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MEMORANDUM

Date: October 23, 2019
To: Frank Holleman, Southern Environmental Law Center (SELC)
From: Anthony Brown, aquilogic, Inc.
Taly Williams, aquilogic, Inc.
Stacey King, PE, aquilogic, Inc.

Subject: Review of Contaminant Conditions
CSXT Bramlette Road Former Manufactured Gas Plant (MGP)
Greenville, South Carolina
Project No.: 019-12

Aquilogic, Inc. (**aquilogic**) has been retained by Southern Environmental Law Center (SELC) to provide expert consultation and analysis in connection with the Bramlette Road site (the Site) in Greenville County, South Carolina (**Figure 1**). The Site is currently owned by CSX Transportation, Inc. (CSXT). CSXT owns five adjoining parcels of land. One of these parcels (Parcel 1) was formerly occupied by the Bramlette Manufactured Gas Plant (MGP). The MGP operated from 1917 to 1952. Historical activities at the MGP polluted the other land parcels. An inactive, illegal landfill (the Vaughn Landfill) is present at another parcel (Parcel 3). Between 1988 and 1992, the Vaughn Landfill accepted a variety of construction and demolition wastes.

Duke Energy Carolinas, LLC (Duke Energy) is currently conducting remedial investigation work at the Site. Duke Energy is performing this work pursuant to the terms of a Responsible Party Voluntary Cleanup Contract (VCC 16-5857-RP) with the South Carolina Department of Health and Environment (SCDHEC), dated July 29, 2016. Site photos are provided in **Attachment A**.

For this scope of work, **aquilogic** evaluated groundwater and contaminant conditions at the Site. In particular, **aquilogic** assessed whether contamination associated with the Site could be impacting the Reedy River, which borders the Site to the west, and recommended a remedial approach. The evaluation was based on review of publicly available documentation (from SDHEC's website) and additional documents provided by SELC. As part of the evaluation we addressed the following questions:

1. What are the contaminants of concern (COCs)?
2. What is the magnitude and extent of contamination?
3. Is the extent of contamination fully delineated?
4. Is contamination impacting surface water?

5. What data gaps and deficiencies exist?
6. Is the proposed remedial action appropriate?

PROPOSED REMEDIAL APPROACH

Based on our review, and given the discussion included in this technical memorandum, the following are recommendations regarding remediation, restoration, and additional investigation at the Site:

1. Excavate the Vaughn Landfill in Parcel 3 to access underlying contamination associated with the former MGP. Some excavated material may require drying or solidification prior to transportation to an appropriate disposal facility. Best management practices (BMP) should be developed and implemented to eliminate or reduce any potential impact to wetland habitat during remediation/restoration activities.

   Excavation activities in Parcel 3 should not be limited to the lateral boundaries and vertical limits of the Vaughn Landfill. The excavation should be extended laterally and vertically to remove any contaminated soil or sediments associated with the former MGP.

   Excavated material should be first screened on-site to remove demolition and other debris not suitable for thermal treatment. Materials rejected by a 3-inch screen should be stockpiled and transported to an acceptable disposal facility. Materials which pass through the screen should then be profiled in the field for contaminant presence. This screening should include visual observation of contamination (e.g., non-aqueous phase liquid [NAPL]) and detection of volatile organic compounds (VOCs) using a flame-ionization detector (FID). Clean materials suitable for use as backfill should be stockpiled on-site until needed. Confirmatory soil samples should be collected from the "clean" material and analyzed for contaminant presence to confirm the material is suitable for on-site backfill.

   Contaminated materials should be passed through an on-site treatment process to reduce contaminant concentrations (e.g., thermal desorption) and then reused on-site for backfill or transported off-site to a suitable disposal facility. Again, confirmatory soil samples should be collected from the treated material and analyzed for contaminant presence to confirm the material is suitable for on-site backfill.

2. Remove contaminated sediment along the course of the current drainage ditch across Parcels 3, 4 and 5 to the confluence of the drainage ditch with the Reedy River (**Figure 1**). Excavation could involve the removal of as much as a 50-foot wide swath to a depth of approximately 3 feet centered on the drainage ditch.

   The lateral and vertical extents for the excavation along the drainage ditch should be based upon the results of field screening for contaminant presence and confirmatory analysis of selected soil and sediment samples. Excavated material should be handled in the same manner as soil and sediment removed from the excavation program detailed above.

Additional remedial work on Parcels 1 and 2 may be required. The need for additional remediation at Parcels 1 and 2 will be based upon the results of additional contaminant investigation at those parcels.

3. Implement a long-term groundwater remedy to prevent the discharge of contaminated water to the Reedy River. After the completion of excavation activities, residual groundwater contamination will remain within the natural geologic strata. The addition of a pump-and-treat (P&T) system should prevent the current discharge of contaminated groundwater to surface water.

   The P&T system would need to treat the COCs, notably VOCs, semi-volatile organic compounds (SVOCs) and dissolved metals, present in groundwater proximate to the Reedy River. The treatment system should reduce concentrations of COCs to below regulatory standards or background concentrations. The treated groundwater could then be re-injected up-gradient or discharged to the Reedy River. The P&T system would operate until concentrations of COCs in the groundwater proximate to the Reedy River were below regulatory standards or background concentrations.

   The P&T system could be designed to solely intercept contaminated groundwater before it discharges to the Reedy River or address contaminated groundwater across the entire Site. The latter system would require more extraction wells and a larger treatment system capacity as compared to an interceptor P&T system. However, a site-wide P&T system would likely have a shorter operation and maintenance (O&M) period than the interceptor P&T system, could still prevent the discharge of contaminated groundwater to the Reedy River, and could restore contaminated groundwater beneath the Site to an acceptable condition in a more expeditious manner.

4. Restore Parcels 3, 4, and 5 to a natural wetland and/or an improved wetland. A restoration program may cause temporary impacts to the wetland ecosystem; however, after restoration, a healthier (and uncontaminated) wetland system would persist for many decades to come.

   Numerous wetland remediation and restoration programs have been completed across the country to address contamination discharging to, and present within, wetlands. Therefore, such a program could be implemented at the Site. At a minimum, restoration activities could include the following benefits:

   - Expanding and improving the wetland habitat for wildlife
   - Creating a more diverse and vibrant ecosystem

- Establishing vegetation to improve water quality and increase food availability for herbivores and other organisms
- Increasing the supply of macro- and micro-invertebrates that are a food source for birds
- Improving bird watching opportunities at the Site
- Providing a community resource for education and recreation

5. Resample MW-29TZ to confirm initial results.

6. Install MW-30TZ as planned.

7. Conduct a geophysical survey 300 feet on either side of Bramlette Road between the railroad line and the Reedy River. The geophysical survey should be used to identify zones of preferential flow (e.g., fracture zones) in this area that might facilitate the discharge of contaminated groundwater to the Reedy River. Additional monitoring wells in this area should be located in consideration of this geophysical data.

8. Install monitoring wells, both in the shallow sediments and transition zone, to the west of MW-02 and MW-29TZ closer to the Reedy River.

9. Install monitoring wells screened at greater depths (i.e., below the TZ interval) at MW-29TZ and MW-01, and possibly MW-30TZ and the wells west of MW-02 and MW-29TZ recommended herein.

10. Sample all wells proximate to the current drainage channel on a consistent basis. Based on the results from a complete round of sampling at these wells, additional monitoring wells (screened at various depths) may be needed along the current drainage channel and between the channel and the Reedy River.

11. Analyze groundwater samples from each monitoring well on two occasions (low- and high-water conditions) for VOC and SVOC constituents, Title 22 metals, anions including sulfate, and general water quality parameters. This analysis should allow for an improved assessment of contamination associated with the former MGP.

12. Conduct periodic sampling of the Reedy River on a semi-annual basis (coincident with low- and high-flow conditions). At the existing sampling locations (SW-7 through 12) and new locations 100 feet south of Bramlette Road and 100 feet south of SW-12, water samples should be collected at various depths and distances from the easterly riverbank. Water samples should be collected 2 and 12 inches above the bed of the Reedy River at locations 10 and 20-feet in from the easterly riverbank.

    In addition to VOC and SVOC constituents, water samples from each location should be analyzed on two occasions (low- and high-water conditions) for Title 22 metals, anions including sulfate, and general water quality parameters. This analysis should allow for an improved assessment of contamination associated with the former MGP.

Conduct a residual NAPL assessment in Parcels 2, 4, and 5 to further characterize the horizontal and vertical extent of contamination. The recent 2019 NAPL assessment focused on Parcel 3 and the drainage ditch area of Parcel 2. The excavation work in 2001 and 2002 focused on Parcel 1 (i.e., the former MGP) and the main drainage ditch along the southern edge of Parcel 2. Although excavation activities in Parcel 1 extended laterally until cleanup target concentrations levels were reached, excavation in these areas was also constrained to certain depths and limited by site boundaries and landfill debris. Excavation activities undoubtedly removed portions of the contaminant source areas; however, contamination was not removed to its full vertical or lateral extent. Therefore, ongoing sources of groundwater contamination remain at the former MGP and along the former drainage ditch.

Based upon the results related to newly installed MW-29TZ, the additional investigation recommended herein, the need for additional excavation or other remedial measures at Parcels 1 and 2 can be evaluated.

13. Implement a more defined sediment sampling program at the Reedy River proximate to Bramlette Road and the confluence of the current drainage channel and the Reedy River. Sediment samples should be collected close to the easterly riverbank at locations 300 feet north, 100 feet north, 100 feet south, and 300 feet south of both Bramlette Road and the confluence of the current discharge channel with the Reedy River. At these locations, sediment should be collected at depths of 2, 12 and 24 inches. In addition, at these locations, sediment cores should be retrieved and immediately frozen. Sediment pore-water samples would then be extracted at the analytical laboratory at depths of 2, 12, 24 and 48 inches.

14. Analyze sediment samples from each location for VOC and SVOC constituents, Title 22 metals, anions including sulfate, and general sediment quality parameters. This analysis should allow for an improved assessment of contamination associated with the former MGP.

15. Perform additional investigation of soil contamination, NAPL, and groundwater contamination in the southwestern corner at the former MGP, along the drainage ditch between the former MGP and Vaughn Landfill, and in the southern landfill area around MW-21. In addition to VOC and SVOC constituents, soil samples should be analyzed for Title 22 metals, anions including sulfate, and general soil quality parameters. This analysis should allow for an improved assessment of contamination associated with the former MGP.

16. Collect additional surface water and sediment samples from the drainage channel between the former MGP and the Reedy River. This should include sampling and analysis of suspended sediment, to confirm whether site-derived contamination is continuing to flow into the Reedy River. In addition to VOC and SVOC constituents, water and sediment samples from each location should be analyzed for Title 22 metals, anions including sulfate, and general water/sediment quality parameters. This analysis should allow for an improved assessment of contamination associated with the former MGP

17. Locate and appropriately destroy the 298-foot deep water supply well located on Parcel 1 or 2. This well could provide a preferential vertical conduit for the migration of contamination to greater depths. In addition, groundwater monitoring wells should be installed immediately down-gradient of the supply well location to assess the potential for contamination. These monitoring wells should be screened at various depths (shallow, transition zone, and bedrock).

18. Identify and evaluate any information about groundwater monitoring wells that were installed on CSXT property on the west side of the Reedy River in 1993 (i.e., investigate whether contamination may be passing under the Reedy River).

EVALUATION SUMMARY

1. What are the COCs?

The COCs currently identified at the Site are coal tar-derived hydrocarbons including VOCs and SVOCs. Benzene and naphthalene are used as indicator compounds for these two groups of COCs.

In 2000, benzo(a)pyrene was determined to be the most potent carcinogenic PAH in soils at the Site and a risk-based soil concentration of 0.087 milligrams per kilogram (mg/kg) was established (Duke Energy, 2000b, Appendix A). The benzo(a)pyrene cleanup criterion was based upon ingestion of soil in a residential setting. For comparison purposes, the risk-based site cleanup criteria as well as the residential and industrial US Environmental Protection Agency (EPA) Regional Screening Levels (RSLs) for benzene, naphthalene, and benzo(a)pyrene in soils are provided below.

Compound	EPA Industrial Screening Level (ug/kg)	EPA Residential Screening Level (ug/kg)	Risk-based Site Cleanup Criteria (ug/kg)
Benzene	5,100	1,200	-
Naphthalene	17,000	3,800	-
Benzo(a)pyrene	2,100	110	87
Total Carcinogenic PAHs			**319**
Total PAHs			**900**

Notes:
ug/kg: micrograms per kilogram

Excavation and removal of contaminated soil was undertaken at the former MGP in 2001-2002. However, residual soil contamination and pockets of NAPL (i.e., coal tar) remain beneath the Site and constitute an ongoing source of groundwater contamination.

Heavy metals at concentrations in excess of their EPA maximum contaminant levels (MCLs) have been detected in samples at the Site. However, Duke Energy and its consultants concluded that these metals concentrations either (1) reflect natural background concentrations, or (2) are associated with discrete sources of contamination within the Vaughn Landfill and are not associated with historical MGP operations. However, there are insufficient data to conclude whether the detected metals concentrations are associated with the MGP, the Vaughn Landfill, or represent background conditions.

Groundwater samples taken at the Site have been analyzed for cyanide, a contaminant commonly associated with MGP sites. In 1999, cyanide was detected in groundwater samples taken from several monitoring wells across the Site, prior to the partial remediation of the former MGP. However, cyanide was only detected at a concentration greater than its MCL (200 micrograms per liter [ug/L]) in one sample (MW8, 220 ug/L, June 15, 1999). We could not identify any more recent analysis for cyanide in soil or groundwater samples taken at the Site.

2. What is the magnitude and extent of contamination?

Sixty-two thousand tons of contaminated soil were excavated from the former MGP in 2001-2002 (Duke Energy, 2003, Section 7.0). However, soil contamination still remains at the Site as the lateral extent of excavation work was constrained by site boundaries and landfill debris.

During MGP operations, coal tar contaminated wastewater was discharged into a ditch which ran beneath East Bramlette Road into an area of the Reedy River floodplain. Residual coal tar exists in soils along the line of the ditch and on the floodplain beneath the Vaughn Landfill. A drainage channel currently flows southwards through the Site and discharges into the Reedy River near the southerly end of Parcel 5.

In December 2018, six sediment samples were collected along the Reedy River (i.e., SW-07-SED to SW-12-SED) (**Figure 2**). SVOCs were only detected in sediment sample SW-12-SED collected at the southern boundary of Parcel 5 near Willard Street. The SW-12-SED location is downstream of the point where the current drainage channel discharges into the Reedy River. SVOCs were not detected in any of the other Reedy River sediment samples, all of which are upstream of the drainage channel confluence.

In the first half of 2019, SVOC contamination was detected in grab sediment samples SW-01-SED to SW-06-SED, WT1 and WT2. Sediment samples SW-06-SED, WT1, and WT2 were taken from locations directly within the current drainage channel that crosses the Site (**Figure 2**). SW-06-SED is located just south of the Vaughn Landfill in Parcel 3, and the WT samples are from the current drainage channel just before the channel discharges into the Reedy River. Total carcinogenic PAH concentrations of 2,412 ug/kg, 9,823 ug/kg, 6,608 ug/kg, and 17,551 ug/kg were detected in sediment samples SW-12-SED, SW-06-SED, WT1, and WT2, respectively.

Carcinogenic PAHs	SW-12-SED (ug/kg)	SW-06-SED (ug/kg)	WT1 (ug/kg)	WT2 (ug/kg)
Benzo(a)anthracene	503	2,160	1,240	3,290
Benzo(a)pyrene	435	1,840	1,010	3,480
Benzo(b)fluoranthene	562	2,170	1,510	4,010
Benzo(k)fluoranthene	236	715	567	1,520
Chrysene	490	1,910	1,620	2,960
Dibenzo(a,h)anthracene	ND	256	ND	391
Indeno(1,2,3-cd)pyrene	186	772	661	1,900
Total Carcinogenic PAHs	**2,412**	**9,823**	**6,608**	**17,551**

Notes:
ND: non-detect

In August 2019, samples of suspended sediment collected from the drainage channel just before its discharge to the Reedy River (**Figure 2**) were found to contain total carcinogenic PAH concentrations of 10,176 ug/kg, 28,200 ug/kg, and 20,270 ug/kg.

