E Geology and Hydrogeology

E.1 [Not Assigned]

Not applicable.

E.2 [Not Assigned]

Not applicable.

E.3 General Hydrogeologic Information [40 CFR 270.14(c)(2)]

This section provides a description of the general hydrogeologic characteristics at the UCC facility. These characteristics were essential in providing a basis and understanding of site hydrogeologic characteristics. The characteristics summarized in this section were developed during various previous investigations and pertinent information is summarized in this section.

E.3.1 Regional Geology

Camden County is in the southeastern corner of Georgia (Figure 1). The county is bordered on the north by Brantley and Glynn counties; on the west by Charlton County; on the south by Nassau County, Florida; and on the east by the Atlantic Intracoastal Waterway. Camden County crosses three watersheds: the Satilla on the north, the Cumberland-St. Simons on the east, and the St. Mary's on the south (CH2M HILL Engineers, Inc. [CH2M] 2008a).

Camden County is underlain by approximately 5,500 feet of Cretaceous to Holocene stratigraphy (Wait and Davis 1986). This stratigraphy consists of unconsolidated to semi-consolidated clastic Coastal Plain sediments and semi-consolidated and consolidated carbonate Coastal Plain sediments striking southwest to northeast and thickening with dip to the southeast. The strata unconformably overlie Proterozoic felsic volcanic rocks in northern Camden County and Paleozoic metamorphic rocks in southern Camden County (Chowns and Williams 1983). The UCC Woodbine facility is east of a structural dome that is located northwest of Woodbine and northwest of the Southeast Georgia Embayment (CH2M 2008a).

E.3.2 Regional Hydrogeology

Groundwater is the primary source of water supply in the Camden County area. The UCC facility is underlain, in descending order, by the surficial aquifer system (Holocene to Upper Miocene), the Brunswick aquifer system (Middle Miocene to late Oligocene), a confining unit (Oligocene), and the Floridan aquifer.

The surficial aquifer system consists of interlayered sand, clay, and thin limestone beds of Miocene and younger age (Clarke et al. 1990). The system is subdivided into three zones: (1) the water table zone, (2) a confined upper water-bearing zone, and (3) a confined lower water-bearing zone (Leeth 1999). The water table zone is assigned to the Satilla and Cypresshead Formations and the confined water-bearing zones to the Ebenezer Formation. The water table zone is reported to yield approximately 2 to 140 gallons per minute (gpm) and have a transmissivity of 14 to 6,700 square feet per day (ft^2/day) in Glynn and Camden counties (Clarke et al. 1990; Leeth 1999). The extents of the confined water-bearing units are not known but are believed to occur in areas such as the Southeast Georgia Embayment (Clarke 2003).

The Brunswick aquifer system (upper and lower) consists of poorly sorted, fine-to-coarse, slightly phosphatic and calcareous or dolomitic quartz sand of Miocene age. The upper Brunswick aquifer consists of the Coosawhatchie and Marks Head Formations and the lower Brunswick aquifer within the Tiger Leap Formation (Weems and Edwards 2001). The upper Brunswick aquifer is separated from the overlying surficial aquifer by a clay of the Coosawhatchie Formation. The upper and lower Brunswick aquifers are separated by a clay of the Parachula Formation. The transmissivities of the lower Brunswick aquifer range from 2,000 to 4,700 ft^2/day, with yields 340 to 750 gpm (Clarke et al. 1990; Gill 2001; and Radtke et al. 2001). The transmissivities of the upper Brunswick aquifer range from 20 to 3,500 ft^2/day, with a maximum yield 750 gpm in Glynn County (Gill 2001; Radtke et al. 2001; CH2M 2008a).

E.3.3 Site Geology and Hydrogeology

E.3.3.1 Site Geology

The UCC Woodbine facility is located in the Barrier Island District of the Atlantic Coastal Plain Physiographic Province (Clark and Zisa 1976). Pleistocene sea levels advanced and retreated several times over the Barrier Island Sequence District, forming a stepped progression of decreasing elevations toward the sea. These former, higher sea levels formed barrier island/salt marsh environments generally similar to the present coast. The former sea levels deposited shoreline complexes parallel to the present shoreline. There has been slight to moderate dissection of these former terraces by streams, leading to the development of marshes in poorly drained low areas.

