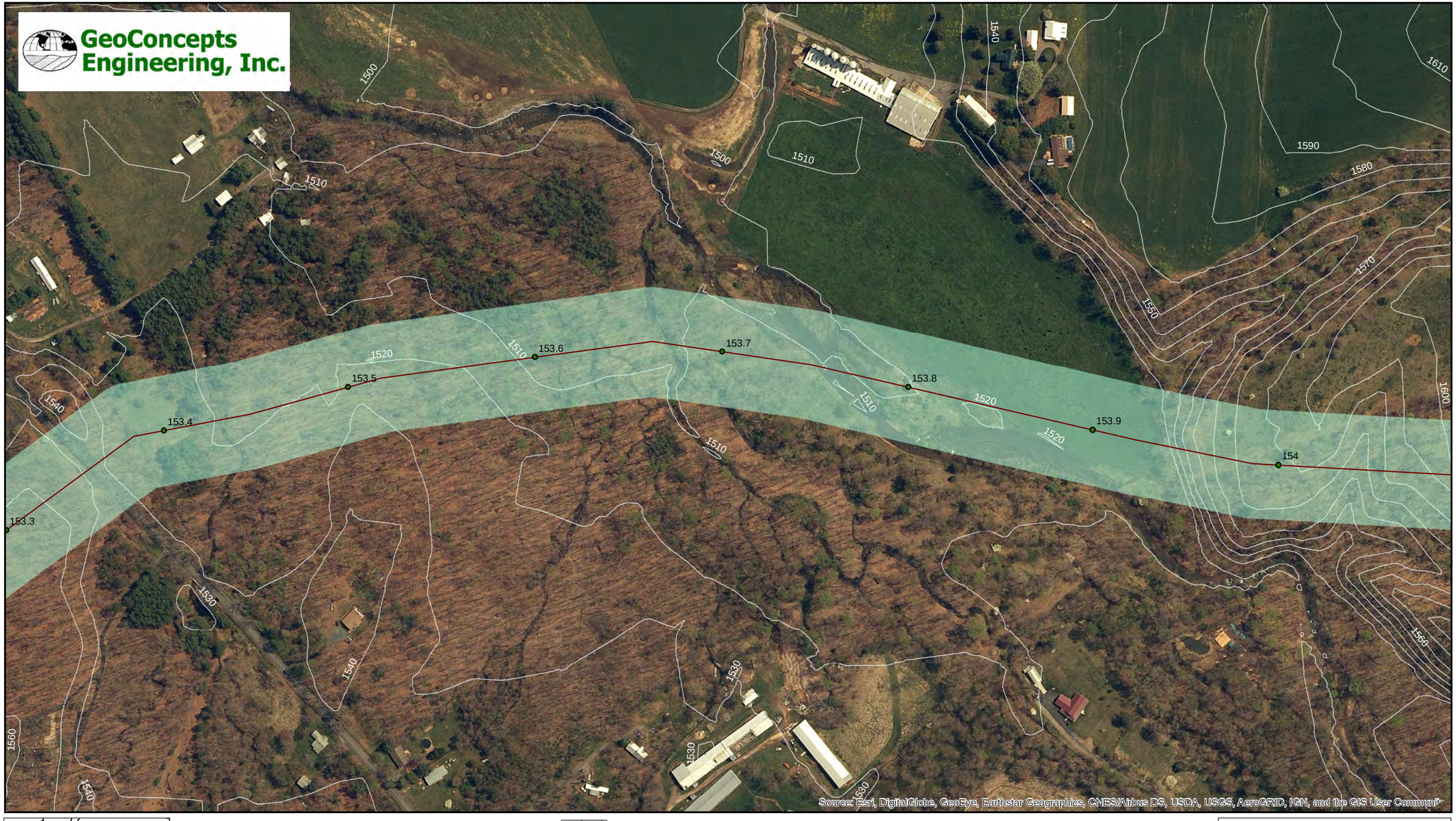
ATLANTIC COAST PIPELINE

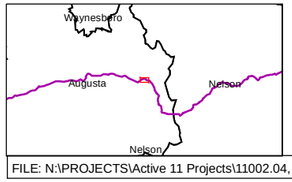
11002.04

FILE: N:\PROJECTS\Active 11 Projects\11002.04, Dominion Resources Pipeline - Randolph and Pocahontas Co\Final\GIS Data for Final\reportmap Contour.mxd | REVISED: 02/14/2017 | SCALE: 1:3,000 when printed at 11x17

DRAWN BY: JDV

GeoConcepts Engineering, Inc.





- Mileposts (0.1 mile)
- Centerline
- 300' Corridor
- 0.50 KRA
- All Point Features
- All Area Features
- 300' Corridor Closed Depressions
- Suspect Closed Depressions
- Randolph Caves
- Pocahontas Caves
- Virginia Caves

0 250 500
Feet

CONTOUR MAP 154

ATLANTIC COAST PIPELINE

11002.04

FILE: N:\PROJECTS\Active 11 Projects\11002.04, Dominion Resources Pipeline - Randolph and Pocahontas Co\Final\GIS Data for Final\reportmap Contour.mxd | REVISED: 02/14/2017 | SCALE: 1:3,000 when printed at 11x17

DRAWN BY: JDV

APPENDIX C
Tables

TABLE 1. Suspect Closed Depressions (Data Review)

Feature_ID	easting	northing	Area_SF	Map Unit	Formation	Geologic Period	State	County
sCD01	2174711.71	13853562.15	10259	O€co	Conococheague Formation	Ordovician - Cambrian	VA	Augusta
sCD02	2172496.98	13859014.30	14982	Ob	Beekmantown Group	Ordovician	VA	Augusta
sCD03	2170894.09	13860006.24	31524	Ob	Beekmantown Group	Ordovician	VA	Augusta
sCD04	2173107.90	13862449.06	25651	Ob	Beekmantown Group	Ordovician	VA	Augusta
sCD05	2171361.21	13865574.48	19059	Ob	Beekmantown Group	Ordovician	VA	Augusta
sCD06	2172108.88	13873784.39	7640	Ob	Beekmantown Group	Ordovician	VA	Augusta
sCD07	2173460.25	13885939.77	8866	Ob	Beekmantown Group	Ordovician	VA	Augusta
sCD08	2173530.46	13887516.31	10076	Ob	Beekmantown Group	Ordovician	VA	Augusta
sCD09	2172419.88	13893260.72	10756	O€co	Conococheague Formation	Ordovician - Cambrian	VA	Augusta
sCD10	2171949.52	13893700.85	10126	O€co	Conococheague Formation	Ordovician - Cambrian	VA	Augusta
sCD11	2172382.06	13892719.33	21478	O€co	Conococheague Formation	Ordovician - Cambrian	VA	Augusta
sCD12	2172098.40	13899441.94	27279	O€co	Conococheague Formation	Ordovician - Cambrian	VA	Augusta
sCD13	2169365.69	13900088.55	5097	O€co	Conococheague Formation	Ordovician - Cambrian	VA	Augusta
sCD14	2173380.84	13862339.74	6908	Ob	Beekmantown Group	Ordovician	VA	Augusta
sCD15	2173665.82	13862309.42	5214	Ob	Beekmantown Group	Ordovician	VA	Augusta
sCD16	2172439.97	13864839.15	5089	Ob	Beekmantown Group	Ordovician	VA	Augusta
sCD17	2171520.44	13857446.48	10641	Ob	Beekmantown Group	Ordovician	VA	Augusta
sCD18	2175194.79	13856731.14	1143	O€co	Conococheague Formation	Ordovician - Cambrian	VA	Augusta
sCD19	2172889.47	13854765.49	5931	O€co	Conococheague Formation	Ordovician - Cambrian	VA	Augusta
sCD20	2173046.15	13854001.88	4499	O€co	Conococheague Formation	Ordovician - Cambrian	VA	Augusta
sCD21	2178922.17	13844495.42	324308	Ob	Beekmantown Group	Ordovician	VA	Augusta
sCD22	2187806.32	13836296.62	7365	Ob	Beekmantown Group	Ordovician	VA	Augusta
sCD23	2169466.15	13900088.03	2959	O€co	Conococheague Formation	Ordovician - Cambrian	VA	Augusta
sCD24	2169559.97	13900628.82	6282	O€co	Conococheague Formation	Ordovician - Cambrian	VA	Augusta
sCD25	2169592.39	13900747.48	10005	O€co	Conococheague Formation	Ordovician - Cambrian	VA	Augusta
sCD26	2170060.65	13901275.18	988	O€co	Conococheague Formation	Ordovician - Cambrian	VA	Augusta
sCD27	2169896.74	13901030.48	1389	O€co	Conococheague Formation	Ordovician - Cambrian	VA	Augusta
sCD28	2169972.64	13901143.05	2640	O€co	Conococheague Formation	Ordovician - Cambrian	VA	Augusta
sCD29	2169971.34	13901082.05	1834	O€co	Conococheague Formation	Ordovician - Cambrian	VA	Augusta
sCD30	2169813.10	13901195.36	6321	O€co	Conococheague Formation	Ordovician - Cambrian	VA	Augusta
sCD31	2170158.59	13901500.45	6490	O€co	Conococheague Formation	Ordovician - Cambrian	VA	Augusta
sCD32	2168855.41	13899184.41	138554	O€co	Conococheague Formation	Ordovician - Cambrian	VA	Augusta
sCD33	2169441.18	13900195.27	2495	O€co	Conococheague Formation	Ordovician - Cambrian	VA	Augusta
sCD37	2216569.69	13811674.70	2402	€e	Elbrook Formation	Cambrian	VA	Augusta
sCD38	2220777.25	13809707.01	11859	€e	Elbrook Formation	Cambrian	VA	Augusta
sCD39	2220466.87	13810093.83	4804	€e	Elbrook Formation	Cambrian	VA	Augusta
sCD40	2220776.12	13810128.34	131	€e	Elbrook Formation	Cambrian	VA	Augusta
sCD41	2221386.06	13805972.20	45139	€wb	Waynesboro Formation	Cambrian	VA	Augusta
sCD42	2223619.38	13802463.04	51390	€wb	Waynesboro Formation	Cambrian	VA	Augusta
sCD43	2226064.38	13795896.42	40690	€s	Shady Dolomite	Cambrian	VA	Augusta
sCD44	2225563.22	13795622.98	5425	€s	Shady Dolomite	Cambrian	VA	Augusta
sCD45	2226589.19	13792455.28	48037	€s	Shady Dolomite	Cambrian	VA	Augusta
sCD46	2226299.84	13792860.38	26373	€s	Shady Dolomite	Cambrian	VA	Augusta
sCD47	2227066.62	13792679.53	28257	€s	Shady Dolomite	Cambrian	VA	Augusta
sCD48	2025894.14	13861118.29	6077	DSu	Ridgeley Sandstone, Helderberg and Cayuga Groups	Lower Devonian - Upper Silurian	VA	Bath
sCD49	2025643.33	13861270.90	2747	DSu	Ridgeley Sandstone, Helderberg and Cayuga Groups	Lower Devonian - Upper Silurian	VA	Bath
sCD50	2027129.53	13859810.35	2920	DSu	Ridgeley Sandstone, Helderberg and Cayuga Groups	Lower Devonian - Upper Silurian	VA	Bath
sCD51	2027123.65	13861013.68	13413	DSu	Ridgeley Sandstone, Helderberg and Cayuga Groups	Lower Devonian - Upper Silurian	VA	Bath
sCD52	2077366.03	13854407.26	1137	DSu	Ridgeley Sandstone, Helderberg and Cayuga Groups	Lower Devonian - Upper Silurian	VA	Bath
sCD53	2078342.02	13854941.46	2074	DSu	Ridgeley Sandstone, Helderberg and Cayuga Groups	Lower Devonian - Upper Silurian	VA	Bath
sCD54	2080996.89	13857340.21	116754	DSu	Ridgeley Sandstone, Helderberg and Cayuga Groups	Lower Devonian - Upper Silurian	VA	Bath
sCD34	1892268.63	13989142.62	11810	Pnnr	New River	Pennsylvanian	WV	Randolph
sCD35	1892528.27	13989054.72	1557	Pnnr	New River	Pennsylvanian	WV	Randolph
sCD36	1896839.69	13982705.59	2641	Pnnr	New River	Pennsylvanian	WV	Randolph
Note: Coordinate System = UTM 17N, US Feet								

TABLE 2. 300-Foot Survey Corridor Closed Depressions (Data Review)

Feature_ID	easting	northing	Map Unit	Geological Formation	Geologic Period	State	County
cCD05	2173217.12	13886049.35	Ob	Beekmantown Group	Ordovician	VA	Augusta
cCD06	2173432.33	13885444.01	Ob	Beekmantown Group	Ordovician	VA	Augusta
cCD07	2173367.51	13885196.72	Ob	Beekmantown Group	Ordovician	VA	Augusta
cCD08	2173522.20	13882093.11	Ob	Beekmantown Group	Ordovician	VA	Augusta
cCD09	2173278.21	13881803.38	Ob	Beekmantown Group	Ordovician	VA	Augusta
cCD10	2172913.64	13881762.49	Ob	Beekmantown Group	Ordovician	VA	Augusta
cCD11	2172934.80	13881126.36	Ob	Beekmantown Group	Ordovician	VA	Augusta
cCD12	2173231.63	13881449.33	Ob	Beekmantown Group	Ordovician	VA	Augusta
cCD13	2172810.10	13879915.67	Ob	Beekmantown Group	Ordovician	VA	Augusta
cCD14	2172254.51	13876973.32	Ob	Beekmantown Group	Ordovician	VA	Augusta
cCD15	2170366.97	13871533.66	O€co	Conococheague Formation	Ordovician - Cambrian	VA	Augusta
cCD16	2171131.73	13866417.14	Ob	Beekmantown Group	Ordovician	VA	Augusta
cCD17	2170899.32	13866374.28	Ob	Beekmantown Group	Ordovician	VA	Augusta
cCD18	2170776.62	13866428.01	Ob	Beekmantown Group	Ordovician	VA	Augusta
cCD19	2182065.35	13845234.23	€e	Elbrook Formation	Cambrian	VA	Augusta
cCD20	2171543.09	13898032.23	O€co	Conococheague Formation	Ordovician - Cambrian	VA	Augusta
cCD21	2189396.57	13836327.28	Ob	Beekmantown Group	Ordovician	VA	Augusta
cCD22	2171347.68	13873419.07	Ob	Beekmantown Group	Ordovician	VA	Augusta
cCD23	2171749.80	13862944.93	Ob	Beekmantown Group	Ordovician	VA	Augusta
cCD24	2172265.92	13859892.35	Ob	Beekmantown Group	Ordovician	VA	Augusta
cCD25	2181656.87	13845162.19	€e	Elbrook Formation	Cambrian	VA	Augusta
cCD31	2222130.67	13806547.55	€wb	Waynesboro Formation	Cambrian	VA	Augusta
cCD32	2221733.10	13807512.83	€e	Elbrook Formation	Cambrian	VA	Augusta
cCD33	2221037.22	13808269.06	€e	Elbrook Formation	Cambrian	VA	Augusta
cCD34	2224215.30	13802207.39	€wb	Waynesboro Formation	Cambrian	VA	Augusta
cCD51	2226557.13	13795764.90	[s	Shady Dolomite	Cambrian	VA	Augusta
cCD62	2096253.94	13875320.21	Dmn	Millboro Shale and Needmore Formation	Devonian	VA	Augusta
cCD99	2226558.38	13798789.67	[wb	Waynesboro Formation	Cambrian	VA	Augusta
cCD100	2187831.28	13836848.01	Ob	Beekmantown Group	Ordovician	VA	Augusta
cCD101	2114241.33	13887823.01	Db	Brallier Formation	Devonian	VA	Augusta
cCD102	2114323.80	13888134.98	Db	Brallier Formation	Devonian	VA	Augusta
cCD103	2114568.13	13888446.33	Db	Brallier Formation	Devonian	VA	Augusta
cCD104	2115265.37	13888691.01	Db	Brallier Formation	Devonian	VA	Augusta
cCD105	2115135.33	13888755.75	Db	Brallier Formation	Devonian	VA	Augusta
cCD106	2115017.45	13888821.97	Db	Brallier Formation	Devonian	VA	Augusta
cCD107	2115114.41	13889094.2	Db	Brallier Formation	Devonian	VA	Augusta
cCD108	2115357.17	13891306.52	Db	Brallier Formation	Devonian	VA	Augusta
cCD109	2118807.66	13893468.62	Db	Brallier Formation	Devonian	VA	Augusta
cCD110	2119117.96	13893709.31	Db	Brallier Formation	Devonian	VA	Augusta
cCD111	2120049.10	13900200.01	Db	Brallier Formation	Devonian	VA	Augusta
cCD112	2112929.44	13885197.56	Db	Brallier Formation	Devonian	VA	Augusta
cCD113	2111176.42	13883796.96	Db	Brallier Formation	Devonian	VA	Augusta
cCD116	2110296.15	13881284.56	Db	Brallier Formation	Devonian	VA	Augusta
cCD117	2183889.25	13843692.3	[e	Elbrook Formation	Cambrian	VA	Augusta
cCD159	2083760.29	13863348.09	DSu	Ridgeley Sandstone, Helderber and Cayuga Groups	Lower Devonian - Upper Silurian	VA	Augusta
cCD160	2084700.06	13863973.47	DSu	Ridgeley Sandstone, Helderber and Cayuga Groups	Lower Devonian - Upper Silurian	VA	Augusta
cCD161	2084720.67	13864020.6	DSu	Ridgeley Sandstone, Helderber and Cayuga Groups	Lower Devonian - Upper Silurian	VA	Augusta
cCD162	2087011.79	13867029.34	DSu	Ridgeley Sandstone, Helderber and Cayuga Groups	Lower Devonian - Upper Silurian	VA	Augusta
cCD163	2089118.67	13867976.37	DSu	Ridgeley Sandstone, Helderber and Cayuga Groups	Lower Devonian - Upper Silurian	VA	Augusta
cCD164	2089882.45	13868213.13	DSu	Ridgeley Sandstone, Helderber and Cayuga Groups	Lower Devonian - Upper Silurian	VA	Augusta
cCD165	2120913.39	13902768.48	Db	Brallier Formation		VA	Augusta
cCD03	2034247.14	13857616.03	Skrt	Keefer Sandstone, Rose Hill and Tuscarora Formations	Silurian	VA	Bath
cCD35	2028870.02	13859749.63	DSu	Ridgeley Sandstone, Helderberg and Cayuga Groups	Lower Devonian - Upper Silurian	VA	Bath
cCD60	2076312.34	13851898.23	Dmn	Millboro Shale and Needmore Formation	Devonian	VA	Bath
cCD61	2076660.00	13852474.44	Dmn	Millboro Shale and Needmore Formation	Devonian	VA	Bath
cCD114	2057053.68	13837297.06	Db	Brallier Formation	Devonian	VA	Bath

cCD115	2057035.96	13837230.99	Db	Brallier Formation	Devonian	VA	Bath
cCD118	2017367.87	13872343.64	Oun	Juniata, Oswego, Martinsburg (Reedsville and Dolly Ridge), Eggleston Formation	Ordovician	VA	Bath
cCD119	2016634.68	13872465.76	Oun	Juniata, Oswego, Martinsburg (Reedsville and Dolly Ridge), Eggleston Formation	Ordovician	VA	Bath
cCD120	2017102.03	13871996.03	Oun	Juniata, Oswego, Martinsburg (Reedsville and Dolly Ridge), Eggleston Formation	Ordovician	VA	Bath
cCD124	2033822.17	13853101.23	DSu	Ridgeley Sandstone, Helderber and Cayuga Groups	Lower Devonian - Upper Silurian	VA	Bath
cCD125	2033607.13	13852855.33	DSu	Ridgeley Sandstone, Helderber and Cayuga Groups	Lower Devonian - Upper Silurian	VA	Bath
cCD126	2033489.21	13852842.98	DSu	Ridgeley Sandstone, Helderber and Cayuga Groups	Lower Devonian - Upper Silurian	VA	Bath
cCD127	2034371.54	13853376.44	DSu	Ridgeley Sandstone, Helderber and Cayuga Groups	Lower Devonian - Upper Silurian	VA	Bath
cCD128	2034433.37	13852498.87	DSu	Ridgeley Sandstone, Helderber and Cayuga Groups	Lower Devonian - Upper Silurian	VA	Bath
cCD129	2033767.38	13852737.79	DSu	Ridgeley Sandstone, Helderber and Cayuga Groups	Lower Devonian - Upper Silurian	VA	Bath
cCD130	2033725.46	13852782.96	DSu	Ridgeley Sandstone, Helderber and Cayuga Groups	Lower Devonian - Upper Silurian	VA	Bath
cCD131	2033583.91	13852786.85	DSu	Ridgeley Sandstone, Helderber and Cayuga Groups	Lower Devonian - Upper Silurian	VA	Bath
cCD132	2034529.92	13852207.98	DSu	Ridgeley Sandstone, Helderber and Cayuga Groups	Lower Devonian - Upper Silurian	VA	Bath
cCD133	2033714.38	13852537.78	DSu	Ridgeley Sandstone, Helderber and Cayuga Groups	Lower Devonian - Upper Silurian	VA	Bath
cCD134	2033599.00	13851379.43	DSu	Ridgeley Sandstone, Helderber and Cayuga Groups	Lower Devonian - Upper Silurian	VA	Bath
cCD135	2033459.51	13850897.93	DSu	Ridgeley Sandstone, Helderber and Cayuga Groups	Lower Devonian - Upper Silurian	VA	Bath
cCD136	2034049.42	13850341.48	DSu	Ridgeley Sandstone, Helderber and Cayuga Groups	Lower Devonian - Upper Silurian	VA	Bath
cCD137	2031861.12	13857426.6	Skrt	Keefer Sandstone, Rose Hill and Tuscarora Formations	Silurian	VA	Bath
cCD138	2031515.59	13857385.51	Skrt	Keefer Sandstone, Rose Hill and Tuscarora Formations	Silurian	VA	Bath
cCD139	2031687.11	13857614.34	Skrt	Keefer Sandstone, Rose Hill and Tuscarora Formations	Silurian	VA	Bath
cCD140	2034396.47	13854574.64	Skrt	Keefer Sandstone, Rose Hill and Tuscarora Formations	Silurian	VA	Bath
cCD141	2034189.44	13854255.06	Skrt	Keefer Sandstone, Rose Hill and Tuscarora Formations	Silurian	VA	Bath
cCD142	2034374.70	13854420.35	Skrt	Keefer Sandstone, Rose Hill and Tuscarora Formations	Silurian	VA	Bath
cCD143	2034383.27	13854509.98	Skrt	Keefer Sandstone, Rose Hill and Tuscarora Formations	Silurian	VA	Bath
cCD144	2034535.40	13854057.23	Skrt	Keefer Sandstone, Rose Hill and Tuscarora Formations	Silurian	VA	Bath
cCD145	2034210.49	13853827.98	Skrt	Keefer Sandstone, Rose Hill and Tuscarora Formations	Silurian	VA	Bath
cCD146	2062630.39	13837988.23	DSu	Ridgeley Sandstone, Helderber and Cayuga Groups	Lower Devonian - Upper Silurian	VA	Bath
cCD147	2077222.72	13853235.7	DSu	Ridgeley Sandstone, Helderber and Cayuga Groups	Lower Devonian - Upper Silurian	VA	Bath
cCD148	2077723.63	13854084.29	DSu	Ridgeley Sandstone, Helderber and Cayuga Groups	Lower Devonian - Upper Silurian	VA	Bath
cCD149	2077837.52	13854118.73	DSu	Ridgeley Sandstone, Helderber and Cayuga Groups	Lower Devonian - Upper Silurian	VA	Bath
cCD150	2081788.75	13860778.95	DSu	Ridgeley Sandstone, Helderber and Cayuga Groups	Lower Devonian - Upper Silurian	VA	Bath
cCD151	2081799.71	13860706.35	DSu	Ridgeley Sandstone, Helderber and Cayuga Groups	Lower Devonian - Upper Silurian	VA	Bath
cCD152	2081773.74	13860616.51	DSu	Ridgeley Sandstone, Helderber and Cayuga Groups	Lower Devonian - Upper Silurian	VA	Bath
cCD153	2083514.29	13860624.59	DSu	Ridgeley Sandstone, Helderber and Cayuga Groups	Lower Devonian - Upper Silurian	VA	Bath
cCD154	2083601.04	13860694.86	DSu	Ridgeley Sandstone, Helderber and Cayuga Groups	Lower Devonian - Upper Silurian	VA	Bath
cCD155	2083590.86	13860560.55	DSu	Ridgeley Sandstone, Helderber and Cayuga Groups	Lower Devonian - Upper Silurian	VA	Bath
cCD156	2083586.45	13860775.29	DSu	Ridgeley Sandstone, Helderber and Cayuga Groups	Lower Devonian - Upper Silurian	VA	Bath
cCD157	2083429.35	13860311.63	DSu	Ridgeley Sandstone, Helderber and Cayuga Groups	Lower Devonian - Upper Silurian	VA	Bath
cCD158	2083513.91	13860562.16	DSu	Ridgeley Sandstone, Helderber and Cayuga Groups	Lower Devonian - Upper Silurian	VA	Bath
cCD01	2007832.18	13891945.05	Skrt	Keefer Sandstone, Rose Hill and Tuscarora Formations	Silurian	VA	Highland
cCD02	2008373.69	13891426.19	Skrt	Keefer Sandstone, Rose Hill and Tuscarora Formations	Silurian	VA	Highland
cCD04	2003451.24	13900029.50	Ols	Mocassin Formation, Bays Formation, Unit C, Unit B, Unit A	Ordovician	VA	Highland
cCD36	1984847.63	13909681.31	Dch	Chemung Formation	Devonian	VA	Highland
cCD37	1985092.11	13909623.77	Dch	Chemung Formation	Devonian	VA	Highland
cCD38	1985461.24	13909507.32	Dch	Chemung Formation	Devonian	WV	Highland
cCD52	1999607.65	13905832.81	Db	Brallier Formation	Devonian	VA	Highland
cCD53	1984742.52	13910850.18	Dch	Chemung Formation	Devonian	VA	Highland
cCD54	1988242.94	13910508.08	Dch	Chemung Formation	Devonian	VA	Highland
cCD55	1998868.55	13908315.78	Dch	Chemung Formation	Devonian	VA	Highland
cCD56	1994245.96	13912615.94	Dch	Chemung Formation	Devonian	VA	Highland
cCD57	2010660.76	13890544.09	Skrt	Keefer Sandstone, Rose Hill and Tuscarora Formations	Silurian	VA	Highland
cCD58	2010582.40	13889638.78	Skrt	Keefer Sandstone, Rose Hill and Tuscarora Formations	Silurian	VA	Highland
cCD59	2010528.62	13889567.75	Skrt	Keefer Sandstone, Rose Hill and Tuscarora Formations	Silurian	VA	Highland
cCD63	2003630.75	13899224.44	Ols	Mocassin Formation, Bays Formation, Unit C, Unit B, Unit A	Ordovician	VA	Highland
cCD64	2003925.98	13899332.11	Ols	Mocassin Formation, Bays Formation, Unit C, Unit B, Unit A	Ordovician	VA	Highland
cCD65	2003868.84	13899119.27	Ols	Mocassin Formation, Bays Formation, Unit C, Unit B, Unit A	Ordovician	VA	Highland
cCD66	2003920.12	13899146.6	Ols	Mocassin Formation, Bays Formation, Unit C, Unit B, Unit A	Ordovician	VA	Highland
cCD67	2003787.64	13898985.15	Ols	Mocassin Formation, Bays Formation, Unit C, Unit B, Unit A	Ordovician	VA	Highland

cCD68	2003677.99	13899077.01	Ols	Mocassin Formation, Bays Formation, Unit C, Unit B, Unit A	Ordovician	VA	Highland
cCD69	2003586.56	13899301.44	Ols	Mocassin Formation, Bays Formation, Unit C, Unit B, Unit A	Ordovician	VA	Highland
cCD70	2004032.49	13898912.16	Ols	Mocassin Formation, Bays Formation, Unit C, Unit B, Unit A	Ordovician	VA	Highland
cCD71	2003996.78	13898800.67	Ols	Mocassin Formation, Bays Formation, Unit C, Unit B, Unit A	Ordovician	VA	Highland
cCD72	2004289.63	13898823.79	Ols	Mocassin Formation, Bays Formation, Unit C, Unit B, Unit A	Ordovician	VA	Highland
cCD73	2004304.83	13898953.28	Ols	Mocassin Formation, Bays Formation, Unit C, Unit B, Unit A	Ordovician	VA	Highland
cCD74	2004341.84	13898698.09	Ols	Mocassin Formation, Bays Formation, Unit C, Unit B, Unit A	Ordovician	VA	Highland
cCD75	2003967.51	13898876.82	Ols	Mocassin Formation, Bays Formation, Unit C, Unit B, Unit A	Ordovician	VA	Highland
cCD76	2003546.93	13898845.49	Ols	Mocassin Formation, Bays Formation, Unit C, Unit B, Unit A	Ordovician	VA	Highland
cCD77	2004118.63	13898962.98	Ols	Mocassin Formation, Bays Formation, Unit C, Unit B, Unit A	Ordovician	VA	Highland
cCD78	2004173.95	13898938.54	Ols	Mocassin Formation, Bays Formation, Unit C, Unit B, Unit A	Ordovician	VA	Highland
cCD79	2004031.04	13899272.39	Ols	Mocassin Formation, Bays Formation, Unit C, Unit B, Unit A	Ordovician	VA	Highland
cCD80	2004324.79	13898429.76	Ols	Mocassin Formation, Bays Formation, Unit C, Unit B, Unit A	Ordovician	VA	Highland
cCD81	2004515.01	13898158.45	Ols	Mocassin Formation, Bays Formation, Unit C, Unit B, Unit A	Ordovician	VA	Highland
cCD82	2004519.48	13898086.58	Ols	Mocassin Formation, Bays Formation, Unit C, Unit B, Unit A	Ordovician	VA	Highland
cCD83	2004269.26	13898268.56	Ols	Mocassin Formation, Bays Formation, Unit C, Unit B, Unit A	Ordovician	VA	Highland
cCD84	2003879.13	13898604.24	Ols	Mocassin Formation, Bays Formation, Unit C, Unit B, Unit A	Ordovician	VA	Highland
cCD85	2003496.73	13899150.78	Ols	Mocassin Formation, Bays Formation, Unit C, Unit B, Unit A	Ordovician	VA	Highland
cCD86	2003535.26	13899294.03	Ols	Mocassin Formation, Bays Formation, Unit C, Unit B, Unit A	Ordovician	VA	Highland
cCD87	2003513.04	13899015.6	Ols	Mocassin Formation, Bays Formation, Unit C, Unit B, Unit A	Ordovician	VA	Highland
cCD88	2003459.71	13898900.55	Ols	Mocassin Formation, Bays Formation, Unit C, Unit B, Unit A	Ordovician	VA	Highland
cCD89	2003447.38	13898799.07	Ols	Mocassin Formation, Bays Formation, Unit C, Unit B, Unit A	Ordovician	VA	Highland
cCD90	2003459.50	13898627.87	Ols	Mocassin Formation, Bays Formation, Unit C, Unit B, Unit A	Ordovician	VA	Highland
cCD91	2003459.13	13899254.53	Ols	Mocassin Formation, Bays Formation, Unit C, Unit B, Unit A	Ordovician	VA	Highland
cCD92	2003628.28	13899586.92	Ols	Mocassin Formation, Bays Formation, Unit C, Unit B, Unit A	Ordovician	VA	Highland
cCD93	2003865.36	13899480.11	Ols	Mocassin Formation, Bays Formation, Unit C, Unit B, Unit A	Ordovician	VA	Highland
cCD94	2003750.58	13899379.66	Ols	Mocassin Formation, Bays Formation, Unit C, Unit B, Unit A	Ordovician	VA	Highland
cCD95	2003806.78	13899355.09	Ols	Mocassin Formation, Bays Formation, Unit C, Unit B, Unit A	Ordovician	VA	Highland
cCD96	2004033.67	13899350.68	Ols	Mocassin Formation, Bays Formation, Unit C, Unit B, Unit A	Ordovician	VA	Highland
cCD97	2003958.88	13899217.59	Ols	Mocassin Formation, Bays Formation, Unit C, Unit B, Unit A	Ordovician	VA	Highland
cCD98	2004203.88	13898901.1	Ols	Mocassin Formation, Bays Formation, Unit C, Unit B, Unit A	Ordovician	VA	Highland
cCD121	2011749.71	13885338.59	Dmn	Millboro Shale and Needmore Formation	Devonian	VA	Highland
cCD122	2011655.45	13883993.01	Dmn	Millboro Shale and Needmore Formation	Devonian	VA	Highland
cCD123	2011756.58	13883474.82	Dmn	Millboro Shale and Needmore Formation	Devonian	VA	Highland
cCD26	1911837.45	13940476.95	Mh	Hinton	Mississippian	WV	Pocahontas
cCD39	1967193.82	13910353.40	Db	Brallier	Devonian	WV	Pocahontas
cCD40	1957956.21	13913652.72	Dohl	Oriskany Sandstone	Devonian	WV	Pocahontas
cCD41	1958592.42	13914748.98	Dohl	Oriskany Sandstone	Devonian	WV	Pocahontas
cCD42	1953135.96	13916073.80	Db	Brallier	Devonian	WV	Pocahontas
cCD43	1953082.33	13915912.64	Db	Brallier	Devonian	WV	Pocahontas
cCD44	1929028.82	13921405.67	Mp	Pocono	Mississippian	WV	Pocahontas
cCD45	1924724.91	13923284.16	Mg	Greenbrier	Mississippian	WV	Pocahontas
cCD46	1910029.82	13963378.21	Mg	Greenbrier	Mississippian	WV	Pocahontas
cCD166	1924118.776	13924652.95	Mg	Greenbrier	Mississippian	WV	Pocahontas
cCD167	1924315.805	13924705.96	Mg	Greenbrier	Mississippian	WV	Pocahontas
cCD168	1923185.374	13925899.55	Mg	Greenbrier	Mississippian	WV	Pocahontas
cCD169	1923116.277	13925714.18	Mg	Greenbrier	Mississippian	WV	Pocahontas
cCD170	1912688.433	13929853.07	Mg	Greenbrier	Mississippian	WV	Pocahontas
cCD171	1911943.362	13930778.44	Mg	Greenbrier	Mississippian	WV	Pocahontas
cCD172	1911562.636	13930923.47	Mg	Greenbrier	Mississippian	WV	Pocahontas
cCD173	1913615.786	13951011.98	Mg	Greenbrier	Mississippian	WV	Pocahontas
cCD174	1912728.477	13955225.91	Mg	Greenbrier	Mississippian	WV	Pocahontas
cCD175	1912800.192	13955633.44	Mg	Greenbrier	Mississippian	WV	Pocahontas
cCD176	1913221.157	13955542.07	Mg	Greenbrier	Mississippian	WV	Pocahontas
cCD177	1912397.005	13955550.76	Mg	Greenbrier	Mississippian	WV	Pocahontas
cCD178	1912291.817	13955685.07	Mg	Greenbrier	Mississippian	WV	Pocahontas
cCD179	1912581.788	13956433.49	Mg	Greenbrier	Mississippian	WV	Pocahontas
cCD180	1912676.994	13956330.32	Mg	Greenbrier	Mississippian	WV	Pocahontas

cCD181	1912767.824	13956403.53	Mg	Greenbrier	Mississippian	WV	Pocahontas
cCD182	1912788.955	13956319.74	Mg	Greenbrier	Mississippian	WV	Pocahontas
cCD183	1911909.787	13956716.86	Mg	Greenbrier	Mississippian	WV	Pocahontas
cCD184	1911803.096	13956556.83	Mg	Greenbrier	Mississippian	WV	Pocahontas
cCD185	1912512.314	13957246.87	Mg	Greenbrier	Mississippian	WV	Pocahontas
cCD186	1912631.125	13958450.77	Mg	Greenbrier	Mississippian	WV	Pocahontas
cCD187	1936638.01	13921867.79	Dhs	Hampshire	Devonian	WV	Pocahontas
cCD188	1913379.95	13942660.21	Mbf	Bluefield	Mississippian	WV	Pocahontas
cCD189	1913355.137	13950927.02	Mbf	Bluefield	Mississippian	WV	Pocahontas
cCD190	1913444.397	13950828.52	Mbf	Bluefield	Mississippian	WV	Pocahontas
cCD191	1910778.064	13956294.44	Mbf	Bluefield	Mississippian	WV	Pocahontas
cCD192	1911503.478	13958396.89	Mbf	Bluefield	Mississippian	WV	Pocahontas
cCD193	1911646.221	13958249.23	Mbf	Bluefield	Mississippian	WV	Pocahontas
cCD194	1911954.874	13958682.01	Mbf	Bluefield	Mississippian	WV	Pocahontas
cCD195	1911506.703	13959720.62	Mbf	Bluefield	Mississippian	WV	Pocahontas
cCD196	1911134.224	13959840.09	Mbf	Bluefield	Mississippian	WV	Pocahontas
cCD197	1911344.46	13959968.58	Mbf	Bluefield	Mississippian	WV	Pocahontas
cCD198	1910550.294	13961217.43	Mbf	Bluefield	Mississippian	WV	Pocahontas
cCD214	1961698.565	13910594.16	Dohl	Oriskany Sandstone	Devonian	WV	Pocahontas
cCD215	1961756.643	13910685.62	Dohl	Oriskany Sandstone	Devonian	WV	Pocahontas
cCD216	1961766.256	13910821.89	Dohl	Oriskany Sandstone	Devonian	WV	Pocahontas
cCD217	1961766.359	13910885.21	Dohl	Oriskany Sandstone	Devonian	WV	Pocahontas
cCD218	1961714.49	13910971.2	Dohl	Oriskany Sandstone	Devonian	WV	Pocahontas
cCD219	1961706.56	13911011.58	Dohl	Oriskany Sandstone	Devonian	WV	Pocahontas
cCD220	1961758.324	13911136.32	Dohl	Oriskany Sandstone	Devonian	WV	Pocahontas
cCD221	1961876.098	13911122.94	Dohl	Oriskany Sandstone	Devonian	WV	Pocahontas
cCD222	1961878.694	13911333.2	Dohl	Oriskany Sandstone	Devonian	WV	Pocahontas
cCD223	1961821.993	13911255.75	Dohl	Oriskany Sandstone	Devonian	WV	Pocahontas
cCD224	1962074.64	13911612.36	Dohl	Oriskany Sandstone	Devonian	WV	Pocahontas
cCD225	1964206.762	13910194.36	Dmb	Harrell, Mahantango, Marcellus	Devonian	WV	Pocahontas
cCD226	1908230.497	13933653.12	Mh	Hinton	Mississippian	WV	Pocahontas
cCD227	1908040.024	13933608.86	Mh	Hinton	Mississippian	WV	Pocahontas
cCD228	1908525.875	13934829.94	Mh	Hinton	Mississippian	WV	Pocahontas
cCD229	1908496.443	13934681.28	Mh	Hinton	Mississippian	WV	Pocahontas
cCD230	1908782.061	13934640.34	Mh	Hinton	Mississippian	WV	Pocahontas
cCD231	1908574.948	13934428.02	Mh	Hinton	Mississippian	WV	Pocahontas
cCD232	1908426.033	13934364.47	Mh	Hinton	Mississippian	WV	Pocahontas
cCD233	1961528.41	13911010.11	Stw	Tonoloway, Wills Creek, Williamsport	Silurian	WV	Pocahontas
cCD234	1961668.134	13911373.98	Stw	Tonoloway, Wills Creek, Williamsport	Silurian	WV	Pocahontas
cCD235	1961704.276	13911343.56	Stw	Tonoloway, Wills Creek, Williamsport	Silurian	WV	Pocahontas
cCD236	1961628.091	13911251.2	Stw	Tonoloway, Wills Creek, Williamsport	Silurian	WV	Pocahontas
cCD237	1961770.486	13911288.71	Stw	Tonoloway, Wills Creek, Williamsport	Silurian	WV	Pocahontas
cCD238	1961837.181	13911375.42	Stw	Tonoloway, Wills Creek, Williamsport	Silurian	WV	Pocahontas
cCD239	1961802.678	13911507.15	Stw	Tonoloway, Wills Creek, Williamsport	Silurian	WV	Pocahontas
cCD240	1961646.578	13911641.52	Stw	Tonoloway, Wills Creek, Williamsport	Silurian	WV	Pocahontas
cCD241	1961631.697	13911704.8	Stw	Tonoloway, Wills Creek, Williamsport	Silurian	WV	Pocahontas
cCD242	1961835.329	13911704.34	Stw	Tonoloway, Wills Creek, Williamsport	Silurian	WV	Pocahontas
cCD243	1961752.241	13911828.03	Stw	Tonoloway, Wills Creek, Williamsport	Silurian	WV	Pocahontas
cCD244	1961668.962	13911895.64	Stw	Tonoloway, Wills Creek, Williamsport	Silurian	WV	Pocahontas
cCD245	1961811.102	13911871.8	Stw	Tonoloway, Wills Creek, Williamsport	Silurian	WV	Pocahontas
cCD246	1961873.767	13911863.12	Stw	Tonoloway, Wills Creek, Williamsport	Silurian	WV	Pocahontas
cCD247	1962035.19	13911823.67	Stw	Tonoloway, Wills Creek, Williamsport	Silurian	WV	Pocahontas
cCD248	1962154.655	13911968.88	Stw	Tonoloway, Wills Creek, Williamsport	Silurian	WV	Pocahontas
cCD249	1961668.944	13912030.82	Stw	Tonoloway, Wills Creek, Williamsport	Silurian	WV	Pocahontas
cCD250	1961940.927	13912086.25	Stw	Tonoloway, Wills Creek, Williamsport	Silurian	WV	Pocahontas
cCD251	1962065.193	13912143.32	Stw	Tonoloway, Wills Creek, Williamsport	Silurian	WV	Pocahontas
cCD252	1962081.61	13912061.1	Stw	Tonoloway, Wills Creek, Williamsport	Silurian	WV	Pocahontas
cCD253	1962261.57	13912114.66	Stw	Tonoloway, Wills Creek, Williamsport	Silurian	WV	Pocahontas

cCD254	1910626.333	13937438.66	Mbp	Bluestone, Princeton	Mississippian	WV	Pocahontas
cCD255	1910376.613	13937342.88	Mbp	Bluestone, Princeton	Mississippian	WV	Pocahontas
cCD256	1912208.827	13938906.84	Mbp	Bluestone, Princeton	Mississippian	WV	Pocahontas
cCD257	1961309.958	13912269.13	Smc	McKenzie	Silurian	WV	Pocahontas
cCD258	1915730.241	13927217.36	Mh	Hinton	Mississippian	WV	Pocahontas
cCD259	1961645.755	13911016.74	Stw	Tonoloway, Wills Creek, Williamsport	Silurian	WV	Pocahontas
cCD260	1961622.006	13910979.13	Stw	Tonoloway, Wills Creek, Williamsport	Silurian	WV	Pocahontas
cCD261	1961991.296	13911617.04	Stw	Tonoloway, Wills Creek, Williamsport	Silurian	WV	Pocahontas
cCD262	1911222.812	13937212.45	Mh	Hinton	Mississippian	WV	Pocahontas
cCD27	1891738.66	13988909.97	Pnnr	New River	Pennsylvanian	WV	Randolph
cCD28	1891724.14	13988768.11	Pnnr	New River	Pennsylvanian	WV	Randolph
cCD29	1895499.57	13986358.47	Pnnr	New River	Pennsylvanian	WV	Randolph
cCD30	1897258.69	13982898.79	Pnnr	New River	Pennsylvanian	WV	Randolph
cCD47	1887175.50	14001215.31	Pnnr	New River	Pennsylvanian	WV	Randolph
cCD48	1887280.76	14000969.68	Pnnr	New River	Pennsylvanian	WV	Randolph
cCD49	1880061.91	14029769.83	Pnk	Kanawha	Pennsylvanian	WV	Randolph
cCD50	1880326.21	14029714.79	Pnk	Kanawha	Pennsylvanian	WV	Randolph
cCD199	1887299.781	13997874.65	Mbf	Bluefield	Mississippian	WV	Randolph
cCD200	1880926.298	14020753.16	Pnk	Kanawha	Pennsylvanian	WV	Randolph
cCD201	1881483.774	14020517.44	Pnk	Kanawha	Pennsylvanian	WV	Randolph
cCD202	1881490.295	14021155.92	Pnk	Kanawha	Pennsylvanian	WV	Randolph
cCD203	1881820.031	14022449.47	Pnk	Kanawha	Pennsylvanian	WV	Randolph
cCD204	1881500.966	14025205.17	Pnk	Kanawha	Pennsylvanian	WV	Randolph
cCD205	1881699.23	14026587.14	Pnk	Kanawha	Pennsylvanian	WV	Randolph
cCD206	1881819.809	14027524.66	Pnk	Kanawha	Pennsylvanian	WV	Randolph
cCD207	1880062.226	14029770.12	Pnk	Kanawha	Pennsylvanian	WV	Randolph
cCD208	1880326.844	14029714.62	Pnk	Kanawha	Pennsylvanian	WV	Randolph
cCD209	1880753.599	14030479.32	Pnk	Kanawha	Pennsylvanian	WV	Randolph
cCD210	1881401.983	14033080.96	Pnk	Kanawha	Pennsylvanian	WV	Randolph
cCD211	1882267.929	14035515.32	Pnk	Kanawha	Pennsylvanian	WV	Randolph
cCD212	1880741.734	14030991.37	Pnnr	New River	Pennsylvanian	WV	Randolph
cCD213	1890098.783	14051462.82	Pnnr	New River	Pennsylvanian	WV	Randolph
cCD263	1887206.725	13998800.77	Mh	Hinton	Mississippian	WV	Randolph
cCD264	1887469.499	13998875.93	Mh	Hinton	Mississippian	WV	Randolph
cCD265	1887161.62	14002082.83	Pnnr	New River	Pennsylvanian	WV	Randolph
Note: Coordinate System = UTM 17N, US Feet							

TABLE 3. LIDAR Sinks (Data Review)

Feature_ID	easting	northing	Map Unit	Formation	Geologic Period
LS01	2189865.78	13836543.15	Ob	Beekmantown Group	Ordovician
LS02	2188851.75	13837227.57	Ob	Beekmantown Group	Ordovician
LS03	2187848.27	13838300.49	Ob	Beekmantown Group	Ordovician
LS04	2183886.03	13843708.04	€e	Elbrook Formation	Cambrian
LS05	2170064.31	13901284.29	O€co	Conococheague Formation	Ordovician - Cambrian
LS06	2169972.19	13901140.36	O€co	Conococheague Formation	Ordovician - Cambrian
LS07	2169972.19	13901088.54	O€co	Conococheague Formation	Ordovician - Cambrian
LS08	2169891.59	13901036.73	O€co	Conococheague Formation	Ordovician - Cambrian
LS09	2169580.70	13900754.63	O€co	Conococheague Formation	Ordovician - Cambrian
LS10	2169580.70	13900633.72	O€co	Conococheague Formation	Ordovician - Cambrian
LS11	2170146.32	13901494.47	O€co	Conococheague Formation	Ordovician - Cambrian
LS12	2190341.01	13836188.70	Ob	Beekmantown Group	Ordovician
LS13	2190429.55	13836129.67	Ob	Beekmantown Group	Ordovician
LS14	2190243.78	13836105.37	Ob	Beekmantown Group	Ordovician
LS15	2187835.53	13836858.66	Ob	Beekmantown Group	Ordovician
LS16	2187662.92	13838546.07	Ob	Beekmantown Group	Ordovician
LS17	2187782.71	13838314.30	Ob	Beekmantown Group	Ordovician
LS18	2187773.60	13838332.52	Ob	Beekmantown Group	Ordovician
LS19	2226549.16	13798795.85	€wb	Waynesboro Formation	Cambrian
LS20	2226800.50	13792985.14	€s	Shady Dolomite	Cambrian
Note: Coordinate System = UTM 17N, US Feet					

TABLE 4. Area Features (Field Survey)

Feature ID	easting	northing	Risk_Rank	Karst_ID	Map Unit	Formation	Geologic Period	State	County
a-033-03	2225302.605	13800992.44	Low	Sinkhole	[wb	Waynesboro Formation	Cambrian	VA	Augusta
A033-2	2225210.44	13800926.78	Moderate	Sinkhole	€wb	Waynesboro Formation	Cambrian	VA	Augusta
a033-2	2225206.477	13800896.73	Low	Sinkhole	[wb	Waynesboro Formation	Cambrian	VA	Augusta
A033-3	2225306.53	13801022.33	Low	Sinkhole	€wb	Waynesboro Formation	Cambrian	VA	Augusta
A106-1	2172337.05	13860247.54	High	Sinkhole	Ob	Beekmantown Group	Ordovician	VA	Augusta
a106-1	2172330.696	13860217.7	Moderate	Sinkhole	Ob	Beekmantown Group	Ordovician	VA	Augusta
A131-1	2178853.65	13846885.71	High	Sinkhole	Ob	Beekmantown Group	Ordovician	VA	Augusta
a132-1	2178849.496	13846855.73	Moderate	Sinkhole	Ob	Beekmantown Group	Ordovician	VA	Augusta
A132-2	2179221.71	13846325.10	High	Sinkhole	Ob	Beekmantown Group	Ordovician	VA	Augusta
a132-2	2179216.26	13846296	Moderate	Sinkhole	Ob	Beekmantown Group	Ordovician	VA	Augusta
A148-1	2192273.40	13833374.62	High	Sinkhole	Oeln	Edinburg Formation, Lincholnshire and New Market Limestones	Ordovician	VA	Augusta
a148-1	2192270.448	13833344.71	Low	Sinkhole	Oeln	Edinburg Formation, Lincholnshire and New Market Limestones	Ordovician	VA	Augusta
A148-2	2192543.50	13833041.26	High	Sinkhole	Oeln	Edinburg Formation, Lincholnshire and New Market Limestones	Ordovician	VA	Augusta
a148-2	2192540.403	13833010.14	Low	Sinkhole	Oeln	Edinburg Formation, Lincholnshire and New Market Limestones	Ordovician	VA	Augusta
A162-1	2210936.57	13817641.23	High	Sinkhole	O€co	Conococheague Formation	Ordovician - Cambrian	VA	Augusta
a162-1	2210933.171	13817610.49	High	Sinkhole	O[co	Conococheague Formation	Ordovician - Cambrian	VA	Augusta
A162-2	2211059.84	13817441.55	Moderate	Sinkhole	O€co	Conococheague Formation	Ordovician - Cambrian	VA	Augusta
a162-2	2211055.161	13817411.18	High	Sinkhole	O[co	Conococheague Formation	Ordovician - Cambrian	VA	Augusta
A162-3	2211386.25	13817042.79	Moderate	Sinkhole	O€co	Conococheague Formation	Ordovician - Cambrian	VA	Augusta
a162-3	2211383.05	13817012.76	High	Sinkhole	O[co	Conococheague Formation	Ordovician - Cambrian	VA	Augusta
A165-1	2211813.52	13816398.29	High	Sinkhole	€e	Elbrook Formation	Cambrian	VA	Augusta
a165-1	2211809.68	13816368.29	Moderate	Sinkhole	[e	Elbrook Formation	Cambrian	VA	Augusta
A165-2	2211722.85	13816685.96	Moderate	Sinkhole	O€co	Conococheague Formation	Ordovician - Cambrian	VA	Augusta
a165-2	2211719.104	13816655.22	High	Sinkhole	O[co	Conococheague Formation	Ordovician - Cambrian	VA	Augusta
D006-1	2213304.81	13814867.99	Moderate	Sinkhole	€e	Elbrook Formation	Cambrian	VA	Augusta
d006-1	2213300.713	13814837.19	High	Sinkhole	[e	Elbrook Formation	Cambrian	VA	Augusta
36-024-1	2028572.562	13859889.79	Moderate	Sinkhole	DSu	Ridgeley Sandstone, Helderber and Cayuga Groups	Lower Devonian - Upper Silurian	VA	Bath
c009	2003453.09	13899845.3	Moderate	Sinkhole	Ols	Mocassin Formation, Bays Formation, Unit C, Unit B, Unit A	Ordovician	VA	Highland
C009-1	2003453.40	13899874.21	High	Sinkhole	Ols	Mocassin Formation, Bays Formation, Unit C, Unit B, Unit A	Ordovician	VA	Highland
C010-1	2003628.31	13899613.92	High	Sinkhole	Ols	Mocassin Formation, Bays Formation, Unit C, Unit B, Unit A	Ordovician	VA	Highland
c010-1	2003626.637	13899584.2	Low	Sinkhole	Ols	Mocassin Formation, Bays Formation, Unit C, Unit B, Unit A	Ordovician	VA	Highland
C010-10	2003956.55	13899261.10	Moderate	Sinkhole	Ols	Mocassin Formation, Bays Formation, Unit C, Unit B, Unit A	Ordovician	VA	Highland
c010-10	2003951.959	13899231.8	Low	Sinkhole	Ols	Mocassin Formation, Bays Formation, Unit C, Unit B, Unit A	Ordovician	VA	Highland
C010-11	2003789.34	13899010.95	Moderate	Sinkhole	Ols	Mocassin Formation, Bays Formation, Unit C, Unit B, Unit A	Ordovician	VA	Highland
c010-11	2003784.45	13898982.06	Moderate	Sinkhole	Ols	Mocassin Formation, Bays Formation, Unit C, Unit B, Unit A	Ordovician	VA	Highland
C010-12	2004025.45	13898946.27	High	Sinkhole	Ols	Mocassin Formation, Bays Formation, Unit C, Unit B, Unit A	Ordovician	VA	Highland
c010-2	2003793.38	13899452.49	Moderate	Sinkhole	Ols	Mocassin Formation, Bays Formation, Unit C, Unit B, Unit A	Ordovician	VA	Highland
c010-2	2003789.471	13899421.51	Low	Sinkhole	Ols	Mocassin Formation, Bays Formation, Unit C, Unit B, Unit A	Ordovician	VA	Highland
C010-3	2003594.33	13899321.74	High	Cave	Ols	Mocassin Formation, Bays Formation, Unit C, Unit B, Unit A	Ordovician	VA	Highland
c010-3	2003588.855	13899291.66	High	Sinkhole	Ols	Mocassin Formation, Bays Formation, Unit C, Unit B, Unit A	Ordovician	VA	Highland
C010-5	2003746.03	13899360.73	High	Sinkhole	Ols	Mocassin Formation, Bays Formation, Unit C, Unit B, Unit A	Ordovician	VA	Highland
c010-5	2003744.327	13899332.06	High	Sinkhole	Ols	Mocassin Formation, Bays Formation, Unit C, Unit B, Unit A	Ordovician	VA	Highland
C010-6	2003917.16	13899368.21	High	Sinkhole	Ols	Mocassin Formation, Bays Formation, Unit C, Unit B, Unit A	Ordovician	VA	Highland
c010-6	2003914.437	13899338.03	Moderate	Sinkhole	Ols	Mocassin Formation, Bays Formation, Unit C, Unit B, Unit A	Ordovician	VA	Highland
C010-9	2003891.64	13899155.63	High	Sinkhole	Ols	Mocassin Formation, Bays Formation, Unit C, Unit B, Unit A	Ordovician	VA	Highland
c010-9	2003888.868	13899126.77	High	Sinkhole	Ols	Mocassin Formation, Bays Formation, Unit C, Unit B, Unit A	Ordovician	VA	Highland
c011-1	2004021.408	13898917.22	Moderate	Sinkhole	Ols	Mocassin Formation, Bays Formation, Unit C, Unit B, Unit A	Ordovician	VA	Highland
C011-6	2004557.41	13898418.50	High	Sinkhole	Ols	Mocassin Formation, Bays Formation, Unit C, Unit B, Unit A	Ordovician	VA	Highland
c011-6	2004554.698	13898388.23	Moderate	Sinkhole	Ols	Mocassin Formation, Bays Formation, Unit C, Unit B, Unit A	Ordovician	VA	Highland
C025-1	2007902.85	13892345.18	High	Sinkhole	Skrt	Keefer Sandstone, Rose Hill and Tuscarora Formations	Silurian	VA	Highland
C025-2	2007973.29	13892344.99	High	Sinkhole	Skrt	Keefer Sandstone, Rose Hill and Tuscarora Formations	Silurian	VA	Highland
C028-1	2007797.65	13892539.50	High	Sinkhole	Skrt	Keefer Sandstone, Rose Hill and Tuscarora Formations	Silurian	VA	Highland
c028-1	2007797.072	13892508.88	Moderate	Sinkhole	Skrt	Keefer Sandstone, Rose Hill and Tuscarora Formations	Silurian	VA	Highland
c028-2	2007968.86	13892313.99	Moderate	Sinkhole	Skrt	Keefer Sandstone, Rose Hill and Tuscarora Formations	Silurian	VA	Highland
c028-3	2007897.224	13892310.02	Moderate	Sinkhole	Skrt	Keefer Sandstone, Rose Hill and Tuscarora Formations	Silurian	VA	Highland
C028-4	2007865.34	13892306.19	High	Sinkhole	Skrt	Keefer Sandstone, Rose Hill and Tuscarora Formations	Silurian	VA	Highland

Table 4 - Field_area_all Formatted (Updated).xls

c028-4	2007863.018	13892272.29	Moderate	Sinkhole	Skrt	Keefer Sandstone, Rose Hill and Tuscarora Formations	Silurian	VA	Highland
C028-5	2008072.91	13892145.78	High	Sinkhole	Skrt	Keefer Sandstone, Rose Hill and Tuscarora Formations	Silurian	VA	Highland
c028-5	2008067.273	13892111.12	Moderate	Sinkhole	Skrt	Keefer Sandstone, Rose Hill and Tuscarora Formations	Silurian	VA	Highland
C028-6	2008090.06	13892086.66	High	Sinkhole	Skrt	Keefer Sandstone, Rose Hill and Tuscarora Formations	Silurian	VA	Highland
c028-6	2008089.319	13892055.98	Moderate	Sinkhole	Skrt	Keefer Sandstone, Rose Hill and Tuscarora Formations	Silurian	VA	Highland
C030-1	2011317.06	13889600.53	High	Sinkhole	DSu	Ridgeley Sandstone, Helderber and Cayuga Groups	Lower Devonian - Upper Silurian	VA	Highland
C030-2	2010671.80	13890561.13	High	Sinkhole	Skrt	Keefer Sandstone, Rose Hill and Tuscarora Formations	Silurian	VA	Highland
c032-1	2010666.31	13890529.3	Moderate	Sinkhole	Skrt	Keefer Sandstone, Rose Hill and Tuscarora Formations	Silurian	VA	Highland
c032-2	2011313.016	13889569.17	Moderate	Sinkhole	DSu	Ridgeley Sandstone, Helderber and Cayuga Groups	Lower Devonian - Upper Silurian	VA	Highland
E023-2	1913593.98	13951026.95	High	Sinkhole	Mg	Greenbrier	Mississippian	WV	Pocahontas
e023-2	1913605.065	13951010.88	High	Sinkhole	Mg	Greenbrier	Mississippian	WV	Pocahontas
E028-3	1911982.64	13930729.45	High	Sinkhole	Mg	Greenbrier	Mississippian	WV	Pocahontas
e028-3	1911973.797	13930703.1	Moderate	Sinkhole	Mg	Greenbrier	Mississippian	WV	Pocahontas
E030-1	1923228.721	13925847.36	Low	Sinkhole	Mg	Greenbrier	Mississippian	WV	Pocahontas
e030-6	1921967.961	13925792.88	Low	Sinkhole	Mg	Greenbrier	Mississippian	WV	Pocahontas
E031-1	1921971.30	13925822.78	High	Sinkhole	Mg	Greenbrier	Mississippian	WV	Pocahontas
E031-2	1921950.93	13925876.46	Moderate	Sinkhole	Mg	Greenbrier	Mississippian	WV	Pocahontas
E032-2	1923232.38	13925878.76	High	Sinkhole	Mg	Greenbrier	Mississippian	WV	Pocahontas
E033-2	1924310.82	13924730.82	High	Sinkhole	Mg	Greenbrier	Mississippian	WV	Pocahontas
e033-2	1924309.605	13924700.55	Low	Sinkhole	Mg	Greenbrier	Mississippian	WV	Pocahontas
E033-3	1924118.84	13924695.27	High	Sinkhole	Mg	Greenbrier	Mississippian	WV	Pocahontas
e033-3	1924115.335	13924663.31	Moderate	Sinkhole	Mg	Greenbrier	Mississippian	WV	Pocahontas
E033-4	1924462.99	13923326.25	High	Sinkhole	Mg	Greenbrier	Mississippian	WV	Pocahontas
e033-4	1924460.072	13923295.79	Moderate	Sinkhole	Mg	Greenbrier	Mississippian	WV	Pocahontas
E033-5	1924717.36	13923309.61	High	Sinkhole	Mg	Greenbrier	Mississippian	WV	Pocahontas
e033-5	1924714.501	13923278.77	High	Sinkhole	Mg	Greenbrier	Mississippian	WV	Pocahontas
E036-1	2227096.836	13793441.76	Low	Sinkhole	[s	Shady Dolomite	Cambrian	WV	Pocahontas
e036-1	1931751.413	13922799.95	Low	Sinkhole	Dhs	Hampshire	Devonian	WV	Pocahontas
E051-4	1960367.71	13912915.15	High	Sinkhole	St	Tuscarora Sandstone	Silurian	WV	Pocahontas
E057-1	1962165.88	13911968.25	Moderate	Sinkhole	Stw	Tonoloway, Wills Creek, Williamsport	Silurian	WV	Pocahontas
E057-2	1962105.47	13912062.96	Moderate	Sinkhole	Stw	Tonoloway, Wills Creek, Williamsport	Silurian	WV	Pocahontas
E058-1	1962032.02	13911802.60	High	Sinkhole	Stw	Tonoloway, Wills Creek, Williamsport	Silurian	WV	Pocahontas
E058-3	1962044.09	13911907.14	High	Sinkhole	Stw	Tonoloway, Wills Creek, Williamsport	Silurian	WV	Pocahontas
e086-11	1911456.87	13955914.47	Low	Sinkhole	Mbf	Bluefield	Mississippian	WV	Pocahontas
e086-3	1911387.94	13959942.36	Moderate	Sinkhole	Mbf	Bluefield	Mississippian	WV	Pocahontas
b025-12	1893742.075	13986940.28	Low	Sinkhole	Pnnr	Pottsville	Pennsylvanian	WV	Randolph
b025-13	1894088.353	13986705.41	Moderate	Sinkhole	Pnnr	Pottsville	Pennsylvanian	WV	Randolph
b025-8	1891432.026	13988728.6	Moderate	Sinkhole	Pnnr	Pottsville	Pennsylvanian	WV	Randolph
B074-2	1888034.30	13993663.22	Moderate	Sinkhole	Mh	Hinton	Mississippian	WV	Randolph
b074-2	1888031.934	13993634.75	Low	Sinkhole	Mh	Mauch Chunk	Mississippian	WV	Randolph
B074-3	1888001.46	13993593.12	High	Sinkhole	Mh	Hinton	Mississippian	WV	Randolph
b074-3	1887997.629	13993569.73	Low	Sinkhole	Mh	Mauch Chunk	Mississippian	WV	Randolph
B074-4	1887934.32	13993557.65	High	Sinkhole	Mh	Hinton	Mississippian	WV	Randolph
b074-4	1887928.461	13993533.88	Moderate	Sinkhole	Mh	Mauch Chunk	Mississippian	WV	Randolph
Note: Coordinate System = UTM 17N, US Feet									

Table 5. Point Features (Field Survey)

Feature ID	Easting	Northing	risk_rank	Karst_ID		Formation	Geologic Period	State	County
a002-1	2219211.78	13809702.06	Low	Sinkhole	[e	Elbrook Formation	Cambrian	VA	Augusta
A002-2	13809492.36	2219311.13	Moderate	Sinkhole	€e	Elbrook Formation	Cambrian	VA	Augusta
a002-2	2219308.00	13809463.03	Low	Sinkhole	[e	Elbrook Formation	Cambrian	VA	Augusta
A002-3	13809323.95	2219294.66	Moderate	Sinkhole	€e	Elbrook Formation	Cambrian	VA	Augusta
a002-3	2219291.26	13809298.65	Low	Spring	[e	Elbrook Formation	Cambrian	VA	Augusta
A003-1	13809008.26	2220087.60	High	Sinkhole	€e	Elbrook Formation	Cambrian	VA	Augusta
a003-1	2220083.34	13808976.44	Low	Sinkhole	[e	Elbrook Formation	Cambrian	VA	Augusta
A003-2	13808058.94	2221190.45	Moderate	Sinkhole	€e	Elbrook Formation	Cambrian	VA	Augusta
a003-2	2221184.57	13808025.74	Low	Sinkhole	[e	Elbrook Formation	Cambrian	VA	Augusta
A003-3	13807979.73	2221379.73	High	Sinkhole	€e	Elbrook Formation	Cambrian	VA	Augusta
a003-3	2221379.31	13807949.55	Low	Sinkhole	[e	Elbrook Formation	Cambrian	VA	Augusta
A029-1	13900099.32	2169447.36	Moderate	Sinkhole	O€co	Conococheague Formation	Ordovician - Cambrian	VA	Augusta
A029-2	13900073.54	2169388.00	Moderate	Sinkhole	O€co	Conococheague Formation	Ordovician - Cambrian	VA	Augusta
a032	2224036.88	13803084.04	Low	Sinkhole	[wb	Waynesboro Formation	Cambrian	VA	Augusta
A032-1	13803112.93	2224040.15	High	Sinkhole	€wb	Waynesboro Formation	Cambrian	VA	Augusta
a033	2224661.63	13801572.89	Low	Sinkhole	[wb	Waynesboro Formation	Cambrian	VA	Augusta
A033-1	13801603.10	2224664.88	Moderate	Sinkhole	€wb	Waynesboro Formation	Cambrian	VA	Augusta
A033-2	13800860.50	2225093.90	High	Sinkhole	€wb	Waynesboro Formation	Cambrian	VA	Augusta
a033-2	2225090.75	13800830.93	Low	Sinkhole	[wb	Waynesboro Formation	Cambrian	VA	Augusta
A057-1	13891155.74	2172612.04	High	Sinkhole	O€co	Conococheague Formation	Ordovician - Cambrian	VA	Augusta
A057-2	13889757.78	2172832.99	Moderate	Sinkhole	O€co	Conococheague Formation	Ordovician - Cambrian	VA	Augusta
A057-3	13889288.41	2172785.16	Low	Sinkhole	O€co	Conococheague Formation	Ordovician - Cambrian	VA	Augusta
A057-4	13889286.72	2172765.30	Low	Sinkhole	O€co	Conococheague Formation	Ordovician - Cambrian	VA	Augusta
A057-5	13889246.55	2172764.57	Low	Sinkhole	O€co	Conococheague Formation	Ordovician - Cambrian	VA	Augusta
A057-6	13889209.12	2172775.83	Low	Sinkhole	O€co	Conococheague Formation	Ordovician - Cambrian	VA	Augusta
A057-7	13888862.95	2172633.05	Low	Sinkhole	Ob	Beekmantown Group	Ordovician	VA	Augusta
A057-8	13888807.63	2172607.51	Low	Sinkhole	Ob	Beekmantown Group	Ordovician	VA	Augusta
A072-1	13882182.26	2173544.75	Low	Sinkhole	Ob	Beekmantown Group	Ordovician	VA	Augusta
A072-2	13881789.83	2173255.67	Moderate	Sinkhole	Ob	Beekmantown Group	Ordovician	VA	Augusta
A075-1	13881804.82	2172914.96	Moderate	Sinkhole	Ob	Beekmantown Group	Ordovician	VA	Augusta
A082-1	13876572.08	2172165.18	High	Sinkhole	Ob	Beekmantown Group	Ordovician	VA	Augusta
A083-1	13877070.59	2172240.66	Moderate	Sinkhole	Ob	Beekmantown Group	Ordovician	VA	Augusta
A086-1	13874467.06	2172373.63	low	Sinkhole	Ob	Beekmantown Group	Ordovician	VA	Augusta
A086-2	13874347.02	2172539.08	Moderate	Sinkhole	Ob	Beekmantown Group	Ordovician	VA	Augusta
A086-3	13874152.00	2172488.90	Low	Sinkhole	Ob	Beekmantown Group	Ordovician	VA	Augusta
A086-4	13873436.31	2171341.81	Low	Sinkhole	Ob	Beekmantown Group	Ordovician	VA	Augusta
A092-1	13871553.12	2170345.21	Low	Sinkhole	O€co	Conococheague Formation	Ordovician - Cambrian	VA	Augusta
A096-1	13869845.82	2169775.54	Low	Sinkhole	O€co	Conococheague Formation	Ordovician - Cambrian	VA	Augusta
A096-2	13867337.67	2170353.27	Low	Sinkhole	Ob	Beekmantown Group	Ordovician	VA	Augusta
A096-3	13866667.84	2170877.75	Moderate	Sinkhole	Ob	Beekmantown Group	Ordovician	VA	Augusta
A096-4	13866627.22	2170864.63	Moderate	Sinkhole	Ob	Beekmantown Group	Ordovician	VA	Augusta
A096-5	13866390.26	2170793.22	Moderate	Sinkhole	Ob	Beekmantown Group	Ordovician	VA	Augusta
A096-6	13866334.94	2170909.15	Low	Sinkhole	Ob	Beekmantown Group	Ordovician	VA	Augusta
A096-7	13866202.38	2170842.47	Low	Sinkhole	Ob	Beekmantown Group	Ordovician	VA	Augusta
A096-8	13866043.82	2170754.60	High	Sinkhole	Ob	Beekmantown Group	Ordovician	VA	Augusta
A097-1	13865881.14	2170947.49	Low	Sinkhole	Ob	Beekmantown Group	Ordovician	VA	Augusta
A105-1	13861180.28	2172473.46	High	Sinkhole	Ob	Beekmantown Group	Ordovician	VA	Augusta
A105-2	2172471.67	13861153.20	High	Sinkhole	Ob	Beekmantown Group	Ordovician	VA	Augusta
a138-1	2185082.87	13839140.76	Low	Spring	O[co	Conococheague Formation	Ordovician - Cambrian	VA	Augusta
a138-2	2185125.72	13838956.40	Low	Spring	O[co	Conococheague Formation	Ordovician - Cambrian	VA	Augusta
a138-3	2185139.18	13838874.55	Moderate	Sinkhole	O[co	Conococheague Formation	Ordovician - Cambrian	VA	Augusta
A140-1	13836254.05	2189353.91	Low	Sinkhole	Ob	Beekmantown Group	Ordovician	VA	Augusta
A140-2	13836437.45	2189458.27	High	Cave	Ob	Beekmantown Group	Ordovician	VA	Augusta
A140-4	13836430.45	2189434.98	High	Sinkhole	Ob	Beekmantown Group	Ordovician	VA	Augusta
A142-1	13836351.97	2190025.93	Low	Sinkhole	Ob	Beekmantown Group	Ordovician	VA	Augusta
A142-2	13835930.46	2190077.17	Low	Sinkhole	Ob	Beekmantown Group	Ordovician	VA	Augusta

A142-3	13836088.91	2190174.06	High	Sinkhole	Ob	Beekmantown Group	Ordovician	VA	Augusta
A142-4	13836020.64	2190197.90	Moderate	Sinkhole	Ob	Beekmantown Group	Ordovician	VA	Augusta
A142-5	13836180.12	2190326.84	High	Cave	Ob	Beekmantown Group	Ordovician	VA	Augusta
A142-6	13836113.67	2190397.34	Moderate	Sinkhole	Ob	Beekmantown Group	Ordovician	VA	Augusta
A142-7	13836187.40	2190444.10	High	Sinkhole	Ob	Beekmantown Group	Ordovician	VA	Augusta
A146-1	13835275.05	2190027.37	Low	Sinkhole	Ob	Beekmantown Group	Ordovician	VA	Augusta
A153-1	13826929.64	2201881.15	Moderate	Sinkhole	Ob	Beekmantown Group	Ordovician	VA	Augusta
A159.AR-1	13820861.83	2208450.89	Low	Sinkhole	O€co	Conococheague Formation	Ordovician - Cambrian	VA	Augusta
A159.AR-2	13820622.79	2208570.58	Low	Sinkhole	O€co	Conococheague Formation	Ordovician - Cambrian	VA	Augusta
A159.AR-3	13820507.31	2208629.56	High	Sinkhole	O€co	Conococheague Formation	Ordovician - Cambrian	VA	Augusta
d039	2216970.21	13812427.06	Low	Spring	[e	Elbrook Formation	Cambrian	VA	Augusta
D039 1	13812458.90	2216974.04	Moderate	Spring	€e	Elbrook Formation	Cambrian	VA	Augusta
d040	2217739.12	13811549.95	Low	Spring	[e	Elbrook Formation	Cambrian	VA	Augusta
D040-1	13811580.87	2217743.36	Low	Spring	€e	Elbrook Formation	Cambrian	VA	Augusta
e-020-01	2226011.54	13798694.03	Low	Sinkhole	[wb	Waynesboro Formation	Cambrian	VA	Augusta
E026-1	13796885.81	2226231.94	Moderate	Sinkhole	€wb	Waynesboro Formation	Cambrian	VA	Augusta
E032-1	13795826.58	2226546.65	Moderate	Sinkhole	€s	Shady Dolomite	Cambrian	VA	Augusta
E035-1	13794535.69	2226764.54	Moderate	Sinkhole	€s	Shady Dolomite	Cambrian	VA	Augusta
E062-1	13781826.09	2225952.59	Moderate	Sinkhole	€ch	Chilhowee Group	Cambrian	VA	Augusta
E064-1	13780641.45	2224628.25	Moderate	Sinkhole	€ch	Chilhowee Group	Cambrian	VA	Augusta
F002-1	13863911.99	2085227.92	Moderate	Sinkhole	DSu	Ridgeley Sandstone, Helderber and Cayuga Groups	Lower Devonian - Upper Silurian	VA	Augusta
f002-1	2085227.89	13863879.69	Moderate	Sinkhole	DSu	Ridgeley Sandstone, Helderber and Cayuga Groups	Lower Devonian - Upper Silurian	VA	Augusta
F002-2	13862823.86	2084516.14	High	Sinkhole	DSu	Ridgeley Sandstone, Helderber and Cayuga Groups	Lower Devonian - Upper Silurian	VA	Augusta
F012-1	13868204.18	2089963.01	High	Sinkhole	DSu	Ridgeley Sandstone, Helderber and Cayuga Groups	Lower Devonian - Upper Silurian	VA	Augusta
f012-1	2089959.25	13868176.06	Moderate	Sinkhole	DSu	Ridgeley Sandstone, Helderber and Cayuga Groups	Lower Devonian - Upper Silurian	VA	Augusta
F012-2	13868189.50	2089928.38	High	Sinkhole	DSu	Ridgeley Sandstone, Helderber and Cayuga Groups	Lower Devonian - Upper Silurian	VA	Augusta
f012-2	2089926.02	13868161.14	Moderate	Sinkhole	DSu	Ridgeley Sandstone, Helderber and Cayuga Groups	Lower Devonian - Upper Silurian	VA	Augusta
F012-3	13868408.64	2089994.91	Moderate	Sinkhole	DSu	Ridgeley Sandstone, Helderber and Cayuga Groups	Lower Devonian - Upper Silurian	VA	Augusta
f012-3	2089994.01	13868380.44	High	Sinkhole	DSu	Ridgeley Sandstone, Helderber and Cayuga Groups	Lower Devonian - Upper Silurian	VA	Augusta
052.5-1	2053783.09	13836446.47	Moderate	Sinkhole	Db	Brallier Formation	Devonian	VA	Bath
060-1	13837582.28	2057667.08	Low	Sinkhole	Db	Brallier Formation	Devonian	VA	Bath
062-1	13837513.79	2058547.83	High	Sinkhole	Db	Brallier Formation	Devonian	VA	Bath
075-1	13839373.67	2069639.94	High	Sinkhole	DSu	Ridgeley Sandstone, Helderber and Cayuga Groups	Lower Devonian - Upper Silurian	VA	Bath
075-2	13838878.00	2069004.03	High	Sinkhole	DSu	Ridgeley Sandstone, Helderber and Cayuga Groups	Lower Devonian - Upper Silurian	VA	Bath
075-3	13838830.02	2068962.88	Moderate	Sinkhole	DSu	Ridgeley Sandstone, Helderber and Cayuga Groups	Lower Devonian - Upper Silurian	VA	Bath
077-1	13841688.58	2071121.76	Moderate	Sinkhole	DSu	Ridgeley Sandstone, Helderber and Cayuga Groups	Lower Devonian - Upper Silurian	VA	Bath
077-2	13841181.92	2070646.63	High	Sinkhole	DSu	Ridgeley Sandstone, Helderber and Cayuga Groups	Lower Devonian - Upper Silurian	VA	Bath
078-1	13845542.02	2073394.36	Moderate	Sinkhole	Dmn	Millboro Shale and Needmore Formation	Devonian	VA	Bath
078-10	13843964.78	2072678.30	High	Sinkhole	Dmn	Millboro Shale and Needmore Formation	Devonian	VA	Bath
078-11	13843860.40	2072514.04	Moderate	Sinkhole	Dmn	Millboro Shale and Needmore Formation	Devonian	VA	Bath
078-12	13843775.01	2072575.75	High	Cave	Dmn	Millboro Shale and Needmore Formation	Devonian	VA	Bath
078-13	13843787.27	2072511.35	High	Sinkhole	Dmn	Millboro Shale and Needmore Formation	Devonian	VA	Bath
078-14	13843652.11	2072433.42	High	Sinkhole	Dmn	Millboro Shale and Needmore Formation	Devonian	VA	Bath
078-15	13843597.84	2072440.01	High	Sinkhole	Dmn	Millboro Shale and Needmore Formation	Devonian	VA	Bath
078-16	13843677.25	2072372.90	High	Spring	Dmn	Millboro Shale and Needmore Formation	Devonian	VA	Bath
078-17	13843444.04	2072346.72	High	Sinkhole	Dmn	Millboro Shale and Needmore Formation	Devonian	VA	Bath
078-19	13841912.15	2071291.59	High	Sinkhole	DSu	Ridgeley Sandstone, Helderber and Cayuga Groups	Lower Devonian - Upper Silurian	VA	Bath
078-2	13845226.27	2073351.85	Moderate	Sinkhole	Dmn	Millboro Shale and Needmore Formation	Devonian	VA	Bath
078-20	13841863.10	2071295.33	High	Sinkhole	DSu	Ridgeley Sandstone, Helderber and Cayuga Groups	Lower Devonian - Upper Silurian	VA	Bath
078-21	13841999.60	2071101.71	Low	Sinkhole	Dmn	Millboro Shale and Needmore Formation	Devonian	VA	Bath
078-22	13842006.13	2071032.27	High	Spring	Dmn	Millboro Shale and Needmore Formation	Devonian	VA	Bath
078-23	13845692.60	2073685.16	Low	Sinkhole	Dmn	Millboro Shale and Needmore Formation	Devonian	VA	Bath
078-3	13845272.13	2073245.35	High	Sinkhole	Dmn	Millboro Shale and Needmore Formation	Devonian	VA	Bath
078-4	13845339.94	2073147.87	High	Sinkhole	Dmn	Millboro Shale and Needmore Formation	Devonian	VA	Bath
078-5	13844684.80	2072942.81	High	Sinkhole	Dmn	Millboro Shale and Needmore Formation	Devonian	VA	Bath
078-6	13844589.73	2073019.88	Moderate	Spring	Dmn	Millboro Shale and Needmore Formation	Devonian	VA	Bath
078-7	13844490.73	2072930.27	Moderate	Sinkhole	Dmn	Millboro Shale and Needmore Formation	Devonian	VA	Bath
078-8	13844163.94	2072724.71	High	Sinkhole	Dmn	Millboro Shale and Needmore Formation	Devonian	VA	Bath

Table 5 - Field_dataPoints_all Formatted (Updated).xls

078-9	13844098.98	2072650.67	Moderate	Sinkhole	Dmn	Millboro Shale and Needmore Formation	Devonian	VA	Bath
082-1	13853727.27	2077958.98	Moderate	Sinkhole	DSu	Ridgeley Sandstone, Helderber and Cayuga Groups	Lower Devonian - Upper Silurian	VA	Bath
082-2	13853864.37	2077902.75	High	Sinkhole	DSu	Ridgeley Sandstone, Helderber and Cayuga Groups	Lower Devonian - Upper Silurian	VA	Bath
082-3	13853898.64	2078013.73	High	Sinkhole	DSu	Ridgeley Sandstone, Helderber and Cayuga Groups	Lower Devonian - Upper Silurian	VA	Bath
082-4	13854014.46	2077929.78	Moderate	Sinkhole	DSu	Ridgeley Sandstone, Helderber and Cayuga Groups	Lower Devonian - Upper Silurian	VA	Bath
082-5	13853959.58	2078115.69	Moderate	Sinkhole	DSu	Ridgeley Sandstone, Helderber and Cayuga Groups	Lower Devonian - Upper Silurian	VA	Bath
082-6	13854050.71	2078046.72	Moderate	Sinkhole	DSu	Ridgeley Sandstone, Helderber and Cayuga Groups	Lower Devonian - Upper Silurian	VA	Bath
082-7	13854207.41	2078169.07	Moderate	Sinkhole	DSu	Ridgeley Sandstone, Helderber and Cayuga Groups	Lower Devonian - Upper Silurian	VA	Bath
083-1	13855308.72	2079065.12	High	Sinkhole	DSu	Ridgeley Sandstone, Helderber and Cayuga Groups	Lower Devonian - Upper Silurian	VA	Bath
083-2	13855710.90	2079384.82	Moderate	Sinkhole	DSu	Ridgeley Sandstone, Helderber and Cayuga Groups	Lower Devonian - Upper Silurian	VA	Bath
084-1	13854808.49	2078777.73	High	Sinkhole	DSu	Ridgeley Sandstone, Helderber and Cayuga Groups	Lower Devonian - Upper Silurian	VA	Bath
084-2	13854856.32	2078816.33	Moderate	Sinkhole	DSu	Ridgeley Sandstone, Helderber and Cayuga Groups	Lower Devonian - Upper Silurian	VA	Bath
36-024-1	2029812.67	13859089.75	Low	Spring	DSu	Ridgeley Sandstone, Helderber and Cayuga Groups	Lower Devonian - Upper Silurian	VA	Bath
x001-1	2084513.29	13862790.81	Moderate	Sinkhole	DSu	Ridgeley Sandstone, Helderber and Cayuga Groups	Lower Devonian - Upper Silurian	VA	Bath
C010-13	13898910.79	2003977.05	High	Cave	Ols	Mocassin Formation, Bays Formation, Unit C, Unit B, Unit A	Ordovician	VA	Highland
C010-14	13898888.27	2004068.62	High	Sinkhole	Ols	Mocassin Formation, Bays Formation, Unit C, Unit B, Unit A	Ordovician	VA	Highland
C010-15	13898860.43	2004089.23	High	Sinkhole	Ols	Mocassin Formation, Bays Formation, Unit C, Unit B, Unit A	Ordovician	VA	Highland
C010-16	13898852.87	2004120.74	High	Sinkhole	Ols	Mocassin Formation, Bays Formation, Unit C, Unit B, Unit A	Ordovician	VA	Highland
C010-4	13899357.54	2003626.00	High	Sinkhole	Ols	Mocassin Formation, Bays Formation, Unit C, Unit B, Unit A	Ordovician	VA	Highland
c010-4	2003618.49	13899321.63	Low	Sinkhole	Ols	Mocassin Formation, Bays Formation, Unit C, Unit B, Unit A	Ordovician	VA	Highland
C010-7	13899310.40	2003845.48	High	Sinkhole	Ols	Mocassin Formation, Bays Formation, Unit C, Unit B, Unit A	Ordovician	VA	Highland
c010-7	2003842.36	13899278.96	High	Sinkhole	Ols	Mocassin Formation, Bays Formation, Unit C, Unit B, Unit A	Ordovician	VA	Highland
C010-8	13899215.25	2003832.94	High	Sinkhole	Ols	Mocassin Formation, Bays Formation, Unit C, Unit B, Unit A	Ordovician	VA	Highland
c010-8	2003829.00	13899186.24	Low	Sinkhole	Ols	Mocassin Formation, Bays Formation, Unit C, Unit B, Unit A	Ordovician	VA	Highland
C011-1	13897131.76	2004891.46	Moderate	Sinkhole	Ols	Mocassin Formation, Bays Formation, Unit C, Unit B, Unit A	Ordovician	VA	Highland
C011-2	13897075.94	2004996.07	Moderate	Sinkhole	Oun	Juniata, Oswego, Martinsburg (Reedsville and Dolly Ridge), Eggleston Formation	Ordovician	VA	Highland
c011-2	2003975.51	13898883.30	High	Sinkhole	Ols	Mocassin Formation, Bays Formation, Unit C, Unit B, Unit A	Ordovician	VA	Highland
c011-3	2004065.15	13898859.00	Moderate	Sinkhole	Ols	Mocassin Formation, Bays Formation, Unit C, Unit B, Unit A	Ordovician	VA	Highland
c011-4	2004087.28	13898829.75	High	Sinkhole	Ols	Mocassin Formation, Bays Formation, Unit C, Unit B, Unit A	Ordovician	VA	Highland
c011-5	2004117.19	13898822.50	Low	Sinkhole	Ols	Mocassin Formation, Bays Formation, Unit C, Unit B, Unit A	Ordovician	VA	Highland
c023-1	2004886.72	13897103.06	Moderate	Sinkhole	Ols	Mocassin Formation, Bays Formation, Unit C, Unit B, Unit A	Ordovician	VA	Highland
c023-2	2004994.03	13897046.91	Moderate	Sinkhole	Oun	Juniata, Oswego, Martinsburg (Reedsville and Dolly Ridge), Eggleston Formation	Ordovician	VA	Highland
A007-1	13693844.82	2288340.43	Moderate	Sinkhole	€ca	Candler Formation - phyllite and schist	Cambrian	VA	Nelson
n02-1	2234690.50	13764468.70	Low	Spring	[Zc	Catoctin Formation - metabasalt	Cambrian - late Proterozoic	VA	Nelson
b075-1	1903452.36	13979369.05	Low	Sinkhole	Mbf	Bluefield	Mississippian	WV	Pocahontas
b075-2	1904143.90	13979133.03	Low	Sinkhole	Mbf	Bluefield	Mississippian	WV	Pocahontas
C013-1	13943919.34	1913363.54	High	Spring	Mbf	Bluefield	Mississippian	WV	Pocahontas
C013-2	13943777.89	1913361.34	Moderate	Sinkhole	Mbf	Bluefield	Mississippian	WV	Pocahontas
C013-3	13943607.90	1913212.70	High	Sinkhole	Mbf	Bluefield	Mississippian	WV	Pocahontas
C013-4	13943391.91	1913277.76	High	Spring	Mbf	Bluefield	Mississippian	WV	Pocahontas
E023-1	13949522.10	1914060.70	Moderate	Sinkhole	Mbf	Bluefield	Mississippian	WV	Pocahontas
E023-3	13951110.01	1913547.21	High	Sinkhole	Mg	Greenbrier	Mississippian	WV	Pocahontas
e023-3	1913544.77	13951078.72	High	Sinkhole	Mg	Greenbrier	Mississippian	WV	Pocahontas
E023-4	13951666.46	1913271.47	Low	Spring	Mg	Greenbrier	Mississippian	WV	Pocahontas
E023-5	13948608.08	1914688.26	Moderate	Sinkhole	Mh	Hinton	Mississippian	WV	Pocahontas
E023-6	13950502.92	1913761.67	High	Sinkhole	Mbf	Bluefield	Mississippian	WV	Pocahontas
E023-7	13950761.55	1913707.35	Moderate	Sinkhole	Mbf	Bluefield	Mississippian	WV	Pocahontas
E023-8	13952498.21	1912987.33	High	Sinkhole	Mg	Greenbrier	Mississippian	WV	Pocahontas
E028-1	13930375.09	1912262.09	Low	Sinkhole	Mg	Greenbrier	Mississippian	WV	Pocahontas
E028-2	13930173.23	1913156.72	Moderate	Sinkhole	Mg	Greenbrier	Mississippian	WV	Pocahontas
e028-2	1913151.74	13930140.26	Moderate	Sinkhole	Mg	Greenbrier	Mississippian	WV	Pocahontas
E028-4	13930800.01	1911727.31	Moderate	Sinkhole	Mg	Greenbrier	Mississippian	WV	Pocahontas
e028-4	1911727.70	13930767.75	Low	Sinkhole	Mg	Greenbrier	Mississippian	WV	Pocahontas
E028-5	13930947.89	1911571.48	Moderate	Sinkhole	Mg	Greenbrier	Mississippian	WV	Pocahontas
e028-5	1911575.40	13930921.52	Low	Sinkhole	Mg	Greenbrier	Mississippian	WV	Pocahontas
E028-6	13932330.07	1909475.25	Moderate	Sinkhole	Mh	Hinton	Mississippian	WV	Pocahontas
E030-2	1923219.93	13925799.61	Moderate	Sinkhole	Mg	Greenbrier	Mississippian	WV	Pocahontas
E030-3	1923232.62	13925760.07	Moderate	Sinkhole	Mg	Greenbrier	Mississippian	WV	Pocahontas

Table 5 - Field_dataPoints_all Formatted (Updated).xls

E030-4	1922746.19	13925725.00	High	Sinkhole	Mg	Greenbrier	Mississippian	WV	Pocahontas
E030-5	1922662.62	13925773.55	High	Sinkhole	Mg	Greenbrier	Mississippian	WV	Pocahontas
E030-8	1920453.67	13925475.94	Low	Sinkhole	Mbf	Bluefield	Mississippian	WV	Pocahontas
E030-9	1919107.75	13925563.62	Low	Sinkhole	Mbf	Bluefield	Mississippian	WV	Pocahontas
E031-3	13925755.45	1922751.00	Moderate	Sinkhole	Mg	Greenbrier	Mississippian	WV	Pocahontas
E031-4	13925802.95	1922671.65	High	Sinkhole	Mg	Greenbrier	Mississippian	WV	Pocahontas
E031-5	13925505.09	1920456.97	High	Sinkhole	Mbf	Bluefield	Mississippian	WV	Pocahontas
E031-6	13925595.56	1919111.92	High	Sinkhole	Mbf	Bluefield	Mississippian	WV	Pocahontas
E032-3	13925829.66	1923222.59	High	Sinkhole	Mg	Greenbrier	Mississippian	WV	Pocahontas
E032-4	13925791.57	1923235.16	High	Sinkhole	Mg	Greenbrier	Mississippian	WV	Pocahontas
E033-1	13924863.43	1924324.75	Moderate	Sinkhole	Mg	Greenbrier	Mississippian	WV	Pocahontas
e033-1	1924320.65	13924833.50	Low	Sinkhole	Mg	Greenbrier	Mississippian	WV	Pocahontas
E033-6	13922903.46	1924684.64	High	Sinkhole	Mg	Greenbrier	Mississippian	WV	Pocahontas
e033-6	1924681.92	13922872.79	High	Sinkhole	Mg	Greenbrier	Mississippian	WV	Pocahontas
E033-7	13922907.63	1924670.17	High	Sinkhole	Mg	Greenbrier	Mississippian	WV	Pocahontas
e033-7	1924666.52	13922874.28	High	Sinkhole	Mg	Greenbrier	Mississippian	WV	Pocahontas
E037-1	13922321.57	1930809.82	Low	Spring	Dhs	Hampshire	Devonian	WV	Pocahontas
E051-1	13916099.18	1954245.57	High	Sinkhole	Dmb	Harrell, Mahantango, Marcellus	Devonian	WV	Pocahontas
E051-2	13915149.63	1955935.64	High	Sinkhole	Dmb	Harrell, Mahantango, Marcellus	Devonian	WV	Pocahontas
E051-3	13914976.60	1956177.85	Low	Sinkhole	Dmb	Harrell, Mahantango, Marcellus	Devonian	WV	Pocahontas
E053-1	13916199.02	1953390.92	High	Sinkhole	Db	Brallier	Devonian	WV	Pocahontas
E053-2	13916165.41	1953504.53	High	Sinkhole	Db	Brallier	Devonian	WV	Pocahontas
E053-3	13916185.17	1954092.48	Moderate	Sinkhole	Dmb	Harrell, Mahantango, Marcellus	Devonian	WV	Pocahontas
E057-3	13912299.09	1961410.70	High	Sinkhole	Smc	McKenzie	Silurian	WV	Pocahontas
E058-2	13911951.00	1961991.18	Moderate	Sinkhole	Stw	Tonoloway, Wills Creek, Williamsport	Silurian	WV	Pocahontas
E058-6	13911964.87	1961862.43	High	Sinkhole	Stw	Tonoloway, Wills Creek, Williamsport	Silurian	WV	Pocahontas
e086-1	13955449.38	1912356.83	Moderate	Spring	Mg	Greenbrier	Mississippian	WV	Pocahontas
e086-10	13955990.25	1911559.77	Low	Sinkhole	Mbf	Bluefield	Mississippian	WV	Pocahontas
e086-12	13955097.77	1912148.32	Low	Spring	Mg	Greenbrier	Mississippian	WV	Pocahontas
e086-13	13955644.33	1912806.90	Moderate	Sinkhole	Mg	Greenbrier	Mississippian	WV	Pocahontas
e086-2	13960080.67	1910314.35	High	Sinkhole	Mh	Hinton	Mississippian	WV	Pocahontas
e086-4	13959758.04	1911538.24	Low	Spring	Mbf	Bluefield	Mississippian	WV	Pocahontas
e086-5	13959637.05	1911179.72	Low	Spring	Mbf	Bluefield	Mississippian	WV	Pocahontas
e086-6	13959174.36	1911709.20	Low	Spring	Mbf	Bluefield	Mississippian	WV	Pocahontas
e086-7	13957466.08	1911878.60	Moderate	Sinkhole	Mbf	Bluefield	Mississippian	WV	Pocahontas
e086-8	13956926.94	1911779.35	Low	Sinkhole	Mg	Greenbrier	Mississippian	WV	Pocahontas
e086-9	13957256.51	1912049.66	Moderate	Spring	Mg	Greenbrier	Mississippian	WV	Pocahontas
B025-1	13992495.80	1888025.73	High	Sinkhole	Mh	Hinton	Mississippian	WV	Randolph
b025-1	1888024.21	13992466.10	Moderate	Sinkhole	Mh	Hinton	Mississippian	WV	Randolph
b025-10	1891493.43	13988654.71	Moderate	Sinkhole	Pnnr	New River	Pennsylvanian	WV	Randolph
b025-11	1891734.64	13988653.97	Low	Sinkhole	Pnnr	New River	Pennsylvanian	WV	Randolph
b025-14	1894214.90	13986637.22	Low	Sinkhole	Mbp	Bluestone, Princeton	Mississippian	WV	Randolph
B025-15	13983062.10	1896952.58	High	Sinkhole	Pnnr	New River	Pennsylvanian	WV	Randolph
b025-15	1896950.03	13983030.13	High	Sinkhole	Pnnr	New River	Pennsylvanian	WV	Randolph
B025-16	13982921.88	1897235.46	High	Sinkhole	Pnnr	New River	Pennsylvanian	WV	Randolph
b025-16	1897237.16	13982888.74	High	Sinkhole	Pnnr	New River	Pennsylvanian	WV	Randolph
B025-17	13982736.96	1897056.82	Low	Sinkhole	Pnnr	New River	Pennsylvanian	WV	Randolph
B025-18	13982438.46	1898496.09	Moderate	Sinkhole	Pnnr	New River	Pennsylvanian	WV	Randolph
b025-18	1898496.76	13982405.25	Low	Sinkhole	Pnnr	New River	Pennsylvanian	WV	Randolph
B025-2	13992355.37	1887979.88	High	Spring	Mh	Hinton	Mississippian	WV	Randolph
b025-2	1887975.36	13992325.57	Low	Spring	Mh	Hinton	Mississippian	WV	Randolph
B025-3	13991966.01	1888304.19	Modereate	Spring	Mh	Hinton	Mississippian	WV	Randolph
b025-3	1888302.66	13991934.18	Low	Spring	Mh	Hinton	Mississippian	WV	Randolph
B025-4	13990872.71	1890052.29	Moderate	Sinkhole	Mbp	Bluestone, Princeton	Mississippian	WV	Randolph
b025-4	1890049.19	13990841.77	Low	Sinkhole	Mbp	Bluestone, Princeton	Mississippian	WV	Randolph
b025-5	1891239.60	13989230.63	Moderate	Sinkhole	Pnnr	New River	Pennsylvanian	WV	Randolph
b025-7	1891472.00	13988836.57	Low	Sinkhole	Pnnr	New River	Pennsylvanian	WV	Randolph
b025-9	1891427.01	13988694.51	Low	Sinkhole	Pnnr	New River	Pennsylvanian	WV	Randolph

Table 5 - Field_dataPoints_all Formatted (Updated).xls

B074-1	13993694.57	1887981.40	Moderate	Spring	Mh	Hinton	Mississippian	WV	Randolph
b074-1	1887981.70	13993670.39	Low	Spring	Mh	Hinton	Mississippian	WV	Randolph
B074-5	13993039.91	1888033.24	High	Spring	Mh	Hinton	Mississippian	WV	Randolph
b074-5	1888030.37	13993007.72	Low	Spring	Mh	Hinton	Mississippian	WV	Randolph
B075-1	13979401.14	1903455.43	High	Sinkhole	Mbf	Bluefield	Mississippian	WV	Randolph
B075-2	13979164.50	1904146.92	Moderate	Sinkhole	Mbf	Bluefield	Mississippian	WV	Randolph
E023-2	1914056.91	13949492.42	Moderate	Sinkhole	Mh	Hinton	Mississippian	WV	Randolph
E027-1	1909475.13	13932285.83	Moderate	Sinkhole	Mh	Hinton	Mississippian	WV	Randolph
Note: Coordinate System = UTM 17N, US Feet									

GeoConcepts Engineering, Inc.

APPENDIX D
George Washington National Forest Karst Survey Summary

Appendix D
KARST SURVEY SUMMARY
George Washington National Forest (GWNF), Virginia

Milepost: 96.8-97.2, 105.8-105.9, 121.1-123.2
Geological Maps - Appendix A: Maps 26, 30, 37
Contour Maps - Appendix B: Maps 68-69, 81-83, 111-112

Terrain and Geology – The proposed Atlantic Coast Pipeline (ACP) intercepts the GWNF in karst terrain at three disconnected areas: from MP121.1 to 123.2 just west of Little North Mountain and north of Jenning's Gap in Augusta County; from MP105.8 to 150.9 in the Back Draft area of northeastern Bath County; and from MP96.8 to 97.2 in the Poplar Hollow area of central Bath County. All three karst areas fall within the Folded Appalachian Section of the Valley and Ridge Physiographic Province of Virginia. The section from MP121.1 to 123.2 is mapped as underlain by undivided Upper Silurian and Lower Devonian Limestone; the sections from MP105.8 to 150.9 and from MP96.8 to 97.2 are mapped underlain by the Lower Devonian and Silurian age Helderberg Group carbonates, and the Silurian age Cayugan Group carbonates. A detailed description of the geological units is presented in the main body of the report.

Data Review – The data review identified 18 features within the GWNF karst areas described above. The features are described in Table 1 - GWNF Data Review Summary. One small cave was identified from the proprietary database of the Virginia Speleological Survey (VSS), named "Deuces Wild" Cave. The cave is 18 feet long, completely explored and not considered significant by the VSS.

Field Survey – 96.8-97.2 has not been surveyed as access permission has not been obtained from the landowners. 105.8-105.9 and 122.8-123.4 have been surveyed. Only one feature was located during the field survey, a sinking stream section identified as E035-1 located downgradient from the proposed centerline. Because of its location and drainage characteristics, the feature is considered to be of moderate risk of impact from construction.

TABLE 1. GWNF Data Review Summary

Feature_ID	easting	northing	Map Unit	Geological Formation	Geologic Period	State	County
cCD36	1984847.63	13909681.31	Dch	Chemung Formation	Devonian	VA	Highland
cCD37	1985092.113	13909623.77	Dch	Chemung Formation	Devonian	VA	Highland
cCD38	1985461.236	13909507.32	Dch	Chemung Formation	Devonian	VA	Highland
cCD053	1984742.522	13910850.18	Dch	Chemung Formation	Devonian	VA	Highland
cCD054	1988242.935	13910508.08	Dch	Chemung Formation	Devonian	VA	Highland
cCD056	1994245.964	13912615.94	Dch	Chemung Formation	Devonian	VA	Highland
cCD127	2034371.54	13853376.44	DSu	Ridgeley Sandstone, Helderber and Cayuga Groups	Lower Devonian - Upper Silurian	VA	Bath
cCD128	2034433.374	13852498.87	DSu	Ridgeley Sandstone, Helderber and Cayuga Groups	Lower Devonian - Upper Silurian	VA	Bath
cCD129	2033767.385	13852737.79	DSu	Ridgeley Sandstone, Helderber and Cayuga Groups	Lower Devonian - Upper Silurian	VA	Bath
cCD130	2033725.464	13852782.96	DSu	Ridgeley Sandstone, Helderber and Cayuga Groups	Lower Devonian - Upper Silurian	VA	Bath
cCD132	2034529.918	13852207.98	DSu	Ridgeley Sandstone, Helderber and Cayuga Groups	Lower Devonian - Upper Silurian	VA	Bath
cCD133	2033714.376	13852537.78	DSu	Ridgeley Sandstone, Helderber and Cayuga Groups	Lower Devonian - Upper Silurian	VA	Bath
cCD134	2033598.999	13851379.43	DSu	Ridgeley Sandstone, Helderber and Cayuga Groups	Lower Devonian - Upper Silurian	VA	Bath
cCD03	2034247.143	13857616.03	Skrt	Keefer Sandstone, Rose Hill and Tuscarora Formations	Silurian	VA	Bath
cCD144	2034535.399	13854057.23	Skrt	Keefer Sandstone, Rose Hill and Tuscarora Formations	Silurian	VA	Bath
cCD150	2081788.752	13860778.95	DSu	Ridgeley Sandstone, Helderber and Cayuga Groups	Lower Devonian - Upper Silurian	VA	Bath
cCD151	2081799.713	13860706.35	DSu	Ridgeley Sandstone, Helderber and Cayuga Groups	Lower Devonian - Upper Silurian	VA	Bath
cCD152	2081773.74	13860616.51	DSu	Ridgeley Sandstone, Helderber and Cayuga Groups	Lower Devonian - Upper Silurian	VA	Bath
Note: Coordinate System = UTM 17N, US Feet							

GeoConcepts Engineering, Inc.

APPENDIX E
Monongahela National Forest Karst Survey Summary

Appendix E
KARST SURVEY SUMMARY
Monongahela National Forest (MNF), Pocahontas County, West Virginia

Milepost: 73.1-73.6, 80.7-80.9
Geological Maps - Appendix A: Maps 14-15, 18-19
Contour Maps - Appendix B: Maps 27-28, 36-37

Terrain and Geology Summary – Two areas of karst terrain within the Monongahela National Forest (MNF) are intercepted by the proposed route of the Atlantic Coast Pipeline (ACP): the section from MP80.7 to 80.9 is located along the summit and flanks of Big Ridge, located between Michael Mountain to the west and Allegheny Mountain to the east; and from MP73.1 to 73.6, located on Cloverlick Mountain. Both sections are within the Pocahontas County section of the MNF.

The section from MP80.7 to 80.9 is located within the westernmost section of the Valley and Ridge Physiographic Province of West Virginia. The proposed ACP alignment in this section is mapped as underlain by the Upper Silurian and Lower Devonian age carbonates of the Helderberg Group, and the Silurian age Cayugan Group rocks.

The section from MP73.1 to 73.6 is located within the Allegheny Mountain subsection of the Appalachian Plateau Province. This section of the alignment is mapped as underlain by the Mississippian age rocks of the Bluefield and Hinton Formations of the Mauch Chunk Group. Caves are known to occur within the Reynolds Limestone member of the Bluefield, and the Avis Limestone member of the Hinton.

Data Review – The data review identified 9 features within the MNF karst areas described above. The features are described in Table 1 - MNF Data Review Summary. There were no caves identified within either of the MNF sections.

Field Survey – Both the MP73.1-73.6 and MP80.6-80.8 sections have been surveyed for karst features. Two features were identified within the section from MP80.6 to 80.8, and identified as E058-6 and E057-3, respectively. Both features are small (6 foot diameter) shallow sinkholes, located within 20 feet of the proposed centerline. They both appear to accept surface drainage. Due to their proximity to the proposed centerline, and their drainage characteristics, the two features were designated as being a high risk of impact from construction.

TABLE 1. MNF Data Review Summary

Feature_ID	easting	northing	Map Unit	Geological Formation	Geologic Period	State	County
cCD39	1967193.825	13910353.4	Db	Brallier	Devonian	WV	Pocahontas
cCD251	1962065.193	13912143.32	Stw	Tonoloway, Wills Creek, Williamsport	Silurian	WV	Pocahontas
cCD244	1961668.962	13911895.64	Stw	Tonoloway, Wills Creek, Williamsport	Silurian	WV	Pocahontas
cCD249	1961668.944	13912030.82	Stw	Tonoloway, Wills Creek, Williamsport	Silurian	WV	Pocahontas
cCD253	1962261.57	13912114.66	Stw	Tonoloway, Wills Creek, Williamsport	Silurian	WV	Pocahontas
cCD250	1961940.927	13912086.25	Stw	Tonoloway, Wills Creek, Williamsport	Silurian	WV	Pocahontas
cCD255	1910376.613	13937342.88	Mbp	Bluestone, Princeton	Mississippian	WV	Pocahontas
cCD257	1961309.958	13912269.13	Smc	McKenzie	Silurian	WV	Pocahontas
cCD258	1915730.241	13927217.36	Mh	Hinton	Mississippian	WV	Pocahontas
Note: Coordinate System = UTM 17N, US Feet							

ATLANTIC COAST PIPELINE, LLC
ATLANTIC COAST PIPELINE

Response to Virginia Department of Environmental Quality Request for Information for the Section 401 Water Quality Certification

APPENDIX H

Karst Terrain Assessment, Construction, Monitoring and Mitigation Plan

January 20, 2017

Karst Terrain Assessment Construction, Monitoring and Mitigation Plan

Atlantic Coast Pipeline Randolph and Pocahontas Counties in West Virginia and Highland, Augusta, and Nelson Counties in Virginia

GeoConcepts Engineering, Inc.

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January 20, 2017

Ms. Brittany Moody
Dominion Transmission, Inc.
445 West Main Street
Clarksburg, West Virginia 26301

Subject: **Karst Terrain Assessment, Construction, Monitoring and Mitigation Plan, Atlantic Coast Pipeline, Randolph and Pocahontas Counties in West Virginia, and Highland, Augusta, and Nelson Counties in Virginia (Our 15200)**

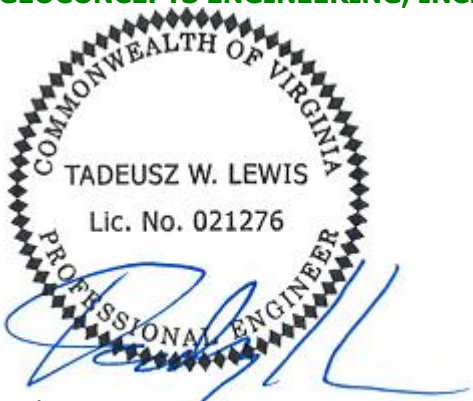
Dear Ms. Moody:

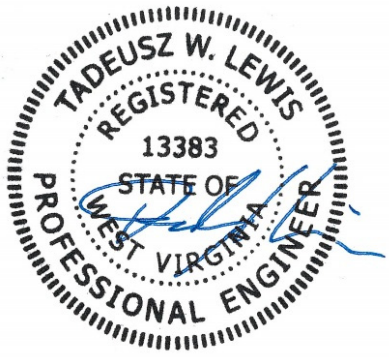
Per your request, GeoConcepts Engineering, Inc. (GeoConcepts) has completed a Karst Terrain Assessment, Construction Monitoring, and Mitigation Plan in support of the development of the Atlantic Coast Pipeline in areas of Randolph and Pocahontas Counties, West Virginia Highland, Augusta, and Nelson Counties, Virginia, and Westmoreland County, PA.

We appreciate the opportunity to serve as your geotechnical consultant on this project. Please do not hesitate to contact me if you have any questions or want to meet to discuss the findings and recommendations contained in the report.

Sincerely,

GEOCONCEPTS ENGINEERING, INC.





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GeoConcepts Engineering, Inc.

ATLANTIC COAST PIPELINE, LLC
ATLANTIC COAST PIPELINE
Docket No. PF15-6-000

and

DOMINION TRANSMISSION, INC
SUPPLY HEADER PROJECT
Docket No. PF15-5-000

Karst Terrain Assessment, Construction, Monitoring, and Mitigation Plan

Prepared by
GeoConcepts Engineering, Inc.
January 2017

GeoConcepts Engineering, Inc.

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Plan Outline

At the request of Atlantic Coast Pipeline, LLC (Atlantic), and Dominion Transmission, Inc. (DTI), GeoConcepts has developed a plan describing the assessment, monitoring, and mitigation activities for the proposed Atlantic Coast Pipeline (ACP) and the Dominion Supply Header Project (SHP) routes through areas of karst terrain. The requested plan is outlined as follows:

Definitions

This section provides a summary of karst-specific terms used in the plan.

Geological Overview

This section provides a brief discussion of karst terrain and features and the overall regional karst geology in the general area of the project. It is of note that the plan as written is a "generic" document due to possible changes that may occur in the specific project alignment. However, regardless of reroutes the alignment will need to pass across each of the provinces discussed in the geological overview section of the plan.

Pre-Construction Assessment and Field Survey

This section describes in detail the pre-construction database and remote sensing review, as well as field survey methods and procedures which are currently being completed.

Construction Monitoring Protocols

This section describes the methods and procedures to be utilized during the construction phase of the ACP/SHP. It includes:

- a description of the pre-excavation electrical resistivity investigation (ERI) methods and procedures, and the manner in which the ERI data will be analyzed, summarized, and presented; and
- a description of the activities to be conducted by the field geologist during excavation and trenching activities, including how the observations will be made and the reporting format and frequency.

Karst Mitigation and Conservation Procedures

This section discusses the best management practices (BMPs) to be utilized for mitigating, remediating, and minimizing impacts to karst features that may be encountered during construction activities. This includes features that either are within or receive drainage from the pipeline right-of-way, or features that are intercepted during the excavation and trenching process, as well as access roads, additional temporary workspace areas, or any other areas where land disturbance necessary for pipeline construction is planned. It is noted that these mitigation and conservation procedures will not apply for existing access roads that do not require land disturbance. The format and manner in which the mitigation and remedial activities will be undertaken and reported are addressed in this section of the plan. The intent is to provide agreed upon solutions to the karst features that may be encountered prior to the start of construction so that those features can be protected. However, in some cases, the actual remedial measure employed may be customized to the specific karst features identified.

Definitions

Karst Specialist – A Licensed Professional Geologist engaged in the practice of engineering geology (or) a Virginia Registered Professional Engineer engaged in the practice of Geotechnical Engineering, with a minimum of 10 years of experience in karst geology characterization and remediation. Practice experience shall be demonstrated by a statement of qualifications.[1]

[1]Adapted from the VA Cave Board Karst Assessment and Survey Guidelines (and) Denton, et al. 2016. All other definitions adapted from Field, 2002.

Cave – A natural hole in the ground, large enough for human entry. This covers the enormous variety of caves that do occur, but eliminates the many artificial tunnels and galleries incorrectly named caves. The size criterion is arbitrary and subjective, but practical, as it eliminates narrow openings irrelevant to explorers but very significant hydrologically, that may be better referred to as *proto-caves*, *sub-conduits*, or *fissures*. A cave may be a single, short length of accessible passage, or an extensive and complex network of tunnels as long as hundreds of kilometers.

Doline; Sinkhole – A basin- or funnel-shaped hollow or depression in limestone, dolostone or other soluble bedrock, ranging in diameter from a few meters up to a kilometer and in depth from a few to several hundred meters. Some dolines are gentle grassy hollows or depressions; others are rocky cliff-bounded basins. A distinction may be made by direct solution of the limestone surface zone (solution dolines), and those formed by collapse over a cave (collapse dolines), but it is generally not possible to establish the origin of individual examples. Generally referred to as a "sinkhole" in the United States, the term doline is more widely accepted by the international geology community.

Throat – An opening within a sinkhole leading into the subsurface through which material passes or has passed from the sinkhole into underlying solutional voids and conduits, which is generally too small to qualify as a cave and often called a *proto-cave*, *sub-conduit*, or *fissure*. Throats may be "open" (i.e. air-filled or water-filled), or "closed/clogged" (filled with debris including but not limited to: loose-soil; gravel; rock; dead-fall wood or brush; or trash).

Parapet – The outer edge or perimeter of a doline (sinkhole).

Ponor – a) Hole or opening in the bottom or side of a depression where a surface stream or lake flows either partially or completely underground into the karst groundwater system. b) Hole in the bottom or side of a doline through which water passes to or from an underground channel. Also known as a swallow hole or swallet.

Solution Cavity – A natural cavity or depression formed by the dissolution of soluble bedrock, typically not large enough to allow the entry of a human being and, therefore, not classified as a cave.

Breccia – Angular fragments of rock commonly, but not always, cemented by finer-grained materials including silica, iron minerals, and calcite to form a new rock. Many fault planes are marked by zones of broken rock, either loose or re-cemented, forming a fault breccia.

Non-Karst Closed Depression – A natural or non-natural topographic depression that is not formed by karst processes and is not floored by bedrock. Examples include (but are not limited to) construction-related soil subsidence, silage pits, farm ponds, scour pools, animal wallows, large animal burrows, and pits created by removal of tree stumps.

Sinking Stream/Swallet – A perennial or intermittent stream whose bed and bank disappear entirely underground, usually through an open throat sinkhole or cave entrance.

Losing Stream – A perennial or intermittent stream which loses flow volume into its bed due to the presence of sub-channel (hyporheic) solution cavities or conduits.

Geological Overview of the Karst Terrain Sections of the Proposed ACP/SHP

Overview of regional karst terrain within the project area

The term "karst" refers to a type of landform or terrain, just like "desert", "marsh", "tundra", "steppe" or "montane". It was named for a province in Slovenia where it was first described in the late 17th and early 18th century by geologists of the former Austro-Hungarian Empire. Simply stated, karst terrain is characterized or diagnosed by the presence of sinkholes, caverns, an irregular "pinnacled" bedrock surface,

and many large springs; however, the development of karst terrain is a result of the presence of soluble bedrock such as limestone, dolomite, marble or gypsum. Any landscape that is underlain by soluble bedrock has the potential to develop a karst terrain landform.

As in any region where soluble bedrock is present, a karst landform regime has developed in three known regions of the proposed ACP/SHP. Folding and faulting of the local carbonate rocks has opened up numerous fractures both parallel with the axis of the geologic structures, as well as perpendicular to them. Surface fractures and joints weather differentially, producing a pinnacled or "saw-tooth" profile at the bedrock/soil interface (referred to as the "epikarst" zone). In contrast, rock-enclosed fractures can be secondarily enlarged by the action of carbon dioxide charged groundwater, in some cases forming water-filled or air-filled conduits. As the regional terrain is "mature" karst, nearly all the fractures have undergone successive cycles of sediment filling and flushing. In areas such as the ACP project area, where there is little topographic relief and a relatively minimal groundwater gradient, the great majority of solution fissures are sediment-filled.

The most prevalent type of karst features in the project area are dolines or sinkholes, and these features comprise the greatest potential geohazard risk to any type of construction in karst terrain. Sinkholes fall into two broad categories, "vault-collapse" sinkholes, and "cover-collapse" sinkholes. Vault-collapse type sinkholes (i.e., where a cavern "vault" or roof has failed catastrophically) are rare in the ACP/SHP Project area (Campbell, et al., 2006). Cover-collapse sinkholes, which are common in the ACP project area, develop by the raveling of fines from the soil overburden into solution channels within the bedrock mass, in which water is the transport medium for the movement of the soil fines. The natural raveling process is generally a very slow one, such that sinkhole development generally occurs over a very long time span. However, various changes at a site can sometimes lead to the very sudden development of sinkholes. The most common changes that will exacerbate sinkhole development are:

1. Increase or redirection of overland or subsurface water flow paths, which accelerates the raveling of soil fines;
2. Removal of vegetation cover and topsoil (i.e., stripping and grubbing), which can reduce the cohesive strength of the soils overlying a conduit; and
3. Sudden changes in the elevation of the water table (such as drought, over-pumping of wells, or quarry dewatering), which removes the neutral buoyancy of the water supporting a conduit's soil plug, and can often result in rapid and catastrophic soil collapse.

Geological Setting

The proposed ACP/SHP will cross three distinct regional provinces of karst geology, from east to west:

1. The **Great Valley subsection of the Valley and Ridge physiographic province**, encompassing the portion of Augusta County, Virginia from the Blue Ridge on the east to Little North Mountain on the west.
2. The **Folded Appalachian subsection of the Ridge and Valley province**, encompassing the westernmost section of Augusta County, and all of Bath County and Highland County, Virginia and extending from the North Mountain area on the east to the Allegheny Mountain on the west.
3. The **Allegheny Front and Appalachian Plateau** provinces of West Virginia, encompassing Pocahontas and Randolph Counties, West Virginia, and the karst section of the SHP located in Westmoreland County, Pennsylvania.

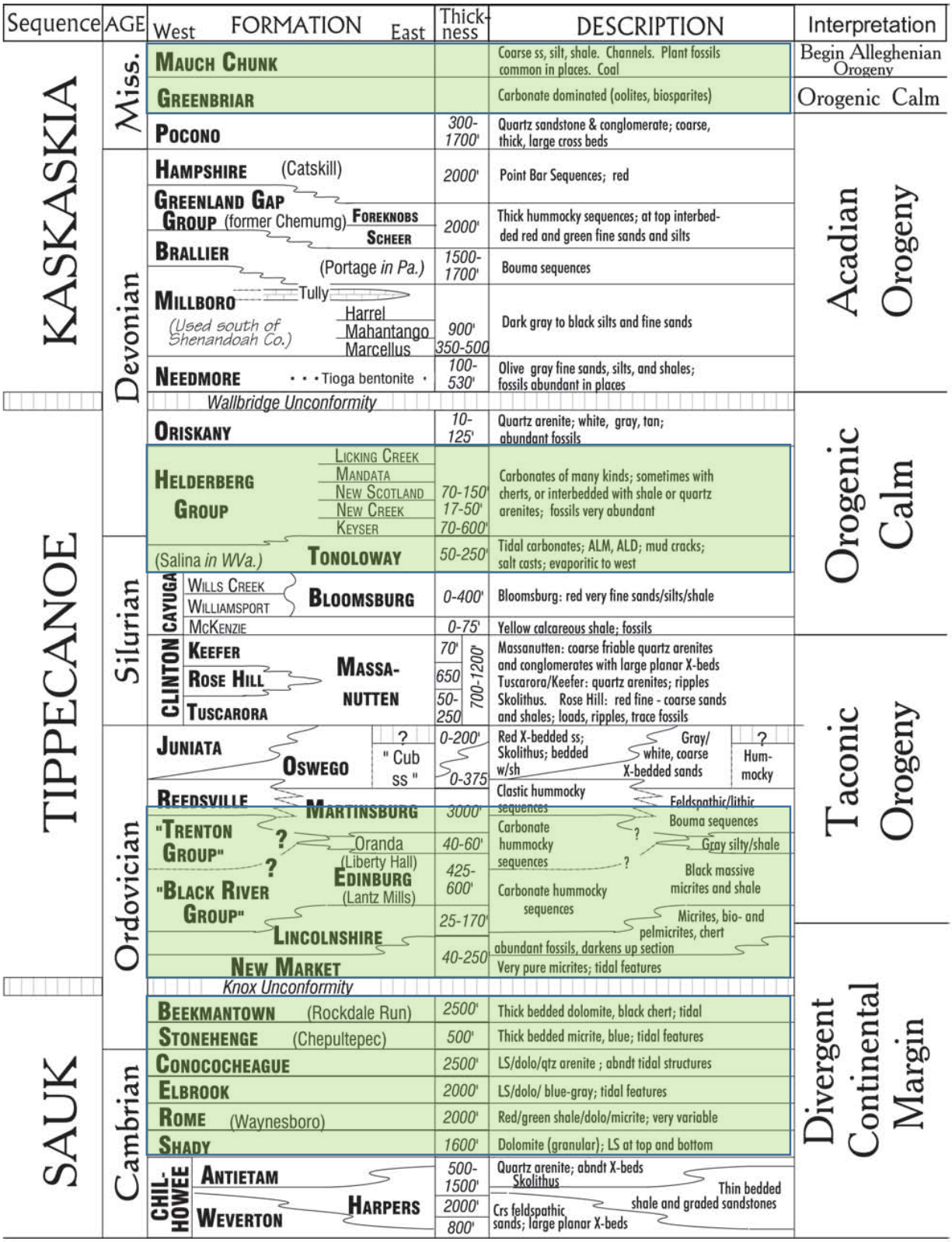

Figure 1. Stratigraphic Column of the central Virginia Great Valley, Folded Appalachians, and eastern Allegheny Front of west central Virginia and eastern West Virginia (Fichter, 2010). (The karst forming units are highlighted in green.)

The Great Valley (Augusta County, VA)

The Great Valley section is a generally downwarped trough (synclinorium) of Paleozoic limestones, shales, and sandstones that lie between the Blue Ridge Massif on the east and the Allegheny Mountains to the west. The Valley extends between the two mountain uplands from northeast to southwest, parallel with the average strike of the bedrock.

The karst terrain of the Great Valley section of the ACP project area is characterized by numerous circular to oval-shaped sinkholes, ranging in size from a few feet to several hundred feet in diameter, the majority of which are completely vegetated and lack any opening to the subsurface ("throat") at their base. Sinkhole depths can vary, but are usually controlled by the angle of repose of the sediments lining their walls. Steep, rock-walled sinkholes are rare in this section, but generally occur in the small hills and uplands that are erosional remnants of the prior valley floor.

The Great Valley section contains large karst springs in the region. It is also characterized by sinkholes called "estavelles", which are insurgences for water during dry periods, and flood or act as springs (resurgences) during wet seasons. There are also numerous caves (i.e., air-filled voids large enough to permit the entry of a human being and that have an entrance to the surface) and subsurface caverns (air-filled voids large enough for human entry with no connection to the surface) in the region. Most of the caves and caverns range in length from a few feet to several miles; however, the average length rarely exceeds 2,500 feet. This is in contrast to the Folded Appalachian and Appalachian Plateau provinces to the west, where some of the longest caves in the region have been surveyed, many of which are more than 10 miles in length. Nevertheless, though not of great length, some of the most voluminous underground chambers in the region occur in the Great Valley section.

A unique type of karst terrain has developed in the eastern portion of Augusta County along the base of the Blue Ridge Mountains. Here, the characteristic karst terrain has been buried beneath a mantle of alluvial material which was shed off the mountains to the east. This alluvium ranges in age from less than 1 million years (Quaternary Period) to over 50 million years (Paleogene Period). The alluvium thins towards the west, and disappears completely west of Waynesboro, Virginia. Although the primary karst terrain is mantled by the alluvium, numerous shallow broad sinkholes are present and indicate the presence of large karst features in the underlying bedrock.

Bedrock Geology

Specifically, the proposed ACP project area in the Great Valley section has been extensively studied and mapped as being underlain by a series of karst-forming carbonate and calcareous clastic rocks (Campbell et al., 2006; DMME, 1993; Rader & Gathright, 2001; Rader & Wilkes, 2001; Hubbard, 1988; Southworth, et al., 2013) ranging in age from the Lower Cambrian to Middle Ordovician geological periods as follows:

Ordovician Period

Martinsburg Formation (Om)

The upper 100 to 200 feet of this formation is a brown, medium-to coarse-grained, fossiliferous sandstone. An olive-green silty shale and dark-gray siltstone comprises the middle portion of this formation, along with a medium-to coarse-grained, locally pebbly sandstone. The Stickley Run Member exists as the lower 400 to 900 feet of the formation. This is a medium-gray to grayish-black, very fine-grained (aphanitic), very thin- to thin-bedded, argillaceous limestone with interbedded medium- to dark-gray, calcareous shale.

Edinburg Formation (Oeln)

A black, fine-grained to aphanitic limestone with layered black shale that commonly contains pyrite, and medium- to light-gray, fine- to coarse-grained, nodular limestone with thin partings of black shale. This formation lies in thicknesses ranging from 450 to 1,000 feet throughout the three subject areas.

Lincolnshire Limestone (Oeln)

Gradational contact with the overlying Edinburg. A light- to very dark-gray, fine- to coarse-grained, medium to very thick-bedded limestone with black chert nodules. The Murat Limestone Member, generally found at the top of the formation, is a light colored, coarse-grained limestone composed of fossil fragments. Thicknesses throughout the subject areas range from 50 to 250 feet.

New Market Limestone (Oeln)

Unconformable upper contact with the Lincolnshire. The upper unit of this formation is a medium-gray, aphanitic, thick-bedded, limestone with scattered calcite crystals. The lower unit is a medium- to dark-gray, fine-grained, thin-bedded, argillaceous, bioturbated limestone that is dolomitic in parts, with its base being a carbonate pebble conglomerate. Formation thicknesses throughout the subject areas range from 100 to 250 feet.

Pinesburg Station Dolomite* (Ob)

This formation is a medium-to light gray, fine-grained, medium- to thick-bedded dolostone, with sparse fossils. When weathered, this dolomite is very light-gray, and exhibits a "butcher-block" structure. A medium-gray, fine-grained limestone exists as the base of this unit. The formation's average thickness is 400 feet.

Rockdale Run Formation* (Ob)

The upper contact with the overlying Pinesburg Station is unconformable. This formation is comprised of a medium-gray, fine-grained, fossiliferous limestone and a light- to medium-gray, fine-grained, laminated dolomitic limestone and dolostone with mottled beds. Thin lenses of gray chert are common near the base of the formation. Formation thickness ranges from 1,500 to 2,400 feet.

Stonehenge Limestone* (Ob)

Upper contact with the Rockdale Run Formation is gradational. The upper 400 to 500 feet is comprised of a medium- to dark-gray and black, fine- to medium-grained limestone, with thin beds of macerated fossil debris. The lower 50 to 150 feet (Stoufferstown Member) is a dark-gray to black, fine-grained limestone with thin sheet-like, crinkly partings due to cleavage, and thin beds of coarse-grained, bioclastic limestone.

***Beekmantown Group (Note – This unit consists of the Pinesburg Station Dolomite, Rockdale Run Formation, and the Stonehenge Limestone)**

Cambrian Period

Conococheague Formation (OCco)

The upper contact with the Stonehenge Limestone of the Beekmantown Group is unconformable. The upper 2,000 feet of this formation is a light- to dark-gray, fine-grained, laminated limestone, dolomitic limestone, and dolostone with flat-pebble conglomerate beds. Some cross laminated sandstone beds occur in the uppermost part of this unit. The Lower 200 to 500 feet (Big Spring Station Member) consists of a light-gray, fine-grained dolostone, medium- to dark-gray, fine-grained laminated limestone and dolomitic limestone, and gray, coarse-grained sandstone and dolomitic sandstone. Beds of flat-pebble conglomerate occur in the dolomite.

Elbrook Formation (Ce)

This unit's thickness ranges from 2,000 to 2,500 feet. The formation is a dark- to medium-gray, fine- to medium-grained limestone, dolomitic limestone, dolostone, and dolomitic shale. These lithologies commonly occur as erosion-surface-bounded sequences of algal limestone overlain by laminated dolomite. Decalcified, ocherous shale-like chips on the ground surface characterize this unit. The lower 300 to 400 feet is green to greenish-gray, fine-grained dolostone, dolomitic limestone, and shale.

Waynesboro Formation (Cw)

The upper contact with the Elbrook Formation is gradational. A dusky-red to olive-gray, fine- to medium-grained sandstone and dusky-red to gray shale exists as the upper 300 feet. The middle 400 feet is a medium- to dark-gray, saccharoidal dolomite and fine-grained limestone. The lower 500 feet is dusky-red, olive-gray, and dark-gray shale and dusky-red to brownish-gray, fine- to medium-grained sandstone. Overall thickness is approximately 1,200 feet.

Tomstown Dolomite/Shady Dolomite (Ct/Cs)

The upper 600 feet is light- to dark-gray, fine- to coarse-grained, medium- to thick-bedded, locally laminated dolostone with white chert rosettes and nodules in the upper 50 feet. The middle unit (about 210 feet) is very light- to medium-gray, medium-grained, very thick-bedded dolostone and high-magnesium dolostone. The lower unit (about 325 feet) is dark-gray to black, very fine-grained, thin- to very thin-bedded limestone and dolomitic limestone with argillaceous laminations. The overall unit thickness ranges from 1,100 to 1,200 feet. The Shady Dolomite is the homologous unit in the southeastern Great Valley at the base of the western edge of the Blue Ridge Mountains.

The Folded Appalachians (Augusta County, Bath County, Highland County, VA)

The western edge of the Great Valley is demarcated by the North Mountain Fault, and the ridges of Little North and Great North Mountain. The rocks underlying this section are younger than those of the Great Valley, dating primarily from the Late Ordovician through the Devonian periods in age. In general, the mountain ridges are underlain by sandstone and siltstone, clastic rocks which are insoluble and not prone to karst terrain development. In contrast, the intervening deep valleys are often floored by carbonate rocks, and a characteristic karst landscape characterized by sinkholes, caves and springs has developed in many cases along the axis and flanks of these valleys (Hubbard, 1988; Rader & Wilkes, 2001; DMME, 1993).

Bedrock Geology

The regional geology of the Folded Appalachians in the project area has been mapped (DMME, 1993) as being underlain by a series of karst-forming carbonate rocks ranging in age from the Lower Ordovician to Lower Devonian geological periods as follows:

Devonian – Silurian Periods

Helderberg Group (Dh)

This group consists of thick- to massive-bedded, dark gray/black micritic limestone with reef structures. The limestone shows some degree of recrystallization. The uppermost Helderberg is typically silicified near its contact with the overlying Oriskany sandstone. In many areas the Helderberg gives off a distinct petroliferous odor when freshly broken. The contact with the overlying Oriskany Sandstone is poorly exposed regionally, but the contact with the underlying Tonoloway Formation is distinct and often unconformable, where the massive bedding of the Helderberg gives way to the thin-bedding of the Tonoloway Formation. The contact can be identified in places by a lag deposit consisting of flat, packstone rip-ups and pebble conglomerate.

The group is a major cave forming unit of the Folded Appalachian section, however, it is of note that the stratigraphy of this unit has been the subject of a much detailed study in recent years (Haynes, et al., 2014). The Helderberg Group consists of a series of individual formations, from oldest to youngest, respectively: the Keyser Limestone, New Creek Limestone, Corriganville Limestone, and Licking Creek Limestone formations. It should be noted that based on biostratigraphic analysis the Keyser Limestone, the basal formation of the Helderberg Group, is considered to straddle the boundary of the Silurian and Devonian periods (Denkler and Harris, 1988a).

The entire Helderberg Group varies regionally, ranging from 85 feet to over 400 feet in thickness. The Keyser is considered the thickest of the individual formations comprising the group, ranging from 50 to 230 feet in thickness.

Silurian Period

Tonoloway Limestone (Sto)

This formation consists of extremely thin-bedded (0.5 inches or less) dark gray micritic limestone interbedded with fissile, calcareous shale. The formation gives off a distinct petroliferous odor when freshly broken. The contact with the overlying Keyser Limestone is distinct; however, it grades into the underlying Wills Creek Limestone. The Tonoloway Formation varies from 150 to 600 feet in thickness.

Wills Creek Limestone (Swc)

This formation consists of thin-bedded (less than 5 inches) dark gray calcareous shale and fossiliferous micrite, which is poorly exposed in the ACP project area. The thickness is variable, ranging from 3 feet to 230 feet.

Ordovician Period

Juniata, Oswego, Reedsville, Dolly Ridge, and Eggleston Formations (Oun)

Karst forming unit present only in the westernmost Valley and Ridge section of the ACP alignment (Highland and Bath Counties). The Dolly Ridge and Eggleston Formations are the only karst-forming units and consist of a medium-gray, fine-grained, thin-bedded, argillaceous limestone with interbedded olive-gray calcareous claystone, silt argillaceous limestone, gray shale, and K-bentonite beds. Thickness is about 400 feet in Bath and Highland Counties. The unit is laterally equivalent to the Middle Ordovician ("Trenton Group") limestones and part of the lower Martinsburg Formation.

Middle Ordovician Limestones, Undivided (Olm)

These limestones consist of the Edinburg Formation, the Lincolnshire Formation, and the New Market Limestone. The Edinburg is a black, fine-grained to aphanitic limestone with layered black shale that commonly contains pyrite, and medium- to light-gray, fine- to coarse-grained, nodular limestone with thin partings of black shale. Thickness is 400 feet to 500 feet. The Edinburg grades downward into the Lincolnshire Formation, a light- to very dark-gray, fine- to coarse-grained, medium- to very thick-bedded limestone with black chert nodules. Thicknesses throughout the ACP project area range from 25 to 250 feet. This unit is underlain by the New Market Limestone. The upper contact with the Lincolnshire is generally unconformable. The upper unit of this formation is a medium-gray, aphanitic, thick-bedded, limestone with scattered calcite crystals. The lower unit is a medium- to dark-gray, fine-grained, thin-bedded, argillaceous, bioturbated limestone that is dolomitic in parts, with its base being a carbonate pebble conglomerate. Formation thicknesses throughout the ACP project area range from 0 to 150 feet.

Beekmantown Formation (Ob)

This formation is a medium- to light-gray, fine-grained, medium- to thick-bedded dolostone, with sparse fossils. When weathered, this dolomite is very light-gray, and exhibits a "butcher-block" structure. A medium-gray, fine-grained limestone exists as the base of this unit. This formation is comprised of a medium-gray, fine-grained, fossiliferous limestone and a light- to medium-gray, fine-grained, laminated dolomitic limestone and dolostone with mottled beds. Thin lenses of gray chert are common near the base of the formation. Formation thickness ranges from 1,500 to 2,400 feet. The Beekmantown Formation typically consists of three members, which although distinct in the Great Valley region are hard to distinguish in the Folded Appalachian province.

The Allegheny Front & Appalachian Plateau (Pocahontas County and Randolph County, WV)

The last section of the folded Appalachian karst is located in eastern Pocahontas County. To the west occurs the relatively flat-bedded geology of the Allegheny Front and Appalachian Plateau provinces. The karst terrain in this area is formed almost exclusively by the carbonate rocks of the Mauch Chunk and Greenbrier Groups.

In general, the Mauch Chunk and Greenbrier Group carbonates exhibit a high density of caves relative to the other two karst sections along the pipeline. There are several factors that contribute to this, the main one being that the units act as a drain system for groundwater infiltrating downward through the fractured clastic rocks above them. Where they are exposed along the mountain flanks, the steep groundwater gradients have enhanced this cavern development. In many places surface water plunges directly into the carbonates via steep-walled, open throat sinkholes (swallets). Most of the caves are linear networks, and exhibit conduit flow, capturing surface streams upgradient which then emerge as springs at the downgradient end.

Bedrock Geology

The Appalachian Plateau section has been mapped (Cardwell, et al., 1968; Davies, 1958) as being underlain by the karst-forming carbonate rocks of the Greenbrier and Mauch Chunk Groups, exclusively. The geology is described from youngest to oldest as follows:

Mississippian Period

Mauch Chunk Group – Includes the Bluestone and Princeton Formations (Mbp), Hinton Formation (Mh), and Bluefield Formation (Mbf). The group is predominantly red, green and medium-gray shale and sandstone, with a few thin limestone lenses in each formation. Although the limestone strata in the unit are considered secondary, the topographic position of the Mauch Chunk along the edges of the eroded upland of the Allegheny Plateau where there is a relatively steep downward hydraulic gradient has enhanced water flow through the carbonate lenses, forming karst conduit networks with high transmissivity (Kozar & Mathes, 2001), thus from a karst hydrology viewpoint this unit is significant.

Greenbrier Group (Mg) – In the project area the Greenbrier Group (or "Big Lime" as it is known locally) is up to 400 feet in thickness. It is primarily a gray to dark gray, massively bedded marine limestone, with interbeds of red and green marine and nonmarine shale and thin discontinuous beds of sandstone. The Group is divided into six stratigraphic units; from oldest to youngest they are: the Denmar Limestone, Taggard Shale, Pickaway Limestone, Union Limestone, Greenville Shale, and Alderson Limestone. The principle cave forming units are the Pickaway and Union limestones.

Pre-Construction Assessment and Field Survey

The proposed ACP/SHP involves the installation of a gas pipeline extending through West Virginia, Virginia, and into southern North Carolina. The currently proposed pipeline construction alignment information shows that the primary route being considered for the pipeline passes across approximately 32.5 miles of karst terrain located in Randolph and Pocahontas Counties in West Virginia, and Highland, Bath, and Augusta Counties in Virginia, based on regional geological mapping.

The "Karst Review Area" (hereinafter referred to as the "KRA") assessed by data desktop review generally extended 0.25-mile from either side of the centerline of the proposed pipeline and alternate routes, and a 300 foot "study corridor" (300FC) extending 150 feet from either side of the centerline for field review. However, if observed or mapped karst features received drainage from the proposed pipeline work area then these features were delineated to the extent possible, and included in the assessment, even if they were outside of these perimeters.

Thus, the pre-construction assessment and field survey scope can be summarized as follows:

- Located and delineated surface karst features (e.g., sinkholes and karst related subsidence, cave entrances, closed depressions, and sinking and losing streams) within the KRA, with particular emphasis on features that had a direct connection with the phreatic zone such as "open-throat" sinkholes, karst windows, cave entrances, abandoned wells, sinking streams, and areas that could affect the integrity of the pipeline, such as actively forming cover-collapse sinks, areas of soil subsidence, or caves which have passages that extend below the proposed right-of-way at elevations less than 15 feet below the surface. Direct field observations were made by conducting a site reconnaissance over the entire 300FC where access was available.
- Delineated zones of karst terrain, subsidence, and drainages based on the surface karst features assessment.
- Prepared a report summarizing the methods and findings of the assessment.

Methods and Procedures

The above scope of services was accomplished by the following means:

Existing Data Review and Analysis

Potential karst features were identified remotely and/or by database review, and then their presence was confirmed in the field. This process helped to focus the actual field location and survey tasks. The following sources were reviewed:

1. The (proprietary) Cave Databases of the Virginia Speleological Survey (VSS) and the West Virginia Speleological Survey (WVSS);
2. Caves of Virginia (Douglas, 1961);
3. Description of Virginia Caves (Holsinger, 1975);
4. Caverns of West Virginia (Davies, 1965);
5. Maps of selected karst features (sinkholes, caves, springs) available from the Virginia Division of Mines and Mineral Resources and the United State Geological Survey (USGS);
6. 2-foot and 4-foot contour interval maps for the KRA (to determine the presence of surface karst features not included in the above listed databases based on the presence of closed, descending contours or other suspect karst "fingerprint" features);
7. LIDAR data (where available);
8. Aerial photographs (both recent and historical);
9. USGS Topographic 7.5-minute topographic quadrangles;
10. Sinkhole and depression locations available from the US Department of Agriculture-Natural Resources Conservation Service (USDA-NRCS) soil studies for the Counties through which the ACP will pass.
11. Weary, D.J. and D.H. Doctor. 2014. Karst in the United States: A digital map compilation and database, USGS open-file report 2014-1156, 23p

In addition, the survey team reviewed the readily available geological literature for bedrock and structural characteristics, relying upon the closest resolution mapping that existed for the particular KRA being examined.

Field Reconnaissance

Upon completion of the existing data review activities for a specific area, GeoConcepts undertook field reconnaissance and survey activities. Specifically, the field reconnaissance entailed:

1. Location and verification of surface karst features identified in the database review;
2. Location of uncatalogued or previously unidentified surface karst features, specifically sinkholes, cave entrances, dry runs and sinking streams.

The field reconnaissance placed particular emphasis on locations where pathways existed to phreatic groundwater such as open-throat sinkholes, cave entrances, karst "windows", and sinking streams. Potential reroutes were identified based on the field observation of sensitive karst features, such as significant caves, sinking streams, or open throat sinkholes.

The 300FC was delineated and the path of the 300FC was examined for karst features (both catalogued and previously unidentified) by field survey. This entailed conducting a site reconnaissance over the 300FC (i.e., the proposed pipeline route) in a systematic manner, to observe any existing surface karst features that fit the criteria. The locations and outlines of all relevant features were recorded using a sub-meter accurate Global Positioning System (GPS) device. For the purpose of this study, the outline (parapet) of sinkholes were defined by the last closed descending contour at mapping interval available for the area under study. Cave entrances were identified as single points, unless the entrance was located within a larger sinkhole structure, in which case the cave entrance was indicated as a point within the sinkhole's parapet. Sinking streams were located as points of entry into the subsurface; however, losing streams were identified as linear features.

All digital data was transmitted in the Universal Transverse Mercator (UTM) Coordinate system. The horizontal datum of reference is NAD83.

Summary Report

The results of the data review and field survey has been summarized in a final report. The report details the methods and findings, and contains an inventory and contained a delineation of karst features and terrain. The frequency and density of karst features was also correlated with the encompassing geological unit at the formational level (e.g., Elbrook Formation, etc.). The report is accompanied by a data set containing the attributed digital points and polygon data as shapefiles with metadata (maps and/or tables). The results of the karst survey work was used during routing and workspace design. In addition, these data will be used during the construction phase to assist in the pre-construction inspection tasks described in the following sections.

Construction Monitoring

The purpose of this section of the plan is to establish a standard set of monitoring protocols for karst features encompassed by the proposed ACP pipeline right-of-way and adjacent areas. The intent of these protocols is to minimize impact to the subterranean environment, ensure water quality, and protect the integrity of the pipeline (Burden, 2012).

I. Geophysical Survey

To obtain more information about the subsurface conditions, and possible karst development along the proposed ACP pipeline alignment, an electrical resistivity investigation (ERI) will be conducted in the areas that are mapped with limestone bedrock. The ERI will be performed along the entire length of the pipeline centerline in karst terrain prior to any earth-disturbance and/or excavation activity.

Instrumentation

The geophysical survey instrument which will be used during this survey is an electrical resistivity meter that maps the resistivity changes in the earth. Resistivity refers to the electrical resistance of a material. The ERI survey will be conducted by introducing a measured current into the earth through two electrodes and measuring the resultant voltage (i.e., potential) across two different electrodes. At the low currents used, voltage is proportional to the current. The meter measures the voltage/current ratio or resistance in Ohms.

The ERI survey will be conducted using an earth resistivity meter which measures the apparent conductivity of the subsurface employing an artificial source that is introduced through point electrodes. The automatic electrode system is designed to optimize survey efficiency by gathering maximum information with a minimum of electrodes. The instrument also uses redundancies in the data set to reduce the effects of lateral heterogeneities in the earth and to calculate uncertainties in the data. The survey will be conducted automatically using a dipole-dipole array system.

Interpretation Method

The ERI data will be converted into a resistivity depth model using a Rapid 2D resistivity inversion model and the least-squares method (RES2DINV). Soundings from each line will be modeled to produce the measured apparent resistivity pseudo-sections. The model will calculate the apparent resistivity pseudo-sections using finite-difference forward modeling. The least-squares optimization technique will be used for the inversion routine that calculates the modeled resistivity section. The generated profiles will include cross-sections that consist of the inverse model resistivity cross-section. The horizontal and vertical scales will be in meters.

The cross-section is the inverse model resistivity pseudo-section. The ER data will be converted into a resistivity depth model (RES2DINV) using a resistivity inversion model by the least-squares method, which will be topographically corrected. RES2DINV will confirm the model reliability by calculating the modeled data into empirical data or the calculated resistivity pseudo-section. The difference between the measured and calculated data is the percent error. The modeled calculated error will be calculated within the five percent range, which is considered very accurate.

Low resistive materials can be caused by certain conductive soils, such as clay, wet silts, and sands, or ionized water. High resistive materials are caused generally by porous soils (i.e., poorly consolidated gravels), laminated bedrock with interstitial clay-filled voids, wood, or large, air-filled cavities. Lower ER anomalies are generally associated with soil-filled voids, saturated sinkhole soils, and water-bearing fractures. High ER anomalies are frequently associated with caverns, buried air filled structures, or weathered, laminated bedrock with air filled cavities.

Resistivity values can vary widely as the geology, mineralogy, and stratigraphy changes from site to site. Therefore, it is important to correlate resistivity results with boring logs for equivalent sections at a specific locality. Typical values are:

Subsurface Material	**Resistivity Range (Ωm)**
Topsoil	1 – 10
Clays	10 – 100
Sands and Gravels (unconsolidated)	600 – 10,000
Fresh Water	3 – 100
Limestone	100 – 10,000
Sandstone	100 – 1,000
Igneous and Metamorphic Rocks	100 – 1,000,000
Open Voids (i.e. caverns, solution conduits)	>10,000

Although the above values are characteristic of various subsurface materials, the absolute resistivity ranges will vary considerably depending on the local geology. Therefore, it is required that the ERI survey is calibrated using soil test/air track borings. In addition, if high ER anomalies are detected, their locations will need to be documented and further investigated. The specific type of investigation will be dictated by the characteristics of each anomaly identified, but typically air track borings will be used to verify anomalies observed during an ERI survey.

II. Inspection Protocols

Inspection protocols will be provided to the contractor and will be reviewed at a pre-construction meeting led by the Karst Specialist (KS). In addition, all geologist or engineering staff utilized during construction will have received training from the KS prior to mobilization to the site regarding the identification and mitigation of karst features that have been previously identified within the project boundaries, or that may be identified during construction.

Pre-Construction Inspection

Prior to the commencement of any earth disturbance activity, the area of the pipeline that will be affected by the planned activities will be inspected by the karst specialist (KS) as follows:

a. The KS will inspect the entire section of the pipeline ROW (right-of-way) in the designated work area, and note any suspect karst features including sinkholes, caves, areas of soil subsidence, or closed depressions.

b. The KS shall conduct a final preconstruction field assessment of seeps and springs within 500 feet of construction workspaces in karst terrain. The KS shall subsequently determine if construction activities could have an impact on the seeps and/or springs, and provide construction alternatives to avoid or mitigate impacts where practical.

c. The locations of observed features will be noted on site drawings and flagged for surveying and/or recorded using sub-meter accuracy GPS instrumentation.

d. The KS will issue a report summarizing the findings of the inspection. Findings will supplement the summary report and shall include an inventory of feature type(s), drainages, and potential impact to the feature by the planned activities, and recommendations to limit impacts if they are expected. This inspection is intended to supplement the aforementioned pre-construction karst assessment and field survey report, as new features may have developed, or existing features described in identified in the original assessment may have changed.

e. Features that are considered to have potential impacts are: caves, sinkholes with open throats, ponors, open solution cavities, abandoned wells, and sinking streams. (Note – If a sinkhole throat is filled, the type of fill, i.e. rock, soil, flood debris, etc., will be described in detail).

f. Features that are not considered to have a potential impact are: soil-bottomed (stable) sinkholes (i.e., no evidence of recent soil raveling or tension cracks along the parapet), karst springs, or non-karst closed depressions. However, it is of note that land disturbance to stable sinkholes can render them unstable. Not structurally unstable in general, but strictly in terms of raveling of surface materials (sediment) and associated contaminants into the subsurface.

g. The pre-construction inspection will have a "shelf-life" of 1 year from the day of the inspection. If work does not commence within 1 year, a new inspection will need to be completed prior to any earth disturbing activities.

h. The pre-construction inspection report shall be delivered to Atlantic/DTI no later than 1-month after the completion of the field survey.

Monitoring of Pre-Identified Features During Construction

Features identified during the pre-construction inspection will be monitored as follows:

a. If an identified feature with potential impact to the subterranean environment falls within the area designated for earth disturbing activities and cannot be avoided, the feature will be documented by field location and photographs, and then assessed for pre-construction remediation by Atlantic/DTI staff with input and guidance to be provided by the KS. Remediation will be in compliance with the USDA-NRCS's Conservation Practice Standard Code 527 "Karst Sinkhole Treatment" (2010) and the West Virginia Department of Environmental Protection Division of Water and Waste Management Ground Water Protection Program Sinkhole Mitigation Guidance, August 8, 2005. (see Appendix A)

b. If a feature that has potential impact falls within the right-of-way but is not intercepted by the excavation, that feature will be monitored during the work by Atlantic/DTI staff for changes such as:

    1. soil subsidence;
    2. rock collapse;
    3. sedimentation;
    4. increased surface water infiltration;
    5. flooding;
    6. clogging; and/or other changes in morphology or function that might indicate potential impact to the epikarst stratum caused by the work.

c. All features, whether remediated or left in an undisturbed natural state, will be monitored by Atlantic/DTI staff, or their designee, for any changes in appearance, drainage, siltation, etc., at 1 year, 2 year, and 5 year intervals after the completion of the earth disturbing activities. If changes in the features are observed, Atlantic/DTI staff will report the condition to the KS who will provide consultation on potential impacts to the karst environment and possible remedial actions.

Monitoring of Features That are Intercepted During Construction

Features that are intercepted during construction shall be monitored as follows:

Level 1 Inspection of Features Intercepted During Construction

If any feature is intercepted during work activities including borings, blasting, and excavation or trenching, the onsite geologist will conduct an initial assessment of the feature to determine if further inspection (Level 2) by the KS will be required. Suspect features shall include:

1. Bedrock enclosed conduits, cave entrances[2] and voids;
2. Solution pockets that extend beyond visual examination range (and therefore may be open);
3. Areas of soft soils;
4. Soil voids;
5. Highly fractured bedrock;
6. Areas of breccia enclosed within the surrounding bedrock.

Level 2 Inspection of Features Intercepted During Construction

If any of the aforementioned features are observed during the Level 1 inspection, work will stop within a 100-foot radius of the feature, and then the KS will conduct a Level 2 inspection as follows:

a. The KS will examine the feature and determine if it has potential impact to the subterranean environment based on potential connectivity with the phreatic aquifer via the epikarst stratum (Moore, et al, 2013). The choice of characterization methods will be determined by the KS, and will include any combination of (but not be limited to):

    1. visual assessment;
    2 geophysical survey;
    3 track drill probes;
    4. infiltration or dye trace testing; or
    5. other techniques utilized to facilitate subsurface characterization of karst features.

b. If the feature is determined to have potential impact to the subterranean environment, the KS will advise Atlantic/DTI staff regarding appropriate remedial actions.

[2]If an opening to a cave is intercepted during construction activities, there should be immediate coordination with the US Fish and Wildlife Service, US Forest Service (if within Forest Service ownership land) Virginia DCR-NHP Karst Program (or) West Virginia Department of Conservation, for investigation.

c. If the feature is determined to not have potential impact to the subterranean environment, work will resume as planned.

d. All features that are intercepted during construction and subsequently remediated will be located by project surveyors exclusively, and monitored by Atlantic/DTI staff, or their designee, for any changes in appearance, drainage, siltation, etc., at 1 year, 2 year, and 5 year intervals after the completion of the earth disturbing activities. If any changes are observed, the KS will provide consultation on potential impact and recommend remedial actions, if necessary.

e. All Level 2 inspections, findings, and remedial activity will be summarized in a report by the KS, to be delivered to Atlantic/DTI after the completion of the field work.

Monitoring of Features That Form During Construction

Features that form during construction will be monitored as follows:

Level 1 Inspection of Features That Form During Construction

If any feature forms during work activities including hydrostatic testing, drilling, blasting, and excavation or trenching, Atlantic/DTI staff will conduct an initial assessment of the feature to determine if further inspection (Level 2) by the KS will be required. Suspect features will include:

a. Cave entrances[3]
b. Sinkholes;
c. Soil subsidence areas; and/or
d. Rock collapses.

This will apply to any of the above features that may form either within the work area, whether located along the proposed disturbance section or anywhere within a 300-foot radius of the work area.

Level 2 Inspection of Features That Form During Construction

If any of the aforementioned features are observed during the Level 1 inspection, work will stop in the area of the feature based on the observed site conditions, and then the KS will conduct a Level 2 Inspection as follows:

a. The KS will examine the feature and determine if it has potential impact to the subterranean environment based on potential hydraulic connectivity with the karst aquifer via the epikarst stratum.

b. The choice of characterization methods will be determined by the KS, and will include any combination of (but not be limited to) the following:

    a. visual assessment;
    b. electrical resistivity survey;
    c. track drill probes;
    d. infiltration testing; and/or
    e. other techniques utilized to perform subsurface characterization of karst features.

c. If the feature is determined to have potential impact to the subterranean environment, the KS will consult with Atlantic/DTI staff regarding appropriate remedial actions.

d. If the feature is determined to not have potential impact to the subterranean environment, work will commence as planned.

e. All features that form during construction, whether remediated or left in an undisturbed natural state, will be located on the site plans by the project surveyors, and will be monitored for any changes in appearance, drainage, siltation, etc. at 1 year, 2 year, and 5 year intervals after the completion of the earth disturbing activities. If any changes are observed, the KS will provide consultation on potential impact to the karst environment and remedial actions, if necessary. This

[3]If an opening to a cave forms during construction activities, should be immediate coordination with the Virginia DCR-NHP Karst Program (or) West Virginia Department of Conservation for investigation.

monitoring will be carried out on all features that form during work activities, regardless of whether they have a potential impact to the karst environment or not.

III. Notification and Consultation

Notification of, and consultation with State and Federal regulatory and administrative agencies will be completed for the following:

1. Any planned invasive subsurface exploration, including: geotechnical soil borings; rock coring; air track borings; test pits; or other invasive investigative measures that have the potential for intercepting subsurface voids, conduits, or caverns.
2. Any karst features that were identified and located prior to construction that will require remediation or mitigation.
3. Any karst features that were identified and located prior to construction that will require periodic monitoring, whether remediated or left in an undisturbed natural state. The results of the monitoring shall be documented and reported to the appropriate agencies.
4. Any karst features that are intercepted during construction. Notification and consultation will take place after the performance of the Level I inspection.
5. Any karst features that form during construction. Notification and consultation will take place after the performance of the Level I inspection.
6. Any karst features that form following construction which are observed during the post-construction karst feature monitoring (*see* Level 2 Inspection of Features that form during construction, part e).

Federal Agencies to be Notified

United States Fish and Wildlife Service (USFWS)
Federal Energy Regulatory Agency (FERC)
United States Forest Service (USFS)[4]

State Agencies to be Notified (Virginia)

Virginia Department of Conservation and Recreation – Natural Heritage Program (DCR-NHP)
Virginia Department of Environmental Quality (VDEQ)

State Agencies to be Notified (West Virginia)

West Virginia Division of Natural Resources (WVDNR)
West Virginia Department of Environmental Protection (WVDEP)

Karst Mitigation and Conservation Procedures

The following procedures will be used to avoid and minimize any impact of pipeline construction and/or O&M activity which might present a risk to environmental receptors, in particular obligate subterranean taxa. Please note that other resource protection measures that may be implemented for the ACP may provide redundancy with regard to the karst mitigation and conservation procedures detailed herein.

Measures to Avoid Impact to the Karst Aquifer and Environment

These measures shall apply to any karst feature which allows the unfiltered and unimpeded flow of surface drainage into the subsurface environment, including (but not limited to): open throat sinkholes, caves which receive surface drainage, sinking streams, and losing stream segments. These avoidance measures were derived from the NiSource Habitat Conservation Plan, Madison Cave Isopod Avoidance and Minimization Measures, and the Columbia Pipeline Group HCP and non-HCP species Best Management Practices

[4] Only if within USFS lands.

Guidance Document. They are intended to prevent impact to the karst aquifer and the subsurface habitat of obligate stygobiont species through protection of groundwater quantity and quality (Burden, 2012).

1. Protect known and/or future mapped recharge areas of cave streams and other karst features by following relevant conservation standards, specifically the FERC 2013 Upland Erosion Control, Revegetation and Maintenance Plan, the FERC 2013 Wetland and Waterbody Construction and Mitigation Procedures, and the ACP Spill Prevention, Containment, and Control (SPCC) plan.
2. Buffers of 300 feet around karst features in all work areas (within and off-ROW including discharge areas) must be clearly marked in the field with signs and/or highly visible flagging until construction related ground disturbing activities are completed. If a karst feature or its 300-ft buffer falls within the 125-ft wide workspace the following steps should be taken:
    a. The workspace should be narrowed (if practicable) to impact as little of the buffer as possible.
    b. No spraying of insecticides or herbicides shall be allowed within the 300-ft buffer.
    c. No refueling, repair or maintenance of vehicle or equipment shall be allowed within the 300-ft buffer.
    d. Soil disturbance within the buffer (i.e. trenching) shall be performed in a manner which prevents sediment from entering the subsurface through the use of carefully designed and continuously maintained sediment and erosion control measures, and shall follow the procedures and BMPs specified in the FERC plans and procedures mentioned in section 1, above.
    e. If the karst feature is located downgradient from the area of soil disturbance, drainage shall be directed away from the karst feature and its 300-ft buffer through the use of diversion trenches, water breaks, or other engineered methods. This shall apply even if the feature itself is located outside of the 125-ft workspace, but the workspace intercepts the 300-ft buffer.
    f. No activity of any kind shall be allowed within the parapet of a sinkhole or within a 25-ft buffer around the parapet, which should remain in an undisturbed, natural state. The sinkhole and the 25-ft parapet buffer should be delineated using temporary fencing.
3. Earth disturbing activities will be conducted in a manner that minimizes alteration of existing grade and hydrology of existing surficial karst features. Pre-existing flow channels will be stabilized but will not otherwise be altered. Concentrated flow caused by construction activities will be dispersed with a suitable spreading or diversion technique. Surface water flow volume will be maintained at historic (or predevelopment) levels as changes to the volume of surface water flow can disturb the subsurface hydrology.
4. Any open-throat sinkholes and cave entrances within 300 feet of the workspace, located downgradient from the centerline which receives drainage from the workspace will be carefully protected using silt fences, diversion trenches, constructed temporary berms around the parapet, or water breaks. If the feature receives flow via a discreet drainage channel, the channel will be equipped with absorptive boom and a double row of silt fences.
5. In addition to the aforementioned requirements, the following will be implemented in construction workspace areas:
    a. If a new open throat, cover-collapse sinkhole forms within the ROW or construction work space, work in that area will stop and the sinkhole will be isolated from the rest of the work area with sandbags or other suitable materials. The sinkhole will be inspected by the KS and appropriate action taken (e.g., pipeline relocated, sinkhole remediated, etc.) to ensure pipeline integrity and protection of the aquatic resource and subterranean habitat. The preferred method for remediation will be the graded/inverted filter method (Ralstein and Oweis, 1999). This technique involves excavation and cleaning out collapsed, soft soils in the weakened zone to limit further soil raveling, and placing rocks or boulders large enough to bridge the bedrock conduit or "throat" at the bottom of the excavation. Progressively finer rock and gravel are then placed and compacted above the base course, above which is placed a layer of permeable

geotextile fabric and soil to the final grade which is then seeded. The advantage of this method is that it allows surface water to continue to infiltrate into the subsurface, but prevents further soil raveling (which is the root cause of cover-collapse sinkholes). The vegetated soil stratum and underlying gravel acts as a natural filter for the water infiltrating to the underlying solution enlarged conduits and fracture system. (see Appendix A).

b. If a subsurface void or conduit should open or be intersected in the process of excavation and/or trenching, work in that area will stop and the void will be isolated from the rest of the work area with sandbags or other suitable materials. The void will be inspected by the KS and the most appropriate remedial method will be determined on a case-by-case basis. Soil voids will be backfilled using the graded filter method as described above. Small conduits (< 1 foot in diameter) may be closed with low mobility grout and/or flowable fill. Large conduits (>1 foot in diameter) will require specific remedial actions (capping, void bridging, or plugging) based on the location and geometry of the conduit (i.e. whether the conduit is located at the bottom, one side, or both sides of the trench).

c. If a subsurface void or conduit should open or be intersected in the process of excavation and/or trenching through which water is flowing (i.e. an underground stream) work in that area will stop, and the void will be isolated from the rest of the work area with sandbags or other suitable materials. The void will be inspected by the KS, and the most appropriate remedial method will be determined on a case-by-case basis. All efforts will be made to ensure that the existing flow path is not interrupted by isolating the stream using trench breakers, and backfilling the location of the saturated karst feature or stream with permeable material such as well-graded stone or other material which will not interfere with the continued flow of water from one side of the trench to the other.

d. In linear excavations adjacent to karst features, spoils will be placed on the upgradient side of the excavation so that if any erosion takes place the stockpiled soil will flow back into the excavation and not downgradient towards the karst feature.

e. Surface water control measures, including, but not limited to: diversion (direct water flow into trench or off right-of-way areas past the area of concern), detention or collection and transportation, will be utilized to prevent construction-influenced surface water from free flowing into open throated surface karst features, and eventually into the subsurface.

f. Open throat surface karst features will not be utilized for the disposal of water. This shall include, but not be limited to: hydrostatic test water, water from trench dewatering, or any other water generated by, or utilized in, construction activities.

6. Blasting will be conducted in a manner that will not compromise the structural integrity or alter the karst hydrology of known or inferred subsurface karst structures. If blasting or hammering is deemed necessary then the following parameters will be adhered to:

   a. The excavation will be carefully inspected for any voids, openings or other tell-tale signs of solution activity.

   b. If the rock removal intercepts an open void, channel, or cave, the work in that area will be stopped until a remedial assessment can be carried out by a qualified geologist or engineer with experience in karst terrain.

   c. All use of explosives will be limited to low-force charges that are designed to transfer the explosive force only to the rock which is designated for removal (e.g., maximum charge of 2 inches per second ground acceleration).

   d. If the track drill used to prepare the hole(s) for the explosive charge(s) encounters a subsurface void larger than 6 inches within the first 10 feet of bedrock, or a group of voids totaling more than 6 inches within the first 10 feet of bedrock, then explosives should not be used (or) a subsurface exploration should be conducted to determine if the voids have connectivity with a deeper structure. The subsurface exploration can be carried out with track drill probes, coring drill, electrical resistivity, or other techniques capable of resolving open voids in the underlying

bedrock. If a track drill or coring rig is used, then all open holes will be grouted shut after the completion of the investigation.

7. Horizontal Directional Drilling (HDD) will not be used in karst terrain.
8. If authorized by the landowner, block (e.g. gate) all access roads and ROWs leading to cave entrances or open throat sinkhole structures to prevent unauthorized access.
9. Comply with requirements of project SPCC plan.
10. A Spill Prevention, Control, and Countermeasures Plan (SPCC) has been developed for the proposed ACP/SHP which will further avoid and minimize potential impact of spills by implementing the following measures:
    g. equipment refueling will not be performed within flagged or marked buffer areas of streambeds, sinkholes, fissures, or areas draining into these or other karst features, except by hand-carried cans (5 gallon maximum capacity) when necessary;
    h. equipment servicing and maintenance areas will be sited outside of flagged or marked buffer areas of streambeds, sinkholes, fissures, or areas draining into these or other karst features;
    i. prevent runoff resulting from construction equipment washing operations to directly enter any karst feature by locating these operations outside of the buffer area;
    j. construction equipment vehicles, materials, hazardous materials, chemicals, fuels, lubricating oils, and petroleum products will not be parked, stored, or serviced within 300 feet of any karst feature;
    k. all equipment will be checked by a construction inspector daily for leaks prior to beginning work in karst areas; damaged or defective equipment will be removed or repaired; and
    l. if a reportable spill has impacted a karst feature:
        i. follow the SPCC Plan and
        ii. call the National Response Center (800-424-8802) and the Virginia Department of Environmental Quality (800-469-8892) or the West Virginia Department of Environmental Protection (304-558-5938), as appropriate.
11. Hydrostatic test water will not be obtained from karst features (only free-flowing streams).
12. Hydrostatic testing water from new pipe installations shall not be discharged into flagged or marked buffer areas of sinkholes, fissures, or other karst features or channels or surface features that flow towards those features. Discharging of hydrostatic testing water shall be performed in the following manner (in order of priority and preference):
    a. Discharge hydrostatic test water downgradient of flagged or marked buffer areas of sinkholes, fissures, or other karst features unless on-the-ground circumstances (e.g., man-made structures, terrain, or other sensitive resources) prevent such discharge.
    b. If water cannot be discharged downgradient as described in 12a, discharge water into uplands greater than 300 feet from flagged or marked buffer areas of sinkholes, fissures, or other karst features unless on-the-ground circumstances (e.g. man-made structures, terrain, other sensitive resources) prevent such discharge.
    c. If the conditions listed in either 12a or 12b are not practicable, discharge water as far from flagged or marked sinkholes, fissures, or other karst features as is practical and utilize additional sediment and water flow control devices to minimize effects.

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Appendix A – Sinkhole Mitigation Guidance Documents

West Virginia Department of Environmental Protection
Division of Water and Waste Management
Groundwater Protection Program

Sinkhole Mitigation Guidance

August 8, 2005

Purpose:

These sinkhole mitigation designs serve to allow the filling of sinkholes while maintaining recharge to the aquifer, reducing potential contamination threats to groundwater, and eliminating safety hazards at sinkhole entries.

General:

Consideration should be given to the method used for removing contaminated materials from sinkholes and reducing or eliminating direct inflow of surface water into sinkholes. Land treatment methods that improve the filtration and infiltration of surface water before it enters the sinkhole should be used along with the mitigation of the sinkhole.

Before selecting a treatment option the following should be considered:

- Land use
- Existing and planned land treatment
- Sinkhole drainage area
- Dimensions of the sinkhole opening
- Safe outlet for diverted surface water
- Environmentally safe disposal of sinkhole "clean out" material
- Availability and quality of filter material
- Safety of equipment and operators and laborers during installation

Treatment selection should be based on the dimensions of the sinkhole drainage area and include direct sinkhole treatment with surface water control measures and filter strips. Whichever treatment option is chosen, it should avoid surface water ponding or the creation of high soil moisture conditions in excess of 72 hours.

Treatment designs apply to sinkholes with excavated depths of 5 to 25 feet and with drainage areas up to 15 acres. Excavations up to 5 feet are sufficient for most sinkholes. Sinkholes with excavation depths of greater than 25 feet or with uncontrolled drainage areas greater than 15 acres may require adjustments to the treatment measure(s) and/or surface water control measure(s). In these cases, geologic and engineering assistance must be obtained and a site-specific treatment design prepared.

Treatment for Sinkholes with Drainage Areas Less than 5 Acres

Treat the sinkhole using the mitigation design in Figure 1 of this guidance document. The treatment site should be inspected after periods of heavy precipitation because some material may run into adjacent sinkhole voids causing a surface depression. In this case, maintenance will include adding soil material at the surface. The existing land use or practice may continue over the treated sinkhole as long as the treatment is maintained.

Treatment for Sinkholes with Drainage Areas of 5 Acres or More and Having a Safe Outlet

The following additional treatment criteria are applicable to sinkholes with drainage areas of 5 acres or more where a safe outlet can be provided to divert surface water away from the sinkhole. A safe outlet is one that does not erode, divert surface water to another sinkhole or injection well, or cause flood damage to crops, property, buildings, or highways/roads.

Surface water control measures should be situated to reduce the internal drainage area around the sinkhole to less than 5 acres. The choice of surface water control measures is generally based on site-specific conditions.

Treatment for Sinkholes with Drainage Areas of 5 to 15 acres and Having No Safe Outlet

Treat the sinkhole using the mitigation design in Figure 2 of this guidance document. The site should be inspected after periods of heavy precipitation because some material may run into adjacent sinkhole voids causing a surface depression. In this case, maintenance will include adding soil material at the surface. The sinkhole should remain as unused land.

Vegetated Buffer Area

A vegetated buffer area should be installed around the sinkhole to improve runoff water quality by filtration and adsorption of contaminants. The vegetated buffer area should be installed within the sinkhole drainage area and should begin at the treated sinkhole.

The minimum width (in feet) of the vegetated buffer area is determined by multiplying the sinkhole drainage area (in acres) by seven. This width should provide beneficial filtering for some distance outside the sinkhole because surface water runoff may be temporarily held before reaching the treated sinkhole.

Appropriate vegetation should be used for the buffer area. Use native vegetation as much as possible. **DO NOT** use noxious plants or weeds. It is recommended that a plant nursery be consulted for the appropriate vegetation.

Acceptable Materials

Engineering fabric - must meet the applicable requirements of AASHTO M-288.

Aggregates – fine aggregates, gravel, or rock rip rap that conforms to the West Virginia Department of Highways, Standard Specifications for Roads and Bridges, Sections 702, 703, and 704.

Specifications

Use the following guidance for installing a mitigation design for sinkholes and sinkhole areas with drainage areas of less than 5 acres:

1. Remove and properly dispose of materials dumped in and around the sinkhole in accordance with applicable federal, state, and local laws.

2. Excavate loose material from the sinkhole and try to expose the solution void(s) in the bottom. Enlarge the sinkhole, as necessary, to allow for installation of the filter material.

3. Select stone that is approximately 1.5 times larger than the solution void(s). Place the stone into the void(s) forming a competent bridge. Stone used for the bridge should have rock strength equal to, at least, moderately hard (*e.g.*, resistant to abrasion or cutting by a knife blade but can be easily dented or broken by light blows with a hammer). Shale or similar soft and non-durable rock is not acceptable.

4. Place a layer of filter material over the bridge to a minimum thickness of 24 inches. Approximately 35 percent of the material should be larger than the opening between the bridge and the void(s). There should be no discernable large openings around the bridge. The material should be either gabion stone, stone for rip rap, or stone for special rock fill that conforms to West Virginia Department of Highways, *Standard Specification Roads and Bridges*, Section 704.

5. Place a layer of smaller size filter material over the previous layer to a minimum thickness of 10 inches. The size of the material should be ¼ to ½ the size of that used in the previous layer. The material should be No. 57 aggregate, which conforms to West Virginia Department of Highways, *Standard Specifications Roads and Bridges*, Sections 703.1.1, 703.1.2, 703.1.3, 704.1.4, and 703.2.1. Unacceptable filter material consists of pea gravel or slags (steel, electromagnetic, or power plant).

6. Place a layer of sand-sized filter material over the previous layer ~~at~~ to a minimum thickness of 10 inches. The sand must be compatible in size with the previous layer to prevent piping. The material should be fine aggregate that conforms to West Virginia Department of Highways, *Standard Specification Roads and Bridges*, Sections 702.1.1, 702.1.2, and 702.1.3.

7. Engineering fabric conforming to AASHTO M 288 may be substituted for the stone and sand filter materials discussed in 5 and 6.

8. Backfill over the top filter layer or engineering fabric with soil material to the surface. This should be mineral soil with at least 12 percent fines. Reuse soil material excavated from the sinkhole as much as possible and place any available topsoil over the backfill. Overfill by about 5 percent to allow for settling.

9. Establish vegetation on the mitigated sinkhole and other disturbed areas of the site.

Use the following guidance for installing a mitigation design for sinkholes and sinkhole areas with drainage areas of 5 to 15 acres:

1. Remove and properly dispose of materials dumped in and around the sinkhole.

2. Excavate loose material from the sinkhole.

3. Place a layer of filter material into the sinkhole, allowing the stone to fill the void(s) below the bottom of excavated sinkhole. The size should be ¼ to ½ the size of the void(s). This material can be WVDOH gabion stone, rip rap stone, or special rock fill stone.

4. Place a layer of the same size filter material to a thickness of about ¾ TD (TD = total depth) above the sinkhole bottom.

5. Place a layer of smaller size filter material over the previous layer to a thickness of about ¼ D. Bring this layer to surface level. The size should be ¼ to ½ the size of the previous layer. The material should be No. 57 aggregate, which conforms to West Virginia Department of Highways, *Standard Specification Roads and Bridges*, Sections 703.1.1, 703.1.2, 703.1.3, 703.2.1, and 704.1.4. Unacceptable stone consists of pea gravel or slags (steel, electrometallurgical, or power plant).

6. Shale or similar soft and non-durable rock is not acceptable.

7. Establish vegetation on the mitigated sinkhole and disturbed areas of the site.

Engineering Fabric Requirements for Subsurface Drainage

Engineering fabric used in the mitigation of sinkholes should meet the applicable requirements of AASTHO M 288, Section 7.2

Engineering Fabric Installation

Proper construction and installation techniques are essential to ensure that the intended function of the engineering fabric is fulfilled.

When sewn seams are necessary, the seam strength must be equal to or greater than 90 percent of the specified grab strength, as measured in accordance with ASTM D 4632.

When sewn seams are used for the seaming of the engineering fabric, the thread must be high strength polypropylene, or polyester. Nylon thread is unacceptable.

For Sinkhole Mitigation Design A, place the engineering fabric loosely, with no wrinkles or folds, and with no void spaces between the fabric and the bridge. Overlap successive sheets of engineering fabric a minimum of 12 inches, with the upstream sheet overlapping the downstream sheet.

Prior to covering, the engineering fabric should be inspected to ensure that it has not been damaged (*e.g.* holes, tears, rips) during installation. An engineer or the engineer's designated representative should conduct the inspection. The designated representative should be a certified field inspector.

Damaged fabric must be repaired immediately. Cover the damaged area with an engineered fabric patch that overlaps to 12 inches beyond the damaged area.

Any damaged engineering fabric that cannot be repaired shall be replaced as directed by the engineer.

Place material over the engineering fabric in such a manner as to avoid stretching and subsequently tearing the fabric. Do not drop stone and soil placement from a height greater then one meter. Do not allow stone with a mass of more than 100 kg to roll down the slope of the sinkhole.

Grading the sinkhole slope is not permitted if the grading will result in the movement of the stone directly above the engineering fabric.

Operation and Maintenance

The owner/operator is responsible for maintaining the mitigated sinkhole and sinkhole area. At a minimum, the following maintenance practices should be performed:

1. Mow grass and plantings as necessary to promote vigorous growth.

2. Inspect mitigation measures at least twice a year and after all major rain events. Repairs to the sinkhole mitigation measures should be made promptly were warranted.

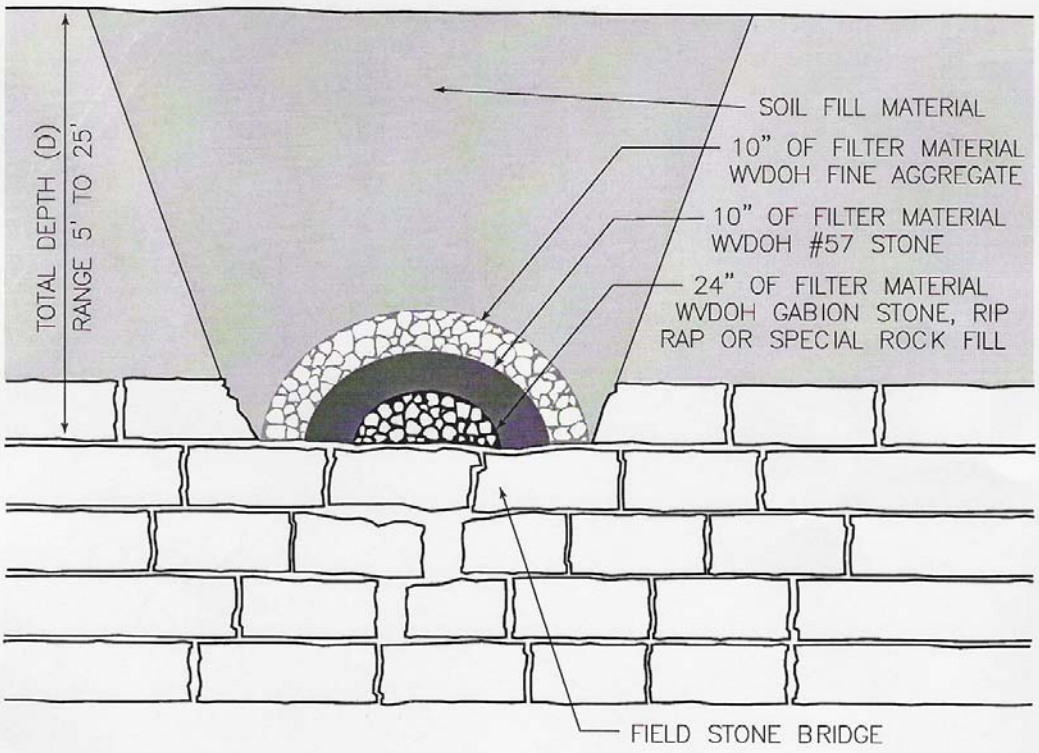
References:

USDA Natural Resources Conservation Center, January 2004. *Maryland Conservation Practice Standard, Sinkhole and Sinkhole Area Treatment, Code 725.*

West Virginia Department of *Highways, Standard Specifications Roads and Bridges*, 2000, Section 702, "Fine Aggregates", Section 703, "Coarse Aggregates", Section 704, "Stone and Crushed Aggregate", Section 715, "Miscellaneous Materials".

WEST VIRGINIA DEPARTMENT OF ENVIRONMENTAL PROTECTION
SINKHOLE MITIGATION GUIDANCE

FIGURE 1



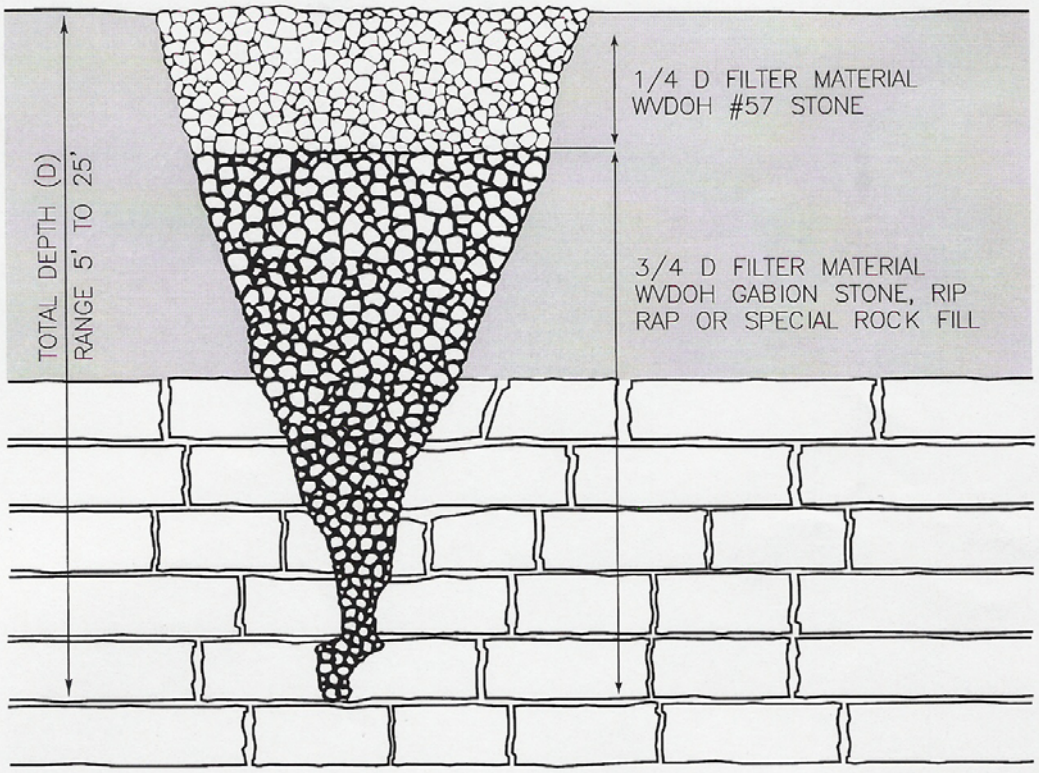
NOTE:
A NONWOVEN GEOTEXTILE MEETING AASHTO M288, SECTIONS 7.1+7.2 MAY BE SUBSTITUTED FOR THE WVDOH #57 STONE AND WVDOH FINE AGGREGATE

SINKHOLE MITIGATION

(DRAINAGE AREA LESS THAN 5 ACRES)

WEST VIRGINIA DEPARTMENT OF ENVIRONMENTAL PROTECTION
SINKHOLE MITIGATION GUIDANCE

FIGURE 2



SINKHOLE MITIGATION

(DRAINAGE AREA 5 TO 15 ACRES)

NATURAL RESOURCES CONSERVATION SERVICE

CONSERVATION PRACTICE STANDARD

KARST SINKHOLE TREATMENT

(No.)

CODE 527

DEFINITION

The treatment of sinkholes in karst areas to reduce contamination of groundwater resources, and/or to improve farm safety.

PURPOSE

This practice may be applied as part of a conservation management system in karst topography, which is an area underlain by solutioned carbonate bedrock with sinkholes and caverns. The practice supports one or more of the following purposes:

- Improve water quality
- Improve farm safety

CONDITIONS WHERE PRACTICE APPLIES

On any land surface or in conjunction with any existing practice where the soils and geologic conditions are characterized by sinkholes or karst topography.

This practice does not apply to erosional or collapse features caused by failure or leakage of underground pipes or constructed surface drainage features (e.g., canals), or due to piping of unstable soil materials, or due to poorly compacted or poorly constructed features.

This practice does not apply to sinkholes that may appear in or beneath structures or in flowing streams. Treatment of sinkholes in these areas will be determined through engineering investigations and structural design solutions.

CRITERIA

General Criteria Applicable to all Purposes

The installation and operation of karst sinkhole treatment(s) will comply with all Federal, State, and local laws, rules, and regulations.

A geologic investigation of the potential impact of the treatment on groundwater, surface water run-in, and the karst features will be conducted by a qualified geologist.

Trash and other material will be removed from the sinkhole and disposed of in an environmentally sound manner.

Excess surface water caused by construction activities will be diverted from the sinkhole area.

Nutrient and pest management plans will be developed for the drainage area of the sinkhole controlled by the landowner.

Vegetative Treatment. All sinkholes treated will have a vegetated buffer established and/or maintained. The buffer will be a minimum of 25-feet wide measured from the rim of the sinkhole. The buffer area may be extended to prevent concentrated flow channels from occurring and entering the sinkhole. The width of the vegetated buffer will be established and maintained in accordance with the type of buffer chosen. The sinkhole and surrounding buffer area will be fenced.

Livestock will be excluded from the vegetative buffer except when grazing would be beneficial to maintenance of the buffer.

Nutrients, herbicides, pesticides, and animal waste will not be applied within an established buffer area. Only mechanical treatments shall be used for weed control.

Appropriate erosion and sediment control measures will be used to reduce the amount of sediment entering sinkhole openings during the establishment of the vegetative buffer.

Surface Water Control. Changes to the volume of surface water that enters a sinkhole may disturb the underground hydrology. To the extent possible, the surface water flow should be maintained at historic (or predevelopment) volumes.

Pre-existing concentrated flow channels will be stabilized but should not otherwise be altered. If a plug or inverted filter is used, the area to be protected will be characterized by a qualified Geologist to enable a suitable design. Concentrated flow caused by construction activities will be dispersed with a suitable spreading or diversion technique.

Sinkhole Treatment/Closing. Adequate protection of most sinkhole and sinkhole areas can be achieved by the use of vegetative buffers and livestock exclusion. However, if an open sinkhole is a safety hazard, it may be treated with a rock filter, gabions, or other methods approved by the State Conservation Engineer or delegated authority.

Sinkholes to be treated or closed via a reverse filter or plug shall be excavated to stable, unweathered bedrock, if possible, prior to construction.

Sinkholes that open into caves shall not be filled under any circumstances. Gated openings may be used for safety reasons.

CONSIDERATIONS

Current and planned land use should be considered. In particular, structures, septic drain fields, wells, feedlots, ponds, and animal waste storage systems should not be located over a sinkhole site or within the impact area.

Sinkholes may be natural conveyances of organic material and nutrients important to cave fauna.

For a sinkhole receiving contaminated overland flow, every effort should be made to first treat the source of the contamination. Although it is important to maintain the hydrology of the karst system, it may be more beneficial to the groundwater quality to divert the contaminated water away from the sinkhole. In some cases, it may be necessary to completely plug a sinkhole with sealing materials rather than treat it with an inverted filter. Acceptable sealing materials are provided in ASTM D 5299, part 6.4. An example of this would be a sinkhole in a feedlot or a site that is difficult to protect by any other method.

The sinkhole treatment should not result in excessive surface water ponding or high soil moisture conditions over an extended period of time.

When filling a sinkhole, mounding of the fill material may be needed to offset future settlement due to consolidation and migration of the fill material into subsurface voids. Additional fill may be required as treatment ages.

Treatment of one sinkhole may have an effect on other sinkholes or solution features in the vicinity.

The use of a conservation easement for the buffer and sinkhole should be considered.

PLANS AND SPECIFICATIONS

Plans and specifications for Sinkhole and Sinkhole Area Treatment will be in keeping with this standard and will describe the requirements for applying the practice to achieve its intended purpose.

Plans and specifications shall include the following:

- Plan view showing sinkhole and sinkhole area Include topographic information and photographs
- The geologic investigation will include a study of potential impacts on the karst resource
- Depth to stable, unweathered bedrock
- Description of planned treatment measures
- The drainage area of sinkhole delineated on a topographic map
- Availability of safe outlet for surface water, if applicable
- Operation and Maintenance requirements
- Special safety requirements

OPERATION AND MAINTENANCE

An operation and maintenance (O&M) plan will provide specific instructions for maintaining the sinkhole and sinkhole area treatment, including reference to periodic inspections and the prompt repair and/or replacement of damaged components.

ATLANTIC COAST PIPELINE, LLC
ATLANTIC COAST PIPELINE

Response to the Virginia Department of Environmental Quality Request for Information for the Section 401 Water Quality Certification

APPENDIX I

Resource Report 2, Section 2.1.6 Groundwater Construction Related Impacts and Mitigation

ATLANTIC COAST PIPELINE – Docket Nos. CP15-554-000, CP15-554-001
SUPPLY HEADER PROJECT – Docket No. CP15-555-000

Excerpt from the Atlantic Coast Pipeline, LLC and Dominion Energy Transmission, Inc. Application to the Federal Energy Regulatory Commission for a Certificate of Public Convenience and Necessity for the Atlantic Coast Pipeline and Supply Header Project (FERC Accession Number 20150918-5212)

2.0 RESOURCE REPORT 2 – WATER USE AND QUALITY

2.1 GROUNDWATER RESOURCES

2.1.6 Groundwater Construction Related Impacts and Mitigation

Standard procedures for construction of the pipeline and aboveground facilities could potentially affect groundwater in several ways. Clearing, grading, trenching, and soil stockpiling activities could temporarily alter overland flow and groundwater recharge or could result in minor fluctuations in groundwater levels and/or increased turbidity. Near-surface soil compaction caused by the operation of heavy construction equipment could reduce the ability of soil to absorb water, which could increase surface runoff and the potential for ponding. These impacts will be minimized or avoided through implementation of the construction practices outlined in the 2013 versions of the FERC's *Upland Erosion Control, Revegetation, and Maintenance Plan* (Plan) and *Wetland and Waterbody Construction and Mitigation Procedures* (Procedures).

Ground disturbance associated with construction of pipelines and aboveground facilities is generally within the upper 10 feet or less of the existing ground surface, which is above the typical minimum depth of the bedrock aquifers in the areas crossed by the Projects. A depth of 10 feet is also above most near-surface aquifers and most wells that might be completed in a localized shallow aquifer. Where near-surface aquifers are present or localized alluvial aquifers occur, they typically consist of unconsolidated alluvial sand and gravel exhibiting rapid recharge and groundwater movement. If disturbed, these aquifers quickly re-establish equilibrium and turbidity levels rapidly subside, such that impacts are localized and temporary. Upon completion of construction, Atlantic and DTI will restore the ground surface as closely as practicable to original contours and reestablish vegetation on the right-of-way to facilitate restoration of preconstruction overland flow and recharge patterns. To minimize the potential impact of hazardous material spills on surficial aquifers during construction and operation of the ACP and SHP, Atlantic and DTI have prepared and will implement a *Spill Prevention, Control, and Countermeasures Plan* (SPCC Plan) (see Appendix 1F of Resource Report 1). Hazardous or toxic materials used on the right-of-way would typically be limited to fuels, oils, lubricants, and in some cases blasting materials. These materials would be handled in accordance with the SPCC Plan and *Blasting Plan*. In addition, to minimize impacts associated with construction water discharges on surficial aquifers Atlantic and DTI will implement measures outlined in the Plan and Procedures during construction dewatering activities.

Karst features that have an opening into the subsurface bedrock have the potential to provide a conduit for impacts to groundwater.[1] Atlantic and DTI conducted a detailed desktop assessment and field survey along those portions of the Projects considered prone to the development of karst to identify sinkholes and other karst features. As warranted, Atlantic and DTI will make minor route adjustments to avoid areas containing dense concentrations of features, such as sinkholes, which are indicative of karst development. Atlantic and DTI have prepared and will implement a *Karst Monitoring and Mitigation Plan* (see Appendix 1F of Resource Report 1), which identifies construction and restoration practices in karst areas. During construction, erosion and sediment controls will be installed along the edge of the construction right-of-way and in other work areas upslope of known sinkholes or other karst features with a direct connection to the phreatic zone of the karst (i.e., groundwater). In addition, refueling, hazardous materials storage, and overnight equipment parking within 300 feet of karst features with direct connection to the phreatic zone will be prohibited. Results of the desktop assessment and field surveys as well as proposed construction and mitigation measures for karst areas are discussed in more detail in Resource Report 6.

Potential project-related groundwater contamination sources may also include accidental spills and leaks of hazardous materials associated with construction; refueling or maintenance of vehicles; and storage of fuel, oil, and other fluids. Spills or leaks from equipment used during construction pose the greatest risk to groundwater resources. If not cleaned up, soils contaminated by spilled materials could leach and add pollutants to groundwater.

To avoid or minimize the potential impact of hazardous material spills during construction and operation of the ACP and SHP, Atlantic and DTI have prepared and will implement a SPCC Plan. The SPCC Plan will specify preventive measures such as regular inspection of storage areas for leaks, replacement of deteriorating containers, and construction of containment systems around hazardous liquids storage facilities. The SPCC Plan will restrict refueling or other liquid transfer areas within 100 feet of wetlands, waterbodies, and springs, and within 300 feet of karst features with a direct connection to the phreatic zone; prohibit refueling within 200 feet of private water supply wells and within 400 feet of municipal water supply wells; and require additional precautions (e.g., secondary containment) when specified setbacks cannot be maintained. In addition, Atlantic and DTI will evaluate recommended measures provided by local agencies where wellhead protection or groundwater protection areas are crossed. The SPCC Plan also will identify emergency response procedures, equipment, and cleanup measures to be implemented in the event of a spill, and require the construction contractor to complete an inventory of construction fuels, lubricants, and other hazardous materials that may be used or stored in designated areas, as well as the amount and type of containers that will be used to store these materials.

It is possible that previously undocumented sites with contaminated soils or groundwater could be discovered during construction of the Projects. Atlantic and DTI have prepared and will implement a *Contaminated Media Plan* to address these circumstances (see Appendix 1F of Resource Report 1). The *Contaminated Media Plan* describes measures to be implemented in the event that signs of contaminated soil and/or groundwater are encountered during construction. Signs of potential contamination could include discoloration of soil, chemical-like

[1] During the ACP and SHP Open Houses, and in comments filed with the FERC, several individuals commented about karst features and the potential to impact groundwater resources.

odors, or sheens on soils or water. Containment measures will be implemented to isolate and contain suspected soil or groundwater contamination, and collect and test samples of the soil or groundwater to identify the contaminants. Once the contaminants are identified, a response plan will be developed for crossing or avoiding the site.

Blasting may be necessary along portions of the proposed ACP and SHP facilities where bedrock is located at or near the ground surface (see Section 6.2 of Resource Report 6). Atlantic and DTI have prepared and will implement a *Blasting Plan* which identifies procedures for the use, storage, and transportation of explosives consistent with safety requirements as defined by Federal, State/Commonwealth, and local agency regulations. The *Blasting Plan* is provided in Appendix 1F of Resource Report 1. Where blasting is necessary, it will be conducted in a manner to minimize possible impacts on nearby public and private water supply wells, springs, or karst features with a direct connection to the phreatic zone.

Without proper planning, blasting could affect groundwater quality and bedrock-based water well systems located in close proximity to the construction right-of-way.[2] The use of controlled blasting techniques, where small, localized detonations are utilized, will avoid or minimize the impacts of blasting and limit rock fracture to the immediate vicinity of these activities. As noted in Sections 2.1.3.2 and 2.1.4, Atlantic and DTI will contact landowners to determine the location of private water wells and private water supply springs within 150 feet of approved construction workspaces. Atlantic and DTI will, with landowner permission, conduct preconstruction and post-construction well testing, and perform necessary repair or restoration to maintain well productivity and water quality, for wells located within 150 feet of the construction area.

Atlantic plans to monitor groundwater quality and yield for public and private supply wells and springs proximate to the Project area, as described in more detail below. Groundwater inventory and sample collection will be conducted before and after construction to determine whether water supplies have been affected by pipeline construction activities. Atlantic and DTI will establish baseline groundwater conditions prior to construction of the Projects through investigative field surveys and a sampling protocol. The surveys will include a groundwater inventory of all wells or springs within 500 feet of the proposed pipelines in karst areas and within 150 feet of the construction workspace along the remainder of the proposed pipelines. In order to conduct these inventories, land owner permission will need to be obtained first.

With landowner permission, water samples will be obtained prior to construction to establish water quality and yield baselines during the varying seasons. These samples will be tested for pH, total suspended solids, total dissolved solids, conductivity, alkalinity, acidity, sulfates, oil/grease, phenolic, iron, manganese, aluminum, fecal coliform, copper, lead, nickel, silver, thallium, zinc, chromium, arsenic, mercury, selenium, cyanide, calcium magnesium, hardness, chlorides, antimony, cadmium, and beryllium. Sampling methods will adhere to the prevailing EPA and State/Commonwealth sampling, analytical and data quality assurance and quality control procedures. The samples will be analyzed using EPA-approved methods and the analysis will be performed by a certified laboratory in each State/Commonwealth.

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[2] In comments filed with the FERC, several individuals commented about blasting during construction and potential impacts on water sources and water quality.

Any well damage claim will be investigated for cause; during this investigation a temporary potable water source will be supplied to the well owner. This temporary potable water source will be supplied by a potable water storage device and/or a temporary water treatment system to restore potable water.

In the event the damage claim investigation yields positive results that construction activities caused or contributed to well damage. Atlantic or DTI will provide a permanent potable water source. This will be supplied by a permanent water treatment system and/or a new well drilled to a deeper aquifer.

To respond to mitigation requested by the ACSA regarding potential blasting near the Augusta Regional Landfill, Atlantic has incorporated a route adjustment that increases the distance between the AP-1 mainline and the landfill.[3] The purpose of this adjustment was an added precaution to mitigate potential impacts of blasting near the landfill's monitoring wells. Atlantic will also develop a site-specific blasting and monitoring plan for this area in consultation with the ACSA.

Atlantic and DTI are evaluating the need to use groundwater for the aboveground facilities. Groundwater may be used for hydrostatic testing of facility piping, dust control, operation and maintenance activities, and domestic uses.

[3] In comments filed with the FERC the ACSA commented that blasting near the Augusta Regional Landfill could damage monitoring wells.