Carcinogenic PAHs	1D (ug/kg)	2D (ug/kg)	3D (ug/kg)
Benzo(a)anthracene	1,760	5,480	ND*
Benzo(a)pyrene	1,730	4,790	9,070
Benzo(b)fluoranthene	2,960	7,480	11,200
Benzo(k)fluoranthene	869	2,800	ND*
Chrysene	1,910	5,100	ND*
Dibenzo(a,h)anthracene	ND	ND	ND*
Indeno(1,2,3-cd)pyrene	947	2,550	ND*
Total Carcinogenic PAHs	**10,176**	**28,200**	**20,270***

Notes:
*Elevated reporting limit due to low solids proportion. Total carcinogenic PAHs may be higher than reported.

These concentrations greatly exceed the risk-based target cleanup level for total carcinogenic PAHs of 319 ug/kg. COCs associated with the Site have discharged to the Reedy River in the past and will continue to discharge via the current drainage channel.

The groundwater flow direction at the Site is west-southwestward; that is, towards the Reedy River (**Figure 3**). A plume of groundwater contamination extends from the southwest corner of the former MGP at least 750 feet in the down-gradient (south-southwest) direction, and 850 feet wide laterally. In March 2019, groundwater was sampled from a newly installed monitoring well (MW-29TZ) approximately 500 feet down-gradient of the former MGP. Benzene and naphthalene were detected in this sample at concentrations of 1,920 ug/L and 4,060 ug/L, respectively. The MCL for benzene is 5 ug/L, and the risk-based screening level (RBSL) for naphthalene is 25 ug/L.

In April 2019, groundwater sampled from newly-installed monitoring well MW-03BR was found to contain 620 ug/l benzene and 2,910 ug/l naphthalene. This monitoring well is screened in bedrock at 59-64 feet below ground surface (bgs) and is the deepest monitoring well at the Site.

3. Is the extent of contamination fully delineated?

The lateral extent of contamination in soil at the former MGP is not delineated to the northeast (beneath West Washington Street), to the west (beneath the landfilled material within the Site boundary), and to the south (beneath and south of East Bramlette Road including the Legacy School area, and Parcels 3-5). The full magnitude and extent of residual contamination along the former wastewater-discharge ditch is unknown. The depth of contamination is also not delineated beneath the former MGP and the drainage ditch.

Investigation activities carried out in the first quarter of 2019 appear to have reasonably delineated the extent of residual NAPL in alluvial soils and saprolite beneath the northern part of the Vaughn Landfill. However, SynTerra (2019, p. 3-4) notes that whilst the southern extent of its NAPL investigation was bounded by RI-SB3, in which no signs of NAPL were observed, this borehole is close to MW-21 and the abandoned MW-6A. While NAPL was not observed in cores collected during the drilling of well MW-21, NAPL accumulated within the well after its installation. In addition, during abandonment of MW-6A, which was immediately adjacent to MW-21, 3 feet of tar-like material was observed in the well screen (SynTerra, 2019, p. 3-3). This indicates that the southern extent of the NAPL contamination has not yet been determined.

The full magnitude and extent of the residual contamination along the length of the drainage channel through Parcels 3, 4, and 5 to the southern boundary of the Site has not yet been determined.

Neither the maximum depth nor the down-gradient extent of benzene and naphthalene (as indicator compounds for VOC and SVOC contamination) contamination in groundwater have been delineated (**Figures 4 through 7**). As mentioned above, benzene and naphthalene were detected at concentrations of 1,920 ug/L and 4,060 ug/L, respectively, in a groundwater sample taken from MW-29TZ. MW-29TZ is located approximately 500 feet down-gradient of the former MGP. No monitoring wells have been installed beyond MW-29TZ north of East Bramlette Road in the down-gradient direction (**Figure 1**).

To the south of East Bramlette Road, high concentrations of benzene and naphthalene (e.g., 244 ug/L and 71.1 ug/L, respectively, July 2017) have been detected in groundwater samples from monitoring well MW-02. MW-02 is screened within alluvium at shallow depth (5 to 15 feet bgs) and MW-29TZ is screened deeper (26 to 31 feet bgs) in the transition zone between saprolite (weathered bedrock) and bedrock. Therefore, in this area, the vertical extent of groundwater contamination has not been delineated.

In April 2019, groundwater sampled from newly-installed monitoring well MW-03BR beneath the Vaughn Landfill in Parcel 3 was found to contain 620 ug/l benzene and 2,910 ug/l naphthalene. This monitoring well is screened in bedrock at 59-64 feet bgs. MW-03BR is the deepest monitoring well at the Site which indicates that the maximum depth of contamination has not been determined.

Contamination was not detected in groundwater samples from monitoring well MW-29S. MW-29S was installed next to MW-29TZ and is screened at a shallow depth (i.e., 5 to 15 feet bgs). However, MW-29S and MW-29TZ were only recently installed and have only been sampled once.

To date, benzene and naphthalene have not been detected in groundwater samples from other monitoring wells installed recently between the western Site boundary and the Reedy River. However, given the lack of complete down-gradient delineation of contamination, contaminated groundwater may be discharging directly to the Reedy River.

A cross-gradient well (MW-18), approximately 880 feet to the south-southeast of MW-02, delineates the lateral extent of the contaminated groundwater plume in that direction. However, as noted, the extent of contamination is not delineated to the north beyond MW-29TZ.

In December 2018, shallow monitoring well MW-30S was installed; however, the adjacent transition zone well (MW-30TZ) has yet to be installed. The schedule for the installation of this well was not provided in the most recent groundwater progress report (i.e., first quarter 2019, Duke Energy, 2019b).

4. Is contamination impacting surface water?

Visual evidence of contamination in the floodplain wetlands east and west of the Vaughn Landfill in Parcel 3 is common (e.g., sheens being reported). However, VOCs and SVOCs have not been detected above their method detection limits (MDLs) in surface water samples collected in this area.

VOCs and SVOCs were not detected in samples taken from the Reedy River in 1996 and 1999. Two of these samples were collected from the Reedy River at the upstream (north) end of the Site, two from the downstream (south) end, and one from an intermediate location. Based on the analytical results for these samples, Duke Energy and its consultants have suggested that contamination from the Site has not impacted the Reedy River. However, contamination has been detected in groundwater samples collected from MW-02 and MW-29TZ (located between the former MGP and the Reedy River) and the down-gradient extent of the groundwater contaminant plume (towards the Reedy River) has not been delineated (i.e., a data gap identified as early as 1996).

In 1996, in its Phase II investigation report, Applied Engineering & Science, Inc. (AES) stated *"(b)ecause of the presence of naphthalene (12 ug/L) in MW-5, and the extent of coal tar found in the floodplain soils west of the landfill, the plume has been shown as reaching the Reedy River. The discharge point of groundwater from the shallow saturated zone within the CSXT properties is expected to be the river, therefore, it is likely that contaminants in groundwater are discharging to the Reedy River. Again, no VOC or SVOC compounds were reported in surface water sample Reedy 2, collected downstream from the plume, but dilution of contaminants may be so great at that point that detection is unlikely and water quality in the river is not affected"* (AES, 1996, p. VII-3).

In its Phase III investigation report, Duke Engineering & Services stated *"(t)he extent of groundwater contamination extending west-southwest from the Landfill is unknown. …No wells were installed along the rail line embankment between MW2 and MW18. As a result, it cannot be stated with certainty that organic compounds are, or are not, discharging to the Reedy River* *through this area"* (Duke Engineering & Services, 2000a, p. 28). The same report suggests that increasing sulfate concentrations and decreasing iron concentrations observed in water samples taken from the Reedy River from upstream to downstream locations could be an indication of contaminated groundwater discharging into the river (Duke Engineering & Services, 2000a, p. 33).

During the fourth quarter of 2018, water samples were collected from the Reedy River at six locations, including at the upstream (north) and downstream (south) ends of the Site, and at points in between (i.e., SW-7 through SW-12). Again, neither benzene, toluene, ethylbenzene and xylenes (BTEX) nor PAH contamination were detected in these samples. As noted, the absence of contamination in these samples does not preclude the direct discharge of contaminated groundwater to the Reedy River and the subsequent dilution in river flows.

Very high concentrations of COCs have been detected in sediment samples taken from the current drainage channel at the Site (SW-6-SED), immediately prior to the channel's confluence with the Reedy River (WT1 and WT2), and in the Reedy River just south of this confluence (SW-12-SED). However, no COCs were detected in the surface water sample taken at the confluence of the current drainage channel and the Reedy River (SW-12). The sediment samples mentioned above confirm that contamination in the current drainage channel has discharged, and will continue to discharge, to the Reedy River.

In August 2019, three samples of suspended sediment were collected from the drainage channel near its confluence with the Reedy River. These samples contained total carcinogenic PAH concentrations of up to 28,200 ug/kg - well above the risk-based target cleanup level of 319 ug/kg. Given that the samples were collected from suspended sediment, rather than from the channel bottom, the results confirm that contamination will continue to discharge into the Reedy River via surface water.

Water level transducers/loggers were recently installed in monitoring wells. These data have confirmed that there is a hydraulic connection between the Reedy River and groundwater beneath the Site. Duke Energy observed that water levels in monitoring wells at the former MGP respond to fluctuations in river stage in about a day, with levels in the monitoring wells along the Swamp Rabbit Trail responding in less than a day (Duke Energy, 2019a; Duke Energy, 2019b).

5. What data gaps and deficiencies exist?

In June 2000, Duke Engineering & Services prepared the Phase III investigation report for the Site (Duke Engineering & Services, 2000a). This report acknowledged that investigations undertaken to date had not delineated the down-gradient extent of the contaminated groundwater: "*(n)o wells were installed along the rail line embankment between MW2 and*

MW18. As a result, it cannot be stated with certainty that organic compounds are, or are not, discharging to the Reedy River through this area" (Duke Engineering & Services, 2000a, p. 28). Therefore, the report recommended that additional monitoring wells be installed along the railroad embankment adjacent to the Reedy River (Duke Engineering & Services, 2000a). This work was not undertaken until late 2018.

Only one shallow well (MW-30S) was installed opposite the northern part of the Vaughn Landfill. Contamination was not detected in groundwater samples recently collected from this well. A deeper well (MW-30TZ) was planned at this location but was not installed. A schedule for the installation of this well has yet to be provided. A second shallow/deeper monitoring well pair (MW-31S/MW-31TZ) was installed further south, opposite the southern part of the Vaughn Landfill. Benzene and naphthalene contamination above their respective MCL and risk-based screening level (RBSL), were not detected in groundwater samples recently collected from these wells. However, contamination has been detected in groundwater samples from MW-02. In addition, contamination has been detected in a groundwater sample recently collected from MW-29TZ. Therefore, neither the vertical extent nor the down-gradient extent of contamination is delineated between the former MGP and the Reedy River in the vicinity of Bramlette Road.

Additional monitoring wells, both in the shallow sediments (S) and transition zone (TZ), are needed to the west of MW-02 and MW-29TZ closer to the Reedy River. Recently, SynTerra (2019) has proposed additional monitoring wells, both cross-gradient and down-gradient of the current known plume; however, no wells are proposed directly down-gradient of MW-29 and MW-02. MW-30TZ also needs to be installed, as planned. In addition, monitoring wells screened at greater depths (i.e., below the TZ interval) could be required at MW-29TZ, MW-01, possibly MW-30TZ and the wells west of MW-02 and MW-29TZ; depending upon the results of the latest sampling event.

It is recommended that a geophysical survey be conducted 300 feet on either side of Bramlette Road between the railroad line and the Reedy River. The geophysical survey should be used to identify zones of preferential flow (e.g., fracture zones) in this area that might facilitate the discharge of contaminated groundwater to the Reedy River. Additional monitoring wells in this area should be located in consideration of this geophysical data.

Benzene and naphthalene contamination have also recently been detected (30.4 ug/l and 57.5 ug/l, respectively) in shallow groundwater sampled at MW-21, located proximate to the current drainage channel at the Site. Other existing monitoring wells proximate to the channel have not been sampled recently (i.e., MW-03, MW-20, MW-23, MW-24). All wells proximate to the current drainage channel need to be sampled on a consistent basis. Based on the results from a complete round of sampling at these wells, additional monitoring wells (screened at various depths) may be needed along the current drainage channel and between the channel and the Reedy River.

In addition to VOC and SVOC constituents, groundwater samples from each monitoring well should be analyzed on two occasions (low- and high-water conditions) for Title 22 metals, anions including sulfate, and general water quality parameters. This analysis would allow for an improved assessment of contamination associated with the former MGP.

VOC and SVOC contamination has not been detected in water samples from the Reedy River collected in 1996, 1999 and 2018. However, periodic sampling of the Reedy River should be conducted on a semi-annual basis (coincident with low- and high-flow conditions). At the existing sampling locations (SW-7 through 12) and new locations 100 feet south of Bramlette Road and 100 feet south of SW-12, water samples should be collected at various depths and distances from the easterly riverbank. At a minimum, water samples should be collected 2 and 12 inches above the bed of the Reedy River at locations 10- and 20-feet in from the easterly riverbank.

In addition to VOC and SVOC constituents, water samples from each location should be analyzed on two occasions (low- and high-water conditions) for Title 22 metals, anions including sulfate, and general water quality parameters. This analysis would allow for an improved assessment of contamination associated with the former MGP.

In addition to periodic sampling of water within the Reedy River, it is recommended that a more defined sediment sampling program be implemented at the Reedy River proximate to Bramlette Road and the confluence of the current drainage channel and the Reedy River. Sediment samples should be collected close to the easterly riverbank at locations 300 feet north, 100 feet north, 100 feet south, and 300 feet south of both Bramlette Road and the confluence of the current discharge channel with the Reedy River. At these locations, sediment should be collected at depths of 2, 12 and 24 inches. In addition, at these locations, sediment cores would be retrieved and immediately frozen. Sediment pore-water samples should then be extracted at the analytical laboratory at depths of 2, 12, 24 and 48 inches.

In addition to VOC and SVOC constituents, sediment and pore-water samples from each location should be analyzed for Title 22 metals, anions including sulfate, and general sediment quality parameters. This analysis would allow for an improved assessment of contamination associated with the former MGP.

The magnitude and extent of residual coal tar, which constitutes a continuing source of groundwater contamination, has not been delineated in the southwestern corner of the former MGP, along the drainage ditch between the former MGP and the Vaughn Landfill, or at the southern end of the landfill in the vicinity of MW-21. Additional investigation of soil contamination, NAPL, and groundwater contamination is needed in these areas. In addition to VOC and SVOC constituents, soil samples should be analyzed for Title 22 metals, anions including sulfate, and general soil quality parameters. This analysis would allow for an improved assessment of contamination associated with the former MGP.

During operation of the MGP, and prior to landfilling in the wetlands area, the drainage ditch from the MGP flowed into a drainage channel which ran south-southeastwards through the Site and discharged to the Reedy River close to the southern Site boundary at Willard Street. PAH contamination has recently been detected in sediments in the current drainage channel (SW-6-SED), immediately prior to the channel's confluence with the Reedy River (WT1 and WT2), and in the Reedy River just south of this confluence (SW-12-SED). Therefore, contaminated sediments likely exist along the entire length of the current drainage channel. Given this, additional surface water and sediment samples from the drainage channel should be collected between the former MGP and the Reedy River. In addition to VOC and SVOC constituents, water and sediment samples from each location should be analyzed for Title 22 metals, anions including sulfate, and general water/sediment quality parameters. This analysis would allow for an improved assessment of contamination associated with the former MGP.

Recently, suspended sediment samples collected from the drainage ditch near its confluence with the Reedy River have been found to contain PAH contamination. These results suggest that site-derived contamination is continuing to flow into the Reedy River. Additional suspended sediment sampling and analysis should be undertaken to confirm this. In addition to SVOC constituents, sediment samples should be analyzed for Title 22 metals, anions including sulfate, and general water/sediment quality parameters.

During operation of the MGP, a 298-foot deep water supply well was located on the property. This water supply well was reportedly "destroyed or abandoned" (Duke Engineering & Services, 2000a, p. 9), but its location is unknown. A SCDHEC memorandum, dated December 1996, and included in Appendix B of the Phase III investigation report (Duke Engineering & Services, 2000a), states that the status of the water supply well should be determined "soon". There is no evidence in the documents reviewed that the status of this water supply well was confirmed. This well could provide a preferential vertical conduit for the migration of contamination to greater depths. Therefore, the well should be located and appropriately destroyed. In addition, groundwater monitoring wells should be installed immediately down-gradient of the supply well location to assess the potential for contamination. These monitoring wells should be screened at various depths (shallow, transition zone, and bedrock).

The Phase I investigation work plan (AES, 1994) refers to groundwater monitoring wells that were installed on CSXT property on the west side of the Reedy River in 1993. Information about these wells (e.g., location, depth, analytical testing results) should be identified and evaluated.

6. Is the proposed remedial action appropriate?

Prior remedial actions have not fully addressed soil, NAPL, groundwater, and sediment contamination. No additional remedial actions have currently been proposed by Duke Energy. Remediation of the former MGP in 2001-2002 was explicitly intended to address the risk of site trespassers coming into direct contact with contaminated soil. Excavation activities undoubtedly removed portions of the contaminant source areas; however, contamination was not removed to its full vertical extent and the lateral extent of excavation was constrained by site boundaries to the south and east, and landfill debris to the west of Parcel 1 and north of the ditch along Bramlette Road. Therefore, ongoing sources of groundwater contamination remain on the former MGP and along the former drainage ditch.

Also, based upon the results of newly installed MW-29TZ, further investigation and excavation may be required in both Parcels 1 and 2. SynTerra (2019) has recently recommended additional test pits, soil borings, and monitoring wells in these areas.

Since 2000, Duke Energy's has taken the position that removal of contamination beneath the Vaughn Landfill would destroy the wetlands. This position was apparently accepted by SCDHEC since they repeated this position in a letter to the US Army Corps of Engineers in February 2001 (Duke Energy, 2009, p.4). However, numerous wetland remediation and restoration programs have been completed across the country to address contamination discharging to, and present within, wetlands. Therefore, such a program should be implemented at the Site. The program may cause temporary impacts to the wetland ecosystem; however, after restoration, a healthier (and uncontaminated) wetland system would persist for many decades to come.

In 2009, Duke Energy proposed a monitored natural attenuation (MNA) approach to address groundwater contamination. The technical basis for adopting MNA was not fully defined, and the approach was not appropriate given the lack of contaminant delineation and persistence of contamination. In 2010, Duke Energy submitted a plan to introduce oxygen-releasing compound (ORC) at MW-02 because benzene and naphthalene concentrations were increasing in this well (S&ME, Inc. [S&ME], 2010). Such data indicates that MNA is insufficient to address groundwater contamination. It is unclear whether the proposed ORC program was ever completed.

PARCEL DESCRIPTIONS

CSXT owns five parcels of land totaling approximately 30 acres, located both north and south of East Bramlette Road. Parcel 1 is currently vacant and represents the location of the former Bramlette MGP, which was demolished in the late 1950s. It is approximately 3.7 acres in area and is bounded by East Bramlette Road to the south, West Washington Street to the northeast, and Parcel 2 to the west and north.

Parcel 2 is largely vacant, with the exception of a CSXT terminal in its western part. A petroleum bulking facility formerly occupied the eastern area. The parcel is bounded by East Bramlette Road to the south, Parcel 1 to the southeast, West Washington Street to the northeast, and a railroad corridor and public trail (i.e., Swamp Rabbit Trail) to the northwest.

Parcel 3 is vacant with the exception of a small CSXT office building in its northwestern corner and an illegal landfill covering the eastern portion of the parcel. Parcel 3 is bounded by East Bramlette Road to the north, the railroad corridor to the west (with Swamp Rabbit Trail and the Reedy River beyond), Parcel 4 to the south, and buildings including the Legacy Early College Elementary School and City of Greenville Sanitation Department to the east. Parcel 3 lies within the floodplain of the Reedy River and is partly occupied by wetlands. Between 1988 and 1993, an illegal landfilling operation resulted in the deposition of between 8 feet and 14 feet of construction and demolition waste across an approximately 7-acre portion of the parcel.

Parcel 4 is contiguous with Parcel 3 and the boundary between them represents the City of Greenville's northern limit. Parcel 4 contains wetlands and is bounded by the railroad corridor and Swamp Rabbit Trail to the west, Parcel 5 to the south, and vacant land and residences to the east.

Parcel 5 contains wetlands and is bounded by Parcel 4 to the north, the railroad corridor and Swamp Rabbit Trail to the southwest, Willard Street to the southeast, and vacant land and residences to the northeast.

Parcels 4 and 5 are classified as wetlands by the US Fish and Wildlife Services, National Wetlands Inventory (Environmental Resources Management [ERM], 2018b).

The railroad which forms the western/southwestern boundaries of Parcels 3, 4, and 5 is constructed adjacent to an embankment. Beyond the railroad is Swamp Rabbit Trail (a linear, greenway park), with the north-to-south flowing Reedy River beyond.

With the exception of the railroad embankment, and the illegal landfill in Parcel 3, the land within the three parcels south of East Bramlette Road is understood to represent original floodplain at a level of approximately 923 feet above mean sea level (MSL). In contrast, the parcels north of East Bramlette Road have historically been built up to facilitate development. The ground surface at the former MGP (Parcel 1) is between approximately 930 feet and 944 feet above MSL (Duke Engineering & Services, 2000a).

Site Hydro-stratigraphy

The movement of groundwater depends in part on the hydro-stratigraphy beneath the Site. Fill materials overlie natural soils in two areas of the Site: (1) across Parcels 1 and 2 north of East Bramlette Road; and (2) in part of Parcel 3 (i.e., the unpermitted landfilled material).

Investigations undertaken prior to remediation at the former MGP found between 2 feet and 7 feet of mixed soil and debris. Beneath this material, silty clays and clayey sands were encountered to depths between 7 feet and 16 feet, with silty sands below the clayey soils, eventually grading to saprolite (Duke Engineering & Services, 2000a). Bedrock was encountered beneath the former MGP at between 30 feet and 44 feet bgs in 2017 (ERM, 2018b, interpreted from Figure 8). A "transition zone" of relatively higher permeability is recognized immediately above the competent, fractured bedrock (ERM, 2018b).

On the Vaughn Landfill parcel, a 2-foot to 6-foot layer of clayey soil was typically encountered beneath the landfill material. Sands and silty sands underlie the clayey material, grading to saprolite 17 feet to 19 feet beneath the landfill surface. Clays, silty sands, and sands were found to vary in thickness and lateral continuity across the area, indicative of alluvial deposits that might be expected in a floodplain environment. NAPL material was observed at both the top of the clay layer immediately below the landfill material, and near the interface between the sandy soil and saprolite (Duke Engineering & Services, 2000a).

In the June 2000 Investigation and Site Assessment report, Duke Engineering & Services (2000a) refers to the Soil Conservation Service Soil Survey of Greenville County, which indicates that floodplain soils are expected in the area, including alluvial sandy loams (Cartecay soils) and silty clay loams (Chewacia soils). The latter are described as hydric (water saturated) and typical of wetland environments.

The natural soils beneath Parcel 3 (and also Parcels 4 and 5) almost certainly constitute alluvium. It is uncertain whether the soils beneath the former MGP are of a similar origin. However, both areas appear to be broadly characterized by a layer of clay-rich material overlying sandier soil, which in turn overlies saprolite. AES indicated in their 1996 Site Investigation report that hydrogeologic units in a floodplain environment tend to be discontinuous and hydraulically interconnected, and that delineating separate aquifer zones in alluvial deposits is a difficult process and is often speculative (AES, 1996). Consequently, AES considered the saturated zone above the saprolite surface to be one hydraulically connected unit. ERM takes the same approach in their April 2018 Groundwater Remedial Investigation Work Plan Addendum report (ERM, 2018b). Therefore, this summary takes the same view and refers to the materials between any fill material and the saprolite beneath the Site as "alluvial soils".

ERM calculated average groundwater seepage velocities for what it termed the "fill/residuum" (equivalent to the alluvial soils as defined above) and the saprolite as follows (ERM, 2018b):

Hydraulic unit	K	n_e	Hydraulic	Seepage	Monitoring wells

	(feet/day)		gradient	velocity (feet/year)	used for gradient
Fill/residuum	2.5	0.25-0.35	0.0108	28-39	MW-13R/MW-2
Saprolite	3.0	0.35-0.45	0.00785	19-25	MW-09R/MW-20

Notes:
feet/day: feet per day
feet/year: feet per year
K = average hydraulic conductivity based on July 2017 slug test data
n_e = assumed effective porosity

Duke Energy reported geometric mean hydraulic conductivity values derived from slug testing as follows (Duke Energy, 2019a):

- Shallow zone (i.e., alluvial soils): range from 7 feet/day at MW-31S to 16 feet/day at MW-30S
- Transition zone (including saprolite): 0.5 feet/day at MW-31TZ

SynTerra (2019) reported hydraulic conductivities as follows:

- Fill: 8.82 x 10^{-4} centimeters per second (cm/sec)
- Alluvium / saprolite: 1.23 x 10^{-2} to 1.45 x 10^{-3} cm/sec
- Transition zone: 2.00 x 10^{-4} to 8.22 x 10^{-5} cm/sec
- Bedrock: 1.87 x 10^{-5} cm/sec

The groundwater flow direction within the shallow aquifer at the Site is southwestwards to west-southwestwards (AES, 1996; Duke Engineering & Services, 2000a; S&ME, 2016; ERM, 2018b; Duke Energy, 2019b) (**Figure 3**).

The recent installation of water level transducers/loggers in several monitoring wells has demonstrated that groundwater beneath the Site is hydraulically connected to the Reedy River. Duke Energy observed that water levels in monitoring wells at the former MGP respond to fluctuations in river stage in about a day, with levels in the monitoring wells along the Swamp Rabbit Trail responding in less than a day (Duke Energy, 2019a; Duke Energy, 2019b). SynTerra (2019, p.3-5) noted that the Reedy River can act as a gaining stream or a losing stream based on precipitation and ground saturation.

Site History

The MGP commenced operations in 1917 (Duke Engineering & Services, (2000a) and eventually included a retort house, tar extractor and holder, tar and ammonia tanks, purifiers, a water gas plant, and three gas holders. It ceased operating in 1952 and was mostly demolished by 1958 (SCDHEC, 2016). In the 1970s and 1980s the site was used as a trucking facility.

In 1988, a gentleman by the name of Mr. Robert Vaughn offered to purchase a portion of Parcel 3 for use as a landfill site. Mr. Vaughn paid a deposit on the purchase of the site and began unpermitted landfilling activities. However, the transaction was never completed. Landfilling continued until 1994, when the US Army Corps of Engineers advised CSXT that the landfill was located on wetlands and, therefore, in violation of the federal Clean Water Act (CWA). CSXT then ordered Mr. Vaughn to close the landfill (SCDHEC, 2016). The extent of the landfill is shown on **Figure 2**.

INVESTIGATION AND REMEDIATION HISTORY

This section provides a factual summary of the investigation and remedial activities that have been undertaken at the Site since 1994. The following sections provide interpretation and detail with respect to the current situation regarding contamination sources, pathways and receptors.

Phase I Investigation, 1995

In Spring 1994, SCDHEC and US Army Corps of Engineers representatives visited the Vaughn Landfill and observed "*leachate and sludge-like material at the base of the landfill and in the surrounding wetlands*" (AES, 1994, p. I-1). A sample from the wetlands west of the landfill was analyzed and found to contain 3.04 mg/kg toluene. SCDHEC then requested a work plan from CSXT to assess environmental impact at the Vaughn Landfill.

The resulting Phase I investigation, which was undertaken for CSXT by AES, discovered that between 8 feet and 14 feet of construction and demolition waste had been dumped at Parcel 3 (AES, 1995a). The landfill material itself was not observed to contain hazardous materials, but visible tars were noted at the base of the tipped materials in two areas within the northern half of the landfill, and in the surrounding wetlands. Soils characterized by elevated concentrations of VOCs and SVOCs were identified beneath the Vaughn Landfill in a band trending northeast to southwest across Parcel 3. Sediment from a drainage ditch which bisects the Vaughn Landfill, allowing surface water to drain from west to east across Parcel 3, contained elevated VOCs as well as oil and grease.

Three groundwater samples obtained from temporary borings extended to shallow depths beneath the Vaughn Landfill contained elevated VOCs and SVOCs, with benzene present above its EPA MCL of 5 ug/L. It was noted that the groundwater contamination "*likely extends west in the suspected downgradient direction toward the Reedy River*" (AES, 1995, p. V-1). The investigation found no source of the observed tars, but the report noted the presence of the former MGP to the northeast.

Phase II investigation, 1996

A Phase II investigation sought to delineate the extent of the tar related contamination beneath both the Vaughn Landfill and the former MGP (AES, 1995b). The Phase II investigation report documented the observation of visual coal tar contamination at the former MGP, both in the vicinity of former tar tanks (in the southwestern site area) and near the former oil scrubber and purifier (north-eastern area) (AES, 1996). AES interviewed former MGP employees who reported that during the operation of the MGP, wastewater containing coal tar was discharged into a ditch near the southwestern corner of the site. This happened on a daily basis for a period of 20 years or more.

The investigation found evidence, in the form of residual coal tar contaminants, that this wastewater flowed southwestward paralleling East Bramlette Road for a short distance, before entering a culvert running beneath the road and into the floodplain on Parcel 3. The report states, *"as coal tar contaminated wastewater entered the floodplain south of Bramlette Road, the wastewater spread southwest across the floodplain. Aerial photographs of the area taken in the 1950s during gas plant operations indicate the presence of two ponds approximately 700 feet south of Bramlette Road at what is now the southwest corner of the Vaughn Landfill. The ponds are now within the seasonally flooded area west of the landfill. Several samples collected in the area of the ponds… revealed the presence of coal tar in the soil, in some places in layers several inches thick. Much of the coal tar entering the floodplain south of Bramlette probably flowed into the ponds and settled at the bottom"* (AES, 1996, p. III-11).

The AES report also states *"It is evident from the extent of the coal tar, the location of the former coal gasification plant, interviews with former employees of the plant, and aerial photographs that the source of the coal tar is the former Duke Power coal gasification plant at the comer of West Washington Street and Bramlette Road"* (AES, 1996, p. IV-2).

As part of the Phase II investigation, eight groundwater monitoring wells were installed; seven of which were screened in the shallow surficial aquifer and one, extended deeper, was screened in the sand unit below the upper clay formation. During drilling of this deeper well, an approximately 3-inch layer of coal tar was encountered within the 16 foot to 18 foot sampling interval.

Two weeks following installation, 2.75 inches of "free product" had accumulated at the base of the well. Since the report clearly states that this material was encountered at the bottom of the well, it can properly be described as dense non-aqueous phase liquid (DNAPL). The DNAPL was interpreted to be accumulating and migrating through alluvial sand material at the interface with the underlying, less permeable saprolite, at between 7 feet and 9 feet below original ground level.

Groundwater sampling from the eight newly installed monitoring wells indicated the presence of a hydrocarbon contaminant plume extending from the former MGP (Parcel 1), along the drainage ditch paralleling East Bramlette Road (Parcel 2), and beneath the road into Parcel 3. The plume was defined by elevated concentrations of VOCs and SVOCs, although only benzene was identified as being present at concentrations in excess of its MCL, and only at two locations (one beneath the former MGP and one beneath the Vaughn Landfill). The report did not identify MCLs for the majority of the SVOCs of concern, which belong to the PAH sub-group. However, in its comments to the report, SCDHEC noted that maximum concentrations in groundwater had in fact been established for all PAHs (Duke Power Company, 1997, Appendix I).

The discovery of naphthalene (a PAH) in groundwater, in a monitoring well south of the Vaughn Landfill and near the western boundary of Parcel 3, led the Phase II report authors to conclude that *"the plume has been shown as reaching the Reedy River. The discharge point of groundwater from the shallow saturated zone within the CSXT properties is expected to be the river, therefore, it is likely that contaminants in groundwater are discharging to the Reedy River"* (AES, 1996, p. VII-3). A water sample obtained from the river did not exhibit VOC or SVOC contamination, but this sample was collected more than 1,000 feet downstream of the monitoring well in which naphthalene had been detected, and the report suggested that dilution might be sufficient to explain the failure to detect contamination in the river.

As part of the Phase II investigation, a biological survey was undertaken to assess the effects of coal tar contaminants on the diversity and number of plant species in the wetlands adjacent to the Vaughn Landfill. The study concluded that no significant negative correlation existed between organic compounds in the soils and the prevalence of plants.

SCDHEC's comments on the Phase II report included the statement that corrective action would be necessary at this site due to the presence of DNAPL, discharges to the wetlands, and the presence of carcinogens in soil. It was also stated that a method should be devised for removing DNAPL from the monitoring well at the Vaughn Landfill parcel as it accumulated. The detection of several compounds in groundwater at concentrations in excess of 10 percent (%) of their solubility limits was interpreted by SCDHEC as a strong suggestion of the presence of coal tar nearby (Duke Power Company, 1997, Appendix I).

Phase III Investigation and Risk Assessment, 1999

A Phase III investigation sought to further delineate the contamination at both the former MGP and Vaughn Landfill, and in between these two locations. This work was planned and undertaken by the Site Remediation Services Group of Duke Engineering & Services, Inc., a Duke Energy Company. As part of the Phase III investigation, an additional 18 monitoring wells were installed at various depths across the former MGP and Vaughn Landfill. In addition, an aquatic fauna study was undertaken in the wetlands south of the Vaughn Landfill. It concluded that faunal populations were self-sustaining and unlikely to be affected by organic contaminants in the environment.

The additional work improved the delineation of the groundwater contamination plume - but did not "close" it in the down-gradient direction; *"(n)o wells were installed along the rail line embankment between MW2 and MW18. As a result, it cannot be stated with certainty that organic compounds are, or are not, discharging to the Reedy River through this area"* (Duke Engineering & Services, 2000a, p. 28). The report recommended that two additional monitoring wells be installed along the railroad embankment adjacent to the Vaughn Landfill, to investigate whether contaminants may be discharging to the Reedy River.

With respect to the DNAPL beneath the Vaughn Landfill, the Phase III report concluded: *"(a)ttempts to excavate and remove coal tar and coal tar contaminated soil from the wetlands is not recommended. Beneath the Landfill, coal tars reside below the Landfill at the debris-native soil interface, and within the underlying soil structure down to saprolite. The degree and extent of excavation required to remove coal tars from the entire underlying soil stratum would likely result in severe damage, if not complete destruction, of the wetland environment. Since biological assessments have shown that the coal tar constituents are not significantly impacting plant and animal life in the wetlands, attempting to remove those constituents would be counter-productive"* (Duke Engineering & Services, 2000a, p. 39).

The work plan for the Phase III investigation stated that cyanide analysis would be undertaken on some soil samples (Duke Power Company, 1997). The Phase III report did not indicate whether this work was undertaken. Cyanide was detected in groundwater samples from all of the monitoring wells at the former MGP. However, it was detected at concentrations in excess of the MCL in a sample from only one well.

A risk assessment undertaken as part of the Phase III investigation identified exposure to contaminated surface soils by potential trespassers on the former MGP to be the only significant scenario. It was recommended that this risk should be minimized or, if feasible, eliminated by excavating and removing free tars and contaminated near-surface soils within the former MGP and along the ditch leading from the Parcel 1 and 2 onto Parcel 3. Groundwater was acknowledged to be contaminated, but mitigation was not deemed necessary as it was not being used for public water supply. The Reedy River was not identified as a potential receptor in the assessment.

Soil Remediation, 2001-2002

In response to the risk assessment, a Remedial Action Plan (RAP) was developed in September 2000. This RAP envisaged the removal of approximately 27,000 tons of contaminated soil from the former MGP (Parcel 1) and along the former drainage discharge ditch (Parcel 2). The maximum depth of excavation was to be 3 feet, reflecting the aim to eliminate the risk to potential site trespassers from coming into direct contact with the contaminants (Duke Engineering & Services, 2000b).

Remediation excavations commenced in July 2001 and were completed in December 2002. The actions significantly exceeded the original plan in terms of quantity of material removed and depth of excavation (Duke Energy, 2003). Approximately 61,000 tons of soil were excavated (2.5 times the original plan), with excavations being deepened to between 6 feet and 12 feet to remove "*additional and obvious source material*" that might contribute to groundwater contamination (Duke Energy, 2003, Section 7.0). Excavation also extended off-site to the north, to follow contaminated material encroaching beneath the former Suburban Propane facility in Parcel 2. A previously unknown tar tank was discovered, and 2,500 gallons of liquid tar removed.

Excavation of contaminated materials was constrained by the boundaries along East Bramlette Road and West Washington Street to the south and east, respectively; and by "*massive quantities of previously landfilled debris*" in the western corner of the site and in Parcel 2 north of the ditch along East Bramlette Road (Duke Energy, 2003, Section 7.0).

Soil samples for verification analysis were collected every 200 feet along excavation sidewalls. Of the 61 samples collected, 21 had concentrations of PAHs which exceeded the risk-based cleanup level of 319 ug/kg. These samples came from areas where the extent of excavation had been constrained as noted above.

Bottom samples from the excavation were collected, but the report notes that these were *"for information purposes only to document contaminant levels remaining at the site"*, because *"the vertical extent of remedial excavation had been predetermined (surface to 3 ft minimum)"* (Duke Energy, 2003, Section 7.0).

The remedial action report acknowledged that "*(s)ome degree of contamination remains at the Bramlette MGP site. Contaminated materials remain at depths greater than 3 feet within the site. Contaminated materials also remain at depths below landfilled debris around the perimeter of the site, and at near-surface (surface to 3 feet) depths beneath Bramlette Road and West Washington Street. The lateral extent of this remaining contamination is not known, but is not considered to represent risks to human health in the current setting*" (Duke Energy, 2003, Section 14.0).

The RAP provides an additional justification as to why groundwater remediation was not included in the scope of work: *"Efforts to remediate groundwater within the MGP site would be counterproductive as this same groundwater would become recontaminated upon migration into the Landfill site. Excavation and removal of contaminated soils and sediments within the*

CSX/Vaughn Landfill site would likely result in severe damage, if not complete destruction, to the wetland environment" (Duke Energy, 2003, Section 5.0).

Groundwater Monitoring, 2009-2016

Further consideration of the groundwater contamination is provided in a Groundwater Continuous Action Plan (Duke Energy, 2009). The report considered that *"the majority of the contaminated material located on the MGP site has been removed"* and that *"the coal tar located under the landfill debris is the main source of groundwater contamination. The groundwater plume has been relatively stable since 1996, downstream surface water has not been impacted, groundwater outside of the landfill area has not been impacted, and there are no drinking water wells within 1/2 mile of the site"* (Duke Energy, 2009, pp. 4-5). The report repeated the previously stated view that coal tar cannot be removed from beneath the Vaughn Landfill without potentially destroying the wetlands - a view which was apparently accepted by SCDHEC and repeated in a letter from them to the US Army Corps of Engineers in February 2001 (Duke Energy, 2009, p. 4). In conclusion, the report proposed a MNA approach to groundwater remediation.

The proposed MNA approach appears not to have been accepted by SCDHEC, since in 2010 a Corrective Action Plan (CAP) to address groundwater contamination in the vicinity of MW-02 (in the northwestern corner of Parcel 3) was prepared by S&ME. The plan was to use ORC to enhance biodegradation at this location, because benzene and naphthalene concentrations in groundwater had been increasing over time. The report referred to the existence of SCDHEC-mandated target cleanup concentrations for benzene and naphthalene, but these targets are not specified in the text.

It is not known if the ORC approach as advocated by the CAP was ever implemented at MW-02. Sampling of all monitoring wells at the Site has continued on an annual basis, with selected wells sampled every six months (S&ME, 2016).

Responsible Party Voluntary Cleanup Contract, 2016

In July 2016, SCDHEC executed a VCC with Duke Energy. The contract required Duke Energy to submit a work plan for a groundwater remedial investigation to determine the source, nature, and extent of groundwater contamination from the former MGP. The contract specifically excludes impacts from landfilling operations on Parcel 3; however, paragraph 3C does state *"(i)f the selected remedy for addressing the MGP-related Contamination at the Landfill Site requires removal and/or disturbance of the materials deposited in the unpermitted landfill, then the Department will attempt to enter into an agreement with all the potentially responsible parties to implement the selected remedy"* (SCDHEC, 2016, p. 15).

Remedial Investigation and Groundwater Monitoring, 2018-2019

Duke Energy retained Anchor QEA to prepare and execute a remedial investigation work plan per the VCC. Related documentation is not currently available on the SCDHEC website, but a recent (April 2018) Groundwater Remedial Investigation Work Plan Addendum, prepared for Duke Energy by ERM, provides a summary of the work undertaken by Anchor QEA (ERM, 2018b). It appears that Anchor QEA's work was limited to installing and sampling two clusters of three monitoring wells at up- and down-gradient locations at the former MGP, and sampling groundwater from other locations on the former MGP via temporary wells. This work confirmed the presence of residual, coal tar related contamination at the former MGP.

ERM (2018b) proposed additional work to delineate contamination from the former MGP and facilitate risk assessment. The report states that *"the former MGP site and all associated on-site sources have previously been addressed"* (ERM, 2018b, p. 2) and notes that the 2001-2002 remedial actions were conducted under SCDHEC oversight and *"successfully achieved the specific objectives of cleaning up soils and reducing the amount of source material contributing to ground water impacts at the former MGP facility"* (ERM, 2018b, p. 1). It goes on to state that *"the dissolved phase groundwater plume, which has remained stable since 1996, has been delineated and monitored, except in the hydraulically downgradient direction to the southwest near the Reedy River, and vertically at the former Vaughn Landfill"* (ERM, 2018b, p. 14). The "Potential Receptor Evaluation" section of the report does not identify the Reedy River as a potential receptor. However, ERM proposed to undertake both a baseline human health risk assessment (HHRA) and a screening-level ecological risk assessment after the additional proposed investigation had been completed.

ERM's proposed work included the following:

- Advancement of boreholes to identify NAPL beneath the Vaughn Landfill and north of East Bramlette Road
- Installation of monitoring wells to investigate the down-gradient extent of the groundwater plume
- Sampling of water and sediment from wetlands and the Reedy River.

The work plan was approved by SCDHEC on April 24, 2018 (Duke Energy, 2019a).

The additional investigation work was carried out in the fourth quarter of 2018 and the first quarter of 2019 by SynTerra and discussed in progress reports prepared by Duke Energy (2019a; 2019b). The program included:

- Installation of three monitoring wells (MW-30S, MW-31S and MW-31TZ) between the western Site boundary and the Reedy River

- Installation of two monitoring wells (MW-29S and MW-29TZ) on Parcel 2 north of East Bramlette Road
- Installation of one monitoring well (MW-03BR) within the Vaughn Landfill
- Drilling of 51 soil boreholes to investigate the presence of NAPL beneath the Vaughn Landfill and north of East Bramlette Road
- Collection and analysis of surface water and sediment samples from 12 locations, including 6 from the Reedy River
- Installation of water level transducers/data loggers in five monitoring wells.

SynTerra's July 2019 Remedial Investigation Work Plan Addendum (SynTerra, 2019) provides an updated site conceptual model, based on the latest available information. The report identifies and proposes additional investigation work required before a risk assessment can be carried out. The work program includes soil sampling in and around the previously remediated area in Parcels 1 and 2; off-site soil borings east of Parcel 3; groundwater sampling from additional monitoring wells; and further surface water and sediment sampling.

SELC Sediment Sampling, 2019

In 2019, in order to confirm that COCs have previously migrated off-site and to investigate whether off-site migration may be continuing, SELC arranged for the collection and analysis of sediment samples. The samples were collected from the drainage channel where it flows through Parcel 5, just prior to discharging to the Reedy River.

Sediment samples WT-1 and WT-2 were collected in April 2019 at locations approximately 60 feet and 170 feet from the confluence with the Reedy River, as indicated in **Figure 2**. Each sample consisted of a composite of 4 scoops of channel-bottom sediments collected from within a 10-foot radius at each location. The samples were analysed for PAHs.

Samples 1D, 2D and 3D were collected in August 2019 at locations approximately 48 feet, 78 feet, and 178 feet from the confluence with the Reedy River, as indicated in **Figure 2**. Unlike samples WT-1 and WT-2, which were channel-bottom sediments, samples 1D, 2D and 3D represented suspended sediment from the water flowing in the channel. A sampling device was fabricated specifically for this purpose. It comprised a metal collecting pan with a slotted cover (see **Photos 21 and 22 in Attachment A**). When placed in the drainage channel (**Photo 20 in Attachment A**), water flows into the device through the slots, and entrained sediment settles out into the pan. At each sample location, the device was positioned in the drainage channel within a shallow pool characterised by low flow velocity. The device was left in the channel for between 4 and 8 days; that is, as long as necessary to collect sufficient sediment for analysis. The accumulated sediment (**Photo 23 in Attachment A**) was then dispatched for analysis of PAHs.

CURRENT CONTAMINATION

The three phases of investigation work undertaken at the Site prior to remediation activities in 2001-2002 established that the former MGP (Parcel 1) was the source of coal tar related hydrocarbon contamination. "Free-phase" coal tar (i.e., NAPL) was observed in soils beneath the former MGP, along the line of a drainage ditch running along and beneath East Bramlette Road, and beneath the Vaughn Landfill material on Parcel 3.

These observations corroborated the reports of former MGP workers that wastewater containing coal tar was discharged from the plant and into the ditch on a daily basis for 20 years or more (AES, 1996). Although the former MGP is the ultimate source, the residual NAPL present beneath Parcels 2 and 3 constitutes additional, discrete sources of contamination.

Recent work has differentiated the NAPL into two distinct types, based on chemical analysis: tar-like material (TLM), which is viscous residue associated with drainage ditches; and oil-like material (OLM) which is generally found within alluvial soils and has moved with groundwater (SynTerra, 2019).

Coal tar-related contamination has been the primary focus of investigation. There was some consideration given to heavy metals in the early (Phase I and II) investigations, but concentrations of some elements which were initially suspected to be elevated were later concluded to reflect natural background conditions, or discrete sources in the landfill material.

Cyanide is a common contaminant associated with former MGP sites. However, no soil samples collected at the Site have been analyzed for cyanide, - despite the Phase III investigation work plan having stated that they would be (Duke Power Company, 1997). Historical information suggests that the former MGP facilities included purifiers, with which cyanide waste is often associated. However, there is no indication in any of the reviewed documentation that "blue billy" cyanide waste was encountered during investigations or remediation activities. Nevertheless, groundwater samples collected from monitoring wells were analyzed for cyanide as part of the Phase III investigation. Cyanide was detected in eight of the 11 groundwater samples from wells present at the former MGP, and 8 of the 15 wells on the Vaughn Landfill parcel. Only in a sample from one well on the MGP site did the cyanide concentration exceed the MCL of 200 ug/l (MW8, 220 ug/L, June 15, 1999). The maximum concentration detected in a groundwater samples from the Vaughn Landfill parcel was 17 ug/l (MW19, June 15, 1999). These analyses were made prior to the remediation of the former MGP. Documentation of more recent analysis for cyanide has not been found.

Coal Tar Contamination at the MGP site

Between 2000 and 2002, remedial excavations were undertaken at the former MGP and adjacent areas, including along the line of the drainage ditch in Parcel 2. The objective of the work was to remove near-surface contaminants that could pose a risk to anyone trespassing on the former MGP. Although the actual quantity of contaminated material removed (61,000 tons) was significantly more than originally planned (27,000 tons) and the depth of excavation was 9 feet deeper than originally planned (3 feet), there is no question that residual contamination remains at the former MGP.

The lateral extent of excavation was constrained by East Bramlette Road and West Washington Street to the south and east, respectively; and by *"massive quantities of previously landfilled debris"* in the western site corner and north of the ditch along Bramlette Road (Duke Energy, 2003, Section 7.0). Hence, PAHs were detected at concentrations in excess of the risk-based cleanup target (which were based on the direct-ingestion pathway) in 21 of 61 excavation sidewall samples.

The 2003 Duke Energy report indicated that the maximum concentration of benzo(a)pyrene (i.e., a carcinogenic PAH) detected in a sidewall verification sample at the Bramlette Road boundary was 180 mg/kg (46SW) (Duke Energy, 2003, Section 9.0). However, review of the analytical data summary tables indicates that the reported benzo(a)pyrene concentration at location 102SW for example was 4,350 mg/kg and the total PAH concentration was 78,900 mg/kg. Sample 102SW was at the western edge of the remediated area where landfill debris constrained the excavation.

These remaining concentrations greatly exceed the target cleanup criteria of 0.087 mg/kg for benzo(a)pyrene, 0.319 mg/kg for total carcinogenic PAHs, and 0.9 mg/kg for total PAHs. The report also states that higher benzo(a)pyrene concentrations could be present in sidewall samples as suggested by the high laboratory detection limits at the time (Duke Energy, 2003, Section 9.0).

The 2003 work scope did not require cleanup targets to be met beyond a depth of 3 feet. And although the depth of excavation was extended beyond the originally planned 3 feet in some areas, the depth of excavation seems to have been determined by visual observation rather than confirmatory sampling. The report states that material removal was generally terminated when a "grayish, cohesive clay material" was encountered and that excavation bottom samples were collected, but *"for information purposes only to document contaminant levels remaining at the site"* (Duke Energy, 2003, Section 7.0). Samples were analyzed for BTEX, as well as PAH, and benzene was detected at a concentration of 27 mg/kg in one soil sample. No site remediation goal was set for benzene. The greatest present risk associated with contaminants at the former

MGP at the time was determined to be ingestion of carcinogenic PAH compounds adsorbed onto near-surface soils.

The RAP acknowledged that *"(s)ome degree of contamination remains at the Bramlette MGP site. Contaminated materials remain at depths greater than 3 feet within the site. Contaminated materials also remain at depths below landfilled debris around the perimeter of the site, and at near-surface (surface to 3 feet) depths beneath Bramlette Road and West Washington Street. The lateral extent of this remaining contamination is not known, but is not considered to represent risks to human health in the current setting"* (Duke Energy, 2003, Section 14.0).

The investigation work undertaken by Anchor QEA in 2017 encountered NAPL at two locations along the ditch which parallels East Bramlette Road. Groundwater samples collected from temporary wells at nearby locations contained benzene at concentrations above the EPA MCL of 5 ug/L. Naphthalene in excess of the RBSL (based on references related to underground storage tanks [USTs]) of 25 ug/L was detected in four groundwater samples.

Benzene and naphthalene were detected at concentrations of 17.8 ug/l and 36.3 ug/l, respectively, in groundwater sampled from MW-7R in the southwest corner of the former MGP (ERM, 2018b). These results confirm that sources of contamination to groundwater remain beneath, and adjacent to, the former MGP.

In March 2019, nine soil boreholes were drilled along three transects (T1, T2 and T3) to the north of the ditch running on the north side of East Bramlette Road. According to Figure 1 of Duke Energy's (2019b) first quarter 2019 monitoring report, no visual signs of hydrocarbon contamination were observed during the work. However, Figure 3-1 of the later SynTerra (2019) Remedial Investigation Work Plan Addendum report changes the interpretation, with NAPL observed in three of the nine boreholes. The borehole logs, included in Appendix B of the report, confirm the observation of NAPL staining and/or odors within the fill and/or alluvial soils in the boreholes. Five soil samples were collected from the boreholes. Benzene was not detected above the MDL in any sample; whereas, naphthalene was detected in two samples but at concentrations below the method reporting limit (Duke Energy, 2019b, Table 7 and SynTerra, 2019, Table 3-7).

Given the documented occurrence of remaining contamination at the former MGP, as noted above, the statements in ERM's recent work plan addendum are inconsistent. ERM stated that *"the former MGP site and all associated on-site sources have previously been addressed"* (ERM, 2018b, p. 2) and that the 2001-2002 remedial actions *"successfully achieved the specific objectives of cleaning up soils and reducing the amount of source material contributing to ground water impacts at the former MGP facility"* (ERM, 2018b, p. 1).

The specific objective of the 2001-2002 remediation was to eliminate the risk of site trespassers coming into contact with near-surface contaminants. After the completion of excavation activities, contamination remains at shallow depths beyond the site boundaries, but in terms of the direct-contact risk, this is not of concern because the contaminated materials are covered. Excavation of the contaminated material has removed a potential, ongoing source of groundwater contamination. However, source material remains at shallow depths beyond the former MGP boundaries, and at greater depths beneath both the former MGP and adjacent areas.

SynTerra (2019) proposes to re-visit the 2001-2002 remediated area, deploying a photo-ionization detector (PID) and soil gas survey to identify locations for soil coring, test pits, and monitoring well installation. Test pits and boreholes are intended to "*verify adequate removal of near-surface soils impacted by the MGP*" (SynTerra, 2019, p. 4-5).

Coal Tar Contamination at the Landfill Site

Investigations undertaken to date do not suggest that the materials which were deposited as part of the illegal landfilling activity on Parcel 3 include hazardous substances. The VCC between SCDHEC and Duke Energy specifically excludes consideration of any impacts related to these materials.

The landfill material was deposited on land which had previously received coal tar contaminated wastewater from the former MGP. *"It appears that as coal tar contaminated wastewater entered the floodplain south of Bramlette Road, the wastewater spread southwest across the floodplain. Aerial photographs of the area taken in the 1950s during gas plant operations indicate the presence of two ponds approximately 700 feet south of Bramlette Road at what is now the southwest corner of the Vaughn Landfill. The ponds are now within the seasonally flooded area west of the landfill. Several samples collected in the area of the ponds, including WW002 collected in 1995, revealed the presence of coal tar in the soil, in some places in layers several inches thick. Much of the coal tar entering the floodplain south of Bramlette probably flowed into the ponds and settled at the bottom"* (AES, 1996, p. III-11).

The investigations undertaken between 1995 and 1999 encountered "oily" soil beneath the northern and western Vaughn Landfill area, and an accumulation of 2.75 inches of DNAPL in MW3D. The DNAPL was interpreted to be accumulating and migrating through alluvial sand material at the interface with the underlying, less permeable saprolite, at between 7 feet and 9 feet below original ground level. It was concluded that *"(g)roundwater beneath the Landfill is likely contaminated from both upgradient sources within the MGP site and along Ditch 1 leading from the MGP site; and from coal tar deposits beneath the Landfill"* (Duke Engineering & Services, 2000a, p.28).

It is our understanding that no remediation has been undertaken at the Vaughn Landfill. A viewpoint has persisted since 2000 that any attempt to remove coal tar from beneath the Vaughn Landfill might damage or destroy the wetlands (Duke Engineering & Services, 2000a). However, the investigation work described in ERM's 2018 report proposed to assess remedial options for the residual NAPL.

During the first quarter of 2019, 42 soil boreholes were advanced at the Vaughn Landfill parcel to investigate the extent of NAPL. Figure 1 of Duke Energy's (2019b) quarterly report indicates that NAPL was observed during the drilling of 13 boreholes under the northern part of the Vaughn Landfill, and "tar-like material" was observed at two locations further south. (Note that Figure 3-1 of SynTerra's later (2019) report shows only 12 boreholes with NAPL observations. However, the log for borehole T7-SB1, included in Appendix B of the report, indicates that NAPL was observed in this borehole; therefore, it should be indicated as such on Figure 3-1.) The borehole logs, which are included in Appendix B of SynTerra (2019), show that the NAPL observations in the boreholes included both visual signs and odors, and were noted within the alluvial soils beneath the landfilled material. Analytical data provided in Table 7 of Duke Energy (2019b) and Table 3-7 of SynTerra (2019) show that PAHs were detected in soil samples taken between 10 feet and 22 feet bgs.

Table 7 of Duke Energy (2019b) and Table 3-7 of SynTerra (2019) indicate that there were no detections of benzene or naphthalene at concentrations above the industrial EPA RSL for soils of 5.1 mg/kg and 17 mg/kg, respectively. The tables show one detection of benzo(a)pyrene (3.53 mg/kg, T9-SB2[19]) above the EPA's industrial RSL of 2.1 mg/kg. However, these are not the correct soil screening levels that should be used when assessing site soil contamination. In the absence of risk-based soil cleanup criteria, SCDHEC requires the assessment of soil contamination to EPA levels that are protective of unrestricted uses (i.e., residential RSLs). Therefore, use of industrial standards is considered neither standard nor appropriate.

As well, in 2000, risk-based clean up criteria were established for the site based upon benzo(a)pyrene which was determined to be the most potent carcinogenic PAH in soils at the site (Duke Energy, 2000b, Appendix A). The risk-based soil clean up criteria established for the site, based upon ingestion of soil in a residential setting, is as follows:

- Benzo(a) pyrene = 87 ug/kg,
- Total Carcinogenic PAHs = 319 ug/kg, and
- Total PAHs = 900 ug/kg.

For comparison purposes, the residential and industrial EPA RSLs for benzene, naphthalene, and benzo(a)pyrene in soils, as well as the risk-based cleanup criteria for the Site, are provided below.

Compound	EPA Industrial Screening Level (ug/kg)	EPA Residential Screening Level (ug/kg)	Risk-based Site Cleanup Criteria (ug/kg)
Benzene	5,100	1,200	-
Naphthalene	17,000	3,800	-
Benzo(a)pyrene	2,100	110	87
Total Carcinogenic PAHs			319
Total PAHs			900

SynTerra (2019, p. 3-4) notes in relation to the Vaughn Landfill that the "*southern extent of the NAPL investigation is bounded by RI-SB3, immediately south of MW-21 (and abandoned MW-6A). While NAPL was not observed in cores collected during the installation of well MW-21, an accumulation of NAPL within the well has occurred since its installation.*" It should also be noted that, during abandonment of MW-6A, which was immediately adjacent to MW-21, 3 feet of tar-like material was observed in the well screen (as described on p. 3-3 of the report). This indicates that the southern extent of the NAPL has not yet been determined.

Groundwater

Monitoring Well Summary

There are currently 25 groundwater monitoring wells at the Site:

- Eight wells at the former MGP (Parcel 1), which include two three-well clusters, one up-gradient, and one down-gradient targeting the alluvial soils (MW-13R and MW-7R), alluvial soils/saprolite boundary (MW-27 and MW-9R), and bedrock (MW-26 and MW-28). These wells were installed by Anchor QEA in 2017. The other two wells (MW-15 and MW-16) date from the 1999 Phase III assessment and are installed in deep saprolite/bedrock and alluvial soils, respectively.
- One well (MW-25R) outside the Site boundary on the Legacy Early College Elementary School property. This well is screened in the alluvial soils.
- A pair of wells (MW-29S in alluvium and MW-29TZ in the saprolite/bedrock transitional zone) were installed in the first quarter of 2019 in the southwest of Parcel 2.
- Seven wells in Parcel 3, of which five are within the footprint of the Vaughn Landfill. These include (from north to south) MW-01 screened at the fill/alluvium interface; MW-03, MW-20, and MW-03BR, screened respectively at the fill/alluvium interface, within the saprolite, and in bedrock; and MW-21 screened at the fill/alluvium interface. The other two wells in Parcel 3 are located near the western boundary and include (from north to south) MW-02 and MW-18, respectively. These wells are screened in alluvial soils and alluvial soils/saprolite.

- Three wells west of Parcel 3, between the Site boundary and Reedy River, on the Swamp Rabbit Trail. These include MW-30S and MW-31S screened in shallow alluvium, and MW-31TZ screened in the saprolite/bedrock transition zone.
- Two wells on the western boundary of Parcel 4, MW-05 and MW-22, respectively screened in alluvial soils and alluvial soils/saprolite.
- Two wells at the north end of Parcel 5, MW-23 and MW-24, respectively screened in the alluvial soils/saprolite interface and shallow alluvium.

Contaminants in Groundwater

ERM (2018b) reported on the sampling of 21 of the monitoring wells present at the Site in July 2017. The results were combined with the results of analysis of groundwater samples from temporary wells obtained by Anchor QEA. The results were discussed in terms of benzene (the primary VOC of concern) and naphthalene (the primary SVOC of concern). For benzene, the EPA MCL of 5 ug/l was used as the screening criterion. There is no South Carolina MCL for naphthalene in groundwater; the South Carolina RBSL of 25 ug/l, as listed in Appendix C of the SCDHEC Quality Assurance Program Plan for the Underground Storage Tank Management Division, dated February 2016, was considered appropriate for screening (ERM, 2018b).

Some of the findings from the 2018 Groundwater Remedial Investigation Work Plan Addendum (ERM, 2018b) included:

- Benzene was detected at 17.8 ug/l and naphthalene was detected at 36.3 ug/l in a groundwater sample from MW-7R at the former MGP. This is the shallowest well in the southwestern (down-gradient) corner of the site. Benzene and naphthalene were not detected in any other groundwater sample from monitoring wells on the MGP site. However, benzene was detected above 5 ug/l in two additional groundwater samples obtained from temporary wells installed along the East Bramlette Road boundary. Naphthalene was detected at concentrations above 25 ug/l in four additional groundwater samples, with a maximum concentration of 1,520 ug/l (TW-06).
- Benzene was detected at greater than 5 ug/l in all of the six groundwater samples from wells within the Vaughn Landfill parcel. The highest concentration of 263 ug/l was detected in a groundwater sample from MW-20. MW-20 is the deepest of the well cluster installed in the northern part of the Vaughn Landfill, where NAPL was observed during the installation of the shallower well, MW-3D. Naphthalene was also detected in five of the six groundwater samples, excluding the sample from MW-03. A maximum naphthalene concentration of 3,400 ug/l was detected in a groundwater sample from MW-19 screened in alluvial soils and located near the northern site boundary.
- Benzene and naphthalene were detected at concentrations of 244 ug/l and 71.1 ug/l, respectively, in a groundwater sample from MW-02 in the northwestern corner of Parcel 3.

This location is directly down-gradient of the former MGP. The extent of the plume further to the west-southwest, towards the Reedy River, has not been determined.

- Benzene was not detected above the MDL in any groundwater sample collected from Parcels 4 and 5. A low concentration (10.9 ug/l) of naphthalene was only detected in a groundwater sample from MW-18. The absence of benzene and naphthalene (except at MW-18) appear to delineate the extent of contamination in the cross-gradient direction to the south.
- *"Aerobic or moderately reducing conditions and microbial populations favorable for BTEX and polycyclic aromatic hydrocarbon degradation exist around the plume perimeter. Overall, favorable natural attenuation conditions exist at the Site"* (ERM, 2018b, p.9).

ERM described the benzene and naphthalene concentrations as being generally consistent with historical results. Chemographs (concentration over time graphs) were included as Charts 2 and 3, and the concentrations were also tabulated in Table 2, of the May 2016 groundwater monitoring report (S&ME, 2016). The chemographs show that the concentrations of benzene and naphthalene measured in groundwater samples from MW-02 can vary quite widely between sampling events. In fact, benzene and naphthalene were not detected in four of the nine sampling events between May 2012 and May 2016. The reason for this is not known.

The most recent groundwater sampling data, from December 2018 and March 2019, are reported by Duke Energy (2019b). No interpretation of the data is provided in the report, but Table 4 of the report indicates the following:

- Benzene was detected at 1,920 ug/l and naphthalene at 4,060 ug/l in groundwater samples from newly installed monitoring well MW-29TZ, located in the southwestern part of Parcel 2. Benzene and naphthalene were not detected in a groundwater sample from the shallow well at this location (MW-29S).
- Benzene was detected at 25.5 ug/L and naphthalene was detected at 33.8 ug/l in a groundwater sample from MW-7R at the former MGP.
- Benzene was detected at 25.8 ug/l in a groundwater sample from MW-01 and 30.4 ug/l in a groundwater sample from MW-21 at the Vaughn Landfill parcel. Naphthalene was detected at 1,700 ug/l and 57.5 ug/l in these wells, respectively. Neither MW-03 nor MW-20 were able to be sampled because NAPL was observed in these wells. Wells with free product are not typically sampled in order to avoid coating of the sampling equipment and/or damaging of the equipment used to analyze the samples.
- Benzene was detected at 3.4 ug/l and naphthalene at 2.3 ug/l in a groundwater sample from MW-02, located in the northwestern corner of Parcel 3. For comparison purposes, higher concentrations of benzene (244 ug/l) and naphthalene (71.1 ug/l) were detected in a groundwater samples collected from MW-02 in July 2017. This further illustrates the variability of contaminant concentrations over time in this particular well.

- Benzene and naphthalene were not detected above the reporting limit in samples from the three newly installed wells (MW-30S, MW-31S, and MW-31TZ), located along the Swamp Rabbit Trail. These wells have been sampled twice so far, in December 2018 and March 2019.

SynTerra (2019) repeats the above analytical results, and adds one new result - newly-installed monitoring well MW-03BR was sampled on 10 April 2019. Benzene and naphthalene were detected in the sample at concentrations of 620 ug/l and 2910 ug/l, respectively. This well is screened in bedrock at 59-64 feet bgs at the Vaughn Landfill parcel. The detection of benzene and naphthalene demonstrates that the full depth of contamination beneath the Site has not yet been delineated.

The detection of benzene and naphthalene in a sample from new well MW-29TZ to the north of East Bramlette Road demonstrates that the down-gradient extent of the contaminant plume has not been fully delineated to the west and southwest of the former MGP.

Earlier reports suggested that natural attenuation of groundwater contaminants may be occurring at the site. For example, the Phase III investigation report (Duke Engineering & Services, 2000a) noted that sulfate levels were typically lower, and iron levels typically higher, in groundwater samples with high levels of organic contamination; suggesting that biological degradation was occurring. However, AES (1996) pointed out that *"(a)naerobic conditions in a floodplain environment inhibit natural attenuation of contaminants. This may explain why volatile compounds are still found in the coal tar contaminated soils and groundwater after aging for over 50 years"* (AES, 1996, p. VII-2).

SynTerra (2019) proposes to install an additional 31 monitoring wells at a total of 14 locations, with most locations having separate wells installed at shallow, transition zone, and bedrock depths. The locations for new wells include the former MGP (Parcel 1), Parcel 2 downgradient of the former MGP, within Parcel 3, offsite to the east of Parcel 3, and at three locations along the Swamp Rabbit Trail (SynTerra, 2019, Figure 4-1 and Table 4-1). The purpose of the additional wells is "*to completely delineate the horizontal and vertical extent of COIs* [constituents of interest] *in groundwater*" (SynTerra, 2019, p. 4-6).

Surface Water

Drainage

Investigations have established that wastewater from the MGP was discharged into a drainage ditch which flowed from the southwest corner of the MGP, paralleling East Bramlette Road, before passing beneath the road via a culvert and onto the floodplain. This ditch is still present today.

Although the above interpretation is not in doubt, it should be noted that the interpretation of other elements of the surface drainage network west of the former MGP has changed during the history of investigation at the site, as summarized below:

1. Up to 2018 (e.g. see Figure 1 of Duke Energy, 2019a), figures show the outflow ditch from the former MGP running in a culvert under East Bramlette Road into the wetlands east of the Vaughn Landfill, as outlined above. A separate drain runs north-south to the west of the Vaughn Landfill, apparently originating from north-west of the rail line to the north of East Bramlette Road.
2. Figure 1 of Duke Energy (2019b) shows the outflow ditch from the former MGP splitting, with one branch flowing under East Bramlette Road into the wetlands east of the Vaughn Landfill, as outlined above, and the other continuing parallel with East Bramlette Road and then flowing beneath the road via a second culvert into the ditch west of the Vaughn Landfill. In this map there is no drain originating north-west of the railway.
3. The most recent report (SynTerra, 2019) shows the outflow ditch from the former MGP splitting, with one branch flowing under East Bramlette Road into the wetlands east of the Vaughn Landfill, as outlined above, and the other continuing parallel with East Bramlette Road before turning north-westwards and going under the railway line. This map suggests the north-south ditch west of the Vaughn Landfill does not extend northwards beneath East Bramlette Road.

These different interpretations have implications for the determination of how a portion of the contaminants from the former MGP migrated off-site in surface water; however, they do not affect the robust interpretation that a considerable portion flowed beneath East Bramlette Road onto Parcel 3.

The outflow of the culvert beneath East Bramlette Road is actually on property to the east of Parcel 3 (**Figure 1**). From this culvert, the wastewater flowed in a ditch running towards the south-southeast to join another ditch, which then ran south-southwestwards to enter Parcel 3. The portion of this ditch beneath Parcel 3 is now covered by the Vaughn Landfill. **Figure 1** shows that this ditch originally flowed into another drainage channel running the full length of Parcels 3, 4, and 5. It is uncertain whether this drainage channel entered Parcel 3 from a second culvert underneath East Bramlette Road, approximately mid-way along the northern boundary (interpretation 2 described above) or only exists south of East Bramlette Road (interpretation 3, suggested by the latest SynTerra (2019) report). In any case, this channel formerly flowed into ponds near the southern end of the Vaughn Landfill.

This channel still exists but is covered in part by the Vaughn Landfill. The channel *"apparently drained the ponds as it does the floodplain today"* (AES, 1996, p. III-11), and flows into the Reedy River at the southern end of Parcel 5, north of Willard Street.

The present-day situation, with respect to surface water drainage, is understood to be as follows: Drainage water from Parcels 1 and 2 still passes in the culvert beneath East Bramlette Road and flows into seasonal wetlands east of Parcel 3. There is a channel running from west to east through the Vaughn Landfill, which allows the water to drain into the seasonal wetlands in Parcel 3 (west of the Vaughn Landfill). The floodplain west of the Vaughn Landfill contains standing water for most of the year. The water is prevented from entering the Reedy River by the elevated railroad embankment, but the area is drained southwards via the channel to discharge to the river just north of Willard Street. *"This appears to be the only discharge point for surface flow from the CSXT properties east of the Reedy River"* (AES, 1996, p. II-7).

Contaminants in Surface Water

Investigations at Parcel 3 were triggered by the observation of hydrocarbon contamination in the wetlands to the west and east of the Vaughn Landfill. As summarized above, the investigations revealed the presence of residual coal tar (i.e., NAPL) and associated contamination in soil and groundwater. It has been established that during operations of the MGP, coal tar contaminated wastewater was routinely discharged into the drainage ditch which flowed beneath East Bramlette Road and onto the floodplain. The wastewater spread across the floodplain, with much of the coal tar probably settling in two ponds that were present approximately 700 feet south of East Bramlette Road (AES, 1996).

During the fourth quarter of 2018, consultants to Duke Energy collected surface water and sediment samples from six locations along the Reedy River adjacent to Parcels 3, 4, and 5 (i.e., SW-07 to SW-12 and SW-07-SED to SW-12-SED) (**Figure 2**). PAHs were only detected in sediment sample SW-12-SED from the Reedy River at the southern boundary of Parcel 5 near Willard Street. The PAHs detected in sample SW-12-SED confirm that hydrocarbon contaminated water discharged from the former MGP has indeed flowed into the Reedy River via the channel running through Parcels 3, 4, and 5.

This conclusion is corroborated by analytical results from samples collected from the southern end of the drainage channel on Parcel 5 near Willard Street (**Figure 2**). Grab samples WT1 and WT2 were collected from channel-bottom sediments in April 2019. Total carcinogenic PAH concentrations of 6,608 ug/kg and 17,551 ug/kg were detected in WT1 and WT2, respectively. Samples of suspended sediment were collected from the water column 48 feet (1D), 78 feet (2D), and 178 feet (3D) upstream of the drainage channel's exit point into the Reedy River. Total carcinogenic PAH concentrations of 10,176 ug/kg, 28,200 ug/kg, and 20,270 ug/kg were detected in 1D, 2D, and 3D, respectively. These concentrations greatly exceed the risk-based target cleanup level of 319 ug/kg that was established for remediation of the former MGP in 2001-2002. During sampling, care was taken to ensure that the samples represented suspended material from natural flow in the channel, and not channel-bottom sediment. Therefore, the results suggest that there is a continuing outflow of contaminants from the Site to the Reedy River.

Carcinogenic PAHs	WT1 (ug/kg)	WT2 (ug/kg)	1D (ug/kg)	2D (ug/kg)	3D (ug/kg)
Benzo(a)anthracene	1,240	3,290	1,760	5,480	ND*
Benzo(a)pyrene	1,010	3,480	1,730	4,790	9,070
Benzo(b)fluoranthene	1,510	4,010	2,960	7,480	11,200
Benzo(k)fluoranthene	567	1,520	869	2,800	ND*
Chrysene	1,620	2,960	1,910	5,100	ND*
Dibenzo(a,h)anthracene	ND	391	ND	ND	ND*
Indeno(1,2,3-cd)pyrene	661	1,900	947	2,550	ND*
Total Carcinogenic PAHs	**6,608**	**17,551**	**10,176**	**28,200**	**20,270***

*Elevated reporting limit due to low solids proportion. Total carcinogenic PAHs may be higher than reported.

In March 2019, six surface water samples were collected from around the Vaughn Landfill in Parcel 3 (i.e., SW-01 to SW-06) and analyzed for VOCs and SVOCs. Benzene was detected in surface water sample SW-04, located on the west side of the Vaughn Landfill, at a concentration of 2.3 ug/l. BTEX and PAHs were not detected in any of the other samples.

Also, in March 2019, six sediment samples were collected from around the Vaughn Landfill in Parcel 3 (i.e., SW-01-SED to SW-06-SED; see **Figure 2**) and analyzed for VOCs and SVOCs. As shown in the table below, carcinogenic PAHs were detected in each of the samples. Total carcinogenic PAH concentrations ranged from 337.3 ug/kg to 9,823 ug/kg, which exceed the site risk-based target cleanup level of 319 ug/kg.

Carcinogenic PAHs	SW-01-SED (ug/kg)	SW-02-SED (ug/kg)	SW-03-SED (ug/kg)	SW-04-SED (ug/kg)	SW-05-SED (ug/kg)	SW-06-SED (ug/kg)
Benzo(a)anthracene	296 M1	63.9	909	432	1,030	2,160
Benzo(a)pyrene	295 M1	61.5	599	415	584	1,840
Benzo(b)fluoranthene	358 M1	77.7	1,050	537	813	2,170
Benzo(k)fluoranthene	155 M1	31.4	321	212	281	715
Chrysene	266 M1	66.5	890	421	1,240	1,910
Dibenzo(a,h)anthracene	57.1 M1	9.7 J	132	65.2	110	256
Indeno(1,2,3-cd)pyrene	169 M1	26.6	328	188	224	772
Total Carcinogenic PAHs	**1,539 M1**	**337.3**	**4,229**	**2,270.2**	**4,282**	**9,823**

Notes:

J – estimated value

M1 – matrix spike recovery was high

Contamination Summary

Residual pockets of coal tar NAPL remain beneath the southwestern part of the former MGP (Parcel 1), beneath the Vaughn Landfill in the river floodplain (Parcel 3), and along the drainage ditch between the two (Parcel 2 and off-Site). Residual coal tar contamination should also be expected beneath the former ponds located about 700 feet south of Bramlette Road and the drainage channel running through Parcels 4 and 5. These areas have yet to be investigated. The residual NAPL constitutes a continuing source of groundwater contamination.

Neither the down-gradient extent nor the maximum depth of the contaminated groundwater plume has been established, despite this having been acknowledged as a data gap since 1996. This omission is reinforced by the detection of benzene and naphthalene in groundwater from recently installed down-gradient and deep bedrock monitoring wells MW-29TZ and MW-03BR, respectively.

Recent analysis of sediment samples from the current drainage channel and from the Reedy River confirms that contamination has discharged and will continue to discharge to the Reedy River.

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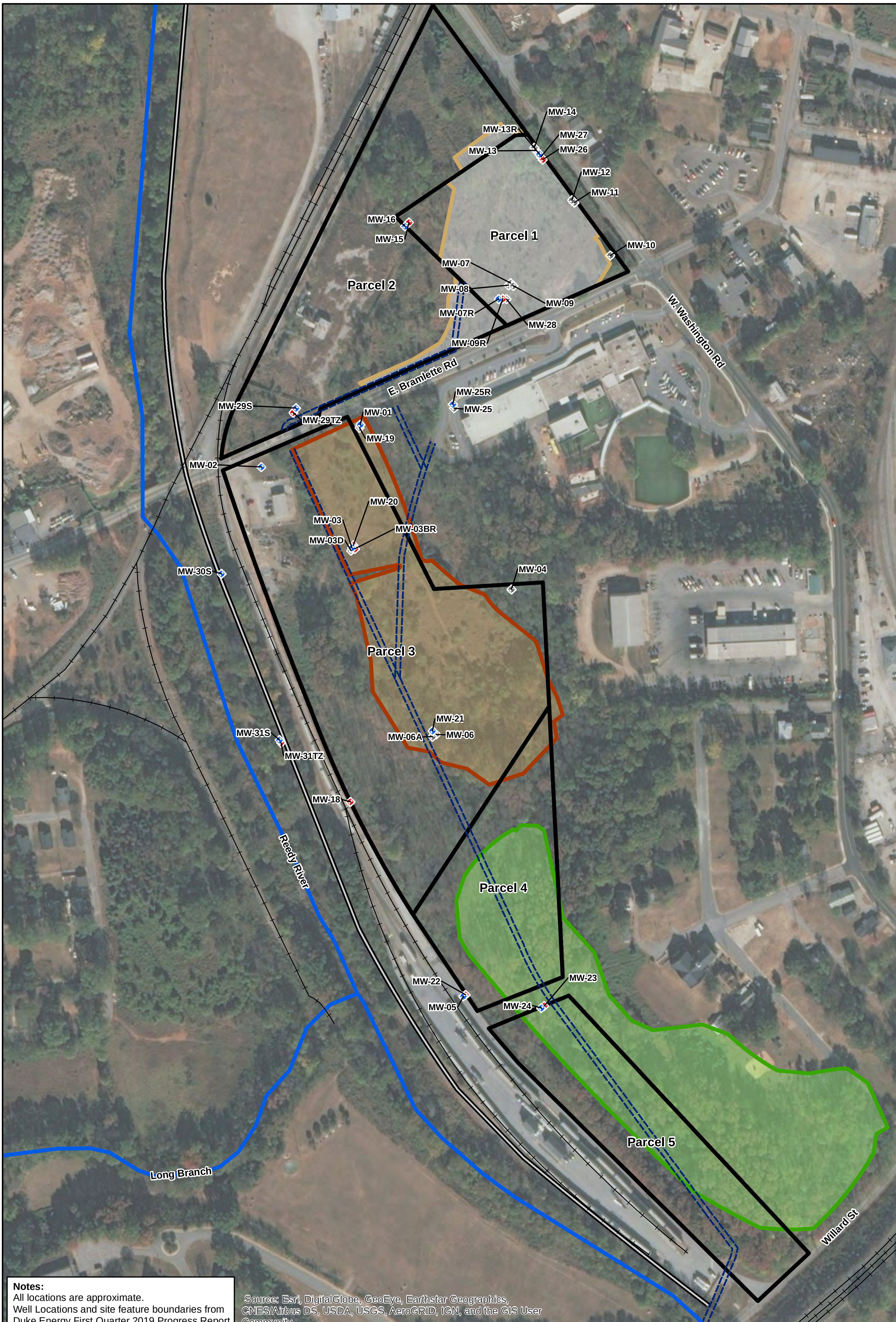
FIGURES



Notes:
All locations are approximate.
Well Locations and site feature boundaries from Duke Energy First Quarter 2019 Progress Report.

Shallow Well
Deep Well
Abandoned Well
Former Drainage Ditch (1964)
Swamp Rabbit Trail
Railroad
River/Stream
Parcel Boundary
Excavated Area (2001 - 2002)
Vaughn Landfill Boundary
Wetlands Boundary

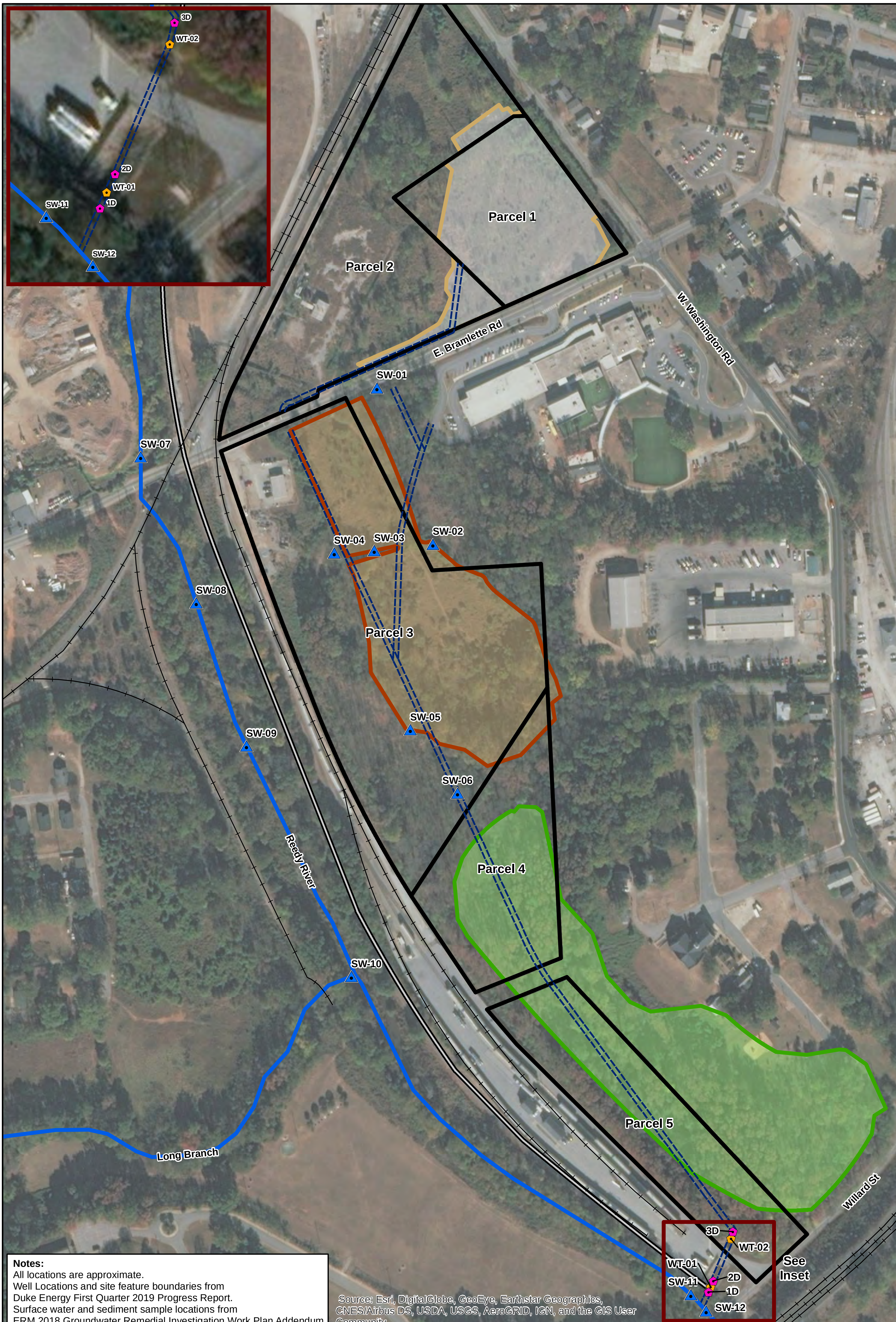
0 230
Scale: Feet

aquilogic, Inc.

CSXT Bramlette Road MGP

Site Map

Date: 10/11/2019 | Project #: 019-12 | **Figure 1**



Notes:
All locations are approximate.
Well Locations and site feature boundaries from Duke Energy First Quarter 2019 Progress Report.
Surface water and sediment sample locations from ERM 2018 Groundwater Remedial Investigation Work Plan Addendum.

Sediment/Surface Water Samples
April 2019 Grab Sediment Samples
August 2019 Grab Sediment Samples
Former Drainage Ditch (1964)
Swamp Rabbit Trail
Railroad
River/Stream
Parcel Boundary
Excavated Area (2001 - 2002)
Vaughn Landfill Boundary
Wetlands Boundary

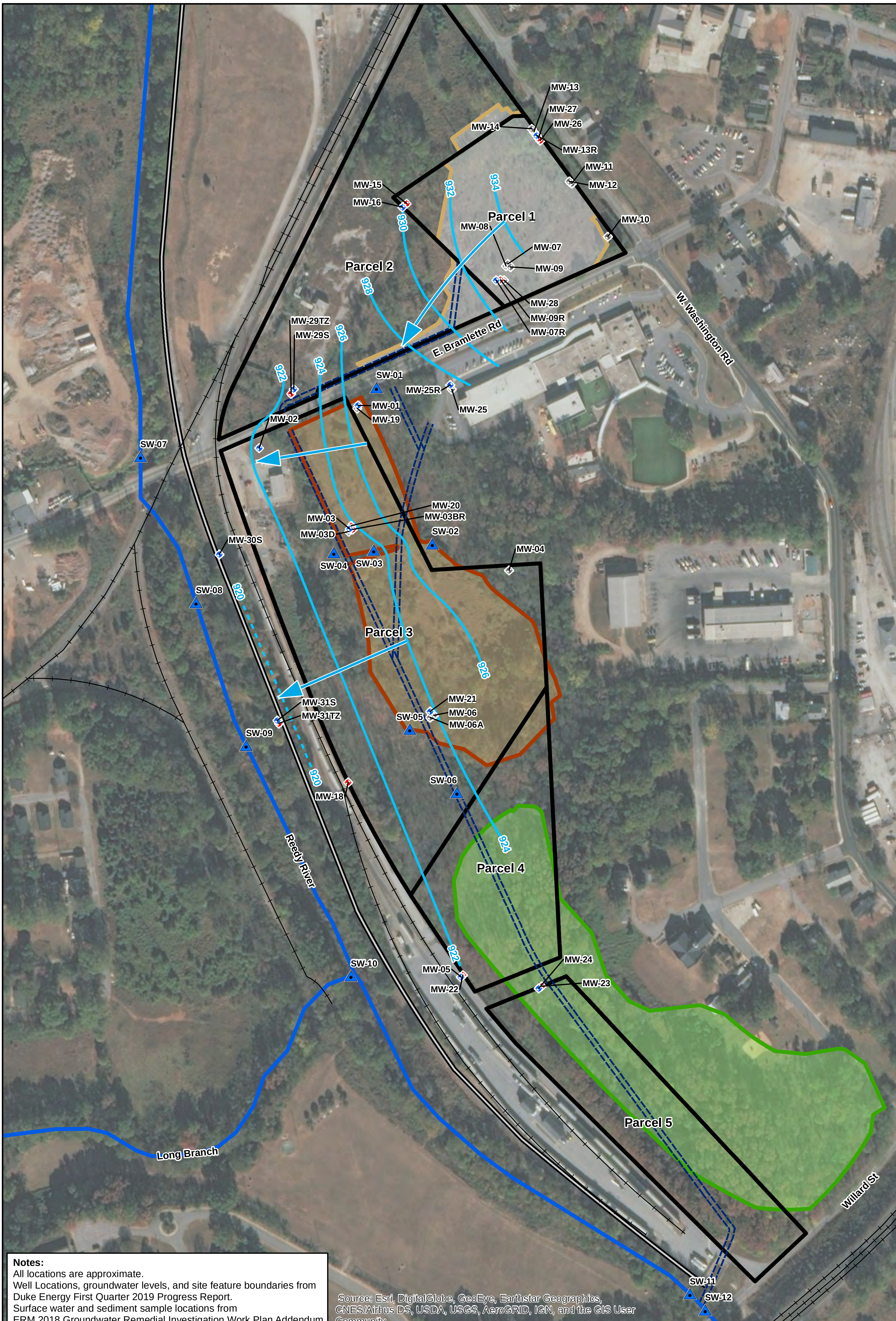
0 230
Scale: Feet

aquilogic, Inc.

CSXT Bramlette Road MGP

Sediment and Surface Water Samples

Date: 10/11/2019	Project #: 019-12	**Figure 2**



Notes:
All locations are approximate.
Well Locations, groundwater levels, and site feature boundaries from Duke Energy First Quarter 2019 Progress Report.
Surface water and sediment sample locations from ERM 2018 Groundwater Remedial Investigation Work Plan Addendum.

Groundwater Elevation Contour
Groundwater Elevation Contour (Inferred)
920 Groundwater Elevation (feet)
Groundwater Flow Direction
Shallow Well
Deep Well
Abandoned Well
Sediment/Surface Water Samples
Former Drainage Ditch (1964)
Swamp Rabbit Trail
Railroad
River/Stream
Parcel Boundary
Excavated Area (2001 - 2002)
Vaughn Landfill Boundary
Wetlands Boundary

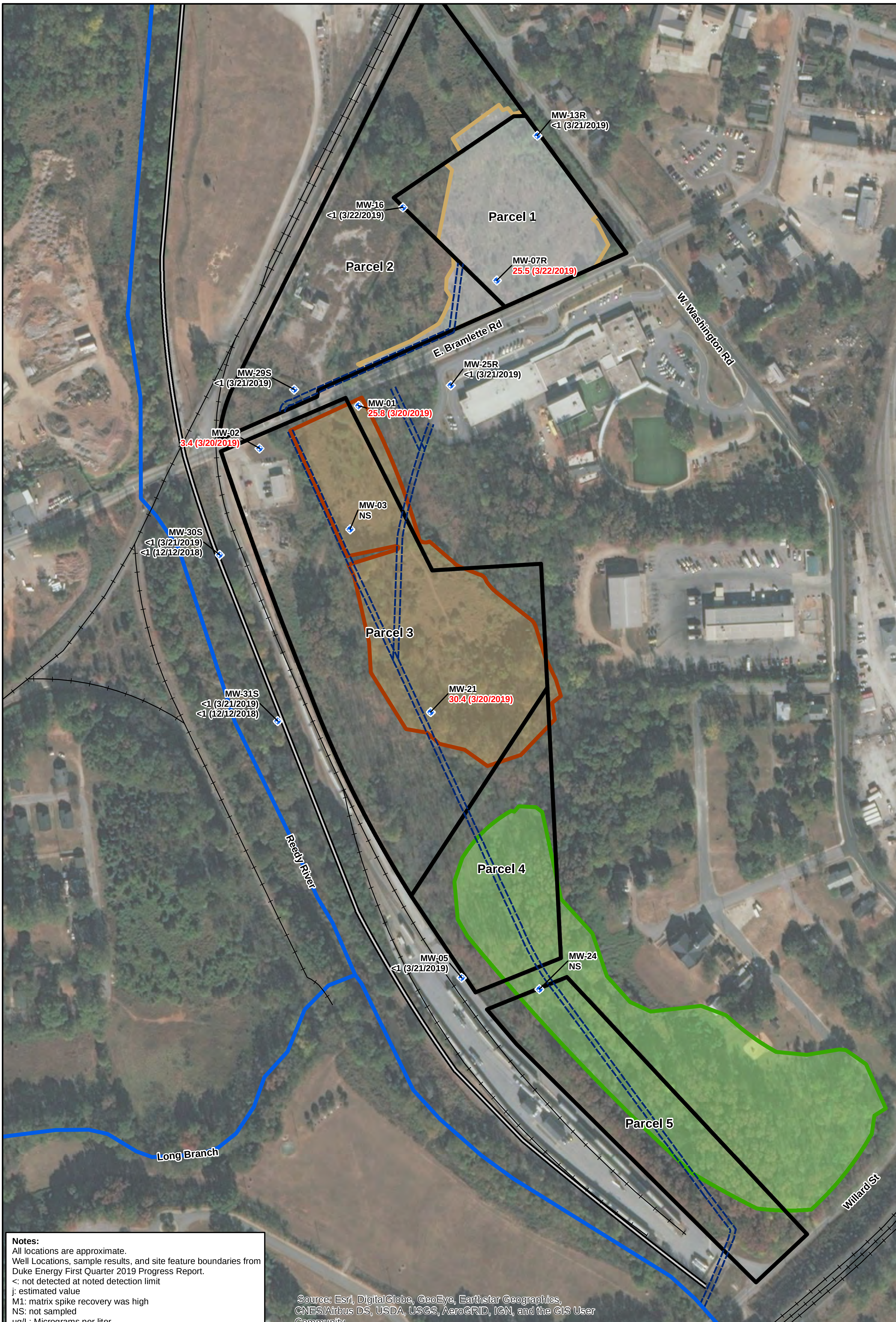
0 230
Scale: Feet

aquilogic, Inc.

CSXT Bramlette Road MGP

Groundwater Flow Contours

Date: 10/11/2019 | Project #: 019-12 | **Figure 3**



Notes:
All locations are approximate.
Well Locations, sample results, and site feature boundaries from Duke Energy First Quarter 2019 Progress Report.
<: not detected at noted detection limit
j: estimated value
M1: matrix spike recovery was high
NS: not sampled
ug/L: Micrograms per liter

Shallow Well
Former Drainage Ditch (1964)
Swamp Rabbit Trail
Railroad
River/Stream
Parcel Boundary
Excavated Area (2001 - 2002)
Vaughn Landfill Boundary
Wetlands Boundary

MW-21 — Well ID
30.4 (3/20/2019) — Sample date
Benzene (ug/L)

0 230
Scale: Feet

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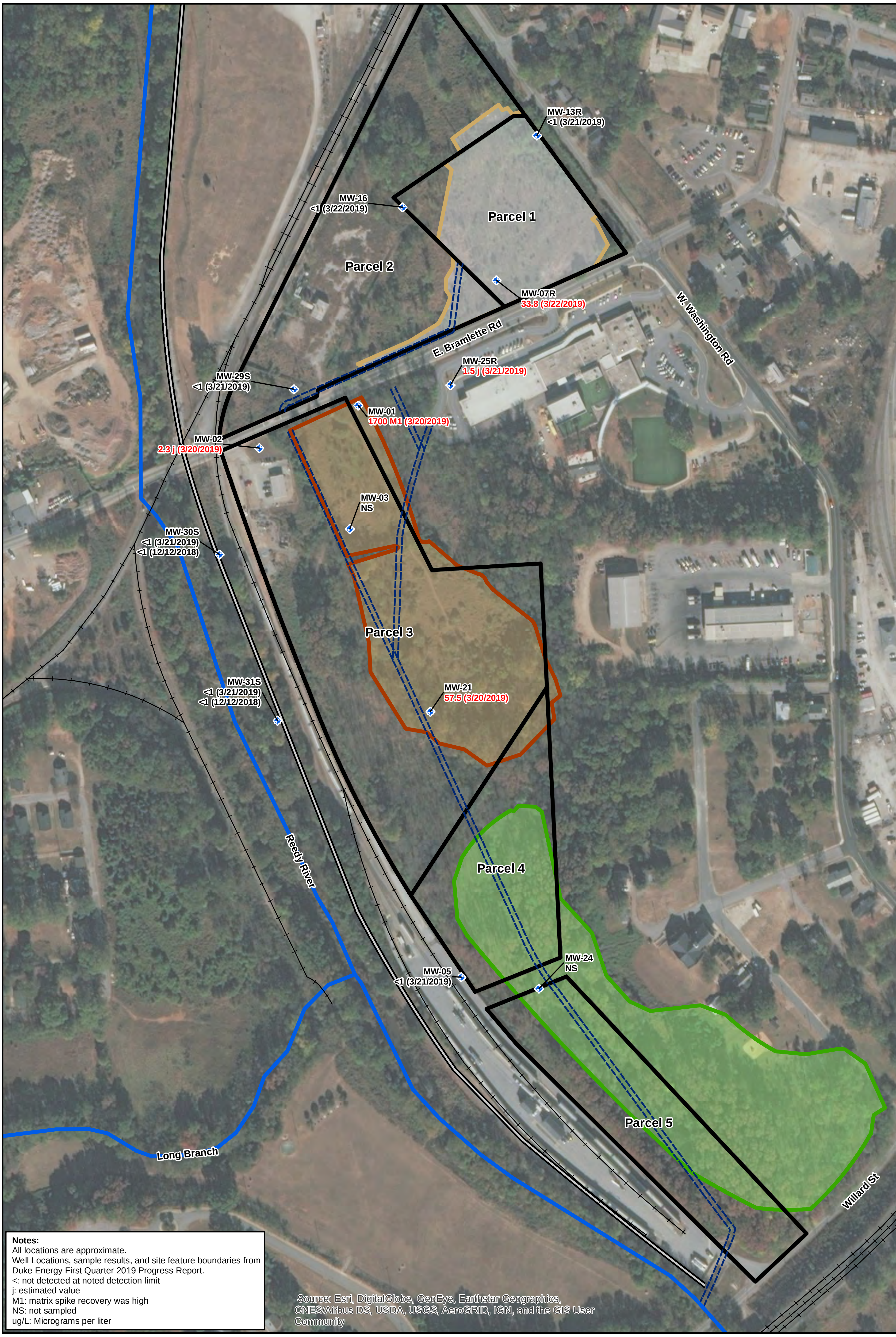
CSXT Bramlette Road MGP

Benzene Concentrations Shallow Wells

Date: 10/11/2019	Project #: 019-12	**Figure 4**



Shallow Well
Former Drainage Ditch (1964)
Swamp Rabbit Trail
Railroad
River/Stream
Parcel Boundary
Excavated Area (2001 - 2002)
Vaughn Landfill Boundary
Wetlands Boundary

MW-21 — Well ID
57.5 (3/20/2019)
Sample date
Naphthalene (ug/L)

0 230
Scale: Feet

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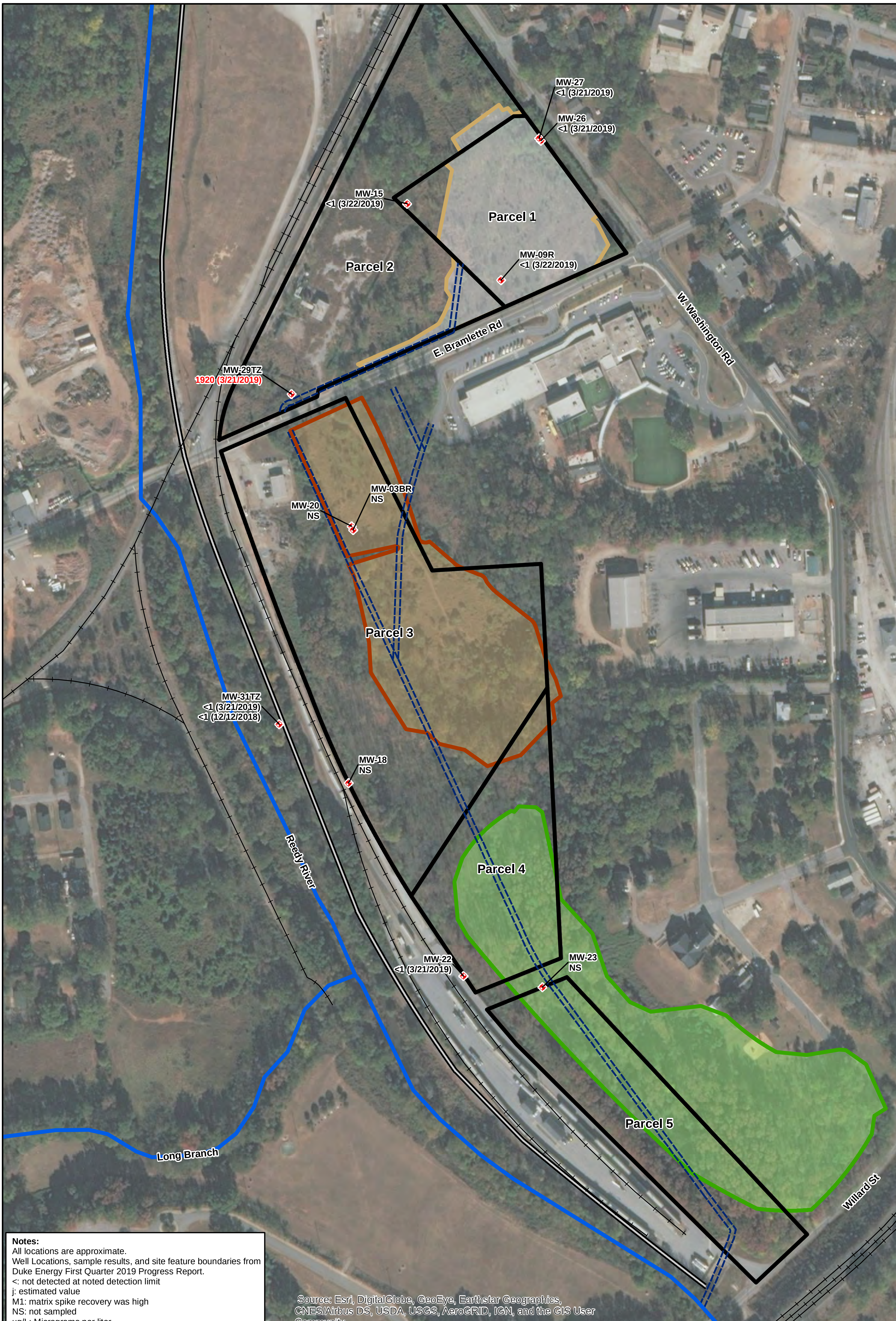
CSXT Bramlette Road MGP

Naphthalene Concentrations Shallow Wells

Date: 10/11/2019	Project #: 019-12	Figure 5



Notes:
All locations are approximate.
Well Locations, sample results, and site feature boundaries from Duke Energy First Quarter 2019 Progress Report.
<: not detected at noted detection limit
j: estimated value
M1: matrix spike recovery was high
NS: not sampled
ug/L: Micrograms per liter

Deep Well
Former Drainage Ditch (1964)
Swamp Rabbit Trail
Railroad
River/Stream
Parcel Boundary
Excavated Area (2001 - 2002)
Vaughn Landfill Boundary
Wetlands Boundary

MW-29TZ — Well ID
1920 (3/21/2019)
Sample date
Benzene (ug/L)

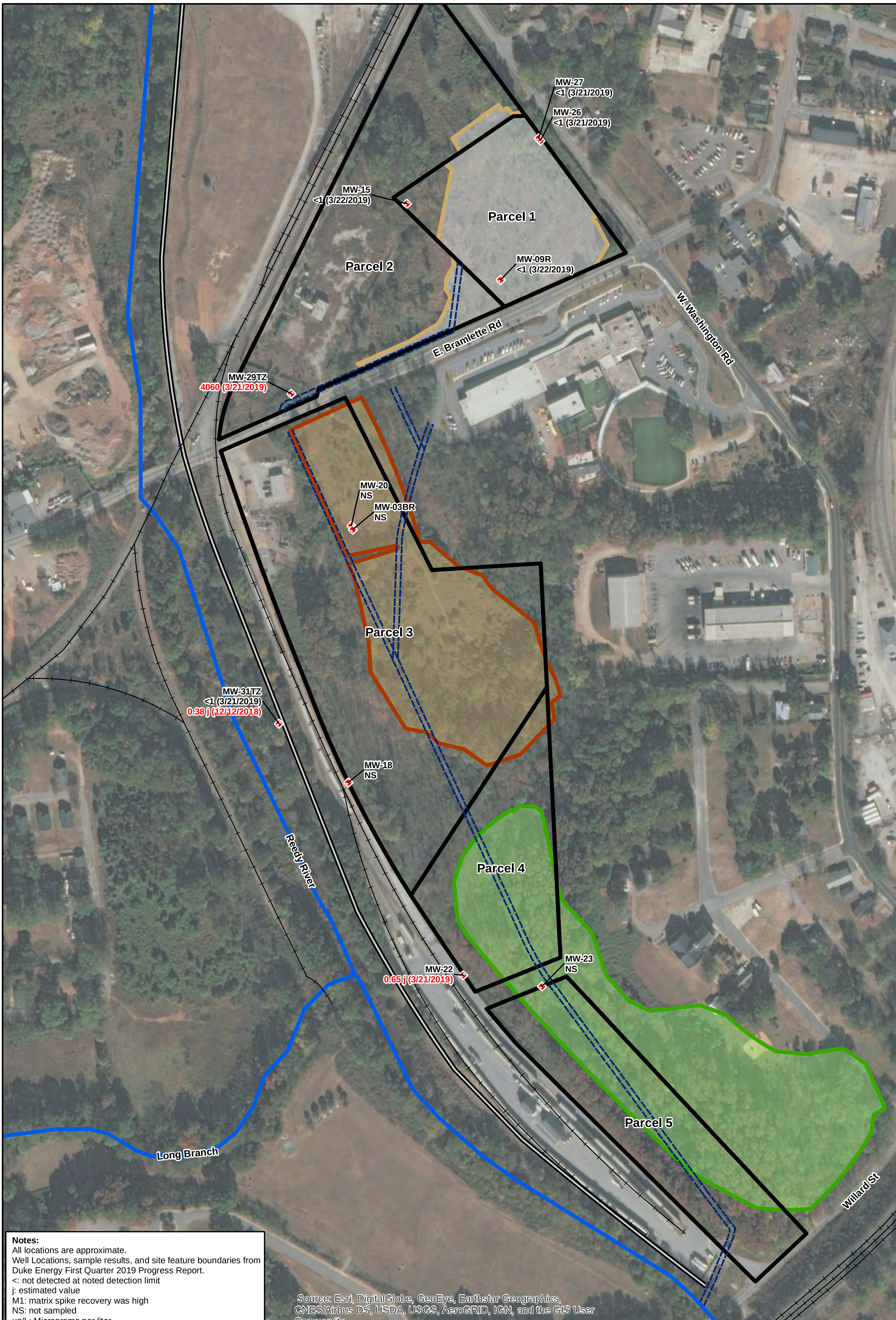
0 230
Scale: Feet

aquilogic, Inc.

CSXT Bramlette Road MGP

Benzene Concentrations Deep Wells

Date: 10/11/2019	Project #: 019-12	**Figure 6**



Notes:
All locations are approximate.
Well Locations, sample results, and site feature boundaries from Duke Energy First Quarter 2019 Progress Report.
<: not detected at noted detection limit
j: estimated value
M1: matrix spike recovery was high
NS: not sampled
ug/L: Micrograms per liter

Deep Well
Former Drainage Ditch (1964)
Swamp Rabbit Trail
Railroad
River/Stream
Parcel Boundary
Excavated Area (2001 - 2002)
Vaughn Landfill Boundary
Wetlands Boundary

MW-29TZ — Well ID
4060 (3/21/2019)
Sample date
Naphthalene (ug/L)

0 230
Scale: Feet

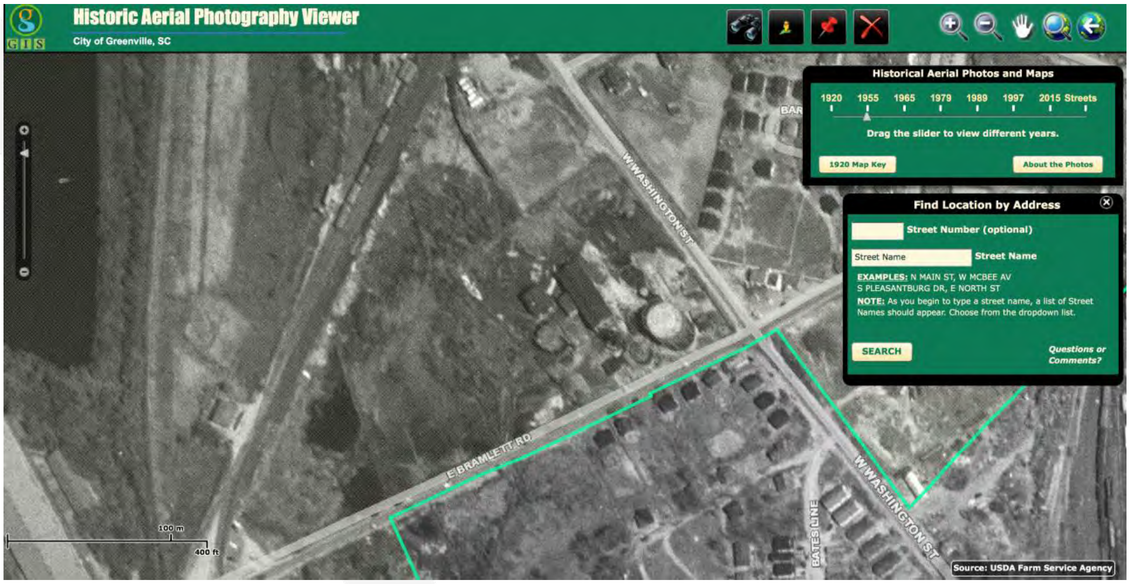
aquilogic, Inc.

CSXT Bramlette Road MGP

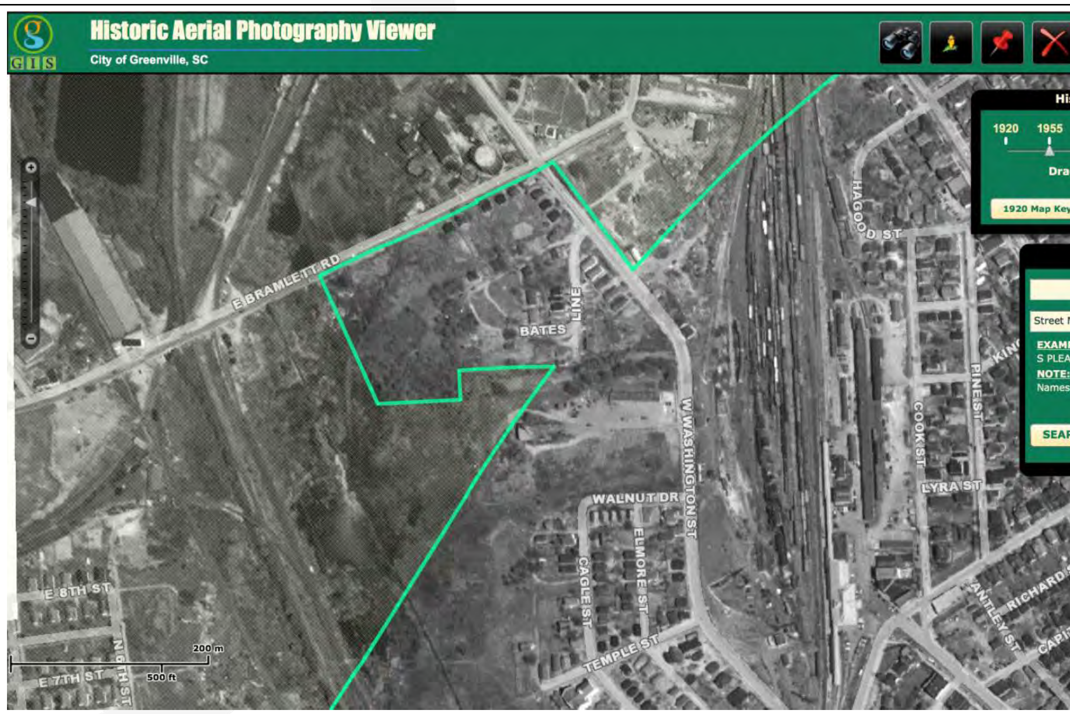
Naphthalene Concentrations Deep Wells

Date: 10/11/2019 | Project #: 019-12 | **Figure 7**

ATTACHMENT A: SITE PHOTOS



Photograph 1: Historical Aerial Photograph



Photograph 2: Historical Aerial Photograph

Photograph 3: Historical Aerial Photograph

Photograph 4: Historical Aerial Photograph

Photograph 5: Parcel 1 facing North from E Bramlette Road

Photograph 6: Parcel 1 facing North from E Bramlette Road

Photograph 7: Parcel 1 facing West from West Washington St

Photograph 8: Parcel 1 facing West from E Bramlette Road

Photograph 9: Parcel 1 facing North from E Bramlette Road

Photograph 10: Parcel 3 facing South from E Bramlette Road

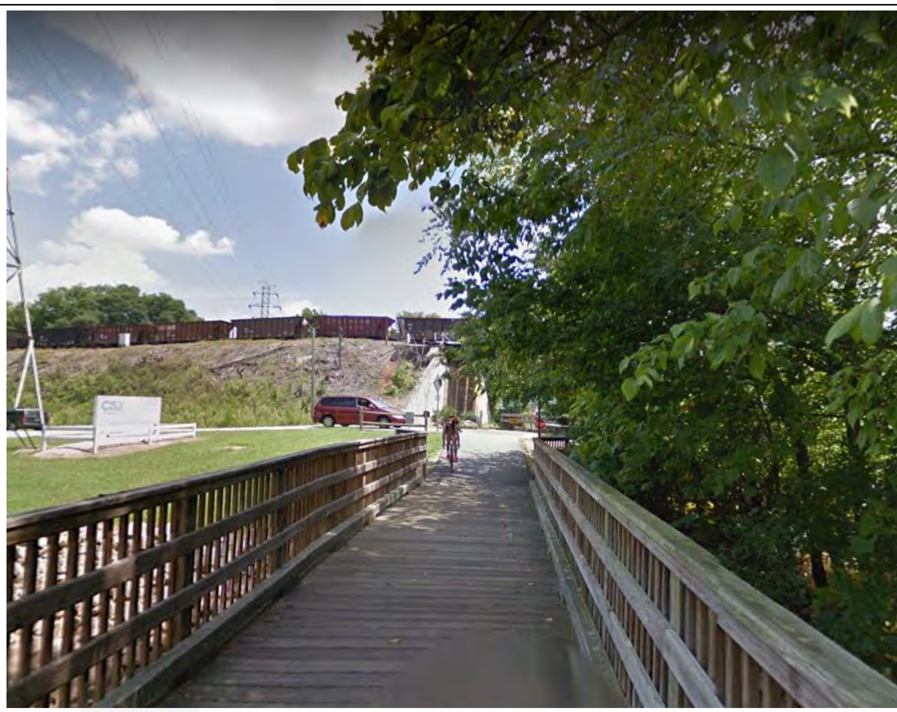
Photograph 11: Legacy Public Charter School from W Washington St facing West

Photograph 12: Legacy Public Charter School from E Bramlette Rd facing South

Photograph 13: Parcel 3 facing South from E Bramlette Road

Photograph 14: Swamp Rabbit Trail facing South from E Bramlette Road

Photograph 15: Swamp Rabbit Trail and CSXT Terminal facing South toward Willard St



Photograph 16: Swamp Rabbit Trail and CSXT Terminal facing South toward Willard St

Photograph 17: South drainage ditch at Willard St facing East from Swamp Rabbit Trail

Photograph 18: Flowing Reedy River at Willard St

Photograph 19: Drainage culvert at Willard St under Swamp Rabbit Trail

Photograph 20: Metal collecting pan in drainage ditch at Willard St

Photograph 21: Metal collecting pan with a slotted cover

Photograph 22: Metal collecting pan with a slotted cover

Photograph 23: Accumulated sediment in metal collecting pan