The UCC Woodbine facility resides on undifferentiated surficial sands (Holocene and Pleistocene), the Satilla Formation (Holocene and Pleistocene), and the Cypresshead Formation (Pliocene). The undifferentiated surficial sands and Satilla Formation cannot be separated due to lithologic similarities and lack of paleontological control likely found at the site (Leeth 1999). These Quaternary sediments are well sorted, fine-to-very-fine quartz sand, with some laterally extensive but discontinuous organic-rich layers that occur at approximately 5 to 10 feet below ground surface (bgs). Pelecypod shells are present but not abundant. There is no distinct marker at the base of the Quaternary sediments, but a partially cemented, reddish brown, iron-stained sand does occur that is typical of the Satilla Formation. Quaternary sediments are generally 35 to 45 feet thick across Camden County, Georgia, including the UCC Woodbine facility (Leeth 1999).

The Cypresshead Formation consists of fine-to-medium sand that grades downward in section to a sandy, clayey silt that is characterized at its base by thin clay and silt interbeds that become calcareous and shelly with depth. Pliocene sediments are differentiated primarily on lithology, specifically, an increase in coarse grain size, an increase in clay content, and a decrease in cementation and iron staining. These sediments range from approximately 35 to 45 feet thick (Leeth 1999).

Humate-cemented sandstone is locally prominent, with large boulders of humate sandstone littering the bases of bluffs. Humate is produced by the percolation of naturally occurring weak acids from the organic topsoil above the sands. The bluffs along the south streambank of Todd Creek on the northern side of the UCC Woodbine facility afford excellent exposures of barrier island facies of the Satilla Formation (Law Engineering and Environmental Services 1993). Sediments observed in lithologic samples at the UCC landfill, from the March 2006 direct-push technology investigation and May 2006 monitoring well installation, consist of fine-to-medium, indistinctly bedded quartz sand approximately 40 to 55 feet thick, with minor discontinuous clay beds that typically occur 40 to 55 feet bgs (CH2M 2008a).

Descriptions of the stratigraphy observed during drilling activities at the facility are documented in boring logs included in Appendix B.

E.3.3.2 Site Hydrogeology

Site hydrogeology is influenced primarily by the presence and proximity of water sources (rainfall) and sinks (Todd Creek and ponds) and by the hydraulic conductivity of the unconsolidated sediments (sand) that compose the surficial aquifer beneath the facility (CH2M 2008a). The surficial aquifer system, consisting of the Satilla/Cypresshead (unconfined water table zone) and Ebenezer (confined upper water-bearing zone and confined lower water-bearing zone) is estimated to be 265 feet thick. Based on literature reviews and investigation activities at the landfill, the unconfined water table unit of the surficial aquifer system at the landfill is greater than 100 feet thick.

The surficial aquifer at the landfill has been further subdivided into two zones: the shallow zone, which is up to 32 feet bgs, and the deep zone, which is approximately 40 to 55 feet bgs. Based on the lithologic data, the deep portion of the surficial aquifer does not appear to be confined or semi-confined. Direct-push technology logs document minor discontinuous clay beds that typically occur at 40 to 55 feet bgs. Due to the discontinuous nature and lack of sitewide correlation for these clay beds, the deeper portion (greater than 40 to 55 feet bgs) of the surficial aquifer may be semi-confined in small areas of the site but not sitewide (CH2M 2008a). Well construction information and logs for current and former facility wells are included in Appendix B.

E.3.4 Site Aquifer Properties

E.3.4.1 Tidal Influences

Based on a 72-hour water table study proximal to the landfill (conducted from March 6 to March 9, 2006, to monitor the impact of high and low tide cycles on site groundwater), groundwater in the shallow and deep groundwater zones within the surficial aquifer is not significantly affected by tides, but the deeper zone exhibits a moderate effect, somewhat greater than the shallow zone as described below. The water table study approach and results are described in detail in the *Revised Refined Conceptual Site Model Work Plan* (CH2M 2006).

The results of the water table study are summarized as follows:

- Tide water height ranged from 6.827 feet above mean lower low water at high tide to 0.223 foot above mean lower low water at low tide.
- Groundwater elevation changes between high tide and low tide in the shallow groundwater zone were minimal, exhibiting a difference of 0.129 to 0.112 foot above mean sea level (amsl).
- Groundwater elevation changes between high tide and low tide in the deep groundwater zone exhibited a difference of 3.066 to 1.437 feet amsl.
- Effect of barometric pressure on groundwater elevations was observed but was insignificant.
- Groundwater flow during both high and low tides within the shallow and deep groundwater zones was constant, as shown in potentiometric surface data plotted for both high and low tide cycles, with groundwater flow to the north toward Todd Creek at a similar hydraulic gradient (0.01 feet per foot [ft/ft]).

The tidal activity in Todd Creek has an amplitude of approximately 6.5 feet. This exerts little, if any, influence on the hydraulic conditions of the shallow portion of the surficial aquifer beneath the facility. However, the tidal activity does affect the deep portion of the surficial aquifer as much as 3 feet at 80 feet south of Todd Creek and 1.4 feet at 260 feet south of Todd Creek in the northern portion of the site.

E.3.4.2 Groundwater Flow

During the 68th semiannual groundwater monitoring event (September 2022), the water levels in the shallow and deep groundwater zone monitoring wells in the surficial aquifer were measured (Table 2). The groundwater flow patterns at the landfill for the shallow and deep groundwater zones of the uppermost aquifer are depicted by the potentiometric surface contours shown on Figures 9 and 10, respectively. The groundwater flow patterns for the shallow and deep groundwater zones in September 2022 remain consistent with the historical groundwater flow patterns (Arcadis 2023). The latest water level measurements continue to indicate that a reasonably uniform water table surface exists beneath the landfill, with a relatively uniform flow direction toward Todd Creek.

E.3.4.3 Hydraulic Conductivity and Groundwater Velocity

Site geology and hydrogeology information was obtained for the landfill from the soil and monitoring well borings advanced in March 2006 and May 2006. Two hydrogeologic cross-sections were constructed based on these borings to illustrate the subsurface geologic and hydrogeologic conditions. Hydrogeologic cross-section A-A' (Figure 11) is generally oriented parallel to the direction of groundwater flow, and hydrogeologic cross-section B-B' (Figure 12) is generally oriented perpendicular to the direction of groundwater flow.

As shown on Figure 9, the groundwater in the shallow zone of the surficial aquifer flows toward Todd Creek (i.e., a generally northern direction) under an estimated hydraulic gradient (i) of 0.006 ft/ft. Based on in situ hydraulic conductivity tests performed on multiple monitoring wells in 1985, the average hydraulic conductivity (K) of the soils is approximately 2.5×10^{-3} centimeters per second or 5×10^{-3} foot per minute. Based on test pit activities at the facility, which are referenced in the 1998 Permit Application, the total porosity of the soils ranged from 32.5% to 34.8% and the average effective porosity (ne), calculated as the difference between the total porosity and the moisture content at a tension of 0.3 bars, was 26.8%. These values are indicative of a sandy soil. Using these values for aquifer properties, the rate of groundwater flow was calculated by the following variation of Darcy's Law:

$$v = Ki/ne$$

where:

- v = groundwater flow rate
- K = hydraulic conductivity
- i = hydraulic gradient
- ne = effective porosity

The hydraulic gradient values are calculated for each event using groundwater elevations and the linear distances between wells. Multiple measurements are used to calculate an average hydraulic gradient. When used in the Darcy equation, these values yield an average linear groundwater flow velocity of approximately 48 feet per year (ft/yr) for the shallow zone of the surficial aquifer (September 2022). When averaged over the last three monitoring events, the average linear groundwater flow velocity is 54 ft/yr (Arcadis 2023).

E.3.4.4 Vertical Hydraulic Gradient

The vertical hydraulic gradient at the landfill was calculated for 16 shallow/deep well pairs for the sampling event (September 2022) using the U.S. Environmental Protection Agency (EPA) Online Tools for Site Assessment Vertical Gradient Calculator (EPA 2015). The September 2022 vertical hydraulic gradients are depicted on Figure 26. As shown on the figure, a downward vertical gradient exists within the interior of the landfill and hydraulically downgradient flow from the landfill, with the exception of an upward vertical gradient adjacent to Todd Creek at well pairs MW-7/MW-19, MW-20/MW-21, MW-23A/MW-24A, MW-17/MW-18, MW-17/MW-25, MW-42/ MW-41, and MW-42/MW-51 (Arcadis 2023).

E.3.5 Site Hydrology

The UCC landfill is located on high ground at the UCC facility, with elevations ranging from approximately 24 to 29 feet amsl. Elevations over the entire UCC facility vary from 5 to 29 feet amsl. The area surrounding the UCC landfill to the north generally consists of a large expanse of tidal herbaceous salt marsh interspersed with numerous tidal creeks, streams, and small islands. The area surrounding the UCC landfill to the east, west, and south includes undeveloped land, inactive SWMUs, and marshlands (Figures 5 and 6). The main sources of tidal flushing are the Satilla River to the north and the Cumberland River to the southeast. The low-lying back-barrier tracts containing Halls Swamp and Copeland Swamp are generally less than 15 feet amsl. Figure 1 shows the location of Copeland Swamp. Halls Swamp is not located within the area shown on Figure 1. Both Halls Swamp and Copeland Swamp are located southwest of the UCC landfill, at distances of approximately 3 miles and 2.5 miles, respectively.

Todd Creek is located north of the UCC property, approximately 260 feet from the landfill (near Landfill Cell A). Todd Creek lies entirely in the 100-year floodplain of the Satilla River (Figure 4). Todd Creek originates approximately 4 miles west of the UCC landfill and meanders in an easterly direction to an area approximately 3 miles east of the UCC landfill, known as Floyd Basin. Floyd Basin discharges into Floyd Creek and Floyd Cut. Floyd Creek meanders southeasterly to the Cumberland River. Floyd Cut is a maintained (dredged) navigation channel that connects Floyd Basin and the upper end of Floyd Creek with the Satilla River.

The drainage basins of Todd and Floyd Creeks cannot be accurately delineated, but the basins consist generally of the salt marsh and intertidal creek streambank areas immediately adjacent to the channel. There is little surface water drainage; therefore, during non-storm conditions, the freshwater flow in both creeks can be attributed primarily to groundwater seepage into the creek channel.

The shoreline of Todd Creek, adjacent to and to the north of the landfill, is actively eroding, and recession of the top of the streambank has been monitored since 1996. Groundwater monitoring wells near the shoreline are potentially threatened by the continued erosion and recession of the shoreline. The continued erosion and recession of the shoreline are discussed in detail in Section E.9d.1.

E.4 Topographic Map Requirements [40 CFR 270.14(c)(2),(3),(4)(i)]

Maps depicting topography (Figures 1 and 3) and groundwater flow (Figures 9 and 10) are discussed in Section B.2. and hydrogeological cross-sections (Figures 11 and 12) are discussed in Section E.3.

E.5 Contaminant Plume Description [40 CFR 270.14(c)(2),(4),(7); Part 261, Appendix VIII]

Certain portions of the information required in this section by the checklist have already been addressed in other sections. A cross reference is presented in the following table.

40 CFR 270.14(c)(2)	A description of the uppermost aquifer and characteristics is included in Section E.3.
40 CFR 270.14(c)(7)(i)	A discussion of wastes previously handled at the facility is included in Section J.1.1.
40 CFR 270.14(c)(7)(ii)	Current and historical analytical results for Appendix IX constituents are provided in Table 4.
40 CFR 270.14(c)(7)(iii) and (iv)	The list of constituents for which compliance monitoring will be undertaken and the proposed concentration limits for each are included in Table A and A-1.
40 CFR 270.14(c)(7)(v), and (vi)	A discussion of the proposed monitoring program is included in Section E.6.

Groundwater monitoring analytical data for Table A constituents were compared to groundwater protection standards (GWPS) established for the facility (Table 4). Groundwater monitoring analytical data review and evaluation consisted of a Mann-Kendall (MK) statistical analysis for a 16-year period (2006 to 2022; Table 3). Although older data are available, the statistical analysis was conducted beginning with the implementation of low-flow sampling procedures in 2006. This approach is consistent with analyses conducted in the groundwater monitoring reports.

To help assess changes in the extent of COCs in the aquifer over time, UCC prepared isoconcentration plume maps for select COCs in the shallow and deep zones. COCs were selected that had sufficiently extensive detections to define a plume (those that had statistical exceedances in POC wells or had detections at three or more spatially distinct wells at concentrations exceeding the GWPS). Where data were present, plume maps were prepared for 1986, 1999, 2009, and 2019. Data from 1986 were selected as representative of initial conditions because there were limited wells present prior to 1986, and the 1989 data were only from POC and background wells. Plume maps consist of the following:

- 1986, 1999, 2009, and 2019 plumes for acetone, naphthalene, sulfide, and vanadium.
- 2009 and 2019 plumes for trichlorophenoxyacetic acid (2,4,5-T) and formaldehyde. Due to insufficient data, plume maps were not prepared for these constituents prior to 2009.
- 2012 and 2019 plumes for p-cresol which was analyzed separately from m-cresol beginning in 2012.

These are presented on Figures 14 through 25. Table 3 provides the 2006 to 2022 MK results. Historical groundwater data and concentrations trend plots are included in Appendix L. A summary of the data evaluation is provided in the following bullets:

- **Acetone:** Acetone is present in the shallow and deep monitoring zones of the aquifer. Concentrations in both zones at the site are substantially below the GWPS (12.714 milligrams per liter [mg/L]); therefore, isoconcentration contours were only prepared for the shallow zone for acetone as a representative depiction of plume stability in the recent past (Figure 14). Based on review of the shallow zone contours, the extent of the plume greater than 0.1 mg/L has reduced substantially from 1986 to 2019 while the horizontal extent of the plume greater than 0.01 mg/L decreased from 1986 to 2009 and has remained stable from 2009 to 2019. Acetone was not detected in the POC wells during the latest sampling round in September 2022 (Table 4). Results of the 2006 to 2022 MK evaluation indicates a stable or decreasing trend at most of the monitoring wells where acetone is present. The upward trend was calculated for several shallow and deep zone monitoring locations, including background location MW-01. However, these wells fall within a stable plume that is well below the GWPS and Todd Creek Target Level (TCTL) (as defined in Section E.9d.3.2).

- **2,4,5-T:** 2,4,5-T isoconcentration contours were prepared for shallow and deep aquifer zones (Figures 15 and 16). In the shallow zone, no GWPS (0.122 mg/L) exceedances were observed between 2009 and 2019 and 2,4,5-T was not detected at any monitoring locations during the sampling conducted in 2022. As shown on Figure 16, the extent of the deeper zone plume has significantly reduced in size from 2009. Where present, 2,4,5-T trends in shallow and deep monitoring locations all were determined to be stable or declining based on the 2006 to 2022 MK evaluation.
- **P-Cresol:** Isoconcentration contours were prepared for p-cresol for 2012 (the first-year p-cresol was analyzed separately from m-cresol) and 2019 (Figures 17 and 18). The overall extent of the p-cresol plume has remained stable in the shallow aquifer with a slight reduction in size from 2012 to 2019. P-cresol has not been detected at any deep zone monitoring locations since 2019. Where present, trends in shallow and deep monitoring locations were determined to be stable or declining based on the 2012 to 2022 MK evaluation.
- **Formaldehyde**: Formaldehyde has been detected in wells across the landfill area during the monitoring period and exceeds the GWPS at POC wells. The formaldehyde plume extends horizontally across the largest area in the shallow and deep zones relative to the other COCs and is also present in background wells at concentrations above the GWPS (0.002 mg/L) (Figures 19 and 20). The extent of the shallow and deep zone plumes has remained stable from 2009 to 2019; however, the extent of the area greater than 0.1 mg/L of the deep zone plume has reduced substantially over time as shown on Figure 20. Of the site wells with sufficient detections for MK analysis, the majority of the wells indicated a downward trend or no significant trend was present. One shallow zone well (MW-20) and the deep zone well (MW-37) reported increasing trends; however, these wells fall within a stable plume. A statistical exceedance of the TCTL was identified at MW-7 based on the result of 2.1 mg/L reported from the sample collected March 23, 2021. An outlier analysis was performed to assess the result and it was determined that the result was a statistical outlier using Rosner’s test.
- **Vanadium:** Vanadium exceedances of the GWPS have been observed in shallow and deep zone monitoring wells during the monitoring period. The vanadium plume extends across a large area of the site in the shallow zone but is observed above GWPS (0.001 mg/L) in the deep zone in a smaller area in the northern portion of the site (Figures 21 and 22). From 2009 to 2019, the shallow zone plume has remained relatively stable while the deep zone plume has reduced in size. Note that from 1986 to 2009, the laboratory reporting limit (RL) for vanadium was greater than the GWPS; therefore, the full extent of plume reduction from 1986 to 2019 is indeterminate. MK results show an upward trend for several shallow and deep zone monitoring locations, including background locations. Vanadium does not exceed the TCTL (as defined in Section E.9d.3.2) in POC wells.
- **Sulfide:** Sulfide does not have a GWPS or TCTL; therefore, concentrations were compared to the background result (95% upper prediction limit value calculated using the most recent 12 observations at MW-1) (Arcadis 2023) from MW-1 (2.04 mg/L). The sulfide data sets prior to 2009 were limited; therefore, the plume extent is highly inferred for the 1986 shallow and deep plumes and the 1999 deep plume. Plume concentrations exceeding 2 mg/L were not provided for these timeframes. The shallow sulfide plume extends over most of the landfill (Figure 23). In the recent past, from 2009 to 2019, there was a substantial reduction in both the extent and concentrations within the shallow zone. The deeper plume covers a smaller horizontal extent of the landfill than the shallow plume. The area covered by the deep plume is similar between 2009 and 2019; however, the northeastern plume area has shown overall reductions. A notable decline in sulfide plume concentrations has occurred in the shallow and deep aquifers. Based on 2006 to 2022 MK results, all shallow zone trends are stable or

declining. Most deep zone trends are stable or declining. However, four deep zone non-POC locations have an increasing trend but only one exceeds the background concentration (MW-19).

- **Naphthalene:** Exceedances of the GWPS (0.001 mg/L) for naphthalene were observed in four shallow zone and two deep zone wells in September 2019. The 2019 deep zone GWPS exceedances only occurred in two downgradient wells (MW-19 and MW-21); therefore, isoconcentration contours were only prepared for the shallow zone plume (Figure 25). The detection limit exceeded the GWPS for 1986 and 1999; therefore, the plume extents are highly inferred during this timeframe. Based on the more recent 2009 and 2019 plume contours, the plume is primarily focused hydraulically downgradient in the northern area of the landfill. The elevated concentration at MW-20 in September 2019 is inconsistent with results for naphthalene collected since April 2008 which are substantially lower than the September 2019 result (Table 4). The MK analysis resulted in most wells exhibiting stable or decreasing trends. Four shallow wells, including POC wells MW-7 and MW-34, resulted in an upward trend based on the 2006 to 2022 MK results. Deep zone wells MW-19 and MW-21 also resulted in upward trends. Naphthalene in the POC wells is less than the TCTL (Table 5).

E.6 General Monitoring Program Requirements [40 CFR 270.14(c)(5); 264.90(b)(4); 264.97]

UCC is not attempting to make the demonstration discussed in 40 CFR 264.90.(b)(4). Information required by 40 CFR 270.14(c)(5) and 264.97 are presented in the following subsections.

E.6.1 Groundwater Monitoring Program Overview

UCC has performed groundwater monitoring since 1989 as part of RCRA post-closure care and corrective action at the closed landfill (SWMU 1) at the former Woodbine facility in Camden County, Georgia. The closed landfill was used for the disposal of both hazardous and nonhazardous waste. The landfill is approximately 22 acres and is completely fenced and is shown on Figure 3. The landfill has been covered with compacted soil and a clean clay cap to prevent erosion (Appendix C). The UCC property north of Todd Creek remains undeveloped and unused. No commercial, industrial, or agricultural activities occur at the landfill.

Groundwater monitoring at SWMU 1 began with quarterly monitoring from September 1989 through May 1999 followed by monitoring on a semiannual basis, which was initiated in November 1999 and has continued to the present. Monitoring is conducted in accordance with the UCC Hazardous Waste Facility Permit No. HW-063(D), amended June 6, 2011, and June 7, 2017.

The objectives of the groundwater monitoring program are to:

- Verify that the landfill cap is effective and that concentrations of constituents in the groundwater are stable and/or decreasing over time.
- Determine if additional corrective action is necessary to protect human health and the environment.

The current groundwater monitoring program associated with the post-closure care requirements includes the following tasks:

- