

Comprehensive Site Assessment Report

Cliffside Steam Station Ash Basin

Site Name and Location	Cliffside Steam Station 573 Duke Power Road Mooresboro, NC 28114
Groundwater Incident No.	Not Assigned
NPDES Permit No.	NC0005088
Date of Report	August 18, 2015
Permittee and Current Property Owner	Duke Energy Carolinas, LLC 526 South Church St Charlotte, NC 28202 800.559.3853
Consultant Information	HDR Engineering, Inc. of the Carolinas 440 South Church St, Suite 900 Charlotte, NC 28202 704.338.6700
Latitude and Longitude of Facility	35° 13' 25" N, 81° 45' 22" W

This document has been reviewed for accuracy and quality
commensurate with the intended application.

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Executive Summary

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List of Acronyms and Abbreviations

µg/L	micrograms per liter
2L Standards	15A NCAC 02L .0202 Groundwater Quality Standards
AMEC	AMEC Environment & Infrastructure
APS	NCDENR DWR Aquifer Protection Section
AST	Aboveground Storage Tank
ASTM	American Society for Testing and Materials
BG	Background
bgs	Below ground surface
BR	Bedrock
CAMA	Coal Ash Management Act
CAP	Corrective Action Plan
CCP	Coal Combustion Products
CCR	Coal Combustion Residuals
COI	Constituent of Interest
COPC	Contaminant of Potential Concern
CSA	Comprehensive Site Assessment
CSM	Conceptual Site Model
CSS	Cliffside Steam Station
DO	Dissolved oxygen
DTW	Depth to Water
Duke Energy	Duke Energy Carolinas, LLC
DWR	NCDENR Division of Water Resources
EDR	Environmental Data Resources
EPD	Georgia Environmental Protection Division
EPRI	Electric Power Research Institute
ESH	Estimated Seasonal High
ESL	Estimated Seasonal Low
GSCM	Geochemical Site conceptual model
GIS	Geographic Information Systems
HFO	Hydrous ferric oxide
HQ	Hazard Quotient
IMAC	Interim Maximum Allowable Concentration
Kd	Sorption Coefficient
mD	millidarcies
MDL	Method detection limit
mg/kg	Milligrams per kilogram
mm	milligrams

MNA	Monitored Natural Attenuation
MRL	Method reporting limit
MW	Megawatt
N	Standard Penetration Testing Values
NRCS	Natural Resources Conservation Service
NCAC	North Carolina Administrative Code
NCDENR	North Carolina Department of Environment and Natural Resources
NCDHHS	North Carolina Department of Health and Human Services
NCNHP	North Carolina Natural Heritage Program
NCWRC	North Carolina Wildlife Resources Commission
ng/L	Nanograms per liter
NHD	USGS National Hydrography Dataset
NORR	Notice of Regulatory Requirements
NPDES	National Pollutant Discharge Elimination System
NTU	Nephelometric Turbidity Unit
NURE	National Uranium Resource Evaluation
PL	Prediction Limit
PMCL	Primary Maximum Contaminant Level
ppb	parts per billion
ppm	parts per million
PSRG	Preliminary Soil Remediation Goal
PWR	Partially Weathered Rock
PWSS	NCDENR Division of Water Resources Public Water Supply Section
RCRA	Resource Conservation and Recovery Act
REC	Recovery
RL	Reporting Limit
RQD	Rock Quality Designation
RSL	USEPA Regional Screening Level
SCM	Site Conceptual Model
SCS	U.S. Department of Agriculture Soil Conservation Service
SLERA	Screening Level Ecological Risk Assessment
SMCL	Secondary Maximum Contaminant Level
SMDP	Scientific/Management Decision Point
SPLP	Synthetic Precipitation Leaching Procedure
SQL	Sample Quantitation Limit
SWAP	NCDENR DWR Source Water Assessment Program
TCLP	Toxicity Characteristic Leaching Procedure
TDS	Total Dissolved Solids
TZ	Transition Zone

UNC	University of North Carolina
UNCC	University of North Carolina at Charlotte
USCS	Unified Soil Classification System
USDA	U.S. Department of Agriculture
USEPA	U.S. Environmental Protection Agency
USGS	U.S. Geological Survey
UST	Underground Storage Tank

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1.0 Introduction

Duke Energy Carolinas, LLC (Duke Energy) owns and operates the Rogers Energy Complex (henceforth referred to as the Cliffside Steam Station (CSS)) located in Mooresboro, in Rutherford and Cleveland counties, North Carolina. CSS began operation in 1940 as a coal-fired generating station. Units 1 through 4 were subsequently retired in October 2011, and currently only Units 5 and 6 operate at CSS. The coal ash residue and other liquid discharges from CSS's coal combustion process have historically been disposed of in the station's ash basins, which consist of the active ash basin, the Units 1-4 inactive ash basin, and the Unit 5 inactive ash basin. Discharge from the ash basin is currently permitted by NCDENR DWR under NPDES Permit NC0005088.

Since 2008, Duke Energy has implemented voluntary and NPDES permit-required compliance groundwater monitoring at CSS. Voluntary groundwater monitoring around the CSS ash basin was performed twice each year from August 2008 until August 2010, with analytical results submitted to the NCDENR DWR. Compliance groundwater monitoring as required by the NPDES Permit began in April 2011. From April 2011 through April 2015, the compliance groundwater monitoring wells at the CSS site have been sampled three times per year for a total of 13 times.

Recent monitoring events have indicated exceedances of 15A NCAC 02L .0200 Groundwater Quality Standards (2L Standards; refer to North Carolina Administrative Code Title 15A Department of Environmental and Natural Resources Division of Water Quality Subchapter 2L Section .0100, .0200, .0300 Classifications and Water Quality Standards Applicable to the Groundwaters of North Carolina) at CSS, prompting the NCDENR's requirement for Duke Energy to perform a groundwater assessment at the site and prepare a Comprehensive Site Assessment (CSA) report. The Coal Ash Management Act of 2014 (CAMA) also directed owners of coal combustion residuals surface impoundments to conduct groundwater monitoring and assessment and submit a Groundwater Assessment Report. This CSA is submitted to meet the requirements of both NCDENR and the CAMA.

1.1 Purpose of Comprehensive Site Assessment

The purpose of this Comprehensive Site Assessment (CSA) is to characterize the extent of contamination resulting from historical production and storage of coal ash, evaluate the chemical and physical characteristics of the contaminants, investigate the geology and hydrogeology of the site including factors relating to contaminant transport, and examine risk to potential receptors and exposure pathways. This CSA was prepared in general accordance with requirements outlined in the following regulations and documents:

- Classifications and Water Quality Standards Applicable to the Groundwaters of North Carolina in Title 15A NCAC 02L .0106(g),
- Coal Ash Management Act in G.S. 130A-309.209(a),
- Notice of Regulatory Requirements (NORR) issued by NCDENR on August 13, 2014,

- Conditional Approval of Revised Groundwater Assessment Work Plan issued by NCDENR on February 16, 2015, and
- Subsequent meetings and correspondence between Duke Energy and NCDENR.

This assessment includes evaluation of possible impacts from the ash basins and related ash storage facilities and consisted of the following activities:

- Completion of soil borings and installation of groundwater monitoring wells to facilitate collection and analysis of chemical, physical, and hydrogeological parameters of subsurface materials encountered within and beyond the waste and compliance boundaries.
- Evaluation of testing data to supplement the site conceptual model (SCM).
- Revision to the receptor survey previously completed in 2014.
- Completion of a screening-level risk assessment.

In this report, constituents are those chemicals or compounds that were identified in the approved work plans for sampling and analysis. If a constituent exceeded its respective regulatory standard or screening level in the medium in which it was found, the constituent was then termed a Constituent of Interest (COI) and evaluated in the human health and ecological screening level risk assessment (Section 12.0).

1.2 Regulatory Background

1.2.1 NCDENR Requirements

The NCDENR DWR regulates wastewater discharges from coal ash ponds to state waters, streams, and lakes, and requires groundwater monitoring and stormwater management at these facilities. Duke Energy's coal-fired power facilities are regulated through federal NPDES wastewater permits. As part of these permits, the facilities must also comply with the state water quality standards and U.S. Environmental Protection Agency (USEPA) water quality criteria.

Groundwater monitoring is performed at Duke Energy facilities in accordance with approved monitoring plans and NPDES permits for each site. Included in these monitoring evaluations is a determination if site-specific background concentrations (i.e., naturally occurring constituents in the soil profile and groundwater) for various constituents (e.g., iron and manganese) are contributing to reported concentrations. For each facility, if it is determined that activities on the property are causing noncompliance with NCDENR DWR regulatory requirements, the agency will coordinate with the permittee to develop and implement a Corrective Action Plan (CAP) in accordance with state regulations.

1.2.2 Notice of Regulatory Requirements

Chapter 143, North Carolina General Statutes, authorizes and directs the Environmental Management Commission of the Department of Environment and Natural Resources to protect and preserve the water and air resources of the State. The NCDENR DWR has the delegated authority to enforce adopted pollution control rules. NCDENR DWR Rule 15A NCAC 02L

.0103(d) states that "...no person shall conduct or cause to be conducted any activity which causes the concentration of any substance to exceed that specified in..." 15A NCAC 02L .0202, Groundwater Quality Standards.

On August 13, 2014, NCDENR issued a Notice of Regulatory Requirements (NORR) letter notifying Duke Energy that exceedances of the groundwater quality standards 15A NCAC 02L .0200 Classifications and Water Quality Standards Applicable to the Groundwaters of North Carolina were reported at 14 coal ash facilities owned and operated by Duke Energy, including CSS. The NORR stipulated that for each coal ash facility, Duke Energy shall conduct a CSA following submittal of a Groundwater Assessment Work Plan (Work Plan) and receptor survey. In accordance with the NORR requirements, a Work Plan was developed, a receptor survey was performed to identify all receptors within a 0.5-mile radius (2,640 feet) of the ash basin compliance boundary, and a CSA was conducted for each coal ash facility. The NORR letter is included as Appendix A.

1.2.3 Coal Ash Management Act Requirements

The Coal Ash Management Act (CAMA) of 2014 (North Carolina General Assembly 2014) requires ash from Duke Energy coal plant sites located in the State either (1) be excavated and relocated to fully lined storage solutions or (2) go through a classification process to determine closure options and schedule. Closure options can include a combination of excavating and relocating ash to a fully lined structural fill, excavating and relocating the ash to a lined landfill (on-site or off-site), and/or capping the ash with an engineered synthetic barrier system, either in place or after being consolidated to a smaller area on-site.

As a component of implementing this objective, CAMA provides instructions for owners of coal combustion residuals surface impoundments to perform various groundwater monitoring and assessment activities. Section §130A-309.209 of the CAMA ruling specifies groundwater assessment and corrective actions, drinking water supply well surveys and provisions of alternate water supply, and reporting requirements as follows:

- (a) *Groundwater Assessment of Coal Combustion Residuals Surface Impoundments.*
 - *The owner of a coal combustion residuals surface impoundment shall conduct groundwater monitoring and assessment as provided in this subsection. The requirements for groundwater monitoring and assessment set out in this subsection are in addition to any other groundwater monitoring and assessment requirements applicable to the owners of coal combustion residuals surface impoundments.*
- (1) *No later than December 31, 2014, the owner of a coal combustion residuals surface impoundment shall submit a proposed Groundwater Assessment Plan for the impoundment to the Department for its review and approval. The Groundwater Assessment Plan shall, at a minimum, provide for all of the following:*
 - a. *A description of all receptors and significant exposure pathways.*

- b. An assessment of the horizontal and vertical extent of soil and groundwater contamination for all contaminants confirmed to be present in groundwater in exceedance of groundwater quality standards.
 - c. A description of all significant factors affecting movement and transport of contaminants.
 - d. A description of the geological and hydrogeological features influencing the chemical and physical character of the contaminants.
- 2) The Department shall approve the Groundwater Assessment Plan if it determines that the Plan complies with the requirements of this subsection and will be sufficient to protect public health, safety, and welfare; the environment; and natural resources.
- (3) No later than 10 days from approval of the Groundwater Assessment Plan, the owner shall begin implementation of the Plan.
- (4) No later than 180 days from approval of the Groundwater Assessment Plan, the owner shall submit a Groundwater Assessment Report to the Department. The Report shall describe all exceedances of groundwater quality standards associated with the impoundment.

1.3 NCDENR-Duke Energy Correspondence

In response to both the NORR letter and CAMA requirements, Duke Energy submitted a Work Plan to NCDENR DWR on September 25, 2014 establishing proposed site assessment activities and schedules for the implementation, completion, and submission of a CSA report in accordance with 15A NCAC 02L .0106(g). The NCDENR DWR reviewed the Work Plan and provided Duke Energy with initial comments on November 4, 2014. A revised Work Plan was subsequently submitted to NCDENR on December 30, 2014 and the NCDENR DWR provided final comments and conditional approval of the revised Work Plan on February 19, 2015. In addition, Duke Energy submitted proposed adjustments to the CSA guideline and requested clarifications regarding groundwater sampling and speciation of selected constituents to NCDENR on May 14 and May 22, 2015. NCDENR provided responses to these proposed revisions and clarifications in June 2015. Copies of relevant correspondence including Work Plan submittals are included in Appendix A.

1.4 Approach to Comprehensive Site Assessment

The CSA approach was developed based on the NORR guidelines and CAMA requirements. Development of the SCM is based on several documents including but not limited to USEPA's Monitored Natural Attenuation tiered approach, ASTM 1689-95 (2014) *Standard Guide for Developing Site Conceptual Models for Contaminated Sites*, and comments received by NCDENR.

1.4.1 NORR Guidance

The NORR letter (Appendix A) outlined general guidelines for the CSA report, including guidance from 15A NCAC 02L .0106(g) as described in Section 1.1. The NORR letter also included Guidelines for Comprehensive Site Assessment for those involved in the investigation of contaminated soil and/or groundwater. The components included in the NORR guidelines were used in developing the site Work Plan and this CSA report.

1.4.2 USEPA Monitored Natural Attenuation Tiered Approach

In accordance with NCDENR requirements and the February 16, 2015 Conditional Approval letter (Appendix A), the elements of the USEPA's Monitored Natural Attenuation (MNA) approach has been utilized as part of the investigation associated with the CSA.

MNA may be used as a component to meet corrective action requirements if the site conditions meet the requirements associated with use of MNA. The approach involves a detailed analysis of site characteristics controlling and sustaining attenuation to support evaluation and selection of MNA as part of a cleanup action for inorganic contaminant plumes in groundwater (USEPA 2007). The site characterization is conducted in a step-wise manner to facilitate collection of data necessary to progressively evaluate the effectiveness of natural attenuation processes within the site aquifer(s). Four general elements are included in the tiered site analysis approach:

- Demonstration of active contaminant removal from groundwater & dissolved plume stability;
- Determination of the mechanism and rate of attenuation;
- Determination of the long-term capacity for attenuation and stability of immobilized contaminants, before, during, and after any proposed remedial activities; and
- Design of performance monitoring program, including defining triggers for assessing the remedial action strategy failure, and establishing a contingency plan.

Duke Energy will evaluate the USEPA MNA approach further during preparation of the CAP.

1.4.3 ASTM Conceptual Site Model Guidance

ASTM standard guidance document E1689-95 "Developing Conceptual Site Models for Contaminated Sites" (2014) was used as a general component of this CSA. The guidance document provides direction in developing site conceptual models (SCMs) used for the integration of technical information from multiple sources, selection of sampling locations to establish background concentrations of substances, identification of data needs and guidance of data collection activities, and evaluation of risks to human and environmental health posed by a contaminated site. According to ASTM E1689-95, six basic activities are associated with developing a SCM:

- Identification of potential contaminants;
- Identification and characterization of the source(s) of contaminants;

- Delineation of potential migration pathways through environmental media, such as groundwater, surface water, soils, sediment, biota, and air;
- Establishment of background areas of contaminants for each contaminated medium;
- Identification and characterization of potential environmental receptors (human and ecological); and
- Determination of the limits of the study area or system boundaries.

Development of a SCM is typically iterative and the complexity of the model should be consistent with the complexity of the site and available data. Information gained through site investigation activities is used to characterize existing physical, biological, and chemical systems at a site. The SCM describes and integrates processes that determine contaminant releases, contaminant migration, and environmental receptor exposure to contaminants. Development of the model is essential to determine potential exposure routes and identifying possible impacts to human health and the environment (ASTM 2014).

The SCM is used to integrate site information, identify data gaps, and determine whether additional information is needed at the site. The model will also be used to facilitate selection of remedial alternatives and effectiveness of remedial actions in reducing the exposure of environmental receptors to contaminants (ASTM 2014).

This CSA was conducted in accordance with the conditionally approved Work Plan to meet the NCDENR, NORR, and CAMA regulatory requirements described in Section 1.2, and using the NORR, USEPA, and ASTM approaches described above. This assessment information will be used to develop a CAP, to be submitted separately, for the site that will provide a demonstration of these criteria in support of the recommended site remedy.

Data obtained from sampling during this CSA are compared to federal and state regulatory standards shown in Table 1-1. Beginning in Section 7.0, laboratory results are compared to the above-referenced regulatory standards and discussed as either “exceeding” or “not exceeding” those standards. The evaluation of exceedances of these standards forms the basis for determining the need for additional work later in this document.

1.5 Limitations and Assumptions

Development of the CSA is based on information provided to HDR by both public and private entities including universities, federal, state and local governments, and information and analytical reports generated by Duke Energy. HDR assumes the information in these documents to be accurate and reliable. This information is used to estimate exposure routes and migration pathways in the subsurface. This CSA was developed using a standard of care ordinarily used by engineering practice under the same or similar circumstances but may include assumptions based on the accuracy and reliability of data from various entities. However, CAMA Section §130A-309.209 requires that “No later than 180 days from approval of the Groundwater Assessment Plan, the owner shall submit a Groundwater Assessment Report to the Department.” The schedule dictated by CAMA is compressed; therefore, data interpretation is limited and subject to change upon receipt of additional data in subsequent

rounds of sampling and additional data collected to resolve data gaps identified in Section 14. The additional data will be used to inform the corrective actions identified in the CAP.

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2.0 Site History and Description

This section provides a description of the CSS site based on relevant historical data and representative information. The purpose of this characterization is to familiarize readers with the site and use the general information as part of the overall ASTM CSM development approach.

2.1 Site Location, Acreage, and Ownership

The CSS site is located on the southern bank of the Broad River and north of McCraw Road (Duke Power Road), in Mooresboro in Rutherford and Cleveland counties, North Carolina (Figure 2-1). The entire CSS site is approximately 1,000 acres in area and is owned by Duke Energy (Figure 2-2). As of the date of this report, site ownership and land use prior to Duke Energy could not be determined from available records.

2.2 Site Description

CSS is a coal-fired electricity generating facility with a current capacity of 1,381 MW. The station began commercial operation in July 1940 with operation of coal-fired Units 1-4 (198 MW total). Coal-fired Unit 5 (556 MW) began operation in 1972, increasing the total plant capacity to 754 MW. Construction of Unit 6, an 825 MW clean-coal unit, began in 2008 and the unit began commercial operation in 2012. Units 1-4 were retired from service in October 2011, and Units 5 and 6 continue to operate and utilize the active ash basin system. Unit 5 operates with both wet bottom ash and wet fly ash handling. Unit 6 operates with both dry bottom ash and dry fly ash handling. A 1907 USGS topographic map depicting eastern portion the site is shown in Figure 2-3.1. A 1955 USGS topographic map depicting the western portion of the site is shown in Figure 2-3.2. Refer to Figure 2-4 for a map of site features.

McCraw Road (Duke Power Road) runs from northwest to southeast in the vicinity of the site. Suck Creek is located west of the active ash basin, and transects the site generally from south to north discharging to the Broad River.

Topography at the CSS site ranges from approximate high elevations of 832 feet above mean sea level (MSL) southwest of the active ash basin and 848 feet and 856 feet west and southwest of the Unit 5 inactive ash basin, respectively to a low elevation of 664 feet at the interface with the Broad River on the northern extent of the site.

Overall topography generally slopes from a south to north direction with an elevation difference of approximately 190 feet over an approximate distance of 4,000 feet. Surface water drainage generally follows site topography and flows from the south to the north across the site except where natural drainage patterns have been modified by the ash basin or other construction. Unnamed drainage features are located near the western and eastern edges of the site and generally flow north to the Broad River. Suck Creek transects the site from south to north, discharging to the Broad River. The approximate pond elevation for the active ash basin is 762 feet. The elevation of the Broad River at the site is approximately 656 feet. Refer to Section 3.2 for a detailed description of the CSS ash basins.

2.3 Adjacent Property, Zoning, and Surrounding Land Uses

The area surrounding CSS generally consists of residential properties, undeveloped land, and the Broad River (Figure 2-5). Properties in the Town of Boiling Springs, Cleveland County are primarily comprised of the CSS, zoned heavy and light industrial, and residential properties to the south, east, and northeast of CSS zoned residential.

Properties located to the west along Hwy 221A and northwest across the Broad River in Rutherford County are zoned rural residential including CSS, which is identified as average rural. The Town of Forest City does not quantify zoning outside the city limits.

2.4 Adjacent Surface Water Bodies and Classifications

The CSS site is located in the Broad River watershed, and the ash basin is adjacent to the Broad River. Suck Creek, a tributary of the Broad River, transects the site flowing from the south to the north into the Broad River. Surface water classifications in North Carolina are defined in 15A NCAC 02B.0101(c). The surface water classification for the Broad River and Suck Creek is Class WS-IV. Class WS-IV waters are protected as water supplies which are generally in moderately to highly developed watersheds. Surface water features located on the site are shown in Figure 2-2.

2.5 Meteorological Setting

2.5.1 Rutherford County

The yearly average daily maximum temperature in Rutherford County is 70.4°F and the average daily maximum temperature ranges from 89.5°F in July to 48.7°F in January (USDA-NRCS 1997). The yearly average minimum temperature is 44.8°F and the average daily minimum temperature ranges from 64.2°F in July to 25.2°F in January.

The total average annual precipitation in Rutherford County is 51 inches, with over half of this rainfall (27 inches) occurring from April through September. Thunderstorms occur approximately 45 days each year.

The average relative humidity in midafternoon is approximately 60 percent, with humidity reaching higher levels at night. The prevailing wind is from the northwest, and average wind speed is highest (10 miles per hour) in winter.

2.5.2 Cleveland County

During summer, the average temperature in Cleveland County is 75.5°F and the average daily maximum temperature is 87°F (USDA-NRCS 2006). During winter, the average temperature is 41.1°F and the average daily minimum temperature is 29.5°F.

The total annual precipitation in Cleveland County is 48.09 inches, with over half of this rainfall (28 inches) occurring from April through October. Thunderstorms occur approximately 41 days each year.

The average relative humidity in midafternoon is approximately 54 percent, with humidity reaching higher levels at night. The prevailing wind is from the northeast, and average wind speed is highest (9 miles per hour) in spring.

2.6 Hydrologic Setting

As previously described, CSS is located adjacent to the south side of the Broad River on the north side of McCraw Road (Duke Power Road) which runs from northwest to southeast in the vicinity of the site. Suck Creek transects the site generally from south to north to the Broad River and is located to the west of the active ash basin. Based on the slope-aquifer system, groundwater at the site is expected to flow downward toward Suck Creek and/or to the north toward the Broad River.

Water levels within the active ash basin pond have fluctuated approximately within a range of 16 feet from May 1983 until mid-2013. The surface water elevation in the active ash pond ranged from 752 to 768 feet. From 2005 to 2009, the pond elevation was raised to improve suspended solids settling. In 2010, a larger excavation occurred and a small rim ditch was put in place. Ash was pushed into a back cove which slightly reduced the pond elevation. In 2012, a 300,000 cubic yard excavation was conducted which helped keep the pond water elevation lower from that point onwards. From late 2011 to early 2013, the pond elevation ranged from 757 to 760 feet.

The ash basins affect the local groundwater elevations adjacent to the basins. Select monitoring wells located downgradient of the active ash basin pond have periodically exhibited groundwater elevations under artesian conditions (water level above ground surface) due to the presence of the basin. The hydrologic setting is described in further detail in Section 5.0.

2.7 Permitted Activities and Permitted Waste

Duke Energy is authorized to discharge wastewater from CSS to receiving waters designated as the Broad River in the Broad River Basin in accordance with NPDES Permit NC0005088, which most recently became effective March 1, 2011. A permit renewal application was submitted to NCDENR DWR on January 28, 2015 and issuance of the new permit is pending. Any other point source discharge to surface waters of the state is prohibited unless it is an allowable non-stormwater discharge or is covered by another permit, authorization, or approval.

The NPDES permit authorizes the following discharges in accordance with effluent limitations, monitoring requirements, and other conditions set forth in the permit:

- Treated wastewater from the ash basin through Outfall 002, containing low volume wastes, coal pile runoff, metal cleaning wastes, treated domestic wastewater, chemical metal cleaning wastes, water treatment system wastewaters, ash transport water, landfill leachate (landfill contains fly and bottom ash, and gypsum from FGD system), cooling towers blow down, runoff from limestone stacking area and gypsum stacking area;
- Emergency yard drainage basin overflow through Outfall 002A; and

- Discharge from the treatment works at a select location into the Broad River, which is classified as Class C waters in the Broad River Basin.

Duke Energy also operates the Cliffside Coal Combustion Products (CCP) Landfill in accordance with the NCDENR Industrial Solid Waste Permit No. 81-06. The landfill was constructed with an engineered liner and leachate collection system and is permitted to receive fly ash, bottom ash, boiler slag, mill rejects, flue gas desulfurization sludge, gypsum, leachate basin sludge, non-hazardous sandblast material, limestone, ball mill rejects, coal, carbon, sulfur pellets, cation and anion resins, sediment from sumps, cooling tower sludge, and filter bags. The landfill is located southwest of the Cliffside Steam Station, northeast of the intersection of Old U.S. Highway 221A and Ballenger Road. Waste placement began in Phase I of the landfill on October 24, 2010. A Permit to Construct has been issued for Phase II of the CCP landfill, and construction commenced in February 2015.

The CSS operates under Title V Air Permit Number 04044T39.

An active Underground Storage Tank is present on the property which is operated under NCDENR UST Permit No. 0-008944

The station has an Asbestos Non Schedule Abatement Permit Number NC24923.

Duke Energy applied for an NPDES Stormwater Permit on July 31, 2014. The permit has not been issued by NCDENR as of the date of this report.

2.8 NPDES and Surface Water Monitoring

The NPDES program regulates wastewater discharges to surface waters to ensure that surface water quality standards are maintained. The NPDES permitting program requires that permits be renewed every five years. CSS received its first NPDES wastewater permit in the early to mid-1970s. The most recent NPDES permit became effective March 1, 2011 and expired on July 31, 2015. Duke Energy submitted a permit renewal application to NCDENR DWR on January 28, 2015. As of the date of this report, a new NPDES permit for CSS has not been issued by the NCDENR DWR, and the site is operating under the March 1, 2011 permit requirements.

The permit requires surface water monitoring as part of the permit conditions. Surface water samples are required to be collected associated with Outfall 002 and Outfall 002A (reference Section 2.10). The sample locations, parameters, and constituents to be measured and analyzed, and the requirements for sampling frequency and reporting results are outlined in the permit.

2.9 NPDES Flow Diagram

The NPDES flow diagram for CSS is provided in Figure 2-6. This diagram shows the current inflows and outflows to the ash basin. Current approximate quantities of inflows into the Active Ash Basin include 9.97 million gallons per day (MGD) from the yard drainage basin, 1.1 MGD

from stormwater, and 1.8 MGD from the ash sluice for Unit 5. The contributing sources to these inflows are depicted on Figure 2-6.

2.10 History of Site Groundwater Monitoring

The location of the ash basin voluntary and compliance monitoring wells, the ash basin waste boundary, and the compliance boundary are shown in Figure 2-7. The compliance boundary for groundwater quality at the CSS ash basin site is defined in accordance with Title 15A NCAC 02L .0107(a) as being established at either 500 feet from the waste boundary or at the property boundary, whichever is closer to the waste.

2.10.1 Voluntary Groundwater Monitoring Wells

Monitoring wells were installed by Duke Energy in 1995/1996, 2005, and 2007 as part of the voluntary monitoring system for groundwater near the active ash basin. Monitoring wells CLMW-1, CLMW-2, CLMW-3S, CLMW-3D, CLMW-4, CLMW-5S, and CLMW-6 were installed in 1995 and 1996. Monitoring wells MW-8S, MW-10S, and MW-11S were installed in 2005. Monitoring wells MW-2D, MW-4D, MW-8D, MW-10D, and MW-11D were installed in 2007. In addition, MW-2D-A was installed in 2011 to replace MW-2D. The existing voluntary wells are shown in Figure 2-7. Duke Energy implemented an enhanced voluntary groundwater monitoring around the CSS active ash basin from August 2008 until August 2010. During this period, the voluntary groundwater monitoring wells were sampled two times per year and the analytical results were submitted to NCDENR DWR.

2.10.2 Compliance Groundwater Monitoring Wells

Groundwater monitoring as required by the CSS NPDES Permit NC0005088 began in April 2011. NPDES Permit Condition A (11), Version 1.1, dated June 15, 2011, lists the groundwater monitoring wells to be sampled, the parameters and constituents to be measured and analyzed, and the requirements for sampling frequency and reporting results (provided in Table 2-1). Locations for the compliance groundwater monitoring wells were approved by the NCDENR DWR Aquifer Protection Section (APS).

The compliance groundwater monitoring system for the CSS active ash basin consists of the following monitoring wells: MW-20D, MW-20DR, MW-21D, MW-22DR, MW-23D, MW-23DR, MW-24D, MW-24DR, and MW-25DR. The compliance monitoring wells were installed by Duke Energy in 2010 and 2011. All compliance monitoring wells listed in Table 2-1 are sampled three times per year (in April, August, and December). Analytical results for the constituents listed in Table 2-1 are submitted to the NCDENR DWR before the last day of the month following the month of sampling for all compliance monitoring wells. The compliance groundwater monitoring is performed in addition to the normal NPDES monitoring of the discharge flows from the ash basin.

Monitoring wells MW-21D and MW-22DR are located to the east of the active ash basin, adjacent to the Duke Energy property boundary. Monitoring wells MW-20D and MW-20DR are located to the north of the active ash basin main dam, adjacent to the Broad River. Monitoring

wells MW-23D and MW-23DR are located on the opposite side of Suck Creek west of the active ash basin and monitoring well MW-25DR is located to the north of the ash basin across the Broad River.

Monitoring wells MW-24D and MW-24DR are located approximately 150 feet outside of the most southern portion of the compliance boundary and are considered by Duke Energy to represent background conditions as both wells are located upgradient and south of the active ash basin. With the exception of monitoring wells MW-24D and MW-24DR, the ash basin monitoring wells were installed at or within the CSS active ash basin compliance boundary. The locations of these compliance monitoring wells are shown in Figure 2-7

From April 2011 through April 2015, the compliance groundwater monitoring wells at the CSS site have been sampled a total of 13 times. During this period, these monitoring wells were sampled in:

- April, August, and December 2011
- April, August, and December 2012
- April, August, and December 2013
- April, August, and December 2014
- April 2015

One or more groundwater quality standards (2L Standards) have been exceeded in groundwater samples collected at every compliance monitoring well. Exceedances have occurred in one or more wells during one or more sampling events for chromium, iron, manganese, pH, sulfate, and total dissolved solids (TDS). Table 2-2 presents exceedances measured at each of these groundwater monitoring wells from April 2011 through April 2015. Duke Energy began sampling for additional parameters during the April 2015 sampling event that were anticipated to be added to the Groundwater Monitoring Plan for the NPDES permit. Exceedances of the Interim Maximum Allowable Concentrations¹ (IMACs) in one or more compliance wells were reported for cobalt and vanadium during this initial expanded parameter sampling event.

2.11 Assessment Activities or Previous Site Investigations

Between 1988 and 2014, several historical site investigations have been conducted onsite due to fuel oil releases associated with fuel storage tanks and/or associated piping. A summary of the historical environmental incidents onsite are provided in Table 2-3.

On March 5, 2014, NCDENR issued a Notice of Deficiency (NOD) associated with conditions observed at the toe of the Unit 5 inactive ash basin; specifically, “a grain-like substance, white and gray in color, was observed originating from several seepage and boil locations at the toe of

¹ Appendix #1 of 15A NCAC Subchapter 02L *Classifications and Water Quality Standards Applicable to The Groundwaters of North Carolina*, lists Interim Maximum Allowable Concentrations (IMACs). The IMACs were issued in 2010 and 2011, however NCDENR has not established a 2L Standard for these constituents as described in 15A NCAC 02L.0202(c). For this reason, IMACs noted in this report are for reference only.

the dam". Duke Energy submitted the *Cliffside Steam Station, Inactive Ash Basin #5 Main Dam (RUTHE-070), Characterization of White Material Observed in Seepage* report dated April 11, 2014 to NCDENR, which presented the results of the characterization of the white material observed in the seepage. A summary of the findings from the April 2014 report, recent observations at the toe of the Unit 5 inactive ash basin, and a discussion of groundwater and seepage data which may have implications relevant to the white material are included in Section 7.0.

2.12 Decommissioning Status

Initial decommissioning activities at CSS began at Units 1-4 after they were retired in October 2011. Plant decommissioning work has continued to prepare the units for final demolition and implosion work. All exterior structures (coal handling, etc.) associated with the units have been removed and abatement work to remove asbestos and PCBs present within the units has been completed. Precipitator and stack removal was completed in late 2014 and 2015 and final demolition work should be completed by early 2016.

In conjunction with decommissioning activities and in accordance with CAMA requirements, Duke Energy will permanently close the CSS ash ponds per the North Carolina CAMA required date associated with the risk ranking that the ash basins receive from the Coal Ash Management Commission.

Duke Energy recently announced its plans for complete excavation of the Units 1-4 inactive ash basin. The coal ash removal is planned to begin at the Units 1-4 inactive ash basin towards the end of 2015, pending permitting. Approximately 423,600 tons of ash will be removed from the basin and relocation is planned for the existing lined Cliffside CCP Landfill.

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3.0 Source Characteristics

This section provides a general description of the CSS coal combustion and ash handling system, the general physical and chemical properties of ash, and the CSS ash basin to characterize primary sources of contamination on the site.

3.1 Coal Combustion and Ash Handling System

Coal ash is produced from the combustion of coal. The coal is dried, pulverized, and conveyed to the burner area of a boiler. The smaller particles produced by coal combustion, referred to as fly ash, are carried upward in the flue gas and are captured by an air pollution control device, such as an electrostatic precipitator. The larger particles of ash that fall to the bottom of the boiler are referred to as bottom ash.

Coal ash residue from the coal combustion process produced by Units 1-4 was historically disposed of in the Inactive Units 1-4 ash basin. Coal ash residue from Unit 5 was historically disposed of in the Inactive Unit 5 ash basin until this basin reached capacity and the discharge was re-routed to the Active Ash Basin. Fly ash from the electrostatic precipitators was collected in hoppers. Bottom ash and boiler slag was collected in the bottom of the boilers. After collection, both fly ash and bottom ash/boiler slag were sluiced to the ash basins using conveyance water withdrawn from the Broad River. Sluice lines are used to convey the water/ash slurry and other flows to the basin. Ash produced by Unit 6 is dry handled and disposed of in the onsite lined NCDENR permitted landfill. Refer to Figure 2-2 for a depiction of these features. CSS currently produces approximately 275,000 tons of ash per year.

During operation of the coal-fired units, the ash basins received variable inflows from the ash removal system and other permitted discharges. Currently, the Active Ash Basin receives variable inflows from the Unit 5 fly ash handling system, Unit 5 bottom ash handling system, cooling tower blowdown, stormwater runoff from yard drainage, coal pile runoff, gypsum pile runoff, limestone pile runoff, landfill leachate, and wastewater streams generated from emission monitoring equipment, precipitators, and Selective Catalytic Reduction (SCR) Unit. Also, treated sanitary wastewater, miscellaneous cleaning wastes, domestic package plant wastewater (through the yard sumps) and water treatment system wastes (filter backwash, demineralizer regeneration waste, reverse osmosis rinse water, and clarifier solids). Duke Energy is in the process of evaluating alternatives for removing these flows from the ash basin to allow total decommissioning of the ash basins onsite.

3.2 Description of Ash Basins and Other Ash Storage Areas

The Units 1-4 ash basin dam was constructed in 1957, and the ash basin began operation the same year. The Unit 1-4 basin was retired in 1977 once it reached capacity, although five small settling cells exist on the western portion of the footprint, which are pumped to the active ash basin. The Units 1-4 inactive ash basin is located northwest of the active ash basin, on the west side of Suck Creek, and immediately east of the retired Units 1-4.

The Unit 5 ash basin main dam and saddle dam were constructed in 1970, in advance of Unit 5 operation. The Unit 5 ash basin received inflows from Unit 5 operations starting in 1972 and until it was retired in 1980 once it reached capacity. The Unit 5 inactive ash basin is located on the western portion of the site, west and southwest of Units 5 and 6. The basin, which receives only stormwater from the drainage area, was made inactive in 1980 and is utilized as a laydown yard for the station.

Construction of the active ash basin began in 1975 and was later expanded in 1980 to its current footprint. The active ash basin is located on the eastern portion of the site, east and southeast of Units 5 and 6.

Two unlined dry ash storage areas are also located within the northwestern portion of the active ash basin and south of the Broad River as depicted in a Duke Energy ash basin engineering drawing. These storage areas were likely created when ash was removed from the active ash basin in the 1980s to provide additional capacity for sluiced ash. The CSA investigation results were not conclusive in identifying the extent of these ash storage areas. There is also potential that one of the areas may be a spoils area remnant from embankment dam construction.

Effluent from the ash basin system is discharged from the active basin to the Broad River through a concrete discharge tower located in the northeast portion of the basin. The concrete discharge tower drains through a 42-inch reinforced concrete pipe (RCP) into a rip-rap-lined channel that discharges to the Broad River. The ash basin pond elevation is controlled by the use of concrete stop logs.

The ash basin system has been an integral part of the station's wastewater treatment system which has received inflows from the ash removal system, station yard drain sump, stormwater flows, and station wastewater. Currently, the inflows from the Unit 5 ash removal system and the station yard drainage basin are discharged through High Density Polyethylene Pipe (HDPE) sluice lines into the active ash basin. The inflows are variable based on Unit 5 and Unit 6 operations.

The following sections provide additional details of the CSS ash basin system.

3.2.1 Active Ash Basin

The active ash basin is located approximately 1,700 feet to the east-southeast of CSS Units 5 and 6 and adjacent to the Broad River as shown in Figure 2-2. The active ash basin is an unlined basin impounded by earthen dams located between the west portion of the basin and Suck Creek and between the northeast portion of the basin and the Broad River. The waste boundary associated with the active ash basin, including associated dams and the ash storage areas, is approximately 117 acres in area. The approximate maximum pond elevation of the active ash basin is 770 feet. The active ash basin contains approximately 5,400,000 tons of ash. The main section of the pond is maintained below 765 feet to have extra storage capacity during a significant flood event.

The active ash basin was constructed in two phases. The first phase consisted of excavation of the Suck Creek diversion canal and construction of the upstream dam to elevation 745 feet and

the downstream dam to elevation 725 feet. This first phase began in 1974 and was completed in 1975. The second phase consisted primarily of raising both dams to elevation 775 feet. The downstream dam was raised in two stages, with the first stage involving construction of the dam to a temporary elevation of 737 feet sometime in late 1979. The second stage construction was essentially completed in late 1980. In 2012, ash from within the southern portion of the active ash basin was removed and placed dry within an upland portion of the ash basin footprint in order to create a settling cell. The ash that was stacked northwest of the settling cell was covered with a soil layer and is currently well vegetated.

The active ash basin was formed by construction of two earth fill dams across Suck Creek bracketing a nearly mile-long meandering reach of the natural stream valley. At the upstream dam, Suck Creek was diverted through a canal and away from the ash basin to the Broad River, its present-day configuration. The maximum height of the upstream dam is about 60 feet above the exterior toe and about 65 feet above the interior toe and has a crest length of 890 feet. The active ash basin downstream dam, located just upstream of the original confluence of Suck Creek with the Broad River, has a maximum height of about 120 feet above the downstream toe and has a crest length of 876 feet. Both dams were designed to have 15-foot wide crests at an elevation of 775 feet. The primary borrow area for construction of the embankment dams was material from within the basin footprint.

The outlet for the active basin (NPDES Outfall 002) is a reinforced concrete drainage tower with bottom discharge into a 42-inch diameter RCP which extends approximately 700 feet (horizontally) beneath the downstream dam at its left (west) abutment. The ash basin receives variable inflows from the Unit 5 fly ash handling system, Unit 5 bottom ash handling system, cooling tower blowdown, stormwater runoff from yard drainage, coal pile runoff, gypsum pile runoff, limestone pile runoff, landfill leachate, and wastewater streams generated from emission monitoring equipment, precipitators, and Selective Catalytic Reduction Unit. Also, treated sanitary wastewater, miscellaneous cleaning wastes, domestic package plant wastewater (through the yard sumps) and water treatment system wastes (filter backwash, demineralizer regeneration waste, reverse osmosis rinse water, and clarifier solids).

3.2.2 Ash Storage Areas

Two unlined dry ash storage areas are located north and adjacent to the active ash basin. These areas are located between the active portion of the ash basin and the Broad River and are heavily vegetated. The ash located in these storage areas was likely removed from the active ash basin during the 1980s. The CSA investigation results were not conclusive in identifying the extent of these ash storage areas. There is also potential that one of the areas may be a spoils area remnant from embankment dam construction. The combined ash storage area footprint is approximately 15 acres and contains approximately 170,000 cubic yards of ash material.

3.2.3 Units 1-4 Inactive Ash Basin

The Units 1-4 inactive ash basin previously received inflows from Units 1-4 operation, primary sluiced bottom ash and fly ash. The upstream, western portions of the ash basin were converted

into holding cells for storm and plant process water. Water from these holding cells is pumped to the active ash basin to the east. The impounded ash material within the inactive basin is capped with a soil cover approximately 2 feet thick.

The Units 1-4 inactive ash basin is an unlined basin impounded by an earthen dam located along the north and northeast side of the basin. The waste boundary associated with the Units 1-4 inactive ash basin is approximately 14.5 acres in area and contains approximately 320,000 tons of ash material.

The Unit 1-4 inactive ash basin dam is an L-shaped earth fill embankment with an overall length of about 1480 feet along the crest. The dam was designed to have a 15-foot wide crest at elevation 706 ft. The current crest elevation is about 703.5 feet. The maximum height of the dam is about 38 feet above the downstream toe.

The outlet for the Units 1-4 inactive ash basin is a reinforced concrete drainage tower with bottom discharge into a 30-inch diameter corrugated metal pipe (CMP) which extends approximately 180 feet (horizontally) through the base of the embankment at a skewed section located near the east end of the dam.

3.2.4 Unit 5 Inactive Ash Basin

The Unit 5 inactive ash basin is located approximately 1,000 feet to the southwest of Unit 5 and approximately 1,000 feet west of Unit 6, south of the Broad River (Figure 2-2). The Unit 5 inactive ash basin is an unlined basin impounded by two earthen dams located along the north and northeast sides of the basin. The waste boundary associated with the Unit 5 inactive ash basin, including its dams, is approximately 58 acres in area. The Unit 5 inactive ash basin contains approximately 806,000 tons of ash material. The majority of the Unit 5 inactive ash basin footprint is currently used as a laydown area.

The Unit 5 inactive ash basin dams are earth fill embankments. The main and saddle dams are the principal embankments which form this ash basin. The crest of the main dam is generally oriented in an east-west direction and parallels the flow of the Broad River to the north. The crest of the saddle dam is generally oriented in a southeast-northwest direction, and the Unit 5 cooling towers are located immediately northwest. The dams were designed to have 20-foot wide crests at elevation 767 feet. The main dam is about 1460 feet long at the crest and has a maximum height of about 97 feet above the toe of the downstream slope. The saddle dam is approximately 590 feet long at the crest and has a maximum height of about 42 feet above the downstream toe.

The outlet for this basin is a reinforced concrete drainage tower with bottom discharge into a 60-inch diameter reinforced concrete pipe (RCP) which extends approximately 500 feet (horizontally) through the left abutment of the main dam. The Unit 5 ash basin and dam construction was completed in 1970, and the basin began receiving inflows with Unit 5 startup in 1972. The basin quickly reached its capacity and was retired in 1980, and a soil layer was placed across the footprint. The majority of the Unit 5 inactive ash basin footprint is currently

used as a laydown area, and precipitation that falls within the ash basin's drainage area is conveyed through the outlet structure.

3.2.5 Coal Combustion Products Landfill

Duke Energy owns and operates the Cliffside Steam Station Coal Combustion Products (CCP) Landfill (NCDENR Division of Waste Management [DWM]), Solid Waste Section Permit No. 8106-INDUS-2009). The CCP landfill is located nearly a mile southwest of the CSS on Duke Energy property and is situated completely within Rutherford County. The CCP landfill is northeast of the intersection of Old U.S. Highway 221A and Ballenger Road. The landfill is permitted to receive fly ash, bottom ash, boiler slag, mill rejects, flue gas desulfurization waste, leachate basin sludge, non-hazardous sandblast material, limestone, ball mill rejects, coal, carbon, sulfur pellets, cation and anion resins, sediment from sumps, cooling tower sludge and filter bags generated by Duke Energy North Carolina coal-fired facilities, including from Cliffside Steam Station. Waste was first placed into the landfill on October 24, 2010.

Once completed, the CCP Landfill is planned to be constructed in five phases and will encompass a total of 86 acres. Phase I has been constructed and encompasses 23.3 acres of the southwestern corner of the landfill footprint. The estimated gross capacity of Phase I is 2,415,000 cubic yards. Phase II is currently being constructed, with the liner system recently reaching completion. Once all construction is complete, Duke Energy will submit a Construction Quality Assurance report to NCDENR's Solid Waste Section for application for a Permit to Operate Phase II of the landfill. Phase II will encompass 15.3 acres immediately north of the Phase I footprint. The estimated gross capacity of Phase II is 1,922,000 cubic yards. The entire landfill facility is projected to have a combined capacity of 13,343,000 cubic yards of waste when complete. The approximate boundary of the CCP Landfill Phase I is shown in Figure 2-2.

The Permit to Construct Phase I of the landfill was issued by NCDENR DWM in June 2009. The original Phase I Permit to Operate was issued by NCDENR DWM in September 2010. A Permit to Construct Phase II of the landfill was originally issued in September 2012 and modified in March 2014. The landfill was constructed with a leachate collection and removal system and an engineered liner system. Phase I contact stormwater and leachate are collected in the leachate collection pipe system and then pumped for treatment in the station's active ash basin. The water quality monitoring system at the landfill currently consists of nine groundwater monitoring wells and two surface water sample locations for Phase I.

3.3 Physical Properties of Ash

Ash in the CSS ash basin consists of fly ash and bottom ash produced from the combustion of coal. The physical and chemical properties of coal ash are determined by reactions that occur during the combustion of the coal and subsequent cooling of the flue gas. In general, coal is dried, pulverized, and conveyed to the burner area of a boiler for combustion. As described in Section 3.1, material that forms larger particles of ash and falls to the bottom of the boiler is referred to as bottom ash. Smaller particles of ash, known as fly ash, are carried upward in the flue gas and are captured by an air pollution control device.

Approximately 70 to 80 percent of the ash produced during coal combustion is fly ash (EPRI 1993). Typically 65 to 90 percent of fly ash has particle sizes that are less than 0.010 millimeter (mm). In general, fly ash has a grain size distribution similar to that of silt. The remaining 20 to 30 percent of ash produced is considered to be bottom ash. Bottom ash consists of angular particles with a porous surface and is normally gray to black in color. Bottom ash particle diameters can vary from approximately 0.05 to 38 mm. In general, bottom ash has a grain size distribution similar to that of fine gravel to medium sand (EPRI 1995).

Based on published literature not specific to this site, the specific gravity of fly ash typically ranges from 2.1 to 2.9 and the specific gravity of bottom ash typically ranges from 2.3 to 3.0. The permeability of fly ash and bottom ash vary based on material density, but would be within the range of a sand-gravel with a similar gradation, grain size distribution and density (EPRI 1995). Permeability and other physical properties of the ash found in the CSS ash basin are presented later in this report.

3.4 Chemical Properties of Ash

In general, the specific mineralogy of coal ash varies based on many factors including the chemical composition of the coal, which is directly related to the geographic region where the coal was mined, the type of boiler where the combustion occurs (i.e., thermodynamics of the boiler), and air pollution control technologies employed.

The overall chemical composition of coal ash resembles that of siliceous rocks from which it was derived, particularly shale. Oxides of silicon, aluminum, iron, and calcium make up more than 90 percent of most siliceous rocks, soils, fly ash, and bottom ash. Other major and minor elements (sulfur, sodium, potassium, magnesium, titanium) make up an additional 8 percent, while trace constituents account for less than 1 percent. The following constituents are considered to be trace elements: arsenic, barium, cadmium, chromium, lead, mercury, selenium, copper, manganese, nickel, lead, vanadium, and zinc (EPRI 2010).

According to Duke Energy, the coal source generally used for combustion at CSS was historically Central Appalachian coal, which had relatively low sulfur content. After 2010, additional pollution control devices were installed at CSS. Northern Appalachian coal and Illinois basin (West Virginia, Pennsylvania, Western Kentucky, and Illinois) coal started to be used as well as the Central Appalachian coal.

The majority of fly ash particles are glassy spheres mainly composed of amorphous or glassy aluminosilicates, crystalline matter, and carbon. Figure 3-1 presents a photograph of ash collected from the ash basin at Duke Energy's Cliffside Steam Station showing a mix of fly ash and bottom ash at 10 µm and 20 µm magnifications. The glassy spheres can be observed in the photograph. The glassy spheres are generally resistant to dissolution. During the later stages of the combustion process and as the combustion gases are cooling after exiting the boiler, molecules from the combustion process condense on the surface of the glassy spheres. These surface condensates consist of soluble salts (e.g. calcium (Ca^{2+}), sulfate (SO_4^{2-}), metals (copper (Cu), zinc (Zn), and other minor elements (e.g. boron (B), selenium (Se), and arsenic (As)) (EPRI 1994).

The major elemental composition of fly ash (approximately 95 percent by weight) is composed of mineral oxides of silicon, aluminum, iron, calcium. Oxides of magnesium, potassium, titanium and sulfur comprise approximately 4 percent by weight (EPRI 1995). Trace elemental composition typically is approximately 1 percent by weight and may include arsenic, antimony, barium, boron, cadmium, chromium, copper, manganese, mercury, nickel, lead, selenium, silver, thallium, zinc, and other elements. For comparison, Figure 3-2 shows the elemental composition of fly ash and bottom ash compared with typical values for shale and volcanic ash. Table 3-1 shows the bulk composition of fly ash and bottom ash compared with typical values for soil and rock. In addition to these constituents, fly ash may contain unburned carbon. Bituminous coal ash typically yields slightly acidic to alkaline solutions with pH levels ranging from approximately 5 to 10 on contact with water. As noted in Table 3-1, aluminum, silicon, calcium, and iron represent the larger fractions of fly ash by weight.

The geochemical factors controlling the reactions associated with leaching of ash are complex. Factors such as the chemical speciation of the constituent, solution pH, solution-to-solid ratio, and other factors control the chemical concentration of the resultant solution. Constituents that are held on the glassy surfaces of fly ash such as boron, arsenic, and selenium may initially leach more readily than other constituents. As noted in Table 3-1 aluminum, silicon, calcium, and iron represent the larger fractions of fly ash and bottom ash by weight. The presence of calcium may limit the release of arsenic by forming calcium-arsenic precipitates. Formation of iron hydroxide compounds may also sequester arsenic and retard or prevent release of arsenic to the environment. Similar processes and reactions may affect other constituents of concern; however, certain constituents such as boron and sulfate will likely remain highly mobile.

In addition to the variability that might be seen in the mineralogical composition of the ash, based on different coal types, different age of ash in the basin, and other factors, it is anticipated that the chemical environment of the ash basin varies over time, distance, and depth.

EPRI (2010) reports that 64 samples of coal combustion products (including fly ash, bottom ash, and flue gas desulfurization residue) from 50 different power plants were subjected to USEPA Method 1311 Toxicity Characteristic Leaching Procedure (TCLP) (USEPA 1992b) leaching and no TCLP result exceeded the TCLP hazardous waste limit. Figure 3-3 provides the results of that testing. The report also presents the trace element concentrations for fly ash and bottom ash compared to USEPA Residential Soil Screening Levels (RSLs) for ingestion and dermal exposure. Figure 3-4 shows the 10th to 90th percentile range for trace element concentrations (mg/kg) in fly ash and the associated USEPA RSLs. The trace element concentrations for arsenic were greater than the RSL for arsenic. The RSLs of the remaining constituents were greater than or within the 10th to 90th percentile range for their trace element concentrations.

Figure 3-5 shows similar data for bottom ash. As with fly ash, the trace element concentrations for arsenic in bottom ash were greater than the RSL for arsenic. The RSL for chromium was within the 10th to 90th percentile range of concentrations for chromium in bottom ash. The 10th to 90th percentile range for the remaining constituents were below their respective RSLs.

Site-specific ash data are discussed in Section 7.0 of this report.

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4.0 Receptor Information

Section §130A-309.201(13) of the CAMA defines receptor as “*any human, plant, animal, or structure which is, or has the potential to be, affected by the release or migration of contaminants. Any well constructed for the purpose of monitoring groundwater and contaminant concentrations shall not be considered a receptor.*” In accordance with the NORR CSA guidance, receptors cited in this section refer to public and private water supply wells (including irrigation wells and unused wells) and surface water features. Refer to Section 12.0 for a discussion of receptors that were evaluated as part of this CSA effort.

The NORR CSA receptor survey guidance requirements include listing and depicting all water supply wells, public or private, including irrigation wells and unused wells (other than those that have been properly abandoned in accordance with 15A NCAC 2C .0100) within a minimum of 1,500 feet of the known extent of contamination. In NCDENR’s June 2015 response to Duke Energy’s proposed adjustments to the CSA guidelines, NCDENR DWR acknowledged the difficulty with determining the known extent of contamination at this time and stated that they expected all drinking water wells located 2,640 feet (0.5-miles) downgradient from the established compliance boundary to be documented in the CSA reports as specified in the CAMA requirements. The approach to the receptor survey in this CSA includes listing and depicting all water supply wells (public or private, including irrigation wells and unused wells) within a 0.5-mile radius of the ash basin compliance boundary.

Note that the NORR CSA guidance requires that subsurface utilities be mapped within 1,500 feet of the known extent of contamination in order to evaluate the potential for preferential pathways. Drawings of underground utilities were not readily available for review. The flow of groundwater from the ash basins and ash storage area is to the Broad River and Suck Creek. Therefore, the mapping of underground features that serve as potential preferential pathways was limited to underground piping and drains located between the ash basin waste boundaries and these surface water features, depicted in Figures 4-3 and 4-4.

4.1 Summary of Previous Receptor Survey Activities

Duke Energy submitted a receptor survey to NCDENR (HDR 2014a) in September 2014, and subsequently submitted to NCDENR a supplement to the receptor survey (HDR 2014b) in November 2014. The purpose of the receptor survey was to identify the potential exposure locations that are critical to be considered in the groundwater transport modeling and human health risk assessment. The supplementary information was obtained from responses to water supply well survey questionnaires mailed to property owners within a 0.5-mile (2,640-foot) radius of the CSS ash basin compliance boundary requesting information on the presence of water supply wells and well usage.

The survey activities included contacting and/or reviewing the following agencies/records to identify public and private water supply sources, confirm the location of wells, and/or identify any wellhead protection areas located within a 0.5-mile radius of the CSS ash basin compliance boundary:

- NCDENR Division of Water Resources Public Water Supply Section's (PWSS) most current Public Water Supply Water Sources GIS point data set;
- NCDENR DWR Source Water Assessment Program (SWAP) online database for public water supply sources;
- Environmental Data Resources (EDR) local/regional water agency records review;
- USGS database;
- Rutherford County Environmental Health Department;
- Cleveland County Health Department Environmental Health Division;
- Broad River Water Authority;
- S&ME, Inc. environmental service and project modernization reports; and
- USGS National Hydrography Dataset.

In addition, a field reconnaissance was performed on March 21, 2014 to identify public and private water supply wells (including irrigation wells and unused or abandoned wells) and surface water features located within a 0.5-mile radius of the CSS ash basin compliance boundary. A windshield survey was conducted from public roadways to identify water meters, fire hydrants, valves, and any potential well heads/well houses. Duke Energy site personnel provided information regarding water supply wells located on Duke Energy property.

During the week of October 8, 2014, 221 water supply well survey questionnaires were mailed to property owners requesting information on the presence of water supply wells and well usage information for each property. The mailing list was compiled from a query of the parcel addresses included in the Rutherford and Cleveland counties' GIS databases utilizing the 0.5-mile offset.

Between July 8 and July 27, 2015, the agencies/records listed above were contacted to provide additional update information. Updated information is provided in Appendix B.

4.2 Summary of CSA Receptor Survey Activities and Findings

As part of this CSA report, the previously completed Receptor Survey activities were updated based on the CSA Guidelines. The update included contacting and/or reviewing the agencies/records to identify public and private water supply sources identified in Section 4.1 and reviewing any questionnaires that were received after the submittal of the November 2014 supplement to the September 2014 receptor survey (i.e. questionnaires received after October 31, 2014).

A summary of the receptor survey findings is provided below. The identified water supply wells are shown in the USGS receptor map on Figure 4-1 and on an aerial photograph on Figure 4-2. Available property and well information for the identified water supply wells is provided in Table 4-1.

Underground features including underground piping and drains identified in the vicinity of the Unit 5 inactive ash basin are shown on Figure 4-3. Underground piping and drains in the vicinity of the Units 1-4 inactive ash basin, the ash storage areas, and the active ash basin are shown in

Figure 4-4. The dams contain engineered drainage features associated with dam drainage and stability. These features are internal or adjacent to the dams and are not included in the underground utility mapping. The underground piping and drains on the CSS site appear to be designed to convey water from various portions of the site toward the Broad River or Suck Creek. It is not expected that the underground piping or drains would act as preferential pathways between the impacted portions of the CSS site to the identified water supply wells.

Figure 4-5 presents surface water features identified on and surrounding the CSS site. The surface water features in the vicinity of the CSS site drain to Suck Creek and the Broad River.

Table 4-2 provides names and addresses of property owners contiguous to the ash basin waste boundary which corresponds to the parcels depicted on Figure 4-6.

- Based on the returned water supply well questionnaires since October 31, 2014, no additional receptors were identified since the November 6, 2014 supplement to the September 2014 receptor survey to NCDENR. Six of the previously “field identified” wells (ID # 10, 39, 40, 41, 42, and 54) were confirmed by the returned questionnaires. These wells are identified as “reported” on Figures 2-8, 2-9, 4-1 and 4-2 and in Table 4-1. Forty-two private water supply wells (including the six previously “field identified” wells recently confirmed) were confirmed to be located on properties within a 0.5-mile radius of the ash basin compliance boundaries based on information provided in returned water supply well questionnaires. These wells are identified as “reported” private water supply wells.
- Twenty-three private water supply wells were identified within a 0.5-mile radius of the CSS ash basin compliance boundaries during the site reconnaissance. These wells are identified as “field identified” private water supply wells.
- Six additional private water supply wells are assumed at residences located within a 0.5-mile radius of the CSS ash basin compliance boundaries, based on the lack of public water supply in the area, and proximity to other residences that have private wells. These wells are identified as “assumed” private water supply wells as questionnaires for these wells were not received.
- No public water supply wells (including irrigation wells and unused wells) were identified within a 0.5-mile radius of the CSS ash basin compliance boundaries.
- No wellhead protection areas were identified within a 0.5-mile radius of the CSS ash basin compliance boundaries.
- Several surface water features that flow toward the Broad River were identified within a 0.5-mile radius of the CSS ash basin compliance boundaries (Figure 4-5).

Further details of receptor survey activities and findings are presented in Appendix B.

4.3 NCDENR Well Water Testing Program

Section § 130A-309.209 (c) of the CAMA requires the owner of a coal combustion residuals surface impoundment to conduct a Drinking Water Supply Well Survey that identifies all drinking water supply wells within one-half mile down-gradient from the established compliance boundary of the impoundment and submit the Survey to the Department. Since the direction of groundwater flow had not been fully established at the sites, DENR required the sampling to include all potential drinking water receptors within a half mile of the compliance boundaries in all directions. Between February and July 2015, NCDENR arranged for independent analytical laboratories to collect and analyze water samples obtained from private wells identified during the Well Survey, if the owner agreed to have their well sampled.

Appendix B provides tabulated results, provided by Duke Energy from NCDENR, sampling results with exceedances of 2L, IMAC, and/or reporting limit standards. Appendix B also includes a water supply well tracking spreadsheet, provided by DENR.

For many of the wells sampled in this program, as with standard practice, samples were split for analysis by Duke Energy's certified (North Carolina Laboratory Certification #248) laboratory. The results were judged by Duke Energy to be substantially the same as the NCDENR results and have been excluded.

5.0 Regional Geology and Hydrogeology

5.1 Regional Geology

North Carolina is divided into three physiographic provinces: the Atlantic Coastal Plain, Piedmont, and Blue Ridge (Fenneman 1938). The CSS site is located in the Piedmont province. The Piedmont province is bounded to the east and southeast by the Atlantic Coastal Plain and to the west by the escarpment of the Blue Ridge Mountains, with a width of 150 miles to 225 miles in the Carolinas (LeGrand 2004).

The topography of the Piedmont region is characterized by low, rounded hills and long, rolling, northeast-southwest trending ridges (Heath 1984). Stream valley to ridge relief in most areas ranges from 75 feet to 200 feet. Along the Coastal Plain boundary, the Piedmont region rises from an elevation of 300 feet above mean sea level, to the base of the Blue Ridge Mountains at an elevation of 1,500 feet (LeGrand 2004).

The CSS site is the Inner Piedmont within the Cat Square terrane, one of a number of tectonostratigraphic terranes that have been defined in the southern and central Appalachians (Figure 5-1; Horton and others 1989; Hibbard and others 2002; Hatcher and others 2007; Merschat and Hatcher 2007). The Cat Square terrane is bounded by the younger-over-older Brindle Creek fault to the west that places the terrane over the Tugaloo terrane of the Inner Piedmont and the Central Piedmont suture to the east (Merschat and Hatcher 2007). It consists of metasedimentary rocks (sillimanite mica schist and gneiss, and biotite gneiss) intruded by granitoid plutons. Subordinate layers and lenses of quartz schist, micaceous quartzite, and calc-silicate rocks are present within the metasedimentary sequence. Rare mafic and ultramafic rocks occur in portions of the eastern Cat Square terrane. The terrane is characterized by gently dipping structures and low-angle thrust faulting and sillimanite and higher amphibolite grade metamorphism (Merschat and Hatcher 2007). A geologic map of the area around the Cliffside Steam Station is shown in Figure 5-2. The fractured bedrock is overlain by a mantle of unconsolidated material known as regolith.

The regolith includes residual soil and saprolite zones and, where present, alluvial deposits. Saprolite, the product of chemical weathering of the underlying bedrock, is typically composed of clay and coarser granular material and reflects the texture and structure of the rock from which it was formed. The weathering products of granitic rocks are quartz-rich and sandy textured. Rocks poor in quartz and rich in feldspar and ferro-magnesium minerals form a more clayey saprolite.

5.2 Regional Hydrogeology

The groundwater system is described as being comprised of two interconnected layers, or mediums: 1) residual soil/saprolite and weathered fractured rock (regolith) overlying 2) fractured crystalline bedrock (Heath 1980; Harned and Daniel 1992; Figure 5-3). The regolith layer is a thoroughly weathered and structureless residual soil that occurs near the ground surface with the degree of weathering decreasing with depth. The residual soil grades into saprolite, a

coarser grained material that retains the structure of the parent bedrock. Beneath the saprolite, partially weathered/fractured bedrock occurs with depth until sound bedrock is encountered. This mantle of residual soil, saprolite, and weathered/ fractured rock is a hydrogeologic unit that covers and crosses various types of rock (LeGrand 1988). This regolith layer serves as the shallow unconfined groundwater system and provides an intergranular medium through which the recharge and discharge of water from the underlying fractured rock occurs. Within the fractured crystalline bedrock layer, the fractures control both the hydraulic conductivity and storage capacity of the rock mass. A transition zone (TZ) at the base of the regolith has been interpreted to be present in many areas of the Piedmont. The zone is Harned and Daniel (1992) described the zone as consisting of partially weathered/fractured bedrock and lesser amounts of saprolite that grades into bedrock and they described the zone as "being the most permeable part of the system, even slightly more permeable than the soil zone". Harned and Daniel (1992) suggested the zone may serve as a conduit of rapid flow and transmission of contaminated water.

Most of the information supporting the existence of the TZ, until recently, was qualitative based on observations made during the drilling of boreholes and water-wells, although some quantitative data are available for the Piedmont region (Stewart 1964; Stewart and others 1964; Nutter and Otton 1969; Harned and Daniel 1992). Schaeffer (2009; 2014a), using a database of 669 horizontal hydraulic conductivity measurements in boreholes at six locations in the Carolina Piedmont, statistically showed that a transition zone of higher hydraulic conductivity exists in the Piedmont groundwater system when considered within Harned and Daniel's (1992) two types of bedrock conceptual framework.

The TZ is described as being comprised of partially weathered rock, open, steeply dipping fractures, and low angle stress relief fractures, either singly or in various combinations below refusal (auger, roller cone, or casing advancer; Schaeffer 2011; 2014b). The TZ has less advanced weathering relative to the regolith and generally the weathering has not progressed to the development of clay minerals that would decrease the permeability of secondary porosity developed during weathering, and new fractures develop during the weathering process, and /or existing fractures are opened. The characteristics of the TZ can vary widely based on the interaction of rock type, degree of weathering, degree of systematic fracturing, presence of stress-relief fracturing, and the general characteristics of the bedrock (foliated/layered, massive, or in between). The TZ is not a continuous layer between the regolith and bedrock; it thins and thickens within short distances and is absent in places (Schaeffer 2011; 2014b). The absence, thinning, and thickening of the TZ is related to the characteristics of the underlying bedrock (Schaeffer 2014b).

As previously mentioned, the TZ may vary due to different rock types and associated rock structure. Harned and Daniel (1992) further divided the bedrock into two conceptual models: 1) foliated/layered (metasedimentary and metavolcanic sequences) and 2) massive/plutonic (plutonic and metaplutonic complexes) structures (Figure 5-4). Strongly foliated/layered rocks are thought to have a well-developed TZ due to the breakup and weathering along the foliation planes or layering, resulting in numerous rock fragments (Harned and Daniel 1992). More massive rocks are thought to develop an indistinct TZ because they do not contain

foliation/layering and tend to weather along relatively widely spaced fractures (Harned and Daniel 1992). Schaeffer (2014a) proved Harned and Daniel's (1992) hypothesis that foliated/layered bedrock would have a better developed TZ than plutonic/massive bedrock. The foliated/layered bedrock TZ has a statistically significant higher hydraulic conductivity than the massive/plutonic bedrock TZ (Schaeffer 2014a).

LeGrand's (1988; 1989) conceptual model of the groundwater setting in the Piedmont incorporates Daniel and Harned's (1992) above two-medium system into an entity that is useful for the description of groundwater conditions. That entity is the surface drainage basin that contains a perennial stream (LeGrand 1988). Each basin is similar to adjacent basins and the conditions are generally repetitive from basin to basin. Within a basin, movement of groundwater is generally restricted to the area extending from the drainage divides to a perennial stream (Slope-Aquifer System; Figure 5-5; LeGrand 1988; 1989; 2004). Rarely does groundwater move beneath a perennial stream to another more distant stream or across drainage divides (LeGrand 1989). The crests of the water table underneath topographic drainage divides represent natural groundwater divides within the slope-aquifer system and may limit the area of influence of wells or contaminant plumes located within their boundaries. The concave topographic areas between the topographic divides may be considered as flow compartments that are open-ended down slope.

Therefore, the groundwater system is a two medium system generally restricted to the local drainage basin. The groundwater occurs in a system composed of two interconnected layers: residual soil/saprolite and weathered rock (TZ) overlying fractured sedimentary rock. The systems are separated by the TZ portion of the residual soil, saprolite, and weathered rock. Typically, the residual soil/saprolite is partially saturated and the water table fluctuates within it. Water movement is generally preferential through the weathered/fractured and fractured bedrock of the TZ (i.e., enhanced permeability zone). The character of such aquifers results from the combined effects of the rock type, fracture system, topography, and weathering. Topography exerts an influence on both weathering and the opening of fractures, while the weathering of the crystalline rock modifies both transmissive and storage characteristics.

The igneous and metamorphic bedrock in the Piedmont consist of interlocking crystals and primary porosity is very low, generally less than 3 percent. Secondary porosity of crystalline bedrock due to weathering and fractures ranges from 1 to 10 percent (Freeze and Cherry 1979); but, porosity values of 1 to 3 percent are more typical (Daniel and Sharpless 1983). Daniel (1990) reported that the porosity of the regolith ranges from 35 to 55 percent near land surface but decreases with depth as the degree of weathering decreases.

In natural areas, groundwater flow paths in the Piedmont are almost invariably restricted to the zone underlying the topographic slope extending from a topographic divide to an adjacent stream. Under natural conditions, the general direction of groundwater flow can be approximated from the surface topography (LeGrand 2004).

Groundwater recharge in the Piedmont is derived entirely from infiltration of local precipitation. Groundwater recharge occurs in areas of higher topography (i.e., hilltops) and groundwater discharge occurs in lowland areas bordering surface water bodies, marshes, and floodplains

(LeGrand 2004). Average annual precipitation in the Piedmont ranges from 42 to 46 inches. Mean annual recharge in the Piedmont ranges from 4.0 to 9.7 inches per year (Daniel 2001).

6.0 Site Geology and Hydrogeology

6.1 Site Geology

The CSS site is located in the Cat Square terrane of the Inner Piedmont terrane. The Cat Square terrane consists of Ordovician to Devonian age, high grade (sillimanite grade) metamorphic rocks including orthogneiss and paragneiss with later granitic intrusions (Merschat and Hatcher, 2007). The Cat Square terrane, within the approximate latitude of the site, is bounded to the west and northwest by the Tugaloo terrane (also part of the Inner Piedmont) and the Carolina terrane to the east and southeast. The Brindle Creek Fault separates the Tugaloo terrane from the Cat Square terrane and is approximately ten miles northwest of the site. The site location and well locations are overlaid on the Geologic Map of the Charlotte 1° x 2° Quadrangle, North Carolina and South Carolina (Goldsmith and others 1988). This map, while accurate in rock description and mapping of contacts, does not identify the Tugaloo and Cat Square terranes of the Inner Piedmont since the 1988 publication of the map pre-dates the identification of these terranes. Field mapping and use of all of the borehole data confirm the geologic units and location of contacts of the units with only a slight variation of the contact of the mapped units based on borehole and field mapping data. The updated bedrock geologic map with the site and boring locations is presented in Figure 6-1. Based on the location of the site the bedrock at the site is composed of biotite gneiss (CZbg) and sillimanite schist (CZss) units. Granite (OCsg), located north of the site, was not encountered at the site in the boreholes. The installed well and sample locations are shown on Figure 6-2.

6.1.1 Soil Classification

Soil conditions encountered in the borings showed minimal variation across the site. Residual soil consists of clayey sand (SC), silty sand (SM), silty sand with gravel (SM), micaceous silty sand (SM), and gravel with silt and sand (GP). The following soils/materials were encountered in the boreholes:

- Ash – Ash was encountered in borings advanced within the active ash basin, the Units 1-4 Inactive ash basin, the Unit 5 Inactive ash basin and the ash storage area. Ash was generally described as gray to dark gray with, non-plastic, dry to wet a silty to sandy texture, consistent with fly ash and bottom ash.
- Fill – Fill material generally consisted of re-worked silts, clays, and sands that were borrowed from one area of the site and re-distributed to other areas. Fill was generally classified as silty sand, clayey sand, and sand with clay and gravel in the boring logs. Fill was used in the construction of dikes and as cover for ash storage areas.
- Alluvium – Alluvium is unconsolidated soil and sediment that has been eroded and redeposited by streams and rivers. Alluvium may consist of a variety of materials ranging from silts and clays to sands and gravels. During site construction and plant operation, alluvial deposits have been removed or covered. Alluvium was encountered in borings along the Broad River during the project subsurface exploration activities and during

geologic mapping. Designations between alluvium and fill are approximate and were challenging to distinguish due to the similarities in material.

- Residuum (Residual soils) – Residuum is the in-place weathered soil that consists primarily of micaceous silty sand, micaceous silt, and clayey sand. This unit was relatively thin at the site. Designations between residuum and fill are approximate and were challenging to distinguish due to the similarities in material.
- Saprolite – Saprolite is soil developed by in-place weathering of rock that retains remnant bedrock structure. Saprolite consists primarily of dense to very dense silty sand and silty sand with gravel noted as micaceous in some boring logs and not noted as micaceous in others. The primary distinction from residuum is that saprolite typically retains some structure (e.g., mineral banding) from the parent rock. Saprolite thickness varies across the site from a very thin mantle where bedrock is near the surface to as much as 72 feet in other areas.

Geotechnical index property testing of the above soil/materials was performed for disturbed and undisturbed samples in accordance with American Society of Testing and Materials (ASTM) standards. Thirty-six undisturbed ('Shelby Tube') samples were submitted for geotechnical index testing. Index property testing for undisturbed samples comprised Unified Soil Classification System (USCS) classification (ASTM D 2487), natural moisture content (ASTM D 2216), Atterberg Limits (ASTM D 4318), grain size distribution, including sieve analysis and hydrometer (ASTM D 422), total porosity calculated from specific gravity (ASTM D 854), and hydraulic conductivity (ASTM D 5084). Two undisturbed samples were unable to receive the full suite of index property tests due to low recovery, wax and gravel mixed in the tube, loose material, or damaged tubes. Twenty-two disturbed ('Split Spoon,' or 'Jar') samples received grain size distribution with hydrometer (ASTM D 422), and natural moisture content (ASTM D 2216). The results of the testing are presented in Section 11.0.

6.1.2 Rock Lithology

The bedrock at the site consists of biotite gneiss and sillimanite schist. The biotite gneiss contains subordinate zones of quartzite, quartz feldspar gneiss, and mica schist. Figure 6-1 shows the extent of each unit. The biotite gneiss is predominantly gray to dark gray, fine to medium grained with some coarse grained zones, thinly to medium banded, and consists of quartz, plagioclase, biotite, and minor amounts of muscovite and garnet. The sillimanite schist is gray to light gray, fine to medium grained and consists of sillimanite, muscovite, quartz, and subordinate amounts of feldspar. It generally occurs as interlayers in the biotite gneiss.

6.1.3 Structural Geology

The Inner Piedmont including the Cat Square terrane has been subjected to intense deformation due to dextral transpression along a south moving orogenic belt at the convergent margin of the terrane and the Laurentian margin (Dennis, 2007). Deformation includes a pervasive foliation, folding including recumbent folds/nappe structures, and shear zones. Sinistral tranpression associated with accretion of the Carolina terrane (Hibbard, 2000) to the southeast has also had an effect on the geologic structure in the Cat Square terrane. This multi-phase deformation occurred primarily as ductile deformation and has resulted in complex

structural components in the bedrock.

Rock core data indicates a dominant 10 to 20 degree dipping foliation in both the biotite gneiss and sillimanite schist. The dip direction of the foliation cannot be determined from the borehole data. A number of shear zones ranging from, 0.1 to 0.5 feet thick along foliation were noted in boring MW-34BRU. Some of these shear zones are noted to have pyrite within the zone.

Data from the rock cores also show two predominant joint sets; a 40 to 50 degree dipping set and a horizontal to sub-horizontal set. Less predominant sets of 20 to 30 degree dipping joints and joints along foliation planes were noted. Based on the degree of folding in Inner Piedmont the 20 to 30 degree dipping joints, sub-horizontal joints and joints along foliation may be the same joint set and related to the dominate foliation. An apparently less pervasive sub-vertical set is observed but is likely due to vertical boreholes being less likely to intercept sub-vertical joints. All of the joint sets are described as having iron oxide and some manganese oxide staining which is an indication of groundwater flow along the joint sets. The degree of openness of the joint is difficult to assess from rock core since the core is often broken at a joint and no longer retains its actual aperture.

6.1.4 Geologic Mapping

Geologic mapping was conducted in April of 2015 at the site and within a 2-mile radius of the site. A Brunton compass was used to measure to the orientation (strike and dip) of structures including foliation, joints, fold axis, and shear zones observed in rock outcrops. Figure 6-1 shows the location and orientation of foliation and joints mapped. The availability of outcrop was a limiting factor in characterizing the complex nature of folding and deformation. The major structures observed during mapping consist of:

- Sub-vertical, continuous, very widely spaced joints striking approximately N83E and dipping ~75 degrees to the south-southeast.
- Foliation ranging in dip from 4 to 29 degrees and ranging in dip direction from 0 to 34 degrees.
- Joint set striking N83W dipping 77 degrees to NE.
- Joint set striking N40W dipping 75 degrees to NE.
- Joint set striking N8W dipping 80 degrees to ENE.
- An anticlinal structure with a fold axis striking N55W and a plunge of 5 to 8 degrees to the southwest. This structure was mapped at the steam plant at a large outcrop apparently excavated as part of the plant construction. Within the overall anticlinal structure there was one recumbent fold noted and one tight "S" fold. These types of folds are assumed to exist within the bedrock across the site but the persistence and intensity of folding cannot be quantified in detail.

The variation in foliation orientations presented in Figure 6-1 is evidence of the complex structure of the bedrock. Figure 6-3 presents the foliation and joint data from the geologic mapping on a lower hemisphere stereonet plot with the major structures annotated.

6.1.5 Fracture Trace Analysis

6.1.5.1 Introduction

Fracture trace analysis is a remote sensing technique used to identify lineaments on topographic maps and aerial photography that may correlate to locations of bedrock fractures exposed at the earth's surface. Although fracture trace analysis is a useful tool to identify potential fracture locations, and hence potential preferential pathways for infiltration and flow of groundwater near a site, results are not definitive. Lineaments identified as part of fracture trace analysis may or may not correspond to actual locations of fractures exposed at the surface, and if fractures are present, it cannot be determined from fracture trace analysis whether these are open or healed.

Strongly linear features at the earth's surface are commonly formed by weathering along steeply dipping to vertical fractures in bedrock. Morphological features such as narrow, sharp crested ridges, narrow linear valleys, linear escarpments, and linear segments of streams otherwise characterized by dendritic patterns are examples. Linear variations in vegetative cover are also sometimes indicative of the presence of exposed fractures, though in many cases these result from unrelated human activity or other geological considerations (e.g. change in lithology).

The effectiveness of fracture trace analysis in the eastern United States, including in the Piedmont region, is hampered by dense vegetative cover and abundant alteration of the surface by present and past human activity (e.g. agriculture, residential development, commercial/industrial activity). The ability to identify small-scale lineaments on aerial photography that might otherwise be apparent is thereby hindered.

Straight (as opposed to curvilinear) features are commonly associated with the presence of steeply dipping fractures. Curvilinear features in some cases are associated with exposed moderately-dipping fractures, but these also can be a result of preferential weathering along lithologic contacts, or along foliation planes or other geologic structure. As part of this study, only strongly linear features were considered, as these are far more commonly indicative of steeply dipping or vertical fractures.

6.1.5.2 Methods

Available geologic maps of the area were consulted prior to performance of aerial photography and topographic map interpretation to identify lithologies and structures in the area, and likely fracture orientations. Both low-altitude aerial photography provided by Duke Energy (from WSP Global, Inc.) covering approximately 4.7 square miles, and USGS 1:24000 scale topographic maps covering an area of approximately 19 square miles were examined.

Maps examined included portions of the USGS 7.5' N.C.-S.C. and Boiling Springs South N.C.-S.C. (1:24,000 Scale) topographic quadrangles. Digital copies of the quadrangles were obtained and viewed on a monitor at up to 7x magnification. Lineaments identified were plotted directly on the digital images. Lineaments identified from topographic map are shown and lineament trends indicated by a rose diagram are included on Figure 6-3.

Photography provided for review included 1"=600' scale, 9 x 9 inch black-and-white (grayscale) contact prints dated April 14, 2014. Stereo coverage was complete across the area shown on Figure 6-4. The photography was examined using a Lietz Sokkia MS-27 mirror stereoscope with magnifying binocular eyepiece. Lineaments identified on the photographs were marked on hard copies of scanned images (600dpi resolution), and subsequently compiled onto a photomosaic base.

Rose diagrams were prepared for lineament trends identified from both aerial-photography and topographic-map interpretation and are included as inserts on the respective figures.

6.1.5.3 Results

A total of 21 well defined lineaments are apparent in the study area. Trends are predominantly toward the east-northeast and north-northwest. A prominent feature over a mile in length along Suck Creek is coincident with a north-northeast trending segment of a fold (synform) axis that transects the area, and may indicate the presence of well developed axial-planar cleavage in this part of the study area. Similarly, discontinuous but strong northeast-trending lineaments in the lower reaches of Ashworth Creek may have developed along an axial-planar cleavage associated with an antiform that trends through the area.

East-northeast lineaments along the Broad River west of the site, and along Second Broad River to the north and northwest, appear to have developed along contacts between the metamorphic sequence and granitic intrusives.

Lineaments identified from aerial photography are shown and lineament trends indicated by a rose diagram are included on Figure 6-4.

Extensive alteration of the land surface in the study area has greatly impacted the ability to identify small scale lineaments on aerial photography with confidence. Results of aerial-photography interpretation were inconclusive. Five lineaments were identified as shown on Figure 6-4.

6.1.6 Effects of Structure on Groundwater Flow

Due to the fact that rock deformation in the form of complex folding occurred primarily in ductile (pressure and temperature) conditions there are not significant discontinuities associated with this folding that result in open discontinuities. Shear zones that have mineralization may be prone to preferential weathering resulting in potential higher conductivity flow paths. Since our investigation did not identify any shear zones in outcrop, and shear zones noted in rock cores are not oriented, it is difficult to quantify the potential affect of shear zones on groundwater flow. The significant structure with respect to groundwater movement include the joint sets discussed in the previous section that were observed to be very continuous and crosscutting of fold structures and fractures that have formed along foliation in brittle (pressure and temperature) conditions.

6.1.7 Soil and Rock Mineralogy and Chemistry

Soil mineralogy and chemistry and rock mineralogy analyses are incomplete as of the date of this report. Soil mineralogy and chemistry results completed as of the issuance of this report and are shown in Table 6-1 (mineralogy), Table 6-2 (chemistry, % oxides), and Table 6-3 (chemistry, elemental composition). The mineralogy and chemical composition of TZ materials are presented in Table 6-4 (mineralogy), Table 6-5 (chemistry; % oxides), and Table 6-6 (chemistry, elemental composition). Whole rock chemistry results (% oxides and elemental composition) are shown in Tables 6-7 and 6-8, respectively. Petrographic analysis of rock (thin-sections) and the remaining soil mineralogy and chemistry analyses will be included in the CSA supplement.

The dominant mineral constituents in the soils are quartz, feldspar (both alkali and plagioclase feldspars), and muscovite/illite. Soils exhibiting a higher degree of weathering show an increase in kaolinite with higher percentage amorphous phase (lacking distinct crystalline structure). Other minerals identified include chlorite, biotite, gibbsite, calcite, dolomite, hornblende/amphibole, pyrite, ilmenite, mullite, and goethite. The major oxides in the soils are SiO_2 (48.10% - 69.43%), Al_2O_3 (18.25% - 26.31%), and Fe_2O_3 (1.33% - 8.76%). MnO ranges from 0.02% to 0.11%). Major transition zone minerals are quartz, illite, biotite, kaolinite, and feldspar. The major oxides are SiO_2 (59.0% - 61.3%), Al_2O_3 (27.5% - 28.7%), and Fe_2O_3 (7.0% - 8.2%). The major oxides in the rock samples are SiO_2 (59.27% - 70.36%), Al_2O_3 (15.54% - 20.4%), and Fe_2O_3 (1.50% - 7.22%). The high SiO_2 in the bedrock samples is consistent with their sedimentary origin.

6.2 Site Hydrogeology

6.2.1 Groundwater Flow Direction

Based on the site investigation, the groundwater system in the natural materials (alluvium, soil, soil/saprolite, and bedrock) at CSS is consistent with the regolith-fractured rock system and is an unconfined, connected aquifer system without confining layers as discussed in Section 5.2. The CSS groundwater system is divided into three layers referred to in this report as the shallow, deep (transition zone), and bedrock to distinguish flow layers within the connected aquifer system.

Accessible voluntary, compliance, and ash basin assessment monitoring wells were gauged for depth to water and total well depth during a comprehensive groundwater elevation measurement event on June 24, 25, and 26, 2015. Depth to water measurements were subtracted from surveyed top of well casing elevations to produce groundwater elevations in shallow, deep, and bedrock monitoring wells. Groundwater flow direction was estimated by contouring these groundwater elevations.

In general, groundwater within the shallow wells (S), transition zone (D) wells, and wells in fractured bedrock (BR), flow from south to north toward the Broad River. The groundwater flow in the shallow and deep wells to the west of the active ash basin and east of Unit 6 flow toward Suck Creek and on to the Broad River. Shallow groundwater flow direction is shown on Figure

6-5. Groundwater flow within the transition zone is shown of Figure 6-6. Groundwater flow within fractured bedrock is shown on Figure 6-7.

This flow direction is away from the direction of the nearest private water supply wells. The Broad River serves as a hydrologic boundary for groundwater within the shallow aquifer, prohibiting shallow groundwater flow from the ash basins to properties across the Broad River north of the CSS site.

The relative position of the groundwater monitoring wells (upgradient/downgradient) in relation to the ash basins or storage area are presented in Table 6-10 for voluntary and compliance wells and Table 6-11 for the assessment wells.

6.2.2 Hydraulic Gradient

Horizontal hydraulic gradient was derived for the shallow, transition zone, and fractured bedrock layers by calculating the difference in hydraulic head over the length of the flow path between two wells with similar well construction (e.g., both wells having 15-foot screens within the same water –bearing unit). The following equation was used to calculate horizontal hydraulic gradient:

$$i = dh / dl$$

where i is the hydraulic gradient; dh is the difference between two hydraulic heads; and dl is the flow path length between the two wells.

Applying this equation to wells installed during the CSA investigation yields the following average horizontal hydraulic gradients (measured in foot/feet):

- S wells: 0.041
- D wells: 0.053
- BR wells: 0.047

A summary of hydraulic gradient calculations is presented in Table 6-9. Note that vertical hydraulic gradients are discussed in Section 11.3.

6.2.3 Effects of Geologic/Hydrogeologic Characteristics on Contaminants

Migration, retardation, and attenuation of constituents in the subsurface is a factor of both physical and chemical properties of the media in which the groundwater passes. Soil samples were collected and analyzed for grain size, total porosity, soil sorption (K_d), and anions/cations to provide data necessary for completion of the three-dimensional groundwater model discussed in Section 13.0. As previously agreed upon with NCDENR, the results of the groundwater model will be presented in the CAP.

6.2.4 Hydrogeologic Site Conceptual Model

The hydrogeologic site conceptual model (SCM) is a conceptual interpretation of the processes and characteristics of a site with respect to the groundwater flow and other hydrologic

processes at the site. The NCDENR document, "Hydrogeologic Investigation and Reporting Policy Memorandum," dated May 31, 2007, was used as general guidance to developing the model. General components of the SCM consist of developing and describing the following aspects of the site: geologic/soil framework, hydrologic framework, and the hydraulic properties of site materials. More specifically, the SCM describes how these aspects of the site affect the groundwater flow at the site. In addition to these site aspects, the SCM:

- Describes the regional and site geology and hydrogeology (Sections 5.0, 5.1, 6.1 and 6.2)
- Presents longitudinal and transverse cross-sections showing the hydrostratigraphic layers, (Section 11.1)
- Develops the hydrostratigraphic layer properties required for the groundwater model, (Section 11.2)
- Presents a groundwater contour map showing the potentiometric surface of the shallow aquifer, (Section 6.2.1) and
- Presents information on horizontal (Section 6.2.2) and vertical groundwater gradients (Section 11.3).

The SCM serves as the basis for developing understanding the hydrogeologic characteristics of the site and for developing a groundwater flow and transport model. Historic site groundwater elevations and ash basin water elevations were used to develop a historic estimated seasonal high groundwater contour map for the site. A fracture trace analysis was also performed for the site, as well as onsite/near-site geologic mapping, to better understand site geology and to confirm and support the SCM.

As anticipated in the initial site conceptual hydrogeologic model presented in the Work Plan dated December 30, 2014, the geological and hydrogeological features influencing the movement, chemical, and physical characteristics of contaminants are related to the Piedmont hydrogeologic system present at the site. The CSA found that the direction of the movement of the contaminants is towards Suck Creek and the Broad River, as anticipated.

An updated SCM, based on data obtained during the CSA activities and refined through completion of groundwater modeling, will be presented in the CAP 90 after submittal of this CSA report.

7.0 Source Characterization

For purposes of this assessment the source area is defined by the ash waste boundary as depicted on Figure 2.2. For the CSS site, sources include the active ash basin, Units 1-4 inactive ash basin, Unit 5 inactive ash basin, and the ash storage area. Source characterization was performed to identify the physical and chemical properties of the ash in the source area. The source characterization involved developing selected physical properties of ash, identifying the constituents found in ash, measuring concentrations of constituents present in the ash porewater, and performing laboratory analyses to estimate constituent concentrations resulting from the leaching process. The physical and chemical properties developed as part of this characterization will be used to better understand impacts to soil and groundwater from the source area and will also be utilized as a part of the groundwater modeling and other evaluation to be performed in the CAP.

At the CSS site, source characterization was performed through the completion of soil borings, installation of monitoring wells, and collection and analysis of associated solid matrix and aqueous samples. Ash samples were collected for analysis of physical characteristics (e.g., grain size, porosity) to provide data for evaluation of retention/transport properties within and beneath the ash basin and ash storage areas. Ash samples were also collected for analysis of chemical characteristics (e.g., total inorganics, leaching potential) to provide data for evaluation of constituent concentrations and distribution. Samples were collected in general accordance with the work plan. Drilling and installation variances are documented in Appendix F. For the purpose of this CSA report and for use throughout this section, the term COI is used to refer to any constituent or parameter that exceeded its applicable regulatory standard.

Ash, ash basin water, porewater (water from wells installed within ash), and seep sample locations used for source characterization are shown on Figure 7-1. Porewater refers to water samples collected from wells installed within the ash basins or ash storage area screened in the ash layer. HDR does not consider porewater results to be representative of groundwater.

A summary of constituents and laboratory methods used for analysis of solid matrix samples (soil, rock and ash) is presented in Table 7-1. Laboratory results of total inorganic and anion/cation analyses of ash samples are presented in Table 7-2.

A summary of laboratory results for aqueous matrix (groundwater, surface water, ash porewater, and seeps) parameters and analytical methods is presented in Table 7-3. Laboratory results of ash basin water samples are presented in Table 7-4. Ash basin porewater sample results are presented in Table 7-5.

7.1 Active Ash Basin

7.1.1 Ash (Sampling and Chemical Characteristics)

Nineteen borings (AB-1S/D, AB-2S/D, AB-3S/SL/I/BRU, AB-4S/SL/D/BR, AB-5S/BRU, AB-6S/D/BR, GWA-20S/D) were advanced within the active ash basin waste boundary to obtain

ash samples for chemical analyses. Only AB-3, AB-4, AB-5, and AB-6 locations encountered ash, as AB-1, AB-2, and GWA-20 were advanced through the embankment dams associated with the basin.

Eight COIs: arsenic, barium, boron, cobalt, iron, manganese, selenium, and vanadium, were reported above the North Carolina Preliminary Soil Remediation Goals (PSRGs) for Industrial Health and/or Protection of Groundwater Standards in ash samples collected from the active ash basin as noted in Table 7-2.

7.1.2 Water (Sampling and Chemical Characteristics)

Two surface water samples (SW-5 and SW-7) were collected from the water surface within the active ash basin. Sample SW-5 was collected from the ash basin settling pond in the southern portion of the basin, and SW-7 was collected near the ash basin discharge tower within the active ash basin.

Seven COIs: aluminum, arsenic, cadmium, cobalt, copper, dissolved oxygen (DO) and thallium results exceeded the 2B Standards, 2L Standards, or IMAC for SW-5 and SW-7 (see Table 7-4 and Table 7-11).

NCDENR sampled the active ash basin discharge water (CLFWW057) in March 2014. The analytical results of this sampling are also presented in Table 7-4. CLFWW057 was intended to be re-sampled from the active ash basin permitted discharge to the Broad River during the assessment activities. During the CSA effort, CLFWW057 was collected from the seep north of the toe of the active ash basin downstream dam and is discussed in Section 7.6.2.2.

7.1.3 Ash Porewater (Sampling and Chemical Characteristics)

Porewater refers to water samples collected from wells installed within the active ash basin area that are screened within the ash layer. HDR does not consider porewater results to be representative of groundwater. Six porewater monitoring wells (AB-3S, AB-3SL, AB-4S, AB-4SL, AB-5S, AB-6S,) were installed within the waste boundary of the active ash basin and were screened within the ash layer.

Eleven COIs: antimony, arsenic, boron, cobalt, iron, manganese, pH, sulfate, thallium, total dissolved solids (TDS), and vanadium results exceeded the 2L Standards or IMAC in porewater samples collected from wells in the active ash basin as noted in Tables 7-5 and 7-12). Porewater sample locations are shown on Figure 7-1.

7.1.4 Ash Porewater Speciation

Speciation is the analysis of the composition of a particular analyte in a system. Speciation is important for understanding the fate and transport of COIs. Six locations, AB-3S/SL, AB-4S/SL, AB-5S, and AB-6S, were sampled for chemical speciation analyses of arsenic (III), arsenic (V), chromium (VI), iron (II), iron (III), manganese (II), manganese (IV), selenium (IV), and selenium (VI). Results for chemical speciation of porewater samples are presented in Table 7-7. Further evaluation of chemical speciation results will be included in the CAP.

7.1.5 Ash Water Speciation

Speciation is the analysis of the composition of a particular analyte in a system. Speciation is important for understanding the fate and transport of COIs. Two locations, SW-5 and SW-7, were sampled for chemical speciation analyses of arsenic (III), arsenic (V), chromium (VI), iron (II), iron (III), manganese (II), manganese (IV), selenium (IV), and selenium (VI). Results for chemical speciation of porewater samples are presented in Table 7-13. Further evaluation of chemical speciation results will be included in the CAP.

7.1.6 Radiological Laboratory Testing

Dissolved radionuclides from naturally occurring sources (e.g. soil or rock) may exist in water. The USEPA regulates various radionuclides in drinking water. For purposes of this assessment, radium-226, radium-228, natural uranium, uranium-233, uranium-234, and uranium-236 were analyzed. One location, AB-3S was sampled for the analytes listed above. Results for radiological laboratory testing of porewater samples are presented in Table 7-8. Further evaluation of radiological laboratory testing results will be included in the CAP.

7.2 Ash Storage Area

7.2.1 Ash (Sampling and Chemical Characteristics)

Eleven borings (AS-1S/D, AS-3BRU, AS-4S/D, AS-6S/D/BR, AS-7S/D/BR) were advanced within the ash storage area waste boundary to obtain ash samples for chemical analyses. Ash was encountered in the AS-1 and AS-7 locations, and an ash sample was collected and analyzed from boing AS-7 only. No ash was encountered in the east ash storage area (AS-4, AS-5, and AS-6 locations).

Five COIs: arsenic, cobalt, iron, manganese, and vanadium were reported above the North Carolina PSRGs for Industrial Health and/or Protection of Groundwater Standards in the ash samples collected from the ash storage area (see Table 7-2).

7.2.2 Ash Porewater (Sampling and Chemical Characteristics)

Porewater refers to water samples collected from wells installed within the ash storage area and screened within the ash layer. HDR does not consider porewater results to be representative of groundwater. One porewater monitoring well (AS-7S) was installed within the waste boundary of the ash storage area and was screened within the ash layer.

Nine COIs: arsenic, boron, cobalt, iron, manganese, sulfate, thallium, TDS, and vanadium results exceeded the 2L Standards or IMAC in the porewater sample collected from the AS-7S well in the ash storage area (see Table 7-5 and Table 7-12). The porewater sample location are shown on Figure 7-1.

7.2.3 Ash Porewater Speciation

Speciation is the analysis of the composition of a particular analyte in a system. Speciation is important for understanding the fate and transport of COIs. One location, AS-7S, was sampled

for chemical speciation analyses of arsenic (III), arsenic (V), chromium (VI), iron (II), iron (III), manganese (II), manganese (IV), selenium (IV), and selenium (VI). Results for chemical speciation of porewater samples are presented in Table 7-7. Further evaluation of chemical speciation results will be included in the CAP.

7.3 Units 1-4 Inactive Ash Basin

7.3.1 Ash (Sampling and Chemical Characteristics)

Eleven borings (IB-1S/D, IB-2S-SL/AL/I/BRU, IB-4S-SL/D/BR, and IB-3S/D) were advanced within the Units 1-4 inactive ash basin waste boundary to obtain ash samples for chemical analyses. Ash was not encountered at the IB-3 boring location, as it was advanced through the embankment dam associated with the basin.

Eight COIs: arsenic, barium, boron, cobalt, iron, manganese, selenium, and vanadium results exceeded either the North Carolina Industrial Health and/or Protection of Groundwater PSRGs in the ash samples collected from the Units 1-4 inactive ash basin as noted in Table 7-2.

7.3.2 Ash Porewater (Sampling and Chemical Characteristics)

Porewater refers to water samples collected from wells installed within the Units 1-4 inactive ash basin and screened within the ash layer. HDR does not consider porewater results to be representative of groundwater. Three porewater monitoring wells (IB-1S, IB-2S-SL, IB-4S-SL) were installed within the Units 1-4 inactive ash basin waste boundary and were screened within the ash layer.

Nine COIs: arsenic, cobalt, iron, manganese, pH, thallium, vanadium, sulfate, and TDS results exceeded the 2L Standards or IMACs in porewater samples collected from wells in the Units 1-4 inactive ash basin (see Table 7-5 and Table 7-12). Porewater sample locations are shown on Figure 7-1.

7.3.3 Ash Porewater Speciation

Speciation is the analysis of the composition of a particular analyte in a system. Speciation is important for understanding the fate and transport of COIs. Three locations, IB-1S, IB-2S-SL, and IB-4S-SL, were sampled for chemical speciation analyses of arsenic (III), arsenic (V), chromium (VI), iron (II), iron (III), manganese (II), manganese (IV), selenium (IV), and selenium (VI). Results for chemical speciation of porewater samples are presented in Table 7-7. Further evaluation of chemical speciation results will be included in the CAP.

7.4 Unit 5 Inactive Ash Basin

7.4.1 Ash (Sampling and Chemical Characteristics)

Seventeen borings (U5-1S/D, U5-2S-SL/D, U5-3S/D, U5-4S/D/BR, U5-5D, U5-6S/D, U5-7S/SL/D, U5-8S/D) were advanced within the Unit 5 inactive ash basin waste boundary to obtain ash samples for chemical analyses. The only borings where ash were encountered were the U5-2 and U5-7 locations. Borings at U5-3, U5-4, and U5-6 were advanced through embankment dams associated with the basin, and U5-1 and U5-8 did not encounter ash were ash was anticipated.

Seven COIs: arsenic, barium, cobalt, iron, manganese, selenium, and vanadium results exceeded either the North Carolina Industrial Health and/or Protection of Groundwater PSRGs in the ash samples collected from the Unit 5 inactive ash basin as noted in Table 7-2.

7.4.2 Porewater (Sampling and Chemical Characteristics)

Porewater refers to water samples collected from wells installed within the Unit 5 inactive ash basin screened within the ash layer. HDR does not consider porewater results to be representative of groundwater. Three porewater monitoring wells (U5-2S-SL, U5-7S and U5-7SL) were installed within the waste boundary of the Unit 5 inactive ash basin and were screened within the ash layer.

Seven COIs: arsenic, iron, manganese, pH, vanadium, sulfate, and TDS results exceeded the 2L Standards or IMAC in porewater samples collected from wells in the ash storage areas and ash basin (see Table 7-5 and Table 7-12). Porewater sample locations are shown on Figure 7-1. A sample was inadvertently not collected from monitoring well U5-2S-SL.

7.4.3 Ash Porewater Speciation

Speciation is the analysis of the composition of a particular analyte in a system. Speciation is important for understanding the fate and transport of COIs. Two locations, U5-7S and U5-7SL, were sampled for chemical speciation analyses of arsenic (III), arsenic (V), chromium (VI), iron (II), iron (III), manganese (II), manganese (IV), selenium (IV), and selenium (VI). Results for chemical speciation of porewater samples are presented in Table 7-7. Further evaluation of chemical speciation results will be included in the CAP.

7.5 Leaching Potential of Ash

In addition to total inorganic testing of ash samples, five ash samples collected from borings completed within the ash basins and ash storage areas were analyzed for leachable inorganics using Synthetic Potential Leach Procedure (SPLP) analysis (see Table 7-6). The purpose of the SPLP testing is to evaluate the leaching potential of COIs that may result in impacts to groundwater above the 2L Standards or IMAC. Although SPLP analytical results are being compared to the 2L Standards, these samples do not represent groundwater samples. The results of the SPLP analyses indicated that the following COIs exceeded their respective 2L Standards or IMAC at locations shown in Figure 7-1 within the active ash basin: antimony,

arsenic, chromium, cobalt, iron, selenium, thallium, and vanadium. Only vanadium exceeded its IMAC in the SPLP results from a sample collected within the Units 1-4 inactive ash basin. Only pH was measured below its 2L Standards in the SPLP results from a sample collected from the Unit 5 inactive ash basin.

Leaching of constituents from ash stored in the ash storage area, Units 1-4 inactive ash basin, or the Unit 5 inactive basin will be likely be different from the leaching that occurs when ash is stored in a saturated condition. The ash in these two different storage environments would experience differences in the time of exposure to the leaching solution, the liquid to solid ratio, and the chemical properties of leaching liquid. This would likely lead to differences in the constituents leached in the two differing environments and in the concentrations of the leached constituents.

In general the infiltration for the ash storage area, Units 1-4 inactive ash basin, and the Unit 5 inactive ash basin will be variable and intermittent, as infiltration is precipitation induced. The infiltration rate is dependent on a number of factors with the primary factors being climate, vegetation, and soil properties. The precipitation and air temperature are the two aspects of climate that most directly affect groundwater infiltration. Vegetation affects the infiltration rate through interception and by means of transpiration. The primary soil properties that affect infiltration are represented by the hydraulic conductivity of the material.

For areas where saturated conditions exist, the infiltration and subsequent groundwater recharge would be represented by Darcy's law. However, in the case of an ash basin the recharge flow rate calculation is complicated by the flow through the earthen dike, and through the material underlying the ash basin (saprolite, transition zone, and bedrock). An area where the surface is saturated or where water is present in the ash basin will receive constant infiltration with the rate being controlled by the factors described above.

The potential migration of contaminants from the ash basin, Units 1-4 inactive ash basin and the Unit 5 inactive ash basin will occur by the movement of ash leachate into the underlying soil layers and groundwater through infiltration. The infiltration of precipitation for the ash storage area and the cinder pit and the infiltration of the ash basin water into the underlying soil material will be modeled in the groundwater model being prepared for the CAP.

7.6 Seeps

7.6.1 Review of NCDENR March 2014 Sampling Results

NCDENR performed a water sampling event at the CSS site in March 2014. This sampling event included seeps, surface water, and ash basin water. The locations and analytical results of this sampling event were provided by NCDENR to Duke Energy and are assumed to be accurate. The location of these samples is presented on Figure 7-1. The results from the NCDENR March 2014 sampling event are provided on Table 7-10. Seep and surface water sample identifiers and their location relative to site features are:

- CLFSD063 (between Unit 6 and Unit 5 inactive ash basin)

- CLFSP051 (Units 1-4 inactive ash basin near Broad River)
- CLFSP058 (northwest of active ash basin near Broad River)
- CLFSP059 (north of ash storage area near Broad River)
- CLFSP061 (west of active ash basin, near Suck Creek)
- CLFTD005 (near S-19 near Broad River)
- CLFTD004 (near S-2 near Broad River)
- CLFTD051 (Units 1-4 inactive ash basin near Broad River)
- CLFTD052 (Units 1-4 inactive ash basin near Broad River)
- CLFSTR053 (Units 1-4 inactive ash basin near Broad River)
- CLFSTR065 (north of active ash basin)
- CLFTD056 (north of active ash basin)
- CLFSTR007 (south of Unit 5 inactive ash basin along Suck Creek)
- CLFSTR062 (north side of Broad River)
- CLFSP060 (north of ash storage area near Broad River)
- CLFSTR055 (northwest of ash storage area near Broad River)
- CLFCVT054, CLFSD003 (north of Unit 5 inactive ash basin)
- CLFPOND011 (Unit 5 inactive ash basin water)
- CLFPOND010 (Unit 5 inactive ash basin southwest Pond)
- CLFSTR001 (northwest of Unit 5 inactive ash basin near Broad River)
- CLFSTR008 (southwest of Unit 5 inactive ash basin)
- CLFWTLD002 (northwest of Unit 5 inactive ash basin near Broad River)
- CLFSP006 (northeast of Unit 5 inactive ash basin)
- CLFSTR009 (southwest of Unit 5 inactive ash basin)

The NCDENR water sample results were reviewed prior to site assessment activities and select seep samples with exceedances of the 2B Standards and/or 2L Standards or IMAC were identified to be re-sampled as part of the CSA assessment activities. A discussion of the seep re-sampling results is provided below.

7.6.2 CSA Seep Sampling and Results - Active Ash Basin

7.6.2.1 Seeps at Active Ash Basin

Seven seeps (S-6, S-7, S-14, S-15, S-16, S-21, and S-22) are associated with the active ash basin at CSS. Seeps S-14, S-15, S-16, S-21 are located at the toe of the active ash basin upstream dam adjacent to Suck Creek. Seep S-6 is located below the toe of the active ash basin downstream dam adjacent to the Broad River. Seep S-7 is located northeast of the active ash basin near the Broad River. Seep S-22 is located along the north face of the active ash basin downstream dam. Seeps S-21 and S-22 were dry at the time of sampling and, therefore, a sample was not obtained. Seep locations are shown on Figure 7-1.

Fourteen COIs exceeded the 2L Standards or IMAC in the total inorganic analysis of seep samples collected at locations S-14, S-15, and S-16: arsenic, barium, beryllium, cadmium, chromium, cobalt, iron, lead, manganese, nickel, selenium, thallium, and vanadium as shown in Table 7-9. Of these reported COIs, only iron, manganese and vanadium exceeded their

respective 2L Standards or IMAC in the dissolved phase and the exceedance values are representative of background data. The turbidity readings collected during collection of these samples (178, 346.8, and 65.7 NTUs, respectively) indicate that the exceedances of the remaining COIs are likely elevated due to suspended soil particles. The USEPA (EPA 2002) recommends that when possible, especially when sampling for contaminants that may be biased by the presence of turbidity, the turbidity reading is desired to stabilize at a value below 10 Nephelometric Turbidity Units (NTUs)

At seep location S-6 exceedances of the 2L Standards or IMAC were reported for boron, cobalt, iron, manganese, and vanadium.

There were no exceedances of an 2L Standards or IMACs at seep location S-7, and many COIs, including boron and sulfate, were not even detected above laboratory detection limits. Based off these results and information related to groundwater flow and topography in the area, S-7 is considered a background seep and surface water location. n.

7.6.2.2 NCDENR Seeps at Active Ash Basin

Three NCDENR-identified seeps (CLFSP061, CLFSP058, and CLFTD056) were planned to be re-sampled during the groundwater assessment activities. Seep location CLFTD0056 at the toe of the active ash basin downstream dam was inadvertently identified as CLFWW057 during the sampling event, and the results are included with the seep sampling results. Seep sample CLFSP061 is located at the toe of the active ash basin upstream dam. Seep sample CLFSP058 is located northwest of the active ash basin downstream dam adjacent to the Broad River. Seep sample CLFWW057 (CLFTD056) is located downstream of the active ash basin toe drain prior to entering the Broad River.

Samples collected from the re-sampled NCDENR-identified seeps exceeded the 2L Standards or IMAC for boron, cobalt, iron, manganese, sulfate, vanadium, and TDS are noted in Table 7-10.

7.6.3 CSA Seep Sampling and Results - Ash Storage Area

7.6.3.1 Seeps at Ash Storage Area

Four seeps (S-4, S-5, S-9, and S-12) are associated with the ash storage area at CSS. Three of the seeps (S-4, S-5, and S-12) are located generally north of the ash storage area near the Broad River. Seep S-9 is located northwest of the ash storage area near Suck Creek. Seep locations are shown on Figure 7-1. Field parameter data was not available for review for these seep locations.

7.6.3.2 NCDENR Seeps at Ash Storage Area

Three NCDENR-identified seeps (CLFSP059, CLFSP060, CLFSTR055) were planned to be sampled during the groundwater assessment.

Sample results reported for CLFSP059 exceeded the 2L Standards for iron and manganese (see Table 7-10). Iron and manganese results did not exceed their respective 2L Standards in

the dissolved phase for seep sample CLFSP059. Seep samples were inadvertently not collected from seep locations CLFSP060 or CLFSTR055.

7.6.4 CSA Seep Sampling and Results – Units 1-4 Inactive Ash Basin

7.6.4.1 Seeps at Units 1-4 Inactive Ash Basin

Four seeps (S-3, S-10, S-11, and S-13) are associated with the Units 1-4 inactive ash basin. Three seeps (S-10, S-11, and S-13) are located near the toe of the Units 1-4 inactive ash basin main dam along the Broad River northeast of the basin. Seep S-3 is located north of the basin along the former Units 1-4 discharge canal. Seep S-13 was dry during the sampling event and, therefore, a sample was not obtained. Seep locations are shown on Figure 7-1.

The following parameters exceeded the 2L Standards or IMAC: arsenic, cobalt, iron, manganese, thallium, vanadium, sulfate, and TDS shown in Table 7-9.

7.6.5 NCDENR Seeps at Units 1-4 Inactive Ash Basin

The following NCDENR-identified seeps (CLFSP051, CLFTD052, and CLFSTR053) were planned to be re-sampled during this groundwater assessment. CLFSTR053 was inadvertently not sampled during this event. Samples collected from these locations exceeded the 2L Standards or IMAC for arsenic, cobalt, iron, manganese, sulfate, TDS, and vanadium as shown on Table 7-10.

7.6.6 CSA Seep Sampling and Results – Unit 5 Inactive Ash Basin

7.6.6.1 Seeps at Unit 5 Inactive Ash Basin

Six seeps (S-2, S-17, S-18, S-19, S-19A and S-20) are associated with the Unit 5 inactive ash basin at CSS. Seep S-20 is on the downstream face of the Unit 5 inactive basin saddle dam. Seeps S-18, S-19 and S-19A are located near the toe of the Unit 5 inactive ash basin main dam between the dam and the Broad River. Seeps S-2 and S-17 are located below the main dam near the Broad River. A sample from seep S-19A was inadvertently not collected during the assessment activities. Seep locations are shown on Figure 7-1.

Exceedances of the 2L Standards or IMAC were reported in these seep samples for arsenic, boron, beryllium, chromium, cobalt, iron, lead, manganese, sulfate, thallium, TDS, and vanadium shown in Table 7-9. Arsenic, beryllium, boron, chromium, sulfate and TDS only exceeded the 2L Standards or IMAC at seep location S-18. There were no exceedances of the 2L Standards or IMAC in the dissolved phase for arsenic, beryllium, chromium, or lead in any of the samples.

7.6.6.2 NCDENR Seeps at Unit 5 Inactive Ash Basin

Three NCDENR-identified seeps (CLFTD005, CLFTD004, CLFSD063) were sampled during this groundwater assessment. Samples collected from these locations exceeded the 2L Standards or IMAC for arsenic, beryllium, boron, chromium, cobalt, iron, lead, manganese, sulfate, thallium, TDS, and vanadium as noted on Table 7-10.

7.6.6.3 White Material at Toe of Unit 5 Inactive Ash Basin Dam

On March 5, 2014, NCDENR, Division of Energy, Mineral and Land Resources, Land Quality Section (LQS) issued a Notice of Deficiency (NOD) associated with conditions observed at the toe of the Unit 5 inactive ash basin main dam. As stated in the NOD, the dam was inspected on March 1 and 4, 2014, by personnel from the LQS. During these inspections, the following conditions were noted. *Several seepage and boil locations have been historically noted at the toe of the dam beyond the rip rap, with clear flow and iron oxide discoloration of the ground surface. During this inspection, a grain-like substance, white and gray in color, was observed originating from several seepage and boil locations at the toe of the dam, in addition to the clear flow.*

The white material at the toe of the dam, water seeping at the toe of the dam, and ash collected from the Unit 5 inactive ash basin were collected. A report providing the results and findings regarding the white material was prepared and submitted to the NCDENR Division of Energy, Mineral and Land Resources.

The characterization found that the white material was not ash and was likely the product of a precipitation reaction as a result of the geochemical activity in the ash basin. Scanning electron microscopy (SEM) results of the ash sample showed the morphology of the ash sample was largely glassy spheres, as is typical for ash and for flyash in-particular. The white material did not exhibit similar spherical morphology as was observed in the ash sample. Energy dispersive X-ray spectroscopy (EDS) results for the ash sample showed it to be rich in aluminum oxide and silica, but with a much larger silica proportion than was observed in the white material.

Based on the results the SEM/EDS analysis of the ash and white material, these samples did not appear to be the same substance. The white material was characterized by SEM/EDS as being rich in aluminum oxide and silica, possibly an aluminum silicate (i.e. a type of clay). The exact origin of this white material is uncertain; however, it is likely that the white material is the product of a precipitation reaction as a result of the geochemical activity in the ash basin. As seepage emerges at the toe of the dam, the geochemical conditions change, producing the white material as a precipitate.

Duke Energy's consultant for regular (generally weekly) inspections of the Unit 5 inactive ash basin main dam is AMEC Foster Wheeler (AMEC). Inspection reports prepared by AMEC documenting inspections between August 29, 2014 and July 21, 2015 were reviewed for notation of observations of the white material in the seepage water at the toe of the dam. The AMEC reports prior to the September 11, 2014 report do not report observation of the white material. The white material was consistently observed and noted in reports between September 11, 2014 and July 21, 2015, with exception of the January 28, 2015 and February 19, 2015 reports where the white material was not observed. The quantity of white material was noted as being consistent until the February 4, 2015 report, when it was noted as being observed in less quantity than had previously been observed. Observed quantities apparently were consistent between February 4, 2015 and July 21, 2015 as no mention of additional or less quantity was noted.

Sampling performed at seeps associated with the toe of the Unit 5 inactive ash basin dam (S-18, S-19, and S-19A) (where the white substance was observed) and downstream of this location (S-2 and S-17) as part of the groundwater assessment activities, reported exceedances of 2L Standards or IMACs for arsenic, beryllium, boron, chromium, cobalt, iron, lead, manganese, sulfate, thallium, TDS, and vanadium (see Table 7-9). Future dam inspections will continue to document observations.

7.6.6.4 Seep Speciation

Speciation is the analysis of the composition of a particular analyte in a system. Speciation is important for understanding the fate and transport of COIs. Fourteen locations were identified for sampling, and NCDENR seep CLFSTR065 was dry at the time of sampling. The remaining 38 locations were sampled for chemical speciation analyses of arsenic (III), arsenic (V), chromium (VI), iron (II), iron (III), manganese (II), manganese (IV), selenium (IV), and selenium (VI). Results for chemical speciation of surface water are presented in Table 7-14. Further evaluation of chemical speciation results will be included in the CAP.

7.7 Constituents of Interest

Based on evaluation of the ash, ash basin, surface water, ash porewater, and seep samples collected in the source area, the constituents listed below were identified as COIs. As noted above, these constituents were identified as COIs based on comparison to the following standards or criteria:

- Ash – compared to North Carolina PSRGs for Industrial Health and/or Protection of Groundwater Standards
- Ash Basin water samples – compared to 2B, and to respective 2L Standards or IMACs
- Ash basin porewater – compared to respective 2L Standards or IMACs

The comparison of these samples to the standards or criteria was performed only for discussion purposes. These comparisons are useful in understanding potential impacts to soil, groundwater and surface water. However, the fact that exceedances of these standards or criteria are identified in this comparison does not necessarily indicate that exceedances of groundwater, surface water, or soil standards are present.

7.7.1 COIs in Ash (based off total inorganics analysis, as shown in Table 7-2)

- Arsenic
- Barium
- Boron
- Cobalt
- Iron
- Manganese
- Selenium
- Vanadium

7.7.2 COIs in Ash Basin Water (based off water quality analysis, ash shown in Table 7-4)

- Aluminum
- Arsenic
- Cadmium
- Cobalt
- Copper
- Thallium

7.7.3 COIs in Ash Porewater (based off water quality analysis, as shown in Table 7-5)

- Antimony
- Arsenic
- Boron
- Cobalt
- Iron
- Manganese
- pH
- Thallium
- Sulfate
- TDS
- Vanadium

7.7.4 COIs in Seeps (based of water quality analysis, as shown in Table 7-7)

- Arsenic
- Barium
- Boron
- Beryllium
- Cadmium
- Chromium
- Cobalt
- Iron
- Lead
- Manganese
- Nickel
- pH
- Selenium
- Sulfate
- Thallium
- TDS
- Vanadium

8.0 Soil and Rock Characterization

The purpose of soil and rock characterization is to evaluate the physical and geochemical properties in the subsurface with regard to constituent presence, retardation, and migration. Soil and rock sampling was performed in general accordance with the procedures described in the Work Plan. Refer to Appendix D for a detailed description of these methods and Appendix E for field and sampling quality control / quality assurance protocols.

Soil, PWR, and bedrock samples were collected from background locations, beneath the active ash basin, beneath the Units 1-4 inactive ash basin, beneath the Unit 5 inactive ash basin, beneath the ash storage area, and from locations beyond the waste boundaries.

Appendix D summarizes the soil and rock sampling plan utilized for groundwater assessment activities. Variances from the proposed sampling plans are also presented in Appendix D. The boring locations are shown on Figure 8-1.

8.1 Background Sample Locations

Background (BG) boring locations were identified based on the SCM at the time the Work Plan was submitted. The BG locations were chosen in areas assumed not to be impacted by and topographically upgradient of the ash basins and ash storage area. Based on the groundwater contours shown on Figures 6-5 through 6-7, and the updated SCM, the BG locations are considered to be hydrologically upgradient of the ash basins and ash storage area. The BG boring locations are considered to be representative of background soil conditions at the site.

8.2 Analytical Methods and Results

Parameters and laboratory methods used for analysis of solid matrix samples are presented in Table 8-1. Total inorganic results for background soil samples are presented in Table 8-2. Total inorganic results for background PWR and bedrock samples are presented in Table 8-3. Total inorganic results for soil samples are presented in Table 8-4. Total inorganic results for PWR and bedrock samples are presented in Table 8-5.

Figure 8-1 depicts the total inorganic results for soil, PWR and bedrock analysis. Cross-section transects are presented on Figure 6-2. Cross-sections presenting the vertical distribution of COIs along each transect are depicted on Figures 8-2 through 8-13.

SPLP results for background soil samples are presented in Table 8-6. SPLP results for soil samples are presented in Table 8-7. Although SPLP analytical results are being compared to the 2L Standards or IMAC, these samples do not represent groundwater samples.

8.3 Comparison of Soil Results to Applicable Levels

The soil analytical results are compared to the North Carolina Preliminary Soil Remediation Goals (PSRGs) for Industrial Health and Protection of Groundwater Standards presented in Table 8-8. Frequency and concentration ranges for soil, PWR and bedrock COI exceedances of

North Carolina PSRGs are presented in Table 8-5. The subsections below provide a summary of COIs with PSRG exceedances in at least one of the samples analyzed. Parameters not listed below were not reported at concentrations exceeding the North Carolina PSRGs in the collected soil samples. Parameters not listed below were not reported at concentrations exceeding the North Carolina PSRGs in the collected soil samples.

8.4 Comparison of Soil Results to Background

In addition to comparison of results to regulatory criteria, soil sample results have also been compared to background concentrations as discussed below. Please refer to 8-1 for soil boring locations. Note that boring locations GWA-32D/BR are located outside the compliance boundaries. No soil samples were collected at GWA-32D/BR due to the relatively shallow depth-to-rock in this location.

8.4.1 Background Soil

Background soil locations are identified as BG-1S, BG-1D, BG-1BR, BG-2D, MW-30S, MW-30D, MW-32S, MW-32D, and MW-32BR. Background soil concentration ranges are listed below for constituents that exceeded the North Carolina PSRGs in at least one soil sampling location at the CSS site. Analytical results with a J qualifier indicate an estimated concentration reported between the laboratory method detection limit and the method reporting limit.

- Arsenic 1.4 milligrams per kilogram (mg/kg) to 7.9 mg/kg
- Cobalt 2.4J mg/kg to 62.6 mg/kg
- Iron 2,760 mg/kg to 78,000 mg/kg
- Manganese 64.7 mg/kg to 1,170 mg/kg
- Selenium 0.77 mg/kg to 8.3 mg/kg
- Thallium 0.62J mg/kg to <4.2 mg/kg
- Vanadium 15 mg/kg to 136 mg/kg

8.4.2 Soil Beneath Active Ash Basin

Soil samples collected beneath the active ash basin are identified as AB-1S/D, AB-2S/D, AB-3I/BRU, AB-4D/BR, AB-5BRU, AB-6D/BR, and GWA-20S/D. The range of constituent concentrations along with a comparison to the range of reported background soil concentrations is provided in Table 8-9.

Constituent concentrations of soils beneath the active ash basin tend to be higher for arsenic, compared to background soil concentrations. Concentrations for iron, selenium, and vanadium are similar to background soil concentrations.

8.4.3 Soil Beneath Ash Storage Area

Soil samples collected beneath the ash storage area are identified as AS-1SB/D, AS-3BRU, AS-4S/D, AS-5S/BRU/BR, AS-6S/D, and AS-7D/BR. The range of constituent concentrations along with a comparison to the range of reported background soil concentrations is provided in Table 8-10.

Constituent concentrations for soil samples collected beneath the ash storage area are similar to, or less than, the background soil concentrations for arsenic, cobalt, iron, manganese, and vanadium.

8.4.4 Soil beneath Units 1-4 Inactive Ash Basin

Soils samples collected beneath the Units 1-4 inactive ash basin are identified as IB-1D, IB-2S-SL, IB-2BRU, IB-3SB, IB-3D, IB-4S-SL, IB-4D, and IB-4BR. The range of constituent concentrations along with a comparison to the range of reported background soil concentrations is provided in Table 8-11.

Constituent concentrations in soil samples collected beneath the Units 1-4 inactive ash basin are similar to the background soil concentrations for arsenic, cobalt, iron, manganese, selenium, and vanadium.

8.4.5 Soil beneath Unit 5 Inactive Ash Basin

Soils samples collected beneath the Unit 5 inactive ash basin are identified as U5-1S/D, U5-2D, U5-3S/D, U5-4S/D/BR, U5-5D, U5-6S/D, U5-7D, and U5-8S/D. A soil sample was also collected from 3.5-5 feet bgs from U5-2D. This sample was collected above the ash in the basin, but was included in the range of concentrations below. The range of constituent concentrations along with a comparison to the range of reported background soil concentrations is provided in Table 8-12.

While arsenic concentrations in some soil beneath the Unit 5 inactive ash basin are higher than concentrations reported in the background soil samples, concentrations for other constituents (i.e., cobalt, iron, manganese, and vanadium) are similar to background concentrations.

8.4.6 Soil Outside the Waste Boundary and within Compliance Boundary

8.4.6.1 Active Ash Basin

Soil samples collected outside of the active ash basin and within the compliance boundary are identified as GWA-21S/BRU/BR, GWA-22S/BRU, GWA-23D, GWA-24S/D, GWA-25S/D, GWA-26S/D, GWA-27D (well offset designation D-A), GWA-28S/BRU/BR, GWA-33S/D/BR, MW-21BR, and MW-22BR. The range of constituent concentrations along with a comparison to the range of reported background soil concentrations and concentrations of soils beneath the active ash basin is provided in Table 8-13.

Concentrations of constituents in soil samples collected from outside the active ash basin and within the compliance boundary are generally lower than concentrations for soils beneath the active ash basin and are similar to background soil concentrations. Two of the sample locations in this area had exceedances of the North Carolina PSRGs for selenium (2.8J mg/kg at MW-22BR and 4.5J mg/kg at GWA-27D) and one location exceeded thallium (0.74J mg/kg at GWA-27D), although these exceedances are estimated values less than the laboratory reporting limits.

8.4.6.2 Ash Storage Area

Soil samples collected from outside the ash storage area and within the compliance boundary are identified as AS-2S/D. The range of constituent concentrations along with a comparison to the range of reported background soil concentrations and concentrations of soils beneath the ash storage area is provided in Table 8-14.

Concentrations of constituents in soils outside the ash storage area and within the compliance boundary are similar to concentrations for soils beneath the ash storage area for cobalt, iron, manganese, and vanadium. Concentrations of all four of these constituents are within the range of background soil concentrations.

8.4.6.3 Units 1-4 Inactive Ash Basin

Soil samples collected from outside the Units 1-4 inactive ash basin and within the compliance boundary are identified as GWA-10S/D, GWA-11S/BRU, GWA-12S/BRU, GWA-13BR, GWA-14S/D, GWA-29D/BR. The range of constituent concentrations along with a comparison to the range of reported background soil concentrations and concentrations of soil samples collected beneath the Units 1-4 inactive ash basin is provided in Table 8-15.

Arsenic concentrations in soil samples collected outside the Units 1-4 inactive ash basin and within the compliance boundary generally are higher than concentrations for both soils beneath the Units 1-4 inactive ash basin and background soils.

Cobalt and manganese concentration in soils outside the Units 1-4 inactive ash basin and within the compliance boundary are similar to the soil concentrations beneath the Units 1-4 inactive ash basin, and to background soil concentrations.

Iron, selenium, thallium, and vanadium concentrations are similar in all three areas.

One sample location in this area had exceedances of the North Carolina PSRGs for selenium (4.4 mg/kg at GWA-14D and one location exceeded thallium (0.85J mg/kg at GWA-13D).

8.4.6.4 Unit 5 Inactive Ash Basin

Soil samples collected from outside of the Unit 5 inactive ash basin and within the compliance boundary are identified as GWA-1BRU, GWA-2S/BRU, GWA-3D, GWA-4S/D, GWA-5S/BRU, GWA-30S/BRU/BR, GWA-31D/BR, MW-34S/D, MW-36S/BRU, MW-38S/D, MW-40S/BRU, and MW-42S/D. The range of constituent concentrations along with a comparison to the range of reported background soil concentrations and concentrations of soils beneath the Unit 5 inactive ash basin is provided in Table 8-16.

Arsenic, cobalt, iron, selenium, and vanadium concentrations in soils outside the Unit 5 inactive ash basin are similar to concentrations in both the soils beneath the Unit 5 inactive ash basin and background soils.

Manganese concentrations in soils outside the Unit 5 inactive ash basin and within the compliance boundary are generally higher than concentrations for soils beneath the Unit 5 inactive ash basin, but similar to background soil concentrations.

Two soil sample locations in this area had exceedances of the North Carolina PSRGs for selenium (2.8J mg/kg at GWA-5D and 6.6J at GWA-3D) and four locations exceeded thallium (0.74J mg/kg at GWA-42D from 38.5-40 feet below ground surface, 0.84J mg/kg at GWA-5D from 13.5-15 feet below ground surface, 0.84J mg/kg at GWA-5D from 18.5-20 feet below ground surface, and 0.89J mg/kg at GWA-42D from 28.5-30 feet below ground surface), although all exceedances are estimated values less than the laboratory method reporting limits.

8.5 Comparison of PWR and Bedrock Results to Background

In addition to comparison of results to regulatory criteria, PWR and bedrock sample results have also been compared to background concentrations as discussed below.

8.5.1 Background PWR and Bedrock

Background PWR samples were obtained from, BG-1D, BG-2D, MW-30D, and MW-32BR. Background soil sample GWA-2D had an exceedance for barium (732 mg/kg), but all other samples background and outside the waste boundary and within the compliance boundary did not exceed barium for North Carolina PSRGs. Results are presented in Table 8-3. Background PWR and bedrock sample concentration ranges are listed below for constituents that exceeded the North Carolina PSRGs at least one soil sampling location at the CSS site. Results with a J qualifier are estimated concentrations.

- Arsenic 3.0J mg/kg to <5.2 mg/kg
- Barium 32.7 mg/kg to 732 mg/kg
- Cobalt 4.1J+ mg/kg to 25.2 mg/kg
- Iron 3,380 mg/kg to 28,800 mg/kg
- Manganese 3.6 mg/kg to 511 mg/kg
- Selenium 3.1J mg/kg to <5.2 mg/kg
- Vanadium 6.9J mg/kg to 66.7 mg/kg

8.5.2 PWR and Bedrock Outside Waste Boundary and within Compliance Boundary

8.5.2.1 Active Ash Basin

PWR and bedrock samples outside the active ash basin and within the compliance boundary are identified as GWA-21S/BRU/BR, GWA-22S/BRU, GWA-23D, GWA-24S/D,GWA-25S/D, GWA-26S/D, GWA-27D, GWA-28S/BRU/BR, GWA-33S/D/BR, MW-21BR, and MW-22BR. The range of constituent concentrations along with a comparison to the range of reported background PWR and bedrock concentrations is provided in Table 8-17.

PWR and bedrock concentrations outside the active ash basin and within the compliance boundary are very similar to background PWR and bedrock concentrations for arsenic, cobalt, iron, manganese, selenium and vanadium.

8.5.2.2 Ash Storage Area

PWR and bedrock samples were not collected from the area outside the ash storage area or within the compliance boundary. The AS-2S/D location is the only boring in this area and PWR and bedrock samples were not part of the sampling plan for this location.

8.5.2.3 Units 1-4 Inactive Ash Basin

PWR and bedrock samples collected outside the Units 1-4 inactive ash basin and within the compliance boundary are identified as GWA-10S/D, GWA-11S/BRU, GWA-12S/BRU, GWA-13BR, GWA-14S/D, and GWA-29D/BR. The range of constituent concentrations along with a comparison to the range of reported background PWR and bedrock concentrations is provided in Table 8-18.

Iron concentrations reported in PWR and bedrock samples collected outside the Units 1-4 inactive ash basin and within the compliance boundary are generally slightly higher than the background concentrations. Arsenic, cobalt, manganese, selenium, thallium, and vanadium concentrations are all similar to the background concentrations.

One sample location in this area had exceedances of the North Carolina PSRGs for selenium (3.9J mg/kg at GWA-13BR), although this exceedance is an estimated value less than the laboratory method reporting limits.

8.5.2.4 Unit 5 Inactive Ash Basin

PWR and bedrock samples collected outside the Unit 5 inactive ash basin and within the compliance boundary are identified as GWA-1BRU, GWA-2S/BRU, GWA-3D, GWA-4S/D, GWA-5S/BRU, GWA-30S/BRU/BR, GWA-31D/BR, MW-34S/D, MW-36S/BRU, MW-38S/D, MW-40S/BRU, and MW-42S/D. The range of constituent concentrations along with a comparison to the range of reported background PWR and bedrock concentrations is provided in Table 8-19.

Arsenic concentrations reported in PWR and bedrock samples collected outside the Unit 5 inactive ash basin and within the compliance boundary are generally higher than the background concentrations. Cobalt, iron, manganese, and vanadium concentrations are all similar to the background concentrations.

9.0 Surface Water and Sediment Characterization

The purpose of surface water and sediment characterization is to evaluate whether storage of ash has resulted in impacts to surface waters in the vicinity of the ash basins and ash storage area. The surface water and sediment characterization sampling was performed in general accordance with the procedures described in the Work Plan. Sampling methodology and variances to that methodology are described in Appendix F. Surface water and sediment sample locations are shown on Figure 9-1.

As described in the approved Work Plan, both unfiltered and filtered (0.45 um filter) samples were collected for analyses of constituents whose results may be biased by the presence of turbidity.^[1] Unless otherwise noted, concentration results discussed are for the unfiltered samples and would represent total concentrations.

9.1 Surface Water

One surface water sample was collected from the pond located in the southern portion of the Unit 5 inactive ash basin (SW-1). Three surface water samples (SW-2, SW-3, and SW-4) were collected from locations along Suck Creek, which generally flows south to north, between the active ash basin, and the ash storage area and the Units 1-4 inactive ash basin. One surface water sample (S-1) was collected from an un-named tributary (as shown on Figure 9-1) to the Broad River located northwest of the Unit 5 inactive ash basin. One surface water sample (S-8) was collected from an un-named tributary to Suck Creek located southwest of the active ash basin. Surface water parameters and laboratory methods used for analysis are presented in Table 7-1. Surface water sample results for total and dissolved fractions of constituents are presented in Table 9-1. Surface water field parameters are presented in Table 9-2.

9.1.1 Comparison of Exceedances to 2B Standards

Surface water analytical results are compared to the North Carolina 2B Standards. Surface water analytical results are compared to the 2B Standards. Exceedances of the 2B Standards were reported for aluminum for total inorganic analyses, pH (one measurement at SW-1) and DO (one measurement at SW-3) in the collected surface water samples at SW-1, SW-2, SW-3, SW-4, S-1 and S-8. Constituents which exceeded the 2B Standards in the surface water samples have been identified as surface water COIs. The dissolved concentrations of aluminum were below the 2B Standards at each location. Note that antimony, beryllium, cadmium, selenium, sodium, and sulfide were not detected in the surface water samples.

^[1] The USEPA (EPA 2002) recommends that when possible, especially when sampling for contaminants that may be biased by the presence of turbidity, the turbidity reading is desired to stabilize at a value below 10 Nephelometric Turbidity Units (NTUs)

9.1.2 Comparison of Exceedances to Background

9.1.2.1 Background Surface Water

The background surface water location is identified as SW-2 and is located on Suck Creek, upgradient of the ash basins and ash storage areas. Aluminum was the only constituent exceeding the 2B Standard in the background surface water sample. The dissolved phase concentration of aluminum reported in SW-2 was less than the 2B Standards.

9.1.2.2 Unit 5 Inactive Ash Basin Surface Water

A pond is located on the south end of the Unit 5 inactive ash basin within the waste boundary. The surface water sample collected from this location is identified as SW-1. SW-1 exceeded 2B Standards for pH (Table 9-2).

9.1.2.3 Suck Creek Surface Water

Suck Creek surface water locations are identified as SW-2, SW-3 and SW-4. Surface water sample SW-2 is considered the background sample location and the results at this location are presented in Section 9.1.2.1. Surface water sample location SW-3 is located west of the toe of the active ash basin upstream dam. Surface water sample SW-4 is located northwest of the active ash basin prior to the confluence with the Broad River.

Concentrations of COIs at these two surface water locations are provided below along with a general comparison to the background surface water analytical results. Aluminum concentrations exceeded the 2B Standards for background location SW-2 as well as downstream locations SW-3 and SW-4. However, the dissolved aluminum concentrations were all below the 2B Standard. Aluminum concentrations reported in SW-3 and SW-4 were less than the SW-2 background aluminum concentration. Field parameters were measured twice at SW-3. The DO concentration measured at SW-3 exceeded the 2B Standards during the first measurement event but was less than the 2B Standards during the second measurement event.

9.1.2.4 Tributary Streams Surface Water

Tributary surface water locations are identified as S-1 and S-8. Aluminum concentrations exceeded the 2B Standards both of these sample locations but were less than the aluminum concentration compared to background location SW-2. Field parameter measurements were not available for sample S-8.

9.1.3 Discussion of Results for Constituents without 2B Standards

Surface water samples were analyzed for the following constituents that do not have 2B Standards: boron, calcium, iron, manganese, mercury, selenium, and vanadium. In lieu of 2B Standards, concentrations of COIs have been compared to background concentrations reported for surface water sample SW-2 as presented in Table 9-1.

9.1.3.1 Background Surface Water

Analytical results reported for background surface water sample SW-2 are presented on Table 9-1.

9.1.3.2 Unit 5 Inactive Ash Basin Surface Water

The Unit 5 inactive ash basin surface water location is identified as SW-1. The reported calcium concentration for SW-1 was higher than the reported background concentration at SW-2. All other reported constituent concentrations were similar to the reported surface water background concentrations.

9.1.3.3 Suck Creek Surface Water

The surface water samples collected from Suck Creek are identified as SW-3 and SW-4. All of the constituents reported in these surface water samples were similar to the reported background concentrations.

9.1.3.4 Tributary Streams Surface Water

The tributary stream surface water locations are identified as S-1 and S-8. The analytical results reported for these surface water sample locations were similar or less than the reported background concentrations.

9.1.4 Results for Select Constituents in Broad River

Surface water sample analytical results collected as part the NPDES permit requirements, were reviewed for an upstream (Upstream) and one downstream (Downstream) location in the Broad River. Twice per year sampling results were reviewed for data from 2011 to 2015. No exceedances of the 2B Standards were reported for the select constituents analyzed. Surface water sample results from the Broad River are presented in Table 9-4.

9.2 Surface Water Speciation

Speciation is the analysis of the composition of a particular analyte in a system. Speciation is important for understanding the fate and transport of COIs. Six locations, SW-1, SW-2, SW-3, SW-4 S-1 and S-8, were sampled for chemical speciation analyses of arsenic (III), arsenic (V), chromium (VI), iron (II), iron (III), manganese (II), manganese (IV), selenium (IV), and selenium (VI). Results for chemical speciation of surface water are presented in Table 9-4. Further evaluation of chemical speciation results will be included in the CAP.

9.3 Sediment

Sediment samples were collected coincidentally with the surface water samples and seep samples, with the exception of the Unit 5 inactive ash basin pond sample location (SW-1), the active ash basin sample locations (SW-5 and SW-7) and CLFSTR064 which could not be located. Sediment samples were analyzed in accordance with the constituent and parameter list used for soil and rock characterization (see Table 8-1). In the absence of NCDENR sediment

criteria, the sediment sample results were compared to North Carolina PSRGs, and are presented in Table 9-6. Sediment sample locations are shown on Figure 7-1. Exceedances of soil PSRGs are summarized in Table 9-6.

Sediment sample results for arsenic, boron, cobalt, iron, manganese, nickel, selenium and vanadium exceeded one or both of the North Carolina PSRGs in all sediment samples. Arsenic, boron, cobalt, iron, manganese, nickel, selenium and vanadium concentrations exceeded the North Carolina PSRGs for Protection of Groundwater in all sediment samples. Antimony and thallium were not detected in sediment samples collected at the CSS site.

10.0 Groundwater Characterization

The purpose of groundwater characterization is to characterize the groundwater on the site for corrective action and compare to the 2L Standards or interim maximum allowable concentrations (IMACs). Groundwater sampling methods and the rationale for sampling locations were in general accordance with the procedures described in the Work Plan. Refer to Appendix G for a detailed description of these methods. Variances from the proposed well installation locations, methods, quantities, and well designations are presented in Appendix D. The groundwater monitoring well installation plan utilized is included in Appendix A.

As described in the approved Work Plan, both unfiltered and filtered (0.45 um filter) samples were collected for analyses of constituents whose results may be biased by the presence of turbidity.^[1] Unless otherwise noted, concentration results discussed are for the unfiltered samples and would represent total concentrations.

10.1 Regional Groundwater Data for Constituents of Interest

Individual sampling events present a snap-shot in time of the hydrogeologic and chemical conditions at a particular monitoring location. When interpreting the results from a sampling event, a number of factors that affect the sample results should be taken into consideration. Among these are the geologic and hydrogeologic setting, the location of the sample points in the regional groundwater flow system, potential interactions between suspected contaminants, and the geological and biological constituents present in the formation (Barcelona 1985).

As a result of these factors, it may be possible that the analytical results of a given constituent are influenced by naturally occurring conditions as opposed to conditions caused by releases from the ash basin. This section presents an overview of the regional and statewide groundwater conditions for the COIs found at the CSS ash basins that have promulgated state or federal standards.

The 2L Standards recognize that the concentrations of naturally occurring substances in groundwater may exceed the standard established in .0202(g). Rule .0202(b)(3) states that when this occurs, the Director of the DWR will determine the standard.

Table 10-1 lists the COIs at the CSS site along with their associated North Carolina 2L Groundwater Standards, IMACs, and federal drinking water standards (Primary Maximum Contaminant Levels [MCLs] and Secondary Maximum Contaminant Levels [SMCLs]). North Carolina 2L Standards are established by NC DENR, whereas federal MCLs and SMCLs are established by the USEPA. Primary MCLs are legally enforceable standards for public water supply systems set to protect human health in drinking water. Secondary MCLs are non-enforceable guidelines set to account for aesthetic considerations, such as taste, color, and odor (USEPA 2014).

^[1] The USEPA (EPA 2002) recommends that when possible, especially when sampling for contaminants that may be biased by the presence of turbidity, the turbidity reading is desired to stabilize at a value below 10 Nephelometric Turbidity Units (NTUs)

Regional background information on COIs at the CSS site are provided (in alphabetical order) below in Sections 10.1.1 through 10.1.10. In addition, regional background information on pH is also provided in Section 10.1.11 as pH levels can affect the leachability of metal ions in groundwater.

10.1.1 Antimony

Antimony is a silvery-white, brittle metal. In nature, antimony combines with other elements to form antimony compounds. Small amounts of antimony are naturally present in rocks, soils, water, and underwater sediments.

Only a few ores of antimony have been encountered in North Carolina. Antimony has been found in combination with other metals, and is found most commonly in Cabarrus County and other areas of the Carolina Slate Belt (Chapman 2013).

In a USGS study of naturally occurring trace minerals in North Carolina, 57 private water supply wells were sampled to obtain trace mineral data. Of the wells sampled, no wells contained antimony above the USEPA PMCL (Chapman 2013). Antimony is compared to IMACs since no 2L Standards have been established for this constituent by NCDENR.

10.1.2 Arsenic

Natural arsenic occurs commonly and comes mainly from the soil. The USEPA estimates that the amount of natural arsenic released into the air as dust from the soil is about equal to the amount of arsenic released by all human activities (EPRI 2008).

Since CSS is located near the border of Cleveland and Rutherford Counties, statistics for both counties are included here. Data collected from 619 private wells across Cleveland and Rutherford Counties from 1998-2010 indicated that 17 samples had arsenic concentrations exceeding the MCL. Summary statistics for both counties are provided in Table 10-2.

Sanders et al. (2011) found strong geological patterns in groundwater arsenic concentrations across the state of North Carolina (see Figure 10-1). The CSS site is located in an area where the average concentrations of naturally occurring arsenic in groundwater is between 1.1 - 2.5 µg/L.

10.1.3 Barium

Two forms of barium, barium sulfate and barium carbonate, are often found in nature as underground ore deposits. Barium is sometimes found naturally in drinking water and food. However, since certain barium compounds (barium sulfate and barium carbonate) do not mix well with water, the amount of barium found in drinking water is typically small.

Barium compounds such as barium acetate, barium chloride, barium hydroxide, barium nitrate, and barium sulfide dissolve more easily in water than barium sulfate and barium carbonate, but because they are not commonly found in nature, they do not usually occur in drinking water unless the water is contaminated by barium compounds that are released from waste sites (EPRI 2008).

Barium is naturally released into the air by soils as they erode in wind and rain, and is released into the soil and water by eroding rocks. Barium released into the air by human activities comes mainly from barium mines, metal production facilities, and industrial boilers that burn coal and oil. Anthropogenic sources of barium in soil and water include copper smelters and oil-drilling waste disposal sites. Industries reporting to the USEPA released 119,646 tons of barium and barium compounds into the environment in 2005 (EPRI 2008).

Regional metamorphic grade greenschist to upper amphibolite in the Piedmont's King's Mountain Belt contains deposits of barium sulfate (barite). Barium is especially common as concretions and vein fillings in limestone and dolostone, which are not common geologic facies in North Carolina; however, at various times in the past century and a half, the Carolinas have been major producers of barite (USEPA 2014).

In a statistical summary of groundwater quality in North Carolina, the Superfund Research Program at the University of North Carolina (UNC) analyzed 180 private well water samples in Cleveland and Rutherford Counties. The samples were tested by the North Carolina State Laboratory of Public Health from 1998 to 2012. The study found an average barium concentration of 50 µg/L. No samples exceeded the 2,000 µg/L PMCL for barium (NCDHHS 2010).

10.1.4 Beryllium

Beryllium is a hard, gray metal that is very lightweight. In nature, it combines with other elements to form beryllium compounds. Small amounts of these compounds are naturally present in soils, rocks, and water. Emeralds and aquamarines are gem-quality examples of a mineral (beryl) that is a beryllium compound.

Beryllium combines with other metals to form mixtures called alloys. Beryllium and its alloys are used to construct lightweight aircraft, missile, and satellite components. Beryllium is also used in nuclear reactors and weapons, X-ray transmission windows, heat shields for spacecraft, rocket fuel, aircraft brakes, bicycle frames, precision mirrors, ceramics, and electrical switches (EPRI 2008).

Most of the beryl occurring in North Carolina is along the south and southwest sides of the Blue Ridge Mountains. The most notable mines include the Biggerstaff, Branchand, and Poteat mines in Mitchell County; the Old Black mine in Avery County; and the Ray mine in Yancey County. The beryl forms golden or pale-green well-formed prismatic crystals ranging in size from a fraction of an inch to about 3 inches in diameter. It is generally found near the cores of bodies of pegmatites of moderate size that contain considerable amounts of perthitic microcline. Production has been negligible, and no regular production appears possible. Green beryl (aquamarine and emerald) was mined commercially many years ago at the Grassy Creek emerald mine and the Grindstaff emerald mine on Crabtree Mountain in Mitchell County. The Ray mine in Yancey County has also produced some golden beryl and aquamarine (Brobst 1962).

Beryllium-containing minerals are also common in granites and pegmatites throughout the Piedmont region; however, to a much lesser degree than the Blue Ridge Mountains Province (Brobst 1962).

Beryllium is concentrated in silicate minerals relative to sulfides and in feldspar minerals relative to ferromagnesium minerals. The greatest known naturally occurring concentrations of beryllium are found in certain pegmatite bodies. Beryllium is not likely to be found in natural water above trace levels due to the insolubility of oxides and hydroxides at the normal pH range (Brobst 1962).

10.1.5 Boron

While boron is relatively abundant on the earth's surface, boron and boron compounds are relatively rare in all geological provinces of North Carolina. Natural sources of boron in the environment include volatilization from seawater, geothermal vents, and weathering of clay-rich sedimentary rocks. Total contributions from anthropogenic sources are less than contributions from natural sources. Anthropogenic sources of boron include agriculture, refuse, coal and oil burning power plants, by-products of glass manufacturing, and sewage and sludge disposal (EPRI 2005).

Boron is usually present in water at low concentrations. Surface waters typically have concentrations of 0.001 to 5 mg/L, with an average concentration of about 0.1 mg/L. Background boron concentrations in groundwater near power plants were compiled from data presented in EPRI technical reports, and ranged from <0.01 to 0.59 mg/L with a median concentration of 0.07 mg/L (EPRI 2005).

10.1.6 Chromium

Chromium is a blue-white metal found naturally only in combination with other substances. It occurs in rocks, soil, plants, and volcanic dust and gases (EPRI 2008). Background concentrations of chromium in groundwater generally follow the media in which they occur. Most chromium concentrations in groundwater are low, averaging less than 1.0 µg/L worldwide. Chromium tends to occur in higher concentrations in felsic igneous rocks (such as granite and metagranite) and ultramafic igneous rocks; however, it is not a major component of the igneous or metamorphic rocks found in the North Carolina Piedmont or the Blue Ridge (Chapman 2013).

In a statistical summary of groundwater quality in North Carolina, the Superfund Research Program at UNC analyzed private well water samples in Cleveland and Rutherford Counties. The samples were tested by the North Carolina State Laboratory of Public Health from 1998-2012. Statistics for both counties are included in Table 10-2. This study found average chromium concentrations were 6 µg/L and 5.1 µg/L in Cleveland and Rutherford Counties, respectively (NC DHHS 2010).

10.1.7 Cobalt

The concentration of cobalt in surface and groundwater in the United States is generally low—between 1 and 10 parts of cobalt in 1 billion parts of water (ppb) in populated areas. The

concentration may be hundreds or thousands of times higher in areas that are rich in cobalt-containing minerals or in areas near mining or smelting operations. In most drinking water, cobalt levels are less than 1 to 2 ppb (USGS 1973). Cobalt is compared to IMACs since no 2L Standards have been established for this constituent by NCDENR.

10.1.8 Iron

Iron is a naturally occurring element that may be present in groundwater from the erosion of natural deposits (NC DHHS 2010). Iron commonly exceeds state and federal regulatory standards in North Carolina groundwater. According to Harden 2009, iron exceedances occurred in over half of the state's ten geozones. The average concentration of iron detected in North Carolina private well water from sampling conducted in 2010 (NC DHHS 2010) is shown in Figure 10-2. A study by the Superfund Research program at UNC found that only 15 of the 100 counties in North Carolina had average concentrations below the SMCL of 300 µg/L. Statistics for Cleveland and Rutherford Counties, where CSS is located, are included in Table 10-2. The study found average iron concentrations were 872.2 µg/L and 471.6 µg/L in Cleveland and Rutherford Counties, respectively.

A 2015 study by NCDENR (*Summary of North Carolina Surface Water Quality Standards 2007-2014*) found that while concentrations vary regionally, "iron occurs naturally at significant concentrations in the groundwaters of NC," with a statewide average concentration of 1320 µg/L. Regional variations from this study are summarized in Table 10-3.

10.1.9 Lead

Lead is a heavy, bluish-gray metal that occurs naturally in the earth's crust. It is rarely found as a pure metal, but is instead typically found with other elements to form lead compounds. Lead is soft and malleable. It combines with other metals to form mixtures called alloys and is commonly found in pipes, weights, firearm ammunition, sheets used to shield humans from radiation, pigments in paint and dye, ceramic glazes, and caulk. The largest use for lead is in vehicle storage batteries (EPRI 2008).

Lead is the 34th most abundant element in the earth's crust, averaging 15 parts per million (ppm). In igneous rocks its concentration ranges from approximately 5 ppm in gabbro to 20 ppm in granite. Typical concentrations in sedimentary rocks range from an average of 7 ppm in sandstone, 9 ppm in carbonates, 20 ppm in shale, to as much as 80 ppm in deep-sea clays (USGS 1973).

A variety of lead-bearing igneous, metamorphic, and sedimentary rock units are distributed throughout North Carolina. The Kings Mountain belt once hosted a lead mine, with minerals such as galena, chalcopyrite, and pyrite present in vein quartz throughout the host rock (Horton 1991).

A statistical summary of groundwater quality in North Carolina was conducted by the Superfund Research Program at UNC. The study found that four North Carolina counties had average lead concentrations which exceeded the PMCL of 15 µg/L. The North Carolina State Laboratory of Public Health tested 659 private well water samples from Cleveland and Rutherford Counties

from 1998-2012. The counties were found to have average groundwater lead concentrations of 17.4 µg/L and 4.6 µg/L respectively. The PMCL of 15 µg/L was exceeded in 21 samples (NC DHHS 2010).

10.1.10 Manganese

Manganese is a naturally occurring silvery-gray transition metal that resembles iron, but is more brittle and is not magnetic. It is found in combination with iron, oxygen, sulfur, or chlorine to form manganese compounds. Manganese occurs naturally in soils, saprolite, and bedrock and is thus a natural component of groundwater (EPRI 2008).

Manganese concentrations tend to cluster by soil system and geozone throughout North Carolina with concentrations from 300 µg/L to 500 µg/L, as shown in Figure 10-3. The Carolina Slate and Milton geozones have the highest proportions of manganese-exceedances, although six other geozones exceeded the state standard as well (Gillespie 2013). Geozones with magmatic-arc rocks and low-grade metamorphic rocks, seen in Figure 10-3 tend to include abundant manganese-bearing mafic minerals are likely to contribute manganese for subsurface water cycling (Gillespie 2013). These rock types are distributed throughout North Carolina and contribute to spatial variations of manganese concentrations throughout the state. High manganese concentrations are associated with silty soils, and sedimentary, unconsolidated, or weathered lithologic units. Low concentrations are associated with non-weathered igneous bedrock and soils with high hydraulic conductivity (Gillespie 2013; Polizzotto 2014).

Manganese is most readily released to the groundwater through the weathering of mafic or siliceous rocks (Gillespie 2013). When manganese-bearing minerals in saprolite, such as biotite, are exposed to acidic weathering, the metal can be liberated from the host-mineral and released to groundwater. It can then migrate through pre-existing fractures during the movement of groundwater through bedrock. If this aqueous-phase manganese is exposed to higher pH in the groundwater system, it will precipitate out of solution. This results in preferential pathways becoming “coated” in manganese oxides and introduces a concentrated source of manganese into groundwater (Gillespie 2013).

Manganese(II) in suspension of silt or clay is commonly oxidized by microorganisms present in soil, leading to the precipitation of manganese minerals (ATSDR 2012).

Roughly 40-50% of North Carolina wells have manganese concentrations higher than the state drinking water standard (Gillespie 2013). Concentrations are spatially variable throughout the state, ranging from less than 0.01 mg/L to more than 2 mg/L. This range of values reflects naturally derived concentrations of the constituent and is largely dependent on the bedrock's mineralogy and extent of weathering (Gillespie 2013).

In a 2015 study by DENR (*Summary of North Carolina Surface Water Quality Standards 2007-2014*) it was found that concentrations vary regionally, however “manganese occurs naturally at significant concentrations in the groundwater of NC,” with a statewide average concentration of 102 µg/L. The study found the regional variations summarized in Table 10-3.

Using the USGS National Uranium Resource Evaluation (NURE) database, all manganese tests within a 20-mile radius of CSS are shown on Figure 10-4.

10.1.11 Mercury

Mercury is a heavy, silvery metal that is liquid at room temperature. Mercury occurs in almost all natural substances, including rocks, soil, water, air, and animals (USGS 1973). The metal occurs naturally in the environment and exists in several forms, including metallic (elemental) mercury, inorganic mercury, and organic mercury (CDC 2012).

Metallic mercury is in its pure form and does not combine with other elements to form compounds. Inorganic mercury combines with other elements, such as chlorine, sulfur, or oxygen, to form mercury compounds that are known as mercury salts. When mercury combines with carbon, the compounds are known as organomercurials (NCDENR 2013).

In addition to its liquidity at room temperature, mercury possesses a number of unique properties. Its high surface tension, uniform thermal expansion, electrical conductivity, high density, and ability to alloy readily make mercury useful in a variety of products and applications (USGS 1973). Due to its high toxicity, many applications of mercury have been phased out in an attempt to limit the amount of human and environmental exposure to mercury and its waste products (CDC 2012).

Mercury is released into the environment by volcanoes, weathering of mercury-containing rocks, forest fires, and other natural sources, as well as by human activities such as mining and the combustion of fossil fuels. Human activity over the past 150 years has increased atmospheric and water levels of the metal (CDC 2012).

The solubility of mercury compounds in water varies. Elemental mercury vapor is insoluble, while the common organic form of mercury, methylmercury, is soluble. Given the necessary conditions, such as anaerobic water or low pH, any form of mercury entering surface waters can be microbially methylated to the soluble form (CDC 2012). The general population is most commonly exposed to mercury from two sources: eating fish that contain methylmercury, or from the release of elemental mercury from the dental amalgam used in fillings (CDC 2012).

The average mercury content of the earth's crust is approximately 80 ppb (USGS 1973 and 2003). North Carolina private well water averages less than the USEPA maximum contaminant level of 2 µg/L and generally less than the 2L Standard of 1 µg/L. Figure 10-5 presents a map of average mercury concentrations detected in North Carolina private well water collected in 2010.

10.1.12 Nickel

Nickel is a hard, lustrous, silvery-white metal that resists corrosion. It occurs in all types of soils, and is frequently in rocks and underwater sediments (EPRI 2008). Nickel combines easily with other metals to form mixtures called alloys. For example, nickel mixed with steel forms stainless steel, a common alloy that resists rust and corrosion. The U.S. nickel coin contains 25% nickel mixed with copper. Nickel and its alloys are also used in batteries, spark plugs, electrical resistance wires, metal jewelry, cookware, and textile dyes (EPRI 2008).

While nickel can exist in oxidation states -1 through +4, the only important oxidation state is Ni(II) under normal environmental conditions (EPRI 2008).

In North Carolina, nickel is frequently found in iron and aluminum-rich soil called laterite (USGS 1973, Horton et al. 1991). Laterite is formed by the weathering of iron- and magnesium-rich rocks in humid, tropical to sub-tropical areas. The repeated processes of dissolution and precipitation lead to a uniform dispersal of nickel that is not amenable to concentration by physical means; therefore, these ores are concentrated by chemical means such as leaching (ATSDR 2012).

There has been interest in a few small residual nickel laterites in the Blue Ridge Mountains geologic province of southwestern North Carolina. The nickeliferous soils form above alpine peridotites and dunites. In general, the anomalous nickel values (as high as 1 to 3% Ni) consist of garnierite and genthite in small veinlets in lateritic soils and in the upper portion of underlying bedrock. The veinlets themselves run as high as 10% Ni. The largest concentration is found in one million tons of 1% Ni soils near Webster, North Carolina (Horton et al. 1991). Despite this abundance, there are no nickel mining operations currently in the U.S., as U.S. supplies are imported or recycled (ATSDR 2012).

Nickel is a natural constituent of soil and is transported into streams and waterways in runoff either from natural weathering or from disturbed soil. Much of this nickel is associated with particulate matter. Nickel also enters bodies of water through atmospheric deposition (ATSDR 2012). The primary source of nickel in drinking-water is leaching from metals in contact with drinking-water, such as pipes and fittings (WHO 1996).

Nickel concentrations in groundwater depend on the soil use, pH, and depth of sampling. Once nickel is in surface and ground water systems, physical and chemical interactions (complexation, precipitation/dissolution, adsorption/desorption, and oxidation/reduction) occur that will determine its fate and that of its constituents (EPA 2009).

Acid rain increases the mobility of nickel in the soil and thus might increase nickel concentrations in groundwater (WHO 1996).

10.1.13 Sulfate

Sulfate is a naturally occurring substance found in minerals, soil, and rocks. It is present in ambient air, groundwater, plants, and food. The principal commercial use of sulfate is in the chemical industry. Sulfate is discharged into water in industrial wastes and through atmospheric deposition (USEPA 2003).

While sulfate has an SMCL, and no enforceable maximum concentration set by the USEPA, ingestion of water with high concentrations of sulfate may be associated with diarrhea, particularly in susceptible populations, such as infants and transients (USEPA 2012).

In the *Piedmont and Blue Ridge Aquifers* chapter of the *USGS Ground Water Atlas of the United States*, the groundwater of this region as a whole is described as "generally suitable for

drinking... but iron, manganese, and sulfate locally occur in objectionable concentrations" (USGS 1997).

10.1.14 Thallium

Pure thallium is a soft, bluish white metal that is widely distributed in trace amounts in the earth's crust. In its pure form, it is odorless and tasteless. It can be found in pure form or mixed with other metals in the form of alloys. It can also be found combined with other substances such as bromine, chlorine, fluorine, and iodine to form salts (EPRI 2008).

Traces of thallium naturally exist in rock and soil. As rock and soil erode, small amounts of thallium can occur in groundwater. In a USGS study of trace metals in soils, the variation in thallium concentrations in A (i.e., surface) and C (i.e., substratum) soil horizons was estimated across the United States.

In a study by the Georgia Environmental Protection Division (EPD) of the Blue Ridge Mountain and Piedmont aquifers, 120 testing sites were sampled for various constituents. Thallium was not detected at any of these sites (MRL = 1 µg/L) (Donahue 2007). The overall thallium concentrations ranged from <0.1 mg/kg to 8.8 mg/kg. North Carolina concentrations from this study are shown on Figure 10-6. Thallium is compared to IMACs since no 2L Standards have been established for this constituent by NCDENR.

10.1.15 Vanadium

Vanadium is widely distributed in the earth's crust at an average concentration of 100 ppm (approximately 100 mg/kg), similar to that of zinc and nickel. Vanadium is the 22nd most abundant element in the earth's crust (EPRI 2008). V(V) and V(IV) are the most important species in natural water, with V(V) likely the most abundant under environmental conditions (Wright and Belitz 2010). Vanadium is compared to IMACs since no 2L Standards have been established for this constituent by NCDENR.

In a study by the Georgia EPD, 120 sites in the Blue Ridge and Piedmont physiographic regions (regions shared with North Carolina) were sampled and detectable traces of vanadium were found in six samples (with a reporting limit of 10 µg/L). Only two of these samples were in basic pH groundwater while the rest were sampled in more acidic waters.

Using the USGS NURE database, all vanadium groundwater test results from water supply wells within a 20-mile radius of CSS are shown on Figure 10-7 and also provided in Table 10-4. Concentrations near CSS range from 0.10 to 13.40 µg/L. These results generally represent concentrations found in deeper aquifers below the uppermost shallow aquifer.

10.1.16 pH

The pH scale is used to measure acidity or alkalinity. A pH value of 7 indicates neutral water. A value lower than the USEPA-established SMCL range (<6.5 Standard Units) is associated with a bitter, metallic tasting water, and corrosion. A value higher than the SMCL range (>8.5

Standard Units) is associated with a slippery feel, soda taste, and deposits in the water (USEPA, 2013).

In a statistical summary of groundwater quality in North Carolina, the Superfund Research Program at UNC analyzed 618 private well water samples for pH in Cleveland and Rutherford Counties. The samples were analyzed by the North Carolina State Laboratory of Public Health from 1998 – 2012. This study found that 16.9% of wells in Cleveland County and 20.3% of wells in Rutherford County had a pH result outside of the USEPA's SMCL range (Table 10-2).

Using the USGS NURE database, all pH tests within a 20-mile radius of CSS are shown on Figure 10-8; with a pH range from 5.1 to 8.7.

10.2 Background Wells

Background (BG) monitoring well locations were identified based on the SCM at the time the Work Plan was submitted. The BG locations were chosen in areas assumed not to be impacted by and topographically upgradient of the ash basins and ash storage areas. Based on the developed groundwater surface water contours (Figures 6-5 through 6-7) and the updated SCM, the BG monitoring well locations are considered to be hydraulically upgradient of the ash basins and ash storage area, and likely representative of background groundwater quality conditions at the site.

Background groundwater monitoring wells include two existing compliance monitoring program groundwater monitoring wells (MW-24D and MW-24DR), and nine newly installed groundwater monitoring wells (BG-1S/D/BR, BG-2D, MW-30S/D, and MW-32S/D/BR located near the southern property boundary. Background groundwater monitoring wells are depicted on Figure 10-9. Well construction details are summarized in Tables 6-10 and 6-11. Boring logs and well construction records are presented in Appendix H. A generalized well construction diagram for newly installed wells is shown in Figure 10-10. Well installation procedures are documented in Appendix G, along with variances from the Work Plan. Boring logs are provided in Appendix H.

Background monitoring wells MW-24D and MW-24DR were previously installed in January 2011 as a compliance monitoring well pair to evaluate background water quality at the site. Monitoring well MW-24D was installed to a depth of 53 feet bgs and screened from 33 to 53 feet bgs. Monitoring well MW-24DR was installed to a depth of 105 feet bgs and screened from 60 to 105 feet bgs. Groundwater flow in the vicinity of MW-24D and MW-24DR is to the north and northwest toward the active ash basin and Suck Creek. Historical groundwater data for MW-24D and MW-24DR dates back to April 2011. The compliance monitoring wells are sampled three times a year (April, August, and December) and 13 sampling events have been conducted to date. This is sufficient data to adequately perform statistics on the historical analytical results at MW-24D and MW-24DR to determine site specific background concentrations at these wells. The statistical evaluation including site-specific groundwater concentrations determined for MW-24D and MW-24DR is provided in Appendix G. Duke Energy recognizes that the NCDENR DWR Director is responsible for establishing site-specific background levels for groundwater as stated in 15A NCAC 02L .0202(a)(3). The concentrations in the statistical report are provided as

information to aid in this determination, and for comparative purposes for groundwater at the site.

Newly installed background monitoring wells BG-2D, MW-32S/D/BR, and MW-30S/D were installed to evaluate background water quality in the regolith, TZ, and within the bedrock upgradient of the Unit 5 inactive ash basin. Groundwater flow in the vicinity of these monitoring wells is generally to the northeast toward the Unit 5 inactive ash basin. Currently, insufficient data are available to qualify BG-2D, MW-32S/D/BR, and MW-30S/D as background monitoring wells and provide associated statistical analysis. As data become available, statistical analysis will be performed and determination made as to whether these new wells are statistically confirmed as background monitoring wells.

Background monitoring wells BG-1S/D/BR were installed to evaluate background water quality in the regolith, TZ, and within the bedrock upgradient of the active ash basin. BG-1S was screened from 20 to 35 feet bgs, BG-1D was screened from 66.5 to 71.5 feet bgs, and BG-1BR was screened from 92 to 97 feet bgs. Currently, insufficient data are available to qualify BG-1S/D/BR as background monitoring wells and provide associated statistical analysis. As data become available, statistical analysis will be performed and determination made as to whether these wells qualify as background monitoring wells.

One shallow, two deep, and two bedrock background wells are located hydraulically upgradient of the active ash basin and two shallow, three deep, and one bedrock background well are located hydraulically upgradient of the Unit 5 inactive ash basin. Based on review of available information, the number of background wells located within the property boundary of the site is adequate for monitoring background groundwater quality. The background wells were strategically placed to maximize physical separation from the ash basin and ash storage areas.

Time series plots, time history plots, stacked time series plots, and correlation plots for compliance wells are depicted in Figure 10-11 through Figure 10-45.

10.3 Discussion of Redox Conditions

Determination of the reduction/oxidation (redox) condition of groundwater is desirable as part of groundwater assessments in order to gain understanding of mobility, degradation, and solubility of contaminants. By applying the framework of the Excel Workbook for Identifying Redox Processes in Ground Water (Jurgens, McMahon, Chapelle, and Eberts 2009) to the analytical results in the following sections, the predominant redox process, or category, to samples collected during the groundwater assessment was assigned. Redox categories include oxic, suboxic, anoxic, and mixed. Assignment of redox category was based upon concentrations of DO, nitrate as nitrogen, manganese (II), iron (II), sulfate, and sulfide as inputs. Constituent criteria appropriate for inputs to the Excel Workbook, as well as an explanation of the redox assignments, can be found in Tables 1 and 2, respectively, of the USGS Open File Report 2009-1004 (Jurgens, McMahon, Chapelle, and Eberts 2009). General redox category results are presented in Table 10-5.

10.4 Groundwater Analytical Results

A total of 131 groundwater monitoring wells were installed at CSS between February and June 2015 as part of the groundwater assessment program. Groundwater monitoring well locations are shown on Figure 11-1. Monitoring well information is provided in Tables 6-10 and 6-11. Monitoring wells were installed in general accordance with procedures described in the Work Plan and a detailed description is provided in Appendix H. Boring logs and well construction records are also provided in Appendix H.

Table 10-6 summarizes parameters and constituent analytical methods for the groundwater samples collected. Groundwater sample results are compared to the North Carolina 2L Standards and IMACs. Background groundwater sample laboratory results for totals and dissolved inorganic parameters are summarized in Table 10-7. Background speciation groundwater results are presented in Table 10-8. Groundwater sample field parameters and laboratory results for totals and dissolved are summarized in Table 10-9 and groundwater speciation results are summarized in Table 10-10. Field parameters are summarized in Tables 7-11 and 7-12. Groundwater sampling results are depicted on Figure 10-46. Variances from the proposed sampling plans are presented in Appendix H. Field and sampling quality control / quality assurance protocols are provided in Appendix E.

Duke Energy conducted speciation of groundwater samples for arsenic, chromium, iron, manganese, and selenium from selected wells along inferred groundwater flow transects. Speciation sampling was performed along flow transects, at ash basin water sample locations, and at compliance wells with historical exceedances of the 2L Standards for speciation constituents. Available speciation results for background groundwater and groundwater samples are provided in the above referenced tables and the remaining results will be included in the CSA supplement.

Well designations and descriptions for the installed assessment monitoring wells include:

- S – Shallow monitoring wells installed in regolith or ash that were screened to bracket the water table surface at the time of installation.
- SL – Monitoring wells that were installed with the bottom of the well screen set above the ash-regolith interface
- S-SL - Monitoring wells that were installed with the bottom of the well screen set above the ash-regolith interface which also bracketed the water table surface at the time of installation.
- I – Intermediate monitoring wells installed in regolith that were screened wholly within the regolith zone, below the ash in the ash basin, and beneath the water table.
- AL – Aluvium monitoring wells were installed with the well screen within an alluvial layer.
- D – Deep monitoring wells were installed with the screened interval within the partially weathered/fractured bedrock transition zone at the base of the regolith.
- BRU – Bedrock Upper monitoring wells are wells that were originally proposed to be “D” wells; however, a partially weathered/fractured bedrock transition zone was not

encountered in the boring. These wells were screened within the first 15 feet of fresh, competent bedrock encountered below the regolith.

- BR – Bedrock monitoring wells were screened across water-bearing fractures within fresh competent bedrock after continuous coring of at least 50 feet into competent bedrock.

Groundwater monitoring wells were developed prior to sampling activities in general accordance with well development procedures detailed in Appendix G. The well development forms are also included in Appendix G. Groundwater samples were collected and analyzed in general accordance with the procedures and methods described in the Work Plan and in Duke Energy's *Low Flow Sampling Plan, Duke Energy Facilities, Ash Basin Groundwater Assessment Program*, dated May 22, 2015. Refer to Appendix D for a detailed description of these methods. Appendix G includes a summary of variances from the well development and sampling plans. Appendix E includes the field and sampling quality control / quality assurance protocols.

Groundwater samples were collected from background locations, beneath the active ash basin, beneath the Units 1-4 inactive ash basin, beneath the Unit 5 inactive ash basin, beneath the ash storage area, and from locations outside the waste boundaries. Groundwater samples were also collected from pre-existing voluntary and compliance wells on the site.

Groundwater isoconcentration contours with respect to each COI are depicted in Figures 10-47 through 10-94. Cross-section transects are presented on Figure 11-95. Cross-sections presenting horizontal and vertical distribution of COIs along each transect are depicted on Figures 10-96 through 10-109. COI concentrations along the flow transects will be modeled in the CAP.

The USEPA recommends that when possible, especially when sampling for constituents that may be biased by the presence of turbidity, that turbidity values in the stabilized well should be less than 10 Nephelometric turbidity units (NTUs) (USEPA 2002). Monitoring wells with analytical results exceeding the 2L Standards for iron and/or manganese have been individually plotted with the associated turbidity values. Maximum contaminant concentrations for groundwater can be found in Section 17.3.

10.4.1 Active Ash Basin

10.4.1.1 Beneath the Active Ash Basin Waste Boundary

A total of 13 groundwater monitoring wells (three shallow, one intermediate, five deep, two upper bedrock, and two bedrock) were installed within the active ash basin waste boundary (beneath the ash in the active ash basin and within the dams associated with the basin). These monitoring wells include AB-1S/D, AB-2S/D, AB-3I/BRU, AB-4D/BR, AB-5BRU, AB-6D/BR, and GWA-20S/D. These groundwater monitoring wells were installed to evaluate groundwater quality beneath the active ash basin.

Five existing voluntary groundwater monitoring wells located within the active ash basin waste boundary were sampled to supplement groundwater quality data for this groundwater

assessment. These wells include CLMW-5S/D, MW-8S/D, and MW-11S. Monitoring well MW-11D is also located within the active ash basin waste boundary but was dry at the time of sampling.

10.4.1.2 Outside the Active Ash Basin Waste Boundary

A total of 21 groundwater monitoring wells (eleven shallow, eleven deep, and two bedrock) were installed outside the waste boundary and within the compliance boundary of the active ash basin. These monitoring wells include GWA-21S/BRU/BR, GWA-22S/BRU, GWA-23D, GWA-24S/D, GWA-25S/D, GWA-26S/D, GWA-27D-A, GWA-28S/BRU/BR, GWA-33S/D/BR, MW-21BR, and MW-22BR. The groundwater monitoring wells located outside the waste boundary and were installed to evaluate the impact of the ash basin on groundwater quality outside the active ash basin waste boundary.

A total of three existing voluntary groundwater monitoring wells (CLMW-6 and MW-10S/D) and six compliance monitoring wells (MW-20D/DR, MW-21D, MW-22DR, and MW-23D/DR) were sampled to supplement groundwater quality data for this groundwater assessment.

10.4.2 Ash Storage Area

10.4.2.1 Beneath the Ash Storage Area Waste Boundary

A total of 13 groundwater monitoring wells (four shallow, four deep, two upper bedrock and three bedrock) were installed within the ash storage area waste boundary and beneath the ash encountered in this area. These monitoring wells include AS-1SB/D, AS-3BRU, AS-4S/D, AS-5S/BRU/BR, AS-6S/D/BR, and AS-7D/BR. These groundwater monitoring wells were installed to evaluate groundwater quality beneath the ash storage area.

Five existing voluntary groundwater monitoring wells located within the active ash basin waste boundary were sampled to supplement groundwater quality data for this groundwater assessment. These wells include CLMW-1, CLMW-2, CLMW-3S/D, and MW-2DA.

10.4.2.2 Outside the Ash Storage Area Waste Boundary

A total of two groundwater monitoring wells (one shallow and one deep) were installed outside the waste boundary of the ash storage area. These monitoring wells are AS-2S/D. The groundwater monitoring wells located outside of the waste boundary were installed to evaluate the impact of the ash storage area on groundwater quality outside the waste boundary.

One existing compliance groundwater monitoring well (MW-25DR) located outside of the ash storage area waste boundary was sampled to supplement groundwater quality data for this groundwater assessment.

10.4.3 Units 1-4 Inactive Ash Basin

10.4.3.1 Beneath the Units 1-4 Inactive Ash Basin Waste Boundary

A total of eight groundwater monitoring wells (one shallow, three deep, one alluvium, one intermediate, one upper bedrock, and one bedrock) were installed beneath the ash in the Units

1-4 inactive ash basin, and within the dams associated with the basin. These monitoring wells include IB-1D, IB-2AL, IB-2I, IB-2BRU, IB-3S, IB-3D, IB-4D, and IB-4BR. These groundwater monitoring wells were installed to evaluate groundwater quality beneath the Units 1-4 inactive ash basin.

10.4.3.2 Outside the Units 1-4 Inactive Ash Basin Waste Boundary

A total of 11 groundwater monitoring wells (four shallow, three deep, two upper bedrock, and two bedrock) were installed outside the waste boundary and within the compliance boundary of the active ash basin. These monitoring wells include GWA-10S/D, GWA-11S/BRU, GWA-12S/BRU, GWA-13BR, GWA-14S/D, and GWA-29D/BR. The groundwater monitoring wells located outside the Units 1-4 inactive ash basin waste boundary were installed to evaluate the impact of the ash basin on groundwater quality outside the waste boundary.

10.4.4 Unit 5 Inactive Ash Basin

10.4.4.1 Beneath the Unit 5 Inactive Ash Basin Waste Boundary

A total of 16 groundwater monitoring wells (five shallow, nine deep, and two bedrock) were installed beneath the ash in the Unit 5 inactive ash basin, in areas within the waste boundary where ash was not encountered, and within the dams associated with the basin. These monitoring wells include U5-1S/D, U5-2D, U5-3S/D, U5-4S/D/BR, U5-5D, U5-6S/D, U5-7D, U5-8S/D and GWA-31D/BR. These groundwater monitoring wells were installed to evaluate groundwater quality beneath the Unit 5 inactive ash basin. Monitoring wells GWA-31BR, U5-3S and U5-4BR were dry at the time of sampling.

10.4.4.2 Outside the Unit 5 Inactive Ash Basin Waste Boundary

A total of 23 groundwater monitoring wells (ten shallow, six deep, six upper bedrock, and one bedrock) were installed outside the waste boundary of the Unit 5 inactive ash basin. These monitoring wells include GWA-1BRU, GWA-2S/BRU, GWA-3D, GWA-4S/D, GWA-5S/BRU, GWA-6S/D, GWA-30S/BRU/BR, MW-34S/D, MW-36S/BRU, MW-38S/D, MW-40S/BRU, and MW-42S/D. The groundwater monitoring wells located outside the waste boundary were installed to evaluate the impact of the ash basin on groundwater quality outside the Unit 5 inactive ash basin waste boundary. Monitoring well GWA-6S was dry at the time of sampling.

10.5 Comparison of Results to 2L Standards

Groundwater results were compared to 2L Standards and IMACs and exceedances are summarized below. Table 10-11 presents groundwater results with exceedances of 2L Standards and IMACs, and Figure 10-46 depicts groundwater sample exceedances of 2L Standards.

10.6 Comparison of Results to Background

10.6.1 Background Wells MW-24D and MW-24DR

Background monitoring well MW-24D and MW-24DR concentration were selected for comparison based on the information presented in Section 10.2, the amount of historical data available and hydraulically upgradient of all the ash basins and ash storage areas. With the exception of antimony, iron, manganese, and vanadium, the results for all other constituents have been reported at less than their respective 2L Standards and IMACs at these wells throughout their monitoring history. The background concentration ranges for the constituents that are considered COIs at CSS are provided below. Results with J qualifiers are estimated concentrations less than the laboratory method reporting limit.

- Antimony <0.5 µg/L to 1.7 µg/L
- Arsenic <0.5 µg/L to 1.8 µg/L
- Barium 3.2J µg/L to 36 µg/L
- Boron <50.0 µg/L
- Chromium 0.18J µg/L to 0.74 µg/L
- Cobalt <0.5 µg/L to 0.54 µg/L
- Iron 34 µg/L to 3,200 µg/L
- Lead <0.1 µg/L to 0.34 µg/L
- Manganese 8 µg/L to 87 µg/L
- Nickel <0.5 µg/L to 0.76 µg/L
- pH 5.1 to 5.4
- Sulfate 520J µg/L to 9,900J+ µg/L
- Thallium 0.051J µg/L to <0.1 µg/L
- TDS 22,000 µg/L to 120,000 µg/L
- Vanadium <0.1 µg/L to 0.33J µg/L

Please refer to Section 10.1 for a comparision of the above-references site-specific constituent concentrations to regional groundwater constituent concentrations.

10.6.2 Newly Installed Background Wells

Recently installed background wells are designated BG-1S/D/BR, BG-2D, MW-30S/D, and MW-32S/D/BR. Newly installed background wells will be compared to CSS well network in the future after additional analysis. With the exception of chromium, cobalt, iron, manganese, and vanadium, the results for all other constituents were reported less than the 2L Standards or IMACs. The chromium exceedance was only reported for monitoring well MW-30S and the dissolved phase result at this location was less than the 2L Standards. With the exception of GWA-32BR, the dissolved phase results for iron in the newly installed background wells were not detected at concentrations attaining the laboratory method reporting limit.

Results with J qualifiers are estimated concentrations less than the laboratory method reporting limit. The background concentration ranges in the newly installed background wells for the constituents that are considered COIs at CSS are provided below.

- Antimony 0.29J to 0.52 µg/L
- Arsenic 0.18J µg/L to 3.4 µg/L
- Barium 4.3J µg/L to 74 µg/L
- Boron 28J µg/L 150 µg/L
- Chromium 0.55 µg/L to 25.6 µg/L
- Cobalt 0.16J µg/L to 6.1 µg/L
- Iron 30.4J µg/L to 3,700 µg/L
- Lead 0.046J µg/L to <1 µg/L
- Manganese 6.3 µg/L to 260 µg/L
- Nickel <0.5J µg/L to 16.7 µg/L
- pH 4.0 to 11.7
- Sulfate <1,000 µg/L to 20,500 µg/L
- Thallium 0.021J µg/L to <1 µg/L
- TDS <25,000 µg/L to 257,000 µg/L
- Vanadium <0.44J µg/L to 17.1 µg/L

10.6.3 Regional Groundwater Data

The details regarding the regional groundwater data are presented in Section 10.1. Regional arsenic concentrations ranged from 1.1 µg/L to 2.5 µg/L. Barium and boron concentrations in the region averaged 50 µg/L and 100 µg/L, respectively. Chromium concentrations for Cleveland and Rutherford Counties ranged from 5.1 µg/L to 6 µg/L. Reported iron concentrations for Cleveland and Rutherford County range from 471.6 µg/L to 872.2 µg/L. The regional concentration for manganese is ranged from 300 µg/L to 500 µg/L. Regional pH concentrations ranged from 5.1 to 8.7. Regional thallium and vanadium concentrations ranged from 300 µg/L to 500 µg/L and 0 µg/L to 13.4 µg/L, respectively.

10.6.4 Active Ash Basin

10.6.4.1 Groundwater Beneath Active Ash Basin Waste Boundary

Groundwater monitoring locations beneath the active ash basin are identified as AB-1S/D, AB-2S/D, AB-3I/BRU, AB-4D/BR, AB-5BRU, AB-6D/BR, CLMW-5S/D, MW-8S/D, MW-11-S/D, and GWA-20S/D. The range of COI concentrations along with a comparison to the range of reported background groundwater concentrations in monitoring wells MW-24D and MW-24DR and the regional groundwater data are provided in Table 10-12.

As expected, concentrations of several constituents in groundwater beneath the active ash basin are higher than background and regional concentrations, including: boron, chromium, cobalt, iron, manganese, mercury, pH, thallium, vanadium, and TDS.

10.6.4.2 Groundwater Outside Active Ash Basin Waste Boundary

Groundwater monitoring locations outside of the active ash basin and within the compliance boundary are identified as CLMW-6, GWA-21S/BRU/BR, GWA-22S/BRU, GWA-23D, GWA-24S/D, GWA-25S/D, GWA-26S/D, GWA-27D (well offset designation D-A), GWA-28S/BRU/BR, GWA-33S/D/BR, MW-20D/DR, MW-21D/BR, MW-22DR/BR, MW-23D/DR, and MW-25DR. The range of COI concentrations along with a comparison to the range of reported background groundwater concentrations in monitoring wells MW-24D and MW-24DR and the regional groundwater data are provided in Table 10-13.

Concentrations of several constituents in groundwater outside the active ash basin are higher than background and regional concentrations, including: antimony, boron, chromium, cobalt, iron, manganese, nickel, pH, vanadium, sulfate and TDS.

10.6.5 Ash Storage Area

10.6.5.1 Groundwater Beneath Ash Storage Area Waste Boundary

Groundwater beneath the ash storage area are identified as AS-1SB/D, AS-3BRU, AS-4S/D, AS-5S/BRU/BR, AS-6S/D, AS-7D/BR, CLMW-1, CLMW-2, CLMW-3S/D, MW-2DA. The range of COI concentrations along with a comparison to the range of reported background groundwater concentrations in monitoring wells MW-24D and MW-24DR and the regional groundwater data are provided in Table 10-14.

As expected, concentrations of several constituents in groundwater beneath the ash storage area are higher than background and regional concentrations, including: antimony, arsenic, barium, boron, chromium, cobalt, manganese, nickel, pH, thallium, vanadium, sulfate and TDS.

10.6.5.2 Groundwater Outside Ash Storage Area Waste Boundary

Groundwater samples collected from outside the ash storage area and within the compliance boundary are identified as AS-2S/D and MW-25DR. The range of COI concentrations along with a comparison to the range of reported background groundwater concentrations in monitoring wells MW-24D and MW-24DR and the regional groundwater data are provided in Table 10-15.

Concentrations of several constituents in groundwater beneath the ash storage area are higher than background and regional concentrations, including: antimony, arsenic, chromium, cobalt, iron, manganese, pH, thallium, vanadium and TDS.

10.6.6 Units 1-4 Inactive Ash Basin

10.6.6.1 Groundwater Beneath Units 1-4 Inactive Ash Basin Waste Boundary

Groundwater beneath the Units 1-4 inactive ash basin are identified as IB-1D, IB-2S-SL, IB-2BRU, IB-3SB, IB-3D, IB-4S-SL, IB-4D, and IB-4BR. The range of COI concentrations along with a comparison to the range of reported background groundwater concentrations in monitoring wells MW-24D and MW-24DR and the regional groundwater data are provided in Table 10-16.

As expected, concentrations of several constituents in groundwater beneath the Units 1-4 inactive ash basin are higher than background and regional concentrations, including: antimony, chromium, cobalt, iron, manganese, pH and vanadium.

10.6.6.2 Groundwater Outside Units 1-4 Inactive Ash Boundary

Groundwater samples collected from outside the Units 1-4 inactive ash basin and within the compliance boundary are identified as GWA-10S/D, GWA-11S/BRU, GWA-12S/BRU, GWA-13BR, GWA-14S/D, GWA-29D/BR. The range of COI concentrations along with a comparison to the range of reported background groundwater concentrations in monitoring wells MW-24D and MW-24DR and the regional groundwater data are provided in Table 10-17.

Concentrations of several constituents in groundwater beneath the Units 1-4 inactive ash basin are higher than background and regional concentrations, including: antimony, arsenic, barium, chromium, cobalt, iron, lead, manganese, pH, sulfate, TDS, thallium and vanadium.

10.6.7 Unit 5 Inactive Ash Basin

10.6.7.1 Groundwater Beneath Unit 5 Inactive Ash Basin Waste Boundary

Groundwater beneath the Unit 5 inactive ash basin are identified as U5-1S/D, U5-2D, U5-3S/D, U5-4S/D/BR, U5-5D, U5-6S/D, U5-7D, U5-8S/D and GWA-31D/BR. The range of COI concentrations along with a comparison to the range of reported background groundwater concentrations in monitoring wells MW-24D and MW-24DR and the regional groundwater data are provided in Table 10-18.

As expected, concentrations of several constituents in groundwater beneath the Unit 5 inactive ash basin are higher than background and regional concentrations, including: antimony, arsenic, barium, beryllium, chromium, cobalt, iron, lead, manganese, nickel, pH, thallium and vanadium.

10.6.7.2 Groundwater Outside Unit 5 Inactive Ash Boundary

Groundwater samples collected from outside of the Unit 5 inactive ash basin and within the compliance boundary are identified as GWA-1BRU, GWA-2S/BRU, GWA-3D, GWA-4S/D, GWA-5S/BRU, GWA-6S/D, GWA-30S/BRU/BR, MW-34S/D, MW-36S/BRU, MW-38S/D, MW-40S/BRU, and MW-42S/D. The range of COI concentrations along with a comparison to the range of reported background groundwater concentrations in monitoring wells MW-24D and MW-24DR and the regional groundwater data are provided in Table 10-19.

Concentrations of several constituents in groundwater beneath the Unit 5 inactive ash basin are higher than background and regional concentrations, including: antimony, chromium, cobalt, iron, manganese, pH, thallium, vanadium, sulfate and TDS.

10.6.7.3 Groundwater Outside Unit 5 Inactive Ash Compliance Boundary

Groundwater samples collected from outside of the Unit 5 inactive ash basin and outside the compliance boundary are identified as GWA-32D/BR. The range of COI concentrations along with a comparison to the range of reported background groundwater concentrations in

monitoring wells MW-24D and MW-24DR and the regional groundwater data are provided in Table 10-20.

Concentrations of two constituents in groundwater outside the Unit 5 inactive ash basin compliance boundary are higher than background and regional concentrations, including: chromium, pH and vanadium.

10.7 Cation and Anion Water Quality Data

Cation and anion concentrations can be used to describe the chemical composition of groundwater in an aquifer. In natural waters, the cations calcium, magnesium, sodium and potassium and the anions, chloride, sulfate, carbonate, and bicarbonate will make up 95% to 100% of the ions in solution.

Cation and anion concentrations at the CSS site from upgradient groundwater monitoring wells and ash basin groundwater monitoring wells are compared in Figures 10-110 and 10-116. In general, calcium, chloride, magnesium, sodium, and sulfate are elevated, but calcium and sulfate are three to four orders of magnitude higher in ash basin groundwater monitoring wells compared to the upgradient monitoring wells.

The relative concentrations and distribution of the cations and anions can be used to compare the relative ionic composition of different water quality samples through the use of Piper diagrams.

Piper diagrams were generated for the site to show comparison of geochemistry between ash basin porewater, surface water, seeps, upgradient and downgradient groundwater monitoring wells and background groundwater monitoring wells. In general, geochemistry of groundwater and surface water at the site is predominantly calcium and magnesium rich geochemical makeup. Piper diagrams are included as Figures 10-117 through 10-132.

10.8 Groundwater Speciation

Forty-six locations were sampled for chemical speciation analyses of arsenic (III), arsenic (V), chromium (VI), iron (II), iron (III), manganese (II), manganese (IV), selenium (IV), and selenium (VI). Results for chemical speciation of surface water are presented in Table 10-10. Further evaluation of chemical speciation results will be included in the CAP.

10.9 Radiological Laboratory Testing

Radionuclides may exist dissolved in water from natural sources (e.g. soil or rock). The USEPA regulates various radionuclides in drinking water. For purposes of this assessment, radium-226, radium-228, natural uranium, uranium-233, uranium-234, and uranium-236 were analyzed. Four locations, BG-1BR, BG-1D, BG-1S and U5-4S, were sampled for the analytes listed above. Results for radiological laboratory testing are presented in Table 10-21. Further evaluation of radiological laboratory testing results will be included in the CAP.

10.10 CCR Rule Groundwater Detection and Assessment Monitoring Parameters

Appendix III to Part 257 Constituents for Detection Monitoring and Appendix IV to Part 257 Constituents for Assessment Monitoring

On April 17, 2015, the USEPA published its final rule “Disposal of Coal Combustion Residuals from Electric Utilities” (Final Rule) to regulate the disposal of CCR as solid waste under Subtitle D of the Resource Conservation and Recovery Act (RCRA). Among other requirements, the Final Rule establishes requirements for a groundwater monitoring program to be implemented for CCR surface impoundments consisting of groundwater detection monitoring and, if necessary, assessment groundwater monitoring and corrective action.

The USEPA selected constituents to be used in the groundwater detection monitoring program as indicators of groundwater contamination from CCR. USEPA selected constituents for detection monitoring that are present in CCR, would be expected to migrate rapidly, and that would provide early detection as to whether contaminants were migrating from the disposal unit. (80 FR 74: 21397).

As stated in the FR (80 FR 74: 21342):

These detection monitoring constituents or inorganic indicator parameters are: boron, calcium, chloride, fluoride, pH, sulfate and total dissolved solids (TDS). These inorganic indicator parameters are known to be leading indicators of releases of contaminants associated with CCR and the Agency strongly recommends that State Directors add these constituents to the list of indicator parameters to be monitored during detection monitoring of groundwater if and when a MSWLF decides to accept CCR. (Emphasis added)

NCDENR requested that figures be included in the CSA report that depict groundwater analytical results for the constituents in 40 CFR 257, Appendix III detection monitoring and 40 CFR 257, Appendix IV assessment monitoring.

Detection monitoring constituents in 40 CFR 257 Appendix III are:

- Boron
- Calcium
- Chloride
- Fluoride (this constituent was not analyzed for in the CSA)
- pH
- Sulfate
- TDS

The analytical results for the detection monitoring constituents are found on Figures 10-133 through 10-136.

Constituents for assessment monitoring listed in 40 CFR 257 Appendix IV are:

- Antimony
- Arsenic
- Barium
- Beryllium
- Cadmium
- Chromium
- Cobalt
- Fluoride (not analyzed for the CSA)
- Lead
- Lithium (not analyzed for the CSA)
- Mercury
- Molybdenum
- Selenium
- Thallium
- Radium 226 and 228 combined

The analytical results for the assessment monitoring constituents are found on Figures 10- 137 through 10-140.

Aluminum, copper, iron, manganese, and sulfide were included in the Appendix IV constituents in the draft rule; USEPA removed these constituents in the Final Rule. These constituents were removed from the Appendix IV list because they lack MCLs and were not shown to be constituents of concern based on either the risk assessment conducted for the CCR Rule or the damage cases referenced in the CCR Rule. Therefore, these constituents are not included on the above-referenced figures. In addition, NCDENR requested that vanadium be included on these figures. Figures 10-151 through 10-156 show vanadium as well as the other constituents listed above in Figures 10-46 where they exceeded the relevant regulatory standards.

11.0 Hydrogeological Investigation

The purpose of the hydrogeological investigation is to characterize site hydrogeological conditions including groundwater flow direction, hydraulic gradient and conductivity, groundwater and contaminant velocity, and slug and aquifer test results. The hydrogeological investigation was performed in general accordance with the procedures described in the Work Plan. Refer to Appendix H for a description of these methods.

11.1 Hydrostratigraphic Layer Development

Soil conditions encountered in the borings showed minimal variation across the site. Residual soil consists of clayey sand (SC), silty sand (SM), silty sand with gravel (SM), micaceous silty sand (SM), and gravel with silt and sand (GP).

The following materials were encountered during the site exploration and are consistent with material descriptions from previous site exploration studies:

- Ash – Ash was encountered in borings advanced within the active ash basin, the Unit 1-4 Inactive ash basin, the Unit 5 inactive ash basin, and the ash storage area. Ash was generally described as gray to dark gray with, non-plastic, dry to wet a silty to sandy texture, consistent with fly ash and bottom ash.
- Fill – Fill material generally consisted of re-worked silts, clays, and sands that were borrowed from one area of the site and re-distributed to other areas. Fill was generally classified as silty sand, clayey sand, and sand with clay and gravel in the boring logs. Fill was used in the construction of dikes and as cover for ash storage areas.
- Alluvium – Alluvium was encountered in borings along the Broad River during the project subsurface exploration activities and during geologic mapping. Alluvium was classified as a well-sorted medium grained sand, sand with silt and gravel, and silty gravel.
- Residuum (Residual soils) – Residuum is the in-place weathered soil that consists primarily of micaceous silty sand, micaceous silt, and clayey sand. This unit was relatively thin at the site.
- Saprolite/Weathered Rock – Saprolite is soil developed by in-place weathering of rock that retains remnant bedrock structure. Saprolite consists primarily of dense to very dense silty sand and silty sand with gravel noted as micaceous in some boring logs and not noted as micaceous in others. Saprolite thickness varies across the site from a very thin mantle where bedrock is near the surface to as much as 75 feet in other areas.
- Partially Weathered/Fractured Rock – Partially weathered (slight to moderate) and/or highly fractured rock encountered below refusal (auger, casing advancer, etc.).
- Bedrock – Sound rock in boreholes, generally slightly weathered to fresh and relatively unfractured.

Based on the CSA site investigation, the groundwater system is consistent with the regolith-fractured bedrock system discussed in Section 5.2. To define the hydrostratigraphic units, the classification system of Schaeffer (2014a), used to show that the TZ is present in the Piedmont

groundwater system (discussed in Section 5-2), was modified to define the hydrostratigraphic layers of the natural groundwater system. The classification system is based on Standard Penetration Testing values (N) and the Recovery (REC) and Rock Quality Designation (RQD) collected during the drilling and logging of the boreholes (Borehole/Well logs in Appendix H). The ash, fill, and alluvial layers are as encountered at the site. The natural system (except alluvium) includes the following layers:

- M1 – Soil/Saprolite: N<50
- M2 – Saprolite/Weathered Rock: N \geq 50 or REC \leq 50%
- TZ – Transition Zone: REC $>$ 50% and RQD $<$ 50%
- BR – Bedrock: REC \geq 85% and RQD \geq 50%.

Rock core runs that fell between the values for TZ and BR (REC $<$ 85% and RQD $>$ 50% or REC $>$ 85% and RQD $<$ 50%) were assigned a hydrostratigraphic based on a review of the borehole logs, rock core photographs, and geologic judgment. The same review was performed in making the final determination of the thickness of the TZ as it could extend into the next core run that meets the BR criterion because of potential core loss or fractured/jointed rock with indications of water movement (Fe/Mn staining).

The above layer designations (M1, M2, TZ, and BR) are used on the geologic cross-sections with locations shown on Figure 11-1 and presented in Figures 11-2 to 11-13 and in the data tables and hydrostratigraphic layer parameter tables presented in this section. The ash, fill and alluvial layers are represented by A, F, and S, respectively on the cross-sections and tables.

The groundwater system consists of three flow layers within a single aquifer system and are referred to in this report as the shallow, deep (transition zone), and bedrock flow layers. Groundwater analytical results are presented in Figure 11-14.

11.2 Hydrostratigraphic Layer Properties

The material properties required for the groundwater flow and transport model (i.e., total porosity, effective porosity, specific yield, and specific storage) for ash, fill, alluvium, and soil/saprolite were developed from laboratory testing (Table 11-1; test data in Appendix H), historic laboratory testing (Table 1-1 in Appendix H), and published data (Domenico and Mifflin 1965). Table 11-1 has a column labeled ‘Estimated Specific Yield/Effective Porosity’ and the values are estimated from the laboratory soil data (grain size analysis) utilizing Fetter-Bear diagrams (worksheets in Appendix H), as described by Johnson (1967). This technique provides a simple method to estimate specific yield; however, there are limitations to the method that may not provide an accurate determination of the specific yield of a single sample (Robson 1993). Specific yield/effective porosity were determined for a number of samples of the A, F, S, M1, and M2 layers to provide an average and range of expected values.

Hydraulic conductivity (horizontal and vertical) of all layers, except the TZ and BR, was developed utilizing existing site data and historic data, in-situ permeability testing (falling head, constant head, and packer testing where appropriate), slug tests in completed monitoring wells,

and laboratory testing of undisturbed samples (ash, fill, soil/saprolite: test results in Appendix H). The effective porosity (primarily fracture porosity) and specific storage of the transition zone and bedrock were estimated from published data (Sanders 1998; Domenico and Mifflin 1965).

11.2.1 Borehole In-Situ Tests

In-situ horizontal (open hole) and vertical (flush bottom) permeability tests, either falling or constant head as appropriate for field conditions, were performed in each of the hydrostratigraphic units above refusal: ash, fill, alluvium, and soil/saprolite. In-situ borehole horizontal permeability tests, either falling or constant head tests as appropriate for field conditions, were performed just below refusal in the first 5 feet of a rock-cored borehole (TZ if present).

The flush bottom test involves advancing the borehole through the overburden with a casing advancer until the test interval is reached. The cutting tool is removed from the casing and the casing is filled with water to the top and the drop of the water level in the casing is measured over a time period of 60 minutes. In the open hole test, after the top of the test interval is reached, the cutting tool but not the casing, is advanced an additional number of feet (five feet in the majority of tests) and drop of the water level in the casing is measured over a time period of 60 minutes. The constant head test is similar except the water level is kept at a constant level in the casing and the water flow-in is measured over 60 minutes. The constant head test was only used when the water level in the borehole was dropping too quickly back to the static water level such that the time interval was insufficient to calculate the hydraulic conductivity. The results from the field permeability testing are summarized in Table 11-2 and the worksheets are provided in Appendix H. Historic field permeability data are summarized in Table 11-3.

Packer tests (shut-in and pressure tests) were conducted in a minimum of five boreholes. The shut-in test is performed by isolating the zone between the packers (in effect, a piezometer) and measuring the resulting water level over time until the water level is stable. The shut-in test provides an estimate of the vertical gradient during the test interval. The pressure test involves forcing water under pressure into rock through the walls of the borehole providing a means of determining the apparent horizontal hydraulic conductivity of the bedrock. Each interval is tested at three pressures with three steps of 20 minutes up and two steps of 5 minutes back down. The pressure test results are summarized in Table 11-2 and the shut-in and packer tests worksheets are provided in Appendix H.

Where possible tests were conducted at borehole locations specified in the Work Plan and at test intervals based on site-specific conditions at the time of the groundwater assessment work. The U.S. Bureau of Reclamation (1995) test method and calculation procedures, as described in Chapter 10 of their Ground Water Manual (2nd Edition), were used for the field permeability and packer tests.

11.2.2 Monitoring Well and Observation Well Slug Tests

Hydraulic conductivity (slug) tests were completed in monitoring wells under the direction of the Lead Geologist/Engineer. Slug tests were performed to meet the requirements of the NCDENR

Memorandum titled, "Performance and Analysis of Aquifer Slug Tests and Pumping Tests Policy," dated May 31, 2007. Water level change during the slug tests was recorded by a data logger. The slug test was performed for no less than 10 minutes, or until such time as the water level in the test well recovered 95 percent of its original pre-test level, whichever occurred first. Slug tests were terminated after one hour even if the 95 percent pre-test level was not achieved. Slug test field data was analyzed and the Aqtesolv (or similar) software using the Bouwer and Rice method.

The slug test results are presented in Table 11-4 and the Slug Test Report is provided in Appendix H. Historic slug test data are presented in Table 11-5.

11.2.3 Laboratory Permeability Tests

Laboratory permeability tests were conducted on undisturbed samples (Shelby tubes) collected during the field investigation. The tests were performed in accordance with ASTM D 5084. The results of the laboratory permeability tests are presented in Table 11-6 and historic laboratory permeability tests are presented in Table 11-7.

11.2.4 Hydrostratigraphic Layer Parameters

The soil material parameters for the A (ash), F (fill), S (alluvium), M1 (soil/saprolite), and M2 (saprolite/weathered rock) were developed by grouping the data into their respective hydrostratigraphic units and calculating the mean, median, and standard deviation of the different parameters. Estimated total porosities are presented in Table 11-8 and the estimated values for effective porosity/specific yield are presented in Table 11-9. The values for specific storage presented in Table 11-9 are based on published data (Domenico and Mifflin 1965).

The hydraulic conductivity parameters were developed by grouping the data into their respective hydrostratigraphic unit and calculating the geometric mean, median, and standard deviation of the different parameters. Vertical hydraulic conductivity values are not available for the TZ and BR units, but are unlikely to be equal. As an initial assumption, vertical hydraulic conductivity for these units can be considered to be equal to the horizontal hydraulic conductivity and adjusted as necessary during flow modeling. Horizontal and vertical hydraulic conductivity parameters are presented Tables 11-10 and 11-11, respectively. The values of secondary (effective) porosity and specific storage for the TZ and BR units are based on published values (Sanders 1998; Domenico and Mifflin 1965) and are presented in Table 11-12. Further development of the above parameters and others required for the flow and contaminant transport model will be provided in the CAP.

11.3 Vertical Hydraulic Gradient

Horizontal hydraulic gradient is calculated by taking the difference in hydraulic head over the distance between two wells with similar well construction. Section 6.2.2 provides additional details for horizontal hydraulic gradients calculated for the site.

Vertical hydraulic gradient was calculated by taking the difference in groundwater elevation in a deep and shallow well pair over the difference in total well depth of the deep and shallow well

pair. A positive output indicates upward flow and a negative output indicates downward flow. Nineteen well pair locations, each consisting of a shallow and deep groundwater monitoring well, were used to calculate vertical hydraulic gradient across the site. Based on review of the results, vertical gradient of groundwater generally is an upward flow on the south side of the site and downward flow on the north side of the site. Locations within the basins generally have upward gradients. Vertical gradient calculations are summarized in Table 11-13.

11.4 Groundwater Velocity

Darcy's Law is an equation that describes the flow rate or flux of fluid through a porous media. To calculate the velocity that water moves through a porous medium, the specific discharge, or Darcy flux, is divided by the effective porosity, n_e . The result is the average linear velocity or seepage velocity of groundwater between two points.

The following equation was used to calculate seepage velocities through each hydrostratigraphic unit present at the site:

$$v = \frac{Ki}{n_e}$$

where v is velocity; K is horizontal hydraulic conductivity; i is horizontal hydraulic gradient; and n_e is the effective porosity

Seepage velocities for groundwater were calculated using horizontal hydraulic gradients established in Section 6.2.2, horizontal hydraulic conductivity values for each hydrostratigraphic unit established in Table 11-9 and effective porosity values established in Tables 11-8 and 11-11. Hydrostratigraphic layers are defined in Section 11.1. Average groundwater velocity results are summarized in Table 11-14. The rate of groundwater migration varies with the hydraulic conductivity and porosity of the site soil and rock materials and ranged from 8.3 ft/yr to 274.9 ft/yr in soils, and 3.0x10⁵ ft/yr to 9.8x10⁷ ft/yr in rock. Groundwater velocities for shallow, deep, and bedrock wells are presented in Figures 11-15, 11-16, and 11-17, respectively.

11.5 Contaminant Velocity

Contaminant velocity depends on factors such as; the rate of groundwater flow, the effective porosity of the aquifer material, and the soil-water partition coefficient, or Kd term. Site specific Kd terms will be developed using samples collected during the site investigation. The testing to develop the Kd terms is still underway and the results will be presented in the CAP. The groundwater modeling to be performed in the CAP will present the velocities for the modeled contaminants.

11.6 Plume's Physical and Chemical Characterization

Plume physical and chemical characterization is detailed below for each constituent detected in porewater and groundwater samples collected and is based on the extent presented on the

isoconcentration maps (Figures 10-47 through 10-94) and cross sections (10-95 through 10-108). These descriptions are based on a single groundwater sampling event.

As described in the approved Work Plan, both unfiltered and filtered (0.45 um filter) samples were collected for analyses of constituents whose results may be biased by the presence of turbidity.^[1] Unless otherwise noted, concentration results discussed are for the unfiltered samples and would represent total concentrations.

- Antimony – Concentrations of antimony exceeding the IMACs in the shallow wells is limited to CLMW-1 the northwest corner of the active ash basin, south of the western portion of the ash storage area. Antimony exceedances of the IMACs in deep wells were identified beneath the ash basins and ash storage area. However, antimony was reported in background sample location MW-24D at concentration exceeding the IMACs. Antimony exceedances of the IMACs in the bedrock monitoring wells are located to the northwest portion of the active ash basin, beneath the ash storage area, and beneath the Units 1-4 inactive ash basin. These concentrations are equal to or less than the concentration of antimony reported in the background sample collected from MW-24D and within the historical range of antimony results reported for MW-24D and MW-24DR.
- Arsenic – Arsenic concentrations exceeding the 2L Standards are limited to the shallow wells in the eastern portion of the ash storage area (AS-4S), the northwest corner of the western portion of the ash storage area (AS-2S), and the east side of the Unit 5 inactive ash basin (U5-6S). Arsenic exceedances in the deep wells exceeded the 2L Standards on the west side of the Unit 5 inactive ash basin (U5-2D). Arsenic exceedances of the 2L Standards were not reported in any groundwater samples collected from the bedrock monitoring well samples.
- Barium – Barium exceedances of the 2L Standards in the shallow monitoring wells are limited to the groundwater sample collected from U5-6S, located on the Unit 5 inactive ash basin saddle dam. One barium exceedance of the 2L Standards was reported in the deep monitoring well GWA-26D, located southwest of the active ash basin. One barium exceedance was reported at bedrock monitoring well GWA-29BR, located beneath the eastern portion of the ash storage area and between the Units 1-4 inactive ash basin and the western portion of the ash storage area.
- Beryllium – Beryllium exceedances of the IMACs were reported for groundwater results near the saddle dam of the Unit 5 inactive ash basin, beneath and south of the Units 1-4 inactive ash basin, and beneath the ash storage area. Exceedances of the beryllium IMAC in the deep monitoring wells were reported at the saddle dam of the Unit 5 inactive ash basin, in one monitoring well on the west side of the western portion of the ash storage area (CLMW-3D), and adjacent to the Broad River between the Units 1-4 inactive ash basin and the western portion of the ash storage area (GWA-29D). A beryllium exceedance of the IMAC in the bedrock wells was reported at monitoring well AS-7BR, located beneath the western portion of the ash storage area.

^[1] The USEPA (EPA 2002) recommends that when possible, especially when sampling for contaminants that may be biased by the presence of turbidity, the turbidity reading is desired to stabilize at a value below 10 Nephelometric Turbidity Units (NTUs)

- Boron – Concentrations of boron which exceed the 2L Standards in the shallow monitoring wells were reported northeast of the active ash basin near the downstream dam (MW-11S) and beneath the western portion of the ash storage area. One exceedance of boron was reporting in monitoring well GWA-27D located to the west of the active ash basin. Boron exceedance of the 2L Standards were not reported in the groundwater samples collected from the bedrock monitoring wells on the site.
- Chromium – Exceedances of the 2L Standards for chromium in the shallow monitoring wells are located at the saddle dam of the Unit 5 inactive ash basin in monitoring well U5-6S and in the eastern portion of the ash storage area in AS-4S. An exceedance of the 2L Standards for chromium was also reported in the western portion of the ash storage area at CLMW-3S and at background well location MW-30S; however, both of the results in the dissolved phase for these sample locations were less than the 2L Standards. Concentrations greater than the 2L Standards for chromium in the deep monitoring wells include locations beneath, south and east of the Unit 5 inactive ash basin, beneath the Units 1-4 inactive ash basin, the ash storage area, and north of the active ash basin. Chromium exceedances in the bedrock wells are located northeast of the Unit 5 inactive ash basin in monitoring well GWA-32BR, and beneath the western portion of ash storage area and the active ash basin.
- Cobalt – Concentrations greater than the IMACs for cobalt are fairly wide-spread across the site in the shallow monitoring wells. The greatest cobalt concentrations are located at the Unit 5 inactive ash basin saddle dam and north of the active ash basin downstream dam adjacent to the Broad River. Cobalt exceedances of the IMAC in the deep wells are located beneath each of the ash basins and beneath the western portion of the ash storage area. Cobalt exceedances of the IMAC in the bedrock wells are reported beneath and north of the active ash basin and beneath and west of the western portion of the ash storage area.
- Iron – Concentrations of iron exceeding the 2L Standards are reported across the site in the shallow wells. Iron concentrations which exceed the background concentration ranges reported for MW-24D and MW-24DR were reported beneath and east of the Unit 5 inactive ash basin, beneath the ash storage area, and beneath, north, and west of the active ash basin. Concentrations of iron exceeding the the 2L Standards are reported across the site in the deep wells. Iron concentrations which exceed the background concentration ranges reported for MW-24D and MW-24DR were reported beneath and east of the Unit 5 inactive ash basin, beneath and east of the Units 1-4 inactive ash basin, and beneath the active ash basin. The iron concentrations exceeding the 2L Standards in the bedrock monitoring wells are generally within the range of background concentrations at MW-24D and MW-24DR with the exception of the sample collected from AB-4BR.
- Lead – Concentrations of lead exceeding the 2L Standards are reported in the shallow monitoring well located at the Unit 5 inactive ash basin saddle dam (U5-6S), and beneath the eastern portion of the ash storage area (AS-4S). A 2L Standards exceedance for lead was reported in the deep monitoring well GWA-29D located between the Units 1-4 inactive ash basin and the western portion of the ash storage area. The dissolved phase results form this sample are less than the 2L Standards for

lead. Lead exceedances of 2L Standards were not reported for any of the bedrock monitoring wells.

- Manganese – Concentrations of manganese exceeding the 2L Standards are found throughout the site in the shallow, deep, and bedrock monitoring wells.
- Mercury – Concentrations of mercury exceeding the 2L Standards is limited to the deep monitoring well located in the central portion of the active ash basin (AB-4D). The dissolved phase concentration in this well was reported at a concentration less than the 2L Standards. No exceedances of the 2L Standards for mercury were reported in the shallow or bedrock wells.
- Nickel – Concentrations of nickel exceeding the 2L Standards in the shallow monitoring wells are located on the east side of the Unit 5 inactive ash basin (U5-6S), the eastern portion of the ash storage (AS-4S), and northwest of the active ash basin and northwest of the active ash basin downstream dam. Nickel 2L Standards exceedances in the deep wells is limited to the monitoring well in the northeast portion of the Unit 5 inactive basin (U5-5D). Nickel exceedances of the 2L Standards were reported in bedrock monitoring well AS-7BR located in the western portion of the ash storage area. The dissolved phase nickel result was below the 2L Standards in this well.
- Sulfate – Concentrations of sulfate greater than the 2L Standards in the shallow monitoring wells are limited to the well located northeast of the Units 1-4 Inactive ash basin (GWA-11S). Sulfate exceedances of the 2L Standards in the deep wells are located north of the Unit 5 inactive ash basin (MW-38D_ and west of the active ash basin (MW-23D). Sulfate exceedances in the deep aquifer are limited to the monitoring well located in the western portion of the ash storage area (AS-7BR).
- TDS – Concentrations of TDS greater than the 2L Standards in the shallow monitoring wells are limited to the well northerneast of the Units 1-4 Inactive ash basin (GWA-11S). Sulfate exceedances in the deep monitoring wells are located north and east of the Unit 5 Inactive ash basin, west of the active ash basin, southwest of the Units 1-4 inactive ash basin, and north of the western portion of the ash storage area. TDS exceedances of the 2L Standards in the bedrock wells are located in the northwest portion of the active ash basin (AB-3BRU) and the ash storage area.
- Thallium – Concentrations greater than the 2L Standards for thallium in the shallow groundwater monitoring wells are located to the east and northeast of the Unit 5 inactive ash basin and under the northern portion of the active ash basin, the ash storage area, and the Units 1-4 inactive ash basin.. Thallium concentrations in the deep monitoring wells were reported in the northeast portion of the Unit 5 Inactive ash basin, at the active ash basin upstream dam (GWA-20D), and between the Units 1-4 inactive ash basin and the western portion of the ash storage area. No exceedances of 2L Standards were reported for thallium in the bedrock monitoring wells.
- Vanadium – The vanadium method reporting limit provided by the analytical laboratory was 1.0 ug/L. The IMAC for vandium is 0.3 ug/L. The vanadium results reported at concentrations less than the laboratory method reporting limit are estimated. During subsequent monitoring events, a laboratory method reporting equal to or less than the IMAC should be utilized.

Boron is mobile when released to groundwater; it does not readily precipitate, and has a relatively low affinity for sorption. Boron was identified by the USEPA as one of the leading indicators for releases of contaminants associated with ash. Because of these characteristics, boron can be used to represent the general extent of groundwater impacted by ash.

11.7 Groundwater / Surface Water Interaction

As discussed in Section 5.2, groundwater flow typically follows the topographic gradient and shallow groundwater generally discharges to nearby surface water bodies (i.e. streams).

Groundwater/surface water interaction appears to be occurring along the stretch of Suck Creek that transects the site. Concentrations of boron, calcium, chloride, sulfate and TDS appear at elevated concentrations at the surface water sample collected downgradient of the toe of the active ash basin upstream dam (SW-3) compared to the background surface water sample (SW-2) collected from the creek. None of these parameters exceed the 2B Standards in the collected surface water samples. This suggests groundwater/surface water interaction at the site which is indicative of migration of parameters from the ash basin to groundwater and ultimately to surface water at the site.

11.8 Estimated Seasonal High Groundwater Elevations – Compliance Wells

Estimated Seasonal Low (ESL) and Estimated Seasonal High (ESH) groundwater elevations were calculated using historical groundwater elevations for select compliance and voluntary wells at the site. The calculated ESL and ESH depth to water (DTW) was performed statistically by multiplying the standard deviation of the historical DTW measurements by a factor of 1.2 then adding to the mean DTW measurement. To obtain the site modification factors for ESL and ESH conditions, the calculated ESL and ESH DTW in the historical site wells were compared to the current groundwater levels on site and the difference was calculated. This difference between ESH and ESL DTW and current conditions was then averaged for the representative site wells to create a modification factor to add to current DTW. Monitoring wells MW-21D, MW-23D, MW-24D, and MW-25D were selected as the most representative wells for natural seasonal fluctuations at the site, as they are located outside of the ash basin embankments and are, therefore, less likely to be influenced by the water level in the ash basins. Appendix H summarizes calculated ESH and ESL groundwater elevations for newly installed groundwater monitoring wells.

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12.0 Screening-Level Risk Assessment

The prescribed goal of the human health and ecological screening level risk assessments is to evaluate the analytical results from the COI sampling and analysis effort and using the various criteria taken from applicable guidance, determine which of the COIs may present an unacceptable risk, in what media, and therefore, should be carried through for further evaluation in a baseline human health or ecological risk assessment or other analysis, if required.

Constituents of Probable Concern (COPCs) are those COIs that have been identified as having possible adverse effects on human or ecological receptors that may have exposure to the COPCs at or near the site. The COPCs serve as the foundation for further evaluation of potential risks to human and ecological receptors.

To support the CSA effort and inform corrective action decisions, a screening level evaluation of potential risks to human health and the environment to identify preliminary, media-specific COPCs has been performed in accordance with applicable federal and state guidance, including the Guidelines for Performing Screening Level Ecological Risk Assessments within the North Carolina Division of Waste Management (NCDENR, 2003). The criteria for identifying COPCs vary by the type of receptor (human or ecological) and media, as shown in the comparison of contaminant concentrations in various media to corresponding risk-based screening levels presented in Tables 12-1 through 12-9.

In the human health and ecological screening level risk assessments, the maximum concentrations detected for all COIs, [or other appropriate data point (i.e., the analytical reporting limit [RL]) in the 2015 sampling and analyses for coal ash detection and assessment monitoring analytes were compared against established and conservative human health and ecological screening toxicity reference values, likely to be protective for even the most sensitive types of receptors.

These comparisons are used to determine which COIs present a potentially unacceptable risk to human and/or ecological receptors and may warrant further evaluation. Those COIs determined to pose a potential for adverse impacts are identified as preliminary COPCs.

Other factors that will be considered qualitatively in the evaluation of final COPCs that would be incorporated into a baseline risk assessment include frequency of detection and a comparison to background. Site- and media-specific risk-based remediation standards may be calculated, pending additional sample collection, if and where additional sampling and site-specific standards are deemed necessary.

12.1 Human Health Screening

12.1.1 Introduction

This screening level human health risk assessment has been prepared in accordance with applicable NCDENR and USEPA guidance and the approved Work Plan.

12.1.2 Conceptual Site Model

The Conceptual Site Model (CSM) is a dynamic tool for understanding site conditions and potential exposure scenarios for human receptors that may be exposed to site-related contamination. The CSM provides graphical representation of the following:

- A source and mechanism of chemical release;
- A retention or transport medium for COPCs;
- A point of contact between the human receptor and the medium; and
- A route of exposure to constituents for the potential human receptor at the contact point.

An exposure pathway is considered complete only if all four “source to receptor” components are present. A CSM has been prepared illustrating potential exposure pathways from the source area to possible receptors (see Figure 12-1). The information in the CSM has been used in conjunction with the analytical data collected as part of the CSA to determine COPCs for the site.

Potential receptors are defined as human populations that may be subject to contaminant exposure. Both current and future land and water use conditions were considered when determining exposure scenarios. Current and future land use of the CSS site and associated ash basins and ash storage areas is expected to remain predominantly industrial as Units 5 and 6 of the coal-fired generating station are currently in operation (HDR, 2014c). Lands surrounding the site include residential, agricultural, and undeveloped areas, as well as Broad River, which supplies water to various municipalities (USEPA, 2014a).

The following potential receptors are identified in the CSM:

- Current/future on-site construction worker with potential exposure to groundwater in trenches, surface and subsurface soil and surface water;
- Current/future on-site outdoor worker with potential exposure to surface soil and surface water;
- Current/future adult and child off-site resident with potential exposure to surface soil and groundwater; and
- Current/future on-site trespasser with potential exposure to surface soil, surface water and sediment.

Other exposure pathways for all potential receptors were evaluated and it was determined that they would not have a significant impact on the risk assessment (e.g., outdoor worker inhalation of inorganics in surface water in open air). Other exposure scenarios will also serve as surrogates that will provide information about the magnitude of these potential risks.

The following presents a description of each receptor and potentially complete exposure pathway.

12.1.2.1 Current/Future Construction Worker

It was assumed that construction activities during decommissioning and restoration activities of CSS could take place on-site and that construction workers would potentially be exposed to COPCs in various media during this timeframe. The potentially complete exposure pathways include incidental ingestion, dermal contact and particulate inhalation exposure to surface and subsurface soil. Construction workers in a trench with contact to groundwater may have inhalation of metal COPCs with inhalation toxicity criteria and incidental ingestion of and dermal contact (over limited parts of the body) with groundwater. Given the presence of the ash basins and ash storage areas, dermal contact and incidental ingestion exposure to surface water would also be considered a potentially complete exposure pathway for this receptor.

12.1.2.2 Current/Future Outdoor Worker

Outdoor workers are assumed to be involved with non-intrusive activities, e.g., landscapers that will maintain the site. This receptor reflects a longer timeframe and different exposure pathways than that of construction workers. Outdoor workers are assumed to have incidental ingestion, dermal contact and particulate inhalation exposure to surface soil as well as dermal contact and incidental ingestion exposure to surface water (e.g., ash basins).

Exposure to COPCs in groundwater is not identified in the CSM because outdoor workers are assumed not to ingest untreated water; any COPCs aerosols or fumes will dissipate in open air, and there is limited opportunity for dermal contact. Construction worker exposure scenarios are considered a conservative surrogate to estimate the potential risk from groundwater to outdoor workers.

12.1.2.3 Current/Future Off-Site Resident (Adult/Child)

The potential for off-site residents to be exposed to COPCs in untreated groundwater is included in the CSM as approximately 100 private water supply wells were identified in Rutherford and Cleveland Counties within a 0.5-mile radius of the ash basin compliance boundary surrounding CSS, as described in Section 4.0 above and the 2014 Drinking Water Supply Well and Receptor Survey and its Supplement (HDR 2014a and b) (Figure 4-1). These exposures will consider all on and off-site monitoring well data, excluding the receptor survey data, which is being handled independent of this risk analysis.

Exposure routes are to include ingestion of groundwater (not incidental, but potable use) as well as dermal contact during bathing/showering and inhalation during bathing/showering for those metals in groundwater with available inhalation-based toxicity criteria.

Residents are assumed to be exposed to contaminants in surface soil during non-intrusive outdoor activities (e.g., gardening); the potential exposure pathways include ingestion, dermal and inhalation of soil particulates.

The Broad River is a public drinking water supply that is treated before consumption (NCBRWA 2014). Therefore, residential exposure to untreated surface water has not been evaluated.

12.1.2.4 Current/Future Trespasser (Adolescent/Adult)

Trespassers may come into direct contact with or incidentally ingest surface water and sediment while on-site and near the Broad River during what is assumed to be predominantly recreational activity. This will occur at different rates depending on the specific activity and setting. The exposure parameters for this scenario will be determined and will incorporate all on- and off-site data for these media.

Exposure routes are to include incidental ingestion, dermal contact and particulate inhalation of surface soil, as well as incidental ingestion and dermal contact with surface water and sediment. This receptor reflects greater exposure to surface water, sediment and soil COPCs compared to potential exposures of similar potential receptors, e.g., off-site recreator.

12.1.3 Human Health Risk-Based Screening Levels

A comparison of contaminant concentrations in various media to corresponding risk-based screening levels has been made and is presented in Tables 12-1 through 12-5. These include:

- Soil: USEPA industrial soil Regional Screening Levels (RSLs) at a target cancer risk of 1E-06 and noncancer Hazard Quotient of 0.1
- Groundwater: USEPA tap water RSLs and NCDENR 2L Standards
- Surface water: USEPA National Recommended Water Quality Criteria and NCDENR 2B Standards, considering the surface water classification for local water bodies
- Sediment: USEPA residential soil RSLs

Tables 12-1 Screening Levels and NCDENR Title 15A, Subchapter 2L Standards; Table 12-2, the Comparison of Soil Sample Concentrations to EPA Residential and Industrial Soil Regional Screening Levels; Table 12-3, the Comparison of Surface Water Sample Concentrations to EPA National Recommended Water Quality Criteria and North Carolina Surface Water Standards; and Table 12-4, the Comparison of Sediment Sample Concentrations to EPA Residential Soil Regional Screening Levels.

Tables 12-1 through 12-4 present the constituents that were detected at concentrations exceeding their relevant human health or other applicable criteria on a media-specific basis, in ground and surface water, sediment, and soil. A summary of the COPCs is provided in Table 12-5.

- In groundwater: zinc was eliminated as a COPC. With the exception of sodium and titanium, which were retained as a result of having no screening value for comparison and cadmium, whose RL exceeded the screening value, all other constituents exceeded their respective screening value. See Table 12-1 for maximum concentrations detected, the detailed screening results, identification of COPCs, and contaminant categories.
- In soil: arsenic, cobalt, manganese, and thallium were detected at concentrations exceeding the industrial soil screening levels and are determined to be COPCs. Sodium is retained by default, due to a lack of a screening value. See Table 12-2 for the soil COPC maximum concentrations, COPCs, and contaminant category data.

- No surface water COPC concentrations exceed their respective screening values, as shown in Table 12-3. Total chromium, copper, iron, lead, manganese, sodium, vanadium, and zinc are retained as COPCs based on a lack of criteria for comparison. Beryllium, boron, cadmium, total chromium, copper, iron, lead, manganese, mercury, selenium, sodium, vanadium, and zinc are retained as COPCs based on a lack of criteria for comparison.
- Sediment COPCs and contaminant categories are presented in Table 12-4, which shows that aluminum, antimony, arsenic, beryllium, cobalt, iron, manganese, molybdenum, nickel, thallium, and vanadium are determined to be COPCs based on exceedances of screening values. Sodium is retained due to a lack of screening value.,

Constituents were not screened out as COPCs based on a comparison to background concentrations, as USEPA recommends all COIs exceeding risk-based screening levels be considered in a baseline risk assessment (USEPA 2002). Statistical background concentrations have been developed as Prediction Limits (PLs), calculated for each constituent using groundwater data in site background wells. PLs are a calculation of the upper limit of possible future values based on the Statistical Analysis of Groundwater Monitoring Data at RCRA Facilities Unified Guidance (USEPA, March 2009). If concentrations of COIs detected exceed the PL, then the groundwater concentrations are assumed to have increased above background levels. Site-specific background concentrations will be considered in the uncertainty section of the baseline risk assessment, if determined to be required.

12.1.4 Site-Specific Risk Based Remediation Standards

Based on the results of the comparison to risk-based screening levels, media-specific remediation standards will be calculated in accordance with the Eligibility Requirements and Procedures for Risk-Based Remediation of Industrial Sites Pursuant to North Carolina General Statute 130A-310.65 to 310.77, should additional sample collection and site-specific standards be deemed necessary.

12.1.5 NCDENR Receptor Well Investigation

Numerous off-site private water supply wells and at least one spring were sampled and analyzed for constituents as part of NCDENR's well testing program of receptors within 1,500 feet of the Cliffside compliance boundary, as described in Section 4.0. At CSS, there were numerous exceedances of the 2L Standards for iron and the Department of Health and Human Services's (DHHS) screening level for hexavalent chromium. Other exceedances of 2L Standards, IMACs, or DHHS screening levels occurred in one or two wells near Cliffside: manganese, vanadium, cobalt, total chromium, and sodium. No COI concentration exceeded applicable federal Safe Drinking Water Act drinking water standards. NCDENR recommended that 15 wells not be utilized for drinking water due to presence of hexavalent and total chromium, iron, manganese, cobalt, and/or sodium in some or all of these wells. No information gathered as part of this assessment suggests that any water supply well is impacted by the CSS ash basins or ash storage area.

12.1.6 Human Health Risk Screening Summary

A CSM was developed to identify potential pathways of exposure from COPC source to human receptor populations; including several possible exposure scenarios. Maximum concentrations of constituents were compared to media-specific screening levels; constituents exceeding screening levels and those having no screening levels or issues with RLs were retained as COPCs, in accordance with guidance. As a result of the screening, the majority of constituents were determined to be COPCs in groundwater; only zinc is excluded. In soil, four constituents exceed their screening values, two others are retained by default. In surface water, eight COIs are retained as COPCs, all due to a lack of screening values, none due to an exceedance of the criteria. A total of 12 constituents are determined to be COPCs in sediment, all but sodium as a result of exceeding their respective screening value.

12.2 Ecological Screening

12.2.1 Introduction

This screening-level ecological risk assessment (SLERA) has been prepared in accordance with the Guidelines for Conducting a Screening Level Ecological Risk Assessments within the North Carolina Division of Waste Management (NCDENR, 2003). An ecological CSM has been developed for this site and is provided as Figure 12-2.

12.2.2 Ecological Setting

12.2.2.1 Site Summary

Refer to Section 2.0 for a description of the CSS site.

12.2.2.2 Regional Ecological Setting

The site is located in the Southern Outer Piedmont eco-region of North Carolina adjacent to Broad River; this eco-region is bordered by the Northern Inner Piedmont and Carolina Slate Belt eco-regions (Griffith et al. 2002).

12.2.2.3 Description of the Eco-Region and Expected Habitats

The region consists of irregular plains and low to moderate gradient streams with less precipitation and elevation than the Inner Piedmont. The common rock types include gneiss, schist and granite covered by deep saprolite and mostly red, clayey subsoil. Land cover consists of mixed white oak forests, croplands and pastures as well as pine plantations (Griffith, et al. 2002).

12.2.2.4 Watershed in which the Site is Located

The site is located in the Broad River Basin watershed. The North Carolina portion of the Broad River Basin encompasses approximately 1,513 miles in all or in part of eight counties. It straddles the southeastern corner of the Blue Ridge eco-region and the southwestern portion of the Piedmont eco-region.

12.2.2.5 Average Rainfall

The average annual precipitation for Mooresboro has been 49.56 inches over the past 30 years. The average for the State of North Carolina is 48.87 inches (Weather DB, 2015).

12.2.2.6 Average Temperature

The average temperature for Mooresboro is 59.25° F. The average winter temperature is 46.6° F. The average spring temperature is 54.5° F. The average summer temperature is 75° F and average fall temperature is 61° F (Weather DB, 2015).

12.2.2.7 Length of Growing Season

According to the North Carolina State University Cooperative Extension, the average growing season for Cleveland County is 196 days, with a standard deviation of 14 days.

12.2.2.8 Threatened and Endangered Species that use Habitats in the Eco-Region

A list of threatened and endangered species for Cleveland and Rutherford Counties is provided in Table 12-10.

12.2.2.9 Site-Specific Ecological Setting

An ecological checklist and habitat figure has been completed for this site and is provided in Appendix I.

The site is located on the Broad River in Rutherford and Cleveland Counties near the town of Boiling Springs, North Carolina. The June 2015 AMEC Natural Resources Technical Report identified 26 potential jurisdictional wetland areas on the site (acreage was not provided). No open water areas were identified. There were 28 potential jurisdictional drainage features; 16 intermittent and 12 perennial streams.

Portions of the Site adjacent to the Broad River and along the western Suck Creek are located within the regulated 100-year flood zone (AMEC, 2015).

Requests for information were submitted to several federal and state agencies, in accordance with the North Carolina Guidelines for Performing Screening Level Ecological Risk Assessments (NCDENR, 2003). A copy of the requests and responses are provided in Appendix I and a summary of the information is provided, as follows.

North Carolina Department of Cultural Resources

In a letter dated June 23, 2015, the North Carolina Department of Cultural Resources indicated that there are “no historic resources which would be affected by the project”.

North Carolina Natural Heritage Program

In a letter dated June 9, 2015, the North Carolina Natural Heritage Program (NCNHP) provided information obtained from their database, both for the CSS site and within a one-mile radius of the site. According to the NCNHP database, there are no records for natural areas or

conservation/managed areas located within the area evaluated. According to the NCNHP, their database identified one Natural Area, Island Ford Flatrocks, located within a one-mile radius of the CSS site. No Managed Areas are documented within a one-mile radius.

North Carolina Wildlife Resources Commission

In a letter dated June 19, 2015, the North Carolina Wildlife Resources Commission (NCWRC) reported the following:

- The site drains to the Broad River in the Broad River basin.
- There are records for the state significantly rare quillback (*Carpoides cyprinus*), seagreen darter (*Etheostoma thalassinum*), Santee shiner (*Cyprinella zanema*), Piedmont shiner (*Notropis* sp. cf. *chlorocephalus*), and Carolina foothills crayfish (*Cambarus johni*) in the Broad River watershed. There are records for the state threatened dwarf-flowered heartleaf (*Hexastylis naniflora*) and the state special concern – vulnerable Pursh's wild-petunia (*Rueillia purshiana*) near the site. In addition, there are historical records for the state endangered dwarf chinquapin oak (*Quercus prinoides*) near the site.
- There is recreational fishing in the Broad River. Recreational species include: largemouth bass, smallmouth bass, muskellunge, redbreast sunfish, and white bass.

United States Department of Agriculture, National Forests in North Carolina

In an email dated May 28, 2015, it was reported that there are no Designated and Proposed Federal Wilderness and Natural Areas, National Preserves and Forests, or Federal Land Designated for the Protection of Natural Ecosystems with a half-mile of the CSS site.

United States Department of the Interior, National Park Service

In an email dated June 3, 2015, the United States Department of the Interior, National Park Service indicated that "the NPS has not identified any resource concerns at this time".

12.2.2.10 On-site and Off-site Land Use

On-site land use is approximately 20% heavy industrial, 10% light industrial, 50% undisturbed, and 20% other. Land use within a one-mile radius of the site is 30% rural, 30% undisturbed, 30% agricultural, and 10% other (e.g., water bodies including Broad River).

12.2.2.11 Habitats within the Site Boundary

Based on the findings of HDR's July 7, 2015 site visit, the following habitats are present on site.

- 300 acres of Mixed Hardwoods
- 45 acres of Oak-Hickory Hardwoods
- 40 acres of Mixed Pines/Pine Plantation
- 96 acres of Bottomland Hardwoods
- 164 acres of Early Successional/Scrub Shrub

- 160 acres of Open Fields
- Aquatic features including ash basins, streams, and wetlands

For a detailed description of habitats, refer to the Checklist for Ecological Assessments provided in Appendix I.

12.2.2.12 Description of Man-made Units that may Act as Habitat

A 25-acre active ash basin and two other basins are present on site and may act as man-made habitat.

12.2.2.13 Site Layout and Topography

The natural topography at the CSS site ranges from approximate high elevations of 832 feet southwest of the active ash basin and 848 feet and 856 feet west and southwest of the Unit 5 inactive ash basin, respectively to a low elevation of 664 feet at the interface with the Broad River on the northern extent of the site. Overall topography generally slopes from a south to north direction with an elevation loss of approximately 190 feet over an approximate distance of 4,000 feet. Surface water drainage generally follows site topography and flows from the south to the north across the site except where natural drainage patterns have been modified by the ash basins, ash storage area, or other construction.

12.2.2.14 Surface Water Runoff Pathways

Swales, drainage ditches, and depressions were observed during HDR's July 15, 2015 site visit. Unnamed drainage features are located near the western and eastern edges of the site and generally flow north toward the Broad River.

12.2.2.15 Soil Types

Based on lithological data included in soil boring and monitoring well installation logs provided by Duke Energy (A.E. Drilling Services, Inc., 1995 and 1996, MACTEC, 2011, and S&ME, Inc., 2005), subsurface stratigraphy consists of the following material types: fill, ash, residual soil, saprolite, alluvium, PWR, and bedrock. In general, residuum, PWR and bedrock were encountered beneath most areas of the site. Alluvium was encountered in borings advanced east of Suck Creek and north of the Broad River. Bedrock was consistently encountered at varying depths across the site (HDR 2014).

AMEC's review of the National Resource Conservation Service (NRCS) Soil Survey indicated the presence of numerous soil map units within the study area. The primary units include Buncombe loamy sands, Chewacla loams, Pacolet-Bethlehem complex, Rion-Ashlar complex, Rion-Cliffside complex, loamy Uthordents, urban land, and open water. Chewacla soil series are considered hydric by the NRCS (AMEC 2015).

12.2.2.16 Species Normally Expected to Use Site under Relatively Unaffected Conditions

Terrestrial communities occur in both natural and disturbed habitats in the study area; these may support a diversity of wildlife species. Information on the species that would normally be

expected to use this and similar sites in the Piedmont eco-region under relatively unaffected conditions was obtained from relevant literature, mainly the *Biodiversity of the Southeastern United States, Upland Terrestrial Communities* (Wiley and Sons 1993) and *Biodiversity of the Southeastern United States, Aquatic Communities* (Wiley and Sons 1993).

Mammal species that may be present include eastern cottontail (*Sylvilagus floridanus*), gray squirrel (*Sciurus carolinensis*), various vole, rat and mice species, red (*Vulpes vulpes*) and gray fox (*Urocyon cinereoargenteus*), raccoon (*Procyon lotor*), Virginia opossum (*Didelphis virginiana*), and white-tailed deer (*Odocoileus virginiana*).

Avian species are the most diverse. Canopy dwellers include the great crested flycatcher (*Myiarchus crinitus*), Carolina chickadee (*Parus carolinensis*), tufted titmouse (*P. bicolor*), white-breasted nuthatch (*Sitta carolinensis*), blue-gray gnatcatcher (*Polioptila caerulea*), red-eyed vireo (*Vireo olivaceus*), yellow-throated vireo (*V. flavifrons*), various warblers and tanagers, and American redstart (*Setophaga ruticilla*).

Subcanopy species include a variety of woodpeckers, eastern pewee (*Contopus virens*), Acadian flycatcher (*Empidonax virescens*), American crow (*Corvus brachyrhynchos*), blue jay (*Cyanocitta cristata*), and Carolina wren (*Thryothorus ludovicianus*).

Catbirds (*Dumetella carolinensis*), brown thrashers (*Toxostoma rufum*), and mockingbirds (*Mimus polyglottos*) are found along adjacent brushy edges, fields, and thickets.

Understory species include wood thrush (*Hylocichla mustelina*), American robin (*Turdus migratorius*), white-eyed vireo (*Vireo griseus*), Kentucky warbler (*Oporornis formosus*), common yellow-throat (*Geothlypis trichas*), and yellow breasted chat (*Icteria virens*). Predatory birds include several hawk and owl species and the turkey vulture (*Cathartes aura*).

Amphibians and reptiles that tend to be associated with the terrestrial-aquatic interface in streams, rivers, and open waters may include certain turtles, e.g., the Striped Mud and Gulf Coast Spiny Softshell turtles; and frogs, snakes, and amphibians such as the Three-lined salamander. For a more detailed description, see Appendix I.

Streams of the southeastern piedmont support a range of aquatic benthic macroinvertebrate groups including mayflies (Ephemeroptera), stoneflies (Plecoptera), caddisflies (Trichoptera), water beetles (Coleoptera), dragonflies and damselflies (Odonata), dobsonflies and alderflies (Megaloptera), true flies (Diptera), worms (Oligochaeta), crayfish (Crustacea), and clams and snails (Mollusca).

Streams, rivers, ponds, and reservoirs support populations of game fish that may include redbreast sunfish (*Lepomis auritus*), bluegill (*Lepomis macrochirus*), warmouth (*Lepomis gulosus*), and largemouth bass (*Micropterus salmoides*). The most widespread non-game fish species are American eel (*Anguilla rostrata*), eastern silvery minnow (*Hybognathus regius*), bluehead chub (*Nocomis leptocephalus*), golden shiner (*Notemigonus crysoleucas*), spottail shiner (*Notropis hudsonius*), whitefin shiner (*N. niveus*), swallowtail shiner (*N. procne*), creek chub (*Semotilus atromaculatus*), creek chubsucker (*Erimyzon oblongus*), silver redhorse

(*Moxostoma anisurum*), yellow bullhead (*Ictalurus natalis*), flat bullhead (*I. platycephalus*), margined madtom (*Noturus insignis*), and tessellated darter (*Etheostoma olmstedi*).

12.2.2.17 Species of Special Concern

For a detailed list of species of special concern that may be present, see Table 12-10.

12.2.2.18 Nearby Critical and/or Sensitive Habitats

For a detailed description, see Section III.D of the Ecological Checklist provided in Appendix I.

12.2.3 Fate and Transport Mechanisms

Potential fate and transport mechanisms at/near the CSS site include erosion, seeps, stormwater runoff and flow of surface water bodies. An Ecological CSM (Figure 12-2) has been prepared illustrating potential exposure pathways from the source area to possible ecological receptors. The information in the ecological CSM has been used in conjunction with the analytical data collected as part of the CSA to develop an understanding of the sources, pathways and media of exposure, as well as, the receptors potentially impacted by site-related COIs.

12.2.4 Comparison to Ecological Screening Levels

The sampling and analysis program completed as part of the CSS CSA investigation is described earlier in this report. Media of primary concern for ecological receptors (i.e., surface water, sediment, and soil) have been sampled extensively, in accordance with the NCDENR approved Work Plan.

The results of the comparison of COI concentrations in various media to risk-based screening levels is presented in Table 12-6 through Table 12-9, these include:

- USEPA Region IV Recommended Ecological Screening Values for soil, surface water and sediment
- USEPA National Recommended Water Quality Criteria and North Carolina Freshwater Aquatic Life Standards

The potential for ecological risk was also estimated by calculating screening hazard quotients (HQ) using the appropriate screening value of each contaminant and comparing that value to the USEPA Region IV Ecological Screening Values. Constituents having a HQ greater than or equal to 1 are identified as COPCs.

Table 12-9 presents a summary of the COIs that were detected at concentrations exceeding their relevant ecological screening media-specific criteria. Those constituents exceeding the relevant criteria are identified as ecological COPCs for purposes of the SLERA.

Note that NCDENR SLERA guidance does not allow for exclusion of constituents as COPCs based on a comparison to background concentrations.

NCDENR guidance requires a determination of which contaminant category the COPCs fall into as a result of the data comparison to screening levels is also presented in the ecological COPC tables (Tables 12-6 through 12-9). These include:

- Category 1 – Contaminants whose maximum detection exceeds the media specific ecological screening value included in the COPC tables.
- Category 2 – Contaminants that generated a laboratory SQL that exceeds the USEPA Region IV media-specific ecological screening value for that contaminant.
- Category 3 – Contaminants that have no USEPA Region IV ecological screening value, but were detected above the laboratory SQLs.
- Category 4 – Contaminants that were not detected above the laboratory SQLs and have no USEPA Region IV ecological screening value.
- Category 5 – Contaminants whose SQL or maximum detection exceeds the North Carolina 2B Standards.

In soil, all constituents except cadmium and lead were detected at concentrations exceeding the ecological soil screening levels. The RL for antimony exceeded its screening value; sodium and strontium have no ecological criteria to use for comparison. These have been retained as COPCs by default. See Table 12-6 for detailed information, including the maximum concentrations detected. For several COPCs, the exceedances are greater than one order of magnitude above the screening levels; these include aluminum, boron, total chromium, cobalt, iron, manganese, molybdenum, selenium, thallium and vanadium.

Based on the comparison of maximum detected concentrations to screening criteria, aluminum and mercury and zinc are identified as ecological COPCs in surface water (freshwater). Barium, cobalt, manganese, molybdenum, strontium and vanadium are retained by default due to the fact that there are no ecological criteria available or an issue related to screening values versus RLs. Further information on the screening performed and characterization as to the contaminant category each COPC falls into is provided in Table 12-7.

COPCs identified in sediment based on a comparison of maximum detected concentrations to available criteria include antimony, arsenic, cadmium, chromium, copper, lead, nickel and zinc; aluminum, barium, beryllium, boron, cobalt, iron, manganese, molybdenum, selenium, sodium, strontium, and vanadium were retained due to issues related to their RL exceeding the screening value or there being no screening value available. Details on the COPC screening and contaminant category are provided in Table 12-8.

Constituents were not screened out as COPCs based on a comparison to background concentrations, as NCDENR SLERA guidance does not allow for screening based on background. Site-specific background concentrations, discussed above in Section 12.1.3, will be considered in the uncertainty section of the baseline ecological risk assessment, if determined to be necessary.

12.2.5 Uncertainty and Data Gaps

There are uncertainties inherent in any environmental investigation and risk evaluation that involve natural heterogeneity of the media, nature, and extent of constituents in the environment, due to their individual fate and transport characteristics, and varied, site-specific conditions. These uncertainties are considered in developing the sampling and analysis plan, data quality assurance processes, and understanding of the site.

These screening level assessments are designed to be very conservative in identifying potential COPCs that would be carried forward into a baseline human health and/or ecological risk assessment. They include all on- and off-site analytical data and use the maximum concentration detected as the comparison point to applicable screening criteria. Also, no constituents were eliminated as COPCs based on background levels; this will be evaluated in the baseline risk assessment, if they are required to be performed. These are highly unlikely to be the actual exposure concentrations, given the natural attenuation, dilution, and distances to potential receptors.

There is a high level of confidence that any constituent with potential to impact human health or ecological receptors has been identified as a result of these assessments.

12.2.6 Scientific/Management Decision Point

If through the HQ analysis it is determined that constituents have been detected at maximum concentrations that exceed applicable screening criteria, it is an indication that additional assessment of potential risks is warranted. This does not mean that impacts are in fact, occurring; only that further data collection or evaluation should be considered.

This determination is known as the Scientific/Management Decision Point (SMDP) and the conclusion reached must be one of the following:

- *There is adequate information to conclude that the ecological risks are negligible; or*
- *Site has inadequate data to complete the risk characterization. Data gaps need to be filled prior to completion of the screening process; or*
- *The information indicates a potential for adverse ecological effects and a more thorough assessment is warranted.*

Given that several COPCs have been identified as having an HQ of greater than 1 in soil, surface water, and sediment, there is adequate information indicating a potential for adverse effects to occur and a baseline ecological risk assessment may be warranted. The need for a separate baseline ecological risk assessment should be considered in light of the other ongoing or planned environmental impact studies for this site.

Given that several COPCs have been identified as having a HQ of greater than 1 in soil, surface water and sediment, there is adequate information indicating a potential for adverse effects to occur and a baseline ecological risk assessment (BERA) may be warranted. The need for a separate BERA is being considered in light of other ongoing or planned environmental impact studies for this site.

12.2.7 Ecological Risk Screening Summary

The SLERA has identified that the potential exists for adverse ecological impacts due to exposure to COPCs in soil, surface water, and/or sediment. Cadmium is the only constituent that has been excluded as a COPC in soil and numerous COPCs exceed their respective screening criteria by one or two orders of magnitude. Notably fewer COIs have been identified in surface water and sediment and several of those are retained by default for having no criteria or due to RL issues, not due to maximum concentrations actually exceeding screening criteria. Potential impacts from limited ecological receptor groundwater exposure are minimal and have not been evaluated. Further evaluation of potential ecological impacts appears to be warranted. For CSS, identification of potential data gaps and overall coordination of further ecological risk assessment efforts, specifically for surface water and sediment impacts should consider any other activities that are ongoing related to ash basin closure activities to avoid duplication of effort. Further evaluation of potential ecological impacts appears to be warranted.

13.0 Groundwater Modeling

Groundwater modeling will be performed and submitted in the CAP in accordance with NC DENR's Conditional Approval letter. The groundwater modeling will consist of groundwater flow and fate and transport modeling, performed with MODFLOW and MT3DMS, and batch geochemical modeling, performed with PHREEQC. The following section presents an overview of the fate and transport modeling, the batch geochemical modeling and the site geochemical conceptual model.

The CAP will also present a discussion of the geochemical properties of the COIs and how these properties relate to the retention and mobility of these constituents.

13.1 Fate and Transport Groundwater Modeling

A three-dimensional groundwater flow and contaminant fate and transport model (MODFLOW/MT3DMS Model) will be developed for the ash basin site. The objective of the modeling will be to predict the following in support of the CAP:

- Predict concentrations of the COIs at the compliance boundary or other locations of interest over time,
- Estimate the groundwater flow and constituent loading to surface water discharge areas, and
- Predict approximate groundwater elevations in the ash for the proposed corrective action.

The model and model report will be developed in general accordance with the guidelines found in the memorandum *Groundwater Modeling Policy, NC DENR DWQ, May 31, 2007* (DENR modeling guidelines).

The groundwater model will be developed from the hydrogeologic conceptual model presented in the CSA, from existing wells and boring information provided by Duke Energy, and from information developed during the site investigation. The model will also be supplemented with additional information developed by HDR from other Piedmont sites, as applicable. The SCM is a conceptual interpretation of the processes and characteristics of a site with respect to the groundwater flow, boundary conditions, and other hydrologic processes at the site.

Although the site is anticipated in general to conform to the LeGrand conceptual groundwater model, due to the configuration of the active ash basin and the additional possible sources (the ash storage area, the Units 1-4 inactive ash basin, and the Unit 5 inactive ash basin), and the boundary conditions present at the site, a three-dimensional groundwater model is warranted.

The groundwater modeling will be performed under the direction of Dr. William Langley, P.E., Department of Civil and Environmental Engineering, University of North Carolina Charlotte (UNCC). Groundwater flow and constituent fate and transport will be modeled using Visual MODFLOW 2011.1 (flow engine USGS MODFLOW 2005) and MT3DMS.

The modeling process, the development of the model, the development of the hydrostratigraphic layers, the model extent (or domain), and the proposed model boundary conditions were described in Section 7.0 of the work plan. To date, no changes to the proposed model development are warranted based on data collected during the site investigation.

The MT3DMS model will use site specific Kd values developed from samples collected along the major flow transects. The testing to develop the Kd terms is underway, but is not complete at this time, therefore the results of that testing will be presented in the CAP. The methods used to develop the Kd terms was presented in Section 7.7.2 of the work plan.

13.2 Batch Geochemical Modeling

As described in the Work Plan, batch geochemical simulations using PHREEQC will be used to estimate sensitivity of the proposed sorption constants used with MT3DMS and to assist in understanding the mechanisms involved in attenuation of selected constituents. Geochemical modeling using PHREEQC can be used to indicate the extent to which a COI is subject to solubility constraints, a variable Kd, or other processes. PHREEQC can also identify postulated solid phases calculation of their respective saturation indices. The specific locations where the batch geochemical modeling will be performed will be determined after the development of the Kd terms and a review of the site data.

13.3 Geochemical Site Conceptual Model

SCMs are developed to be a representation of what is known or suspected about contamination sources, release mechanisms, transport, and fate of those contaminants.² A SCM can be a written and/or graphic presentation of site conditions to reflect the current understanding of the site, identify data gaps, and be updated as new information is collected throughout the project. SCMs can be utilized to develop understanding of the different aspects of site conditions, such as a hydrogeologic conceptual site model, to help understand the site hydrogeologic condition affecting groundwater. SCMs can also be used in a risk assessment to understand contaminant migration and pathways to receptors.

On June 25, 2015, NCDENR made the following request:

Since speciation of groundwater and surface water samples is a critical component of both the site assessments and corrective action, the Division expects a geochemical site conceptual model (SCM) developed as a subsection in the Comprehensive Site Assessment (CSA) Reports. The geochemical SCM should provide a summary of the geochemical interactions between the solution and solid phases along the groundwater flowpath that impact the mobility of metal constituents. At a minimum, the geochemical SCM will describe the adsorption/desorption and mineral precipitation/dissolution processes that are believed to impact dissolved concentrations along the aquifer flowpaths away from the ash basin sources. The model descriptions should include the data upon

² EPA MNA Volume 1

which the conceptual model is based and any calculations (such as mineral saturation indices) that are made to develop the site-specific model.

Metal speciation analyses cover a broad aspect of metals' geochemistry, including solution complexation with other dissolved species and specific association with aquifer solids, such as a metal adsorbed onto HFO or precipitated as a sulfate mineral. A comprehensive speciation analysis that requires a relatively complete groundwater analysis is expected that includes use of an ion speciation computer code (such as PHREEQC) capable of calculating solution complexes, surface complexation onto HFO, and mineral saturation indices. This type of speciation calculation is necessary for the development of a geochemical SCM and understanding metal mobility in an aquifer.

In previous correspondence, NCDENR agreed that the proposed geochemical modeling described in the Work Plan, to be performed using PHREEQC, will be included in the CAP. Specifically, the model descriptions and calculations, such as mineral saturation indices, will be provided in the CAP. This approach will allow completion of the testing to develop the site-specific Kd terms and site mineralogy, and will allow the geochemical modeling to be coordinated with the groundwater flow and transport model.

Elements of the geochemical site conceptual model (GSCM) described below will be incorporated into the fate and transport and the geochemical modeling performed for the CAP. The GSCM will be updated as additional data and information associated with contaminants, site conditions, or processes such as migration of contaminants is developed. The GSCM will be useful in understanding the transport and attenuation factors that affect the mobility of contaminants at the site and the long-term capacity of the site for attenuation and stability of immobilized contaminants.

The GSCM will describe the geochemical aspects of the site sources that influence contaminant transport. Site sources at CSS consist of the active ash basin, the ash storage area, the Unit 1-4 inactive ash basin, and the Unit 5 inactive ash basin. These source areas are subject to different processes that generate leachate migrating into the underlying soil layers and into the groundwater. For example, the ash storage area would generate leachate as a result of infiltration of precipitation, while the active ash basin would generate leachate based on the pond elevation in the basin. General factors affecting the geochemistry of the site are as follows:

Factors Affecting Ash Formation (Primary Source):

- Chemical and mineralogical composition of coal
- Thermodynamics of coal combustion process

Factors Affecting Leaching in the Active Ash Basin (Primary Source Release Mechanism):

- Chemical composition of ash
- Mineral phase of ash
- Physical characteristics of ash
- Inflow of water into/out of basin
- Period of time ash has been in basin
- Geochemical conditions in ash basin
- Precipitation-dissolution reactions
- Sorptive properties of materials in ash

Factors Affecting Leaching in the Ash Storage Area (Primary Source Release Mechanism):

- Chemical composition of ash in storage area
- Mineral phase of ash in storage area
- Physical characteristics of ash in storage area
- Inflow of precipitation in to ash storage area
- Period of time ash has been in storage
- Geochemical conditions in ash storage area
- Precipitation-dissolution reactions
- Sorptive properties of materials in ash

Factors Affecting Leaching in the Units 1-4 Inactive Ash Basin (Primary Source Release Mechanism):

- Chemical composition of ash in storage area
- Mineral phase of ash in storage area
- Physical characteristics of ash in storage area
- Inflow of precipitation in to ash storage area
- Period of time ash has been in storage
- Geochemical conditions in ash storage area
- Precipitation-dissolution reactions
- Sorptive properties of materials in ash

Factors Affecting Leaching in the Unit 5 Inactive Ash Basin (Primary Source Release Mechanism):

- Chemical composition of ash in storage area
- Mineral phase of ash in storage area
- Physical characteristics of ash in storage area
- Inflow of precipitation in to ash storage area
- Period of time ash has been in storage
- Geochemical conditions in ash storage area

- Precipitation-dissolution reactions
- Sorptive properties of materials in ash

Factors Affecting Sorption and Precipitation of Constituents onto Soil/Aquifer Materials Beneath Ash (Secondary Source Release Mechanism):

- Chemical composition of soil
- Physical composition of soil
- Rate of infiltration/percolation of porewater
- Chemical composition of leachate infiltrating into soil
- Sorption capacity of soil
- Geochemistry of groundwater flowing beneath unit

Factors Affecting Desorption and Dissolution of Constituents From Soil/Aquifer Materials Beneath Ash (Secondary Source Release Mechanism):

- Chemical composition of soil
- Physical composition of soil
- Rate of infiltration/percolation of porewater
- Attenuation capacity of soil
- Chemical composition of leachate or precipitation infiltrating into soil
- Geochemistry of groundwater flowing beneath unit

The results of the Kd testing, the results from the site mineralogy testing, and the geochemical modeling developed in the CAP will be used to refine the GSCM.

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14.0 Data Gaps – Conceptual Site Model Uncertainties

14.1 Data Gaps

Through completion of groundwater assessment field activities and evaluation of data collected during those activities, Duke Energy has identified data gaps that will require further evaluation to refine the SCM. The data gaps have been separated into two groups: 1) data gaps resulting from temporal constraints and 2) data gaps resulting from evaluation of data collected during the CSA.

14.1.1 Data Gaps Resulting from Temporal Constraints

Data gaps identified in this category are generally present due to insufficient time to collect, analyze, or evaluate data collected during the CSA activities. It is expected that the majority of these data gaps will be remedied in a CSA supplement to be submitted in consultation with NCDENR.

- Mineralogical characterization of soil and rock: A total of 21 soil, two transition zone, and eight bedrock samples were submitted to three third-party mineralogical testing laboratories for analysis of soil and rock composition. As of the date of this report, Duke Energy has not received results of this testing; however, results should be available for inclusion in the CSA supplement.
- Additional Speciation Analyses: In order to meet the requirements of the NORR, Duke Energy conducted speciation of samples for arsenic, chromium, iron, manganese, and selenium along flow transects, at ash basin water sample locations, and at compliance wells with historical exceedances of the 2L Standards for speciation constituents. The scope and schedule of a second comprehensive groundwater sampling event at the CSS site is currently under discussion in consultation with NCDENR and Duke Energy.

14.1.2 Data Gaps Resulting from Review of Data Obtained During CSA Activities

- Ash Storage Area: Additional investigation is needed to refine the extent of ash in the ash storage area. Ash was not encountered in the eastern portion of the area and ash was not encountered in the southern boring in the western portion of the ash storage area.
- Unit 5 inactive ash basin: Ash was not encountered in the borings installed in the southern portions of this basin. Additional investigation is needed to refine the southern extent of ash in this area.
- Additional Data to Refine Extent and Source of TDS Exceedances: Additional refinement is needed to determine the extent and nature of TDS exceedances in the deep wells MW-23D and at GWA-14D. Additional refinement is needed to determine the extent and nature of exceedances in the area east of the Unit 5 inactive ash basin to the east of MW-42D and GWA-4D. Installation of additional monitoring wells will be required to refine the extent of the exceedances at these locations.

- Seep Samples: Seep sample location CLFSTR065 was dry during several attempted sampling events. Seep sample location CLFSTR064 could not be located during sampling. Seep sample location CLFSTR053 was inadvertently not sampled during the sampling event. Collection of water from these seeps is required to determine whether groundwater is discharging to surface water.
- Groundwater Samples: Groundwater well MW-11D, GWA-31BR, U5-3S, U5-4BR and GWA-6S were dry during several sampling attempts. Collection of water from these wells will be attempted during subsequent monitoring events.
- An ash porewater sample was inadvertently not collected from monitoring well U5-2S-SL located in the Unit 1-4 in-active basin. Additional porewater samples from the in-active basin were collected and used for the CSA. Collection of samples from this well will be conducted during subsequent monitoring events.
- The vanadium method reporting limit provided by the analytical laboratory was 1.0 ug/L. The IMAC for vandium is 0.3 ug/L. The vanadium results reported at concentrations less than the laboratory method reporting limit are estimated. During subsequent monitoring events, a laboratory method reporting equal to or less than the IMAC should be utilized.
- Review of Non-Ash Contamination Information: Review of information regarding areas of non-ash contamination (i.e., petroleum-contaminated areas) to evaluate potential interference with remedial methods is needed, if applicable.

14.2 Site Heterogeneities

Heterogeneities, with regard to groundwater flow, were not identified during completion of the CSA. In general, groundwater within the shallow aquifer, TZ material, and fractured bedrock flows generally north toward the Broad River. Heterogeneities, with regard to COI concentrations, were not identified during completion of this CSA. However, heterogeneities may be identified following completion of the groundwater model for the CSS site.

14.3 Impact of Data Gaps and Site Heterogeneities

Certain data gaps can be addressed with additional groundwater sampling at existing wells. As discussed in Section 15, the second comprehensive groundwater sampling event is planned for August/September 2015. A plan for interim groundwater sampling between submittal of the CSA and implementation of the anticipated CAP is proposed in Section 16 and will further supplement the existing data.

15.0 Planned Sampling for CSA Supplement

In accordance with CAMA, a second comprehensive groundwater sampling event at the CSS site is currently under discussion in consultation with NCDENR and Duke Energy. The second sampling event will be conducted to:

- Supplement data obtained during the initial sampling event;
- Evaluate seasonal variation in groundwater results; and,
- Collect additional samples for chemical speciation of arsenic, chromium, iron, manganese, and selenium.

15.1 Sampling Plan for Inorganic Constituents

The second sampling event for inorganic constituents will consist of the following: sampling all locations (monitoring wells, seeps, surface water, and sediment) that were sampled during the initial sampling event. All samples collected will be analyzed for total inorganic compounds. Samples with exceedances of 2L Standards during the initial sampling event will also be analyzed for dissolved-fraction inorganics.

- Collection of second set of data for all new site assessment wells, seeps and surface water for CSA work plan parameters (including total and dissolved metals using 0.45 µm filters);
- Locations that were previously dry will be re-evaluated and sampled if sufficient water is present to do so; and
- Collection of dissolved metals data using 0.1µm filters from the flow transect wells selected for geochemical modeling.

15.2 Sampling Plan for Speciation Constituents

In consultation with NCDENR and Duke Energy, speciation sampling is anticipated to be performed as follows:

- *Collection of confirmation speciation data where initial data set provided apparent anomalies as identified during the preparation of the CSAs (for hexavalent Cr in particular);*
- *Collection of speciation data gaps that may have been identified during the preparation of the CSA; and*
- *Collection of data gap information identified in the CSA's for existing wells/surface water/seep locations.*

A summary of the proposed sampling program for the second comprehensive sampling event is included in Table 15-1 and anticipated sampling locations are shown on Figure 6-2.

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16.0 Interim Groundwater Monitoring Plan

CAMA requires a schedule for continued / interim groundwater monitoring. Given that Duke Energy has recommended excavation of the Units 1-4 inactive ash basin to a lined landfill starting near the end of 2015, certain groundwater monitoring wells in these areas will be abandoned. As such, Duke Energy plans to conduct interim groundwater monitoring at select wells, as identified in Section 16.3, to bridge the gap between completion of CSA activities and implementation of the proposed CAP.

16.1 Sampling Frequency

One additional interim groundwater sampling is planned to occur during 2015 and the results will be submitted in coordination with NCDENR. Interim groundwater sampling on a quarterly basis is proposed until the CAP is approved by NCDENR. This sampling frequency will allow for evaluation of seasonal fluctuations in COI concentrations, as well as provide additional data for statistical analysis of site-specific background concentrations.

16.2 Constituent and Parameter List

The proposed constituents and parameters for analysis are presented in Table 16-1.

16.3 Proposed Sampling Locations

The proposed sampling locations are presented in Table 16-2 and shown on Figure 6-2.

16.4 Proposed Background Wells

The proposed background wells are BG-1S/D/BR, BG-2D, MW-30S/D, and MW-32S/D/BR. Interim Groundwater Monitoring Plan, background wells are planned to be sampled during the interim groundwater sampling event in 2015.

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17.0 Discussion

17.1 Summary of Completed and Ongoing Work

To date, the following activities have been completed in support of the CSA:

- Installation of 131 groundwater monitoring wells within the active ash basin, Unit 1-4 Inactive ash basin, Unit 5 inactive ash basin, ash storage area, beyond the waste boundaries, and in background locations;
- Completion of topographic and well/boring location surveys;
- Collection of ash samples from borings completed within the active ash basin, Unit 1-4 Inactive ash basin, Unit 5 inactive ash basin, and ash storage area waste boundaries for analysis for total inorganics, TOC, anions/cations, SPLP, and physical properties;
- Collection of soil samples from borings completed within the waste boundaries, beyond the waste boundaries, and background locations and analysis for total inorganics, TOC, anions/cations, SPLP and physical properties;
- Collection of PWR and bedrock samples from borings completed within the waste boundaries, beyond the waste boundaries, and background locations and analysis for total inorganics, TOC, and anions/cations;
- Collection of soil samples for analysis of chemistry and mineralogy;
- Collection of rock samples for chemical analysis;
- Collection of rock samples for petrographic analysis (thin-sections);
- Performance of in-situ horizontal (open hole) and vertical (flush bottom) permeability tests;
- Completion of packer tests in 13 bedrock borings;
- Completion of rising- and falling-head slug tests in 103 newly installed monitoring wells;
- Collection of groundwater samples from 129 newly installed, compliance, and voluntary, monitoring wells, and analysis of samples for total and dissolved inorganics, and anions/cations;
- Speciation of groundwater samples for arsenic, chromium, iron, manganese, and selenium in groundwater samples collected from 59 monitoring wells installed along anticipated groundwater flow transects;
- Collection of 4 surface water samples, 26 groundwater seep samples, and 31 sediment samples, and analysis for total inorganics and anions/cations;
- Speciation of 18 surface water and groundwater seep samples for arsenic, chromium, iron, manganese and selenium;
- Evaluation of solid and aqueous matrix laboratory data;
- Completion of an updated Receptor Survey;
- Completion of fracture trace analysis; and
- Preparation of this CSA Report.

The following activities are on-going (as described in more detail in Section 14.1.1) and will be provided to NCDENR in supplemental information to the CSA report:

- Analysis of soil samples for chemistry and mineralogy and rock samples for chemistry and petrography;
- Evaluation of the need for additional groundwater monitoring wells to better define the horizontal delineation of groundwater exceedances onsite;
- Additional speciation of constituents found to be in excess of their respective 2L Standards.

17.2 Nature and Extent of Contamination

Soil and groundwater beneath the ash basins and ash storage area (within the compliance boundary) have been impacted by ash handling and storage at the CSS Site. However, the presence and magnitude of exceedances for certain constituents may be attributed to naturally occurring conditions and not necessarily attributed to ash handling at the CSS site. The extent of the contamination is noted in the following sections.

Exceedances of 2L Standards and IMACs were observed in nearly all monitoring wells across the site, including in monitoring wells located at the outermost extent of the monitoring well system. Preliminary review of these exceedances indicates, in most cases, the exceedances observed in the outermost extent of the monitoring wells appear to be related to background water quality, naturally occurring conditions and/or sampling conditions. A second round of sampling will be performed at all locations sampled during the CSA. The results from the CSA sampling, the second round of sampling, and the site specific background concentrations will be used to confirm that these observed exceedances do not represent groundwater or surface water impacts related to ash basins or ash storage at the site. The results of this evaluation will be presented in the CSA supplement.

Boron and sulfate are identified by the USEPA as selected constituents that would be expected to migrate rapidly, and that would provide early detections as to whether contaminants were migrating from the disposal unit. Boron and sulfate rarely exceed their respective 2L Standards across the site. Boron exceedances are located within the shallow and deep monitoring wells groundwater table near or within the active ash basin and ash storage area. The active ash basin and ash storage area porewater results for boron are generally higher than the nearby groundwater exceedances and are potentially impacting these locations. Five COPCs are identified as primary risk assessment COPCs due to their widespread presence above associated 2L Standards or IMACs: arsenic, chromium, cobalt, iron, manganese, thallium and vanadium. Arsenic rarely exceeds their respective 2L Standards or IMACs, and does not show indications of significant migration. However, this COI is found at higher concentrations within certain portions of the ash basins and ash storage area compared to background and upgradient areas. Although concentrations of cobalt, iron, and manganese exceed in many background and upgradient locations and widely across the site, concentrations of these parameters are highest in certain areas of the ash basins and ash storage area and in downgradient areas. Exceedances of associated 2L Standards or IMACs for chromium and vanadium exist widely across the site, and concentrations of these parameters are generally similar between areas likely to be impacted and background or other areas of the site likely not influenced by the ash basin or ash storage areas. Three other COIs identified in the shallow

monitoring wells are isolated in specific locations and do not appear to be transported across the site or may be related to turbidity: beryllium, lead and nickel.

In the groundwater located in bedrock, three COPCs are identified as primary risk assessment COPCs due to their widespread presence above associated 2L Standards or IMACs: iron, manganese, and vanadium. Although exceedances of associated 2L Standards or IMACs for iron, manganese and vanadium exist across the site in groundwater in the bedrock, concentrations of these parameters are generally similar between areas likely to be impacted and background or other areas of the site likely not influenced by the ash basin or ash storage areas. Seven other COPCs identified in the bedrock groundwater are isolated in specific locations and do not appear to be transported across the site: antimony, barium, beryllium, cobalt, chromium, sulfate, and TDS.

17.2.1 Groundwater – Shallow Wells

Cobalt, iron, manganese and vanadium were the primary constituents detected in groundwater at concentrations that exceeded the background concentrations and 2L Standards. These constituents were detected above the 2L Standards in a three-dimensional area beneath the active ash basin, ash storage areas or inactive ash basins in the shallow monitoring wells.

The horizontal migration of boron in the shallow layer best represents the dominant flow and transport system.

17.2.2 Groundwater – Deep Wells (Transition Zone)

Cobalt, iron, manganese and vanadium were the primary constituents detected in groundwater at concentrations that exceeded the background concentrations and 2L Standards. These constituents were detected above the 2L Standards in a three-dimensional area beneath the active ash basin, ash storage areas or inactive ash basins in the transition zone layer.

17.2.3 Groundwater - Bedrock Wells

Within the groundwater in bedrock, three COIs are identified as primary constituents in the impacted groundwater in the deep layer are iron, manganese and vanadium. These COIs exceeded the background concentrations and 2L Standards and were observed in a three-dimensional area beneath the active ash basin, ash storage areas or inactive ash basins in the bedrock layer.

17.2.4 Surface Water and Seeps

The background surface water location SW-2 exceeded 2B standards for aluminum. Downgradient surface water samples SW-3 and SW-4 also exceed 2B standards for aluminum, but are at lower concentrations. Surface water samples from seep locations S-1 and S-8 are below or similar to background concentrations (no aluminum exceedances).

17.3 Maximum Contaminant Concentrations

Maximum contaminant concentrations were determined for ash, soil, groundwater, and surface water based on the results of sample analyses for each medium. These concentrations were used to perform screening-level ecological risk assessments based on the North Carolina Division of Waste Management guidelines (NCDENR 2003).

COIs evaluated for maximum contaminant concentrations for groundwater included antimony, arsenic, barium, beryllium, boron, chromium, cobalt, iron, lead, manganese, mercury, sulfate, thallium, TDS, and vanadium. COIs evaluated for maximum contaminant concentrations for porewater included antimony, arsenic, boron, cobalt, iron, manganese, pH, sulfate, thallium, TDS, and vanadium. Maximum constituent concentrations are shown on Figure 10-61 and Table 10-11.

For the COIs identified on the basis of ash basin porewater concentrations, boron is the most prevalent in groundwater with the highest concentration being detected in the shallow monitoring wells and is limited to the area around the active ash basin and within the ash storage area (reference Figures 10-63 through 10-65 and Table 10-11). Groundwater affected by boron discharges to the Broad River via groundwater flow, Suck Creek, and via the unnamed tributaries at the S-1 and S-8 location. The maximum concentration of boron in soil was detected in a sample collected at AB-5BRU, at 43.5-45 feet below ground surface in the active ash basin.

The highest concentration of arsenic in groundwater occurs beneath the Unit 5 Inactive Basin at U5-2D (reference Figures 10-654 through 10-56 and Table 10-11). The CSA data indicate that arsenic has not migrated in the direction of public or private water supply wells.

The highest concentration of cobalt in groundwater was detected in a shallow well (GWA-21S) downgradient of the active ash basin dam. Cobalt was also detected in samples from multiple background well locations (reference Figures 10-69 through 10-71 and Table 10-11).

17.4 Contaminant Migration and Potentially Affected Receptors

In general, groundwater flows from south to north toward the Broad River. The groundwater on the south and east side of Unit 6 flows east and northeast toward Suck Creek and on to the Broad River. Groundwater on the south and west sides of the active ash basin flows to the west and northwest toward Suck Creek. Groundwater on the southwest side of Unit 6 flows northwest to the Broad River.

Water samples collected from one or more of the seeps at the toes of the embankment dams that form the Unit 5 Inactive basin, Unit 4 Inactive Basin, ash storage area, and active ash basin downstream dam which drain towards the Broad River identified the following COIs: Aluminum, arsenic, beryllium, cadmium, chloride, chromium, cobalt, lead, thallium, sulfate and TDS.

Water samples collected from the seeps at the toe of the active ash basin upstream dam which drain to Suck Creek identified the following COIs: Aluminum, arsenic, barium, beryllium, cadmium, chromium, cobalt, lead and thallium.

The human health and ecological CSMs, provided as Figures 12-1 and 12-2 illustrate the potentially affected receptors; these will be reviewed and revised as necessary based on information indicated above.

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18.0 Conclusions

The CSA found that the source and cause of the contamination for certain parameters in some areas of the CSS site is the coal ash contained in the ash basins and ash storage area. The cause of this contamination is leaching of constituents from the coal ash into the underlying soil and groundwater. However, some groundwater, surface water, and soil standards were also exceeded due to naturally occurring elements found in the subsurface.

18.1 Imminent Hazards to Public Health and Safety and Actions Taken to Mitigate them in Accordance to 15A NCAC 02L .0106(f)

15A NCAC 02L .0106(g)(2) requires the site assessment to identify any imminent hazards to public health and safety and the actions taken to mitigate them in accordance with Paragraph (f) of .0106(g).

The CSA found no imminent hazards to public health and safety; therefore, no actions to mitigate imminent hazards are required. However, corrective action at this site is required to address soil and groundwater contamination.

18.2 Receptors and Significant Exposure Pathways

The requirement contained in the NORR and the CAMA concerning receptors was completed with the results provided in Section 4.0. A screening level human health risk assessment and screening level ecological risk assessment was performed with the results provided in Section 12.0. The identified receptors and significant exposure pathways are identified in the human health and ecological CSMs (Figures 12-1 and 12-2).

18.3 Horizontal and Vertical Extent of Soil and Groundwater Contamination and Significant Factors Affecting Contaminant Transport

The CSA identified the horizontal and vertical extent of groundwater contamination within the compliance boundary, and found that the source and cause of the groundwater exceedances within that boundary is the coal ash contained in the ash basins and ash storage area. The cause of contamination is leaching of constituents from the coal ash into the underlying soil and groundwater.

The approximate horizontal and vertical extent of soil contamination is shown with the exception of the areas associated with the data gaps identified in Section 14.1.1 on Figures 8-2 through 8-13.

The approximate horizontal and vertical extent of groundwater contamination is shown with exception of the areas associated with the data gaps identified in Section 14.1.1 on Figures 10-

47 through 10-94. Groundwater contamination is considered to be present where the analytical results were in excess of the site background concentrations and in excess of the 2L Standards. The approximate extent of groundwater contamination is shown on these figures and is limited to the ash basins, ash storage area, and within the compliance boundary associated with the waste boundary at these locations, with exception of the areas associated with the data gaps identified in Section 14.1.1. The assessment found the groundwater COIs to be antimony, arsenic, barium, beryllium, boron, chromium, cobalt, iron, lead, manganese, mercury, nickel, sulfate, thallium, TDS, and vanadium. Iron and manganese are constituents that may be naturally occurring in regional groundwater as previously discussed in Section 10.1.3 and 10.1.4 respectively.

Background monitoring wells contain naturally occurring metals and other constituents at concentrations that exceeded their respective 2L Standards or IMACs. Examples of naturally occurring metals and constituents include antimony, cobalt, iron, manganese and vanadium. Some of these naturally occurring metals and constituents were also detected in newly installed background monitoring well groundwater samples at concentrations greater than 2L Standards or IMACs.

The approximate horizontal and vertical extent of soil contamination is shown on Figures 8-1 through 8-13. Soil contamination is considered to be present where soil analytical results were in excess of the site soil background concentrations or in excess of the soil screening levels protective of groundwater. The assessment found the soil COIs to be antimony, arsenic, cobalt, iron, manganese, selenium, thallium, and vanadium.

The significant factors affecting contaminant transport are those factors that determine how the contaminant reacts with the soil/rock matrix, resulting in retention by the soil/rock matrix and removal of the contaminant from groundwater. The interaction between the contaminant and the retention by soils are affected by the chemical and physical characteristics of the soil, the geochemical conditions present in the matrix (if present), the matrix materials, and the chemical characteristics of the contaminant. Migration of each contaminant is related to the groundwater flow direction, the groundwater flow velocity, and the rate at which a particular contaminant reacts with materials in the respective soil/rock matrix. The data indicates that geologic conditions present beneath the ash basins impedes the vertical migration of contaminants. The CSA found that the direction of mobile contaminant transport is generally in a northerly direction towards Suck Creek and the Broad River, and not towards other off-site receptors. No information gathered as part of this CSA suggests that water supply wells or springs within the 0.5-mile radius of the compliance boundary are impacted by the CSS ash basin system.

The two primary mechanisms that immobilize metals (iron and manganese) and semi-metals (arsenic, boron, and selenium) and prevent their migration in groundwater are sorption and precipitation (Ref NC DENR). The major attenuation mechanism for sulfate, a non-metal, is sorption (EPRI). In these processes, the contaminant is in effect removed from groundwater and partitions onto the surface of the soil/rock matrix (adsorption) or precipitates into a solid phase, in both cases, removing the contaminant from groundwater.

A number of factors specific to the constituent and to site conditions are involved in determining which of these mechanisms occur and how much of the contaminant partitions out of the groundwater.

Sections 7.0, 8.0, 9.0, and 10.0 present the results of testing performed to determine the chemical, physical, and mineralogical characteristics of the soil and rock materials and the site groundwater. As described above, the determination of the mechanism and the amount of the contaminant removed from the groundwater depends on a number of site specific factors. The adsorptive capacity of the site soil/rock materials to the specific groundwater contaminants by development of site specific partition coefficient Kd terms, as described in Section 13.0. The Kd testing will provide site specific values for the ability and capacity of site soils to remove contaminants from groundwater and will assist in understanding the mechanisms affecting contaminant transport at the site. The Kd tests and the associated groundwater modeling will also allow for evaluation of the long-term contaminant loading and the capacity of the site soil and rock material to attenuate this loading. The results of this testing, the groundwater modeling, and the evaluation of the long term groundwater conditions at the site will be presented in the CAP.

18.4 Geological and Hydrogeological Features influencing the Migration, Chemical, and Physical Character of the Contaminants

The initial site conceptual hydrogeologic model presented in the Work Plan dated December 30, 2014, the geological and hydrogeological features influencing the migration, chemical, and physical characteristics of contaminants are related to the Piedmont hydrogeologic system present at the site. The migration of the contaminants is related to the groundwater flow direction, the groundwater flow velocity, and the rate at which a particular contaminant reacts with soil/rock materials. The CSA found that the direction of the migration of the contaminants is towards Suck Creek and the Broad River. The rate of groundwater migration varies with the hydraulic conductivity and porosity of the site soil and rock materials and ranged from 8.3 ft/yr to 274.9 ft/yr in soils, and 3.0×10^5 ft/yr to 9.8×10^7 ft/yr in rock.

The geological and hydrogeological features of the site influence the migration of the contaminants by removal of constituents through sorption or precipitation of contaminants. The degree and the rate at which these actions occur depend on many factors associated with the solution containing the contaminant and the potentially sorbing soil material.

These factors include redox conditions, the concentration of the solution, the chemical composition of the solution and the contaminant, and the mineralogy of the soil or rock matrix. The influence of these factors as determined by the chemical, physical, hydrologic, and mineralogical characterization of the ash, ash basin porewater, the groundwater, and the site soil and rock will be incorporated into the groundwater modeling discussed in Section 13.0. Geological and hydrogeological features at the site do not influence the physical character of the constituents other than through the process of sorption and precipitation. The Kd term

development and the leaching tests results, to be provided in the CAP, will be key to understanding the influences of the site soils and rock on the constituents.

The groundwater model will provide information to allow evaluation of the capacity of the site soil/rock matrix to attenuate the loading imposed by the conditions modeled for the proposed corrective action.

18.5 Proposed Continued Monitoring

A plan for continued monitoring of select monitoring wells and parameters/constituents is presented in Section 16.0 and will be implemented following approval of this CSA report.

18.6 Preliminary Evaluation of Corrective Action Alternatives

Duke Energy recommends removing the ash in the ash basin and ash storage areas via excavation. Approximately 423,600 tons of ash will be relocated to the existing lined landfill at CSS. Coal ash removal will begin at the Units 1-4 Inactive ash basin towards the end of 2015, pending permitting. In conjunction with Units 1-4 decommissioning activities and in accordance with CAMA requirements, Duke Energy will permanently close all CSS ash ponds no later than August 1, 2029. The soil dams will be removed and the unimpacted material used in site re-grading. The depression left after ash removal will be filled with on-site and imported fill material, re-graded, and appropriate vegetation planted to establish a long-term stable, erosion resistant site condition.

Based on the results of soil samples and groundwater samples collected beneath the active ash basin, Units 1-4 inactive ash basin, Unit 5 inactive basin, and groundwater samples collected beneath the ash storage area, after excavation residual contamination will remain. However the degree of contamination and the persistence of this contamination over time cannot be determined at this time. In the subsequent CAP, Duke Energy will pursue corrective action under 15A NCAC 02L .0106 (k) or (l) depending on the results of the groundwater modeling and the evaluation of the site's suitability to use MNA. This would potentially require evaluation of MNA using the approach found in *Monitored Natural Attenuation of Inorganic Contaminants in Groundwater, Volumes 1 and 2* (EPA Reference) and the potential modeling of groundwater surface water interaction. If these approaches are found to not be satisfactory, additional measures such as active remediation by hydraulic capture and treatment, among others, would be evaluated. When properly applied, alternatives such as these can provide effective long term management of sites requiring corrective action.

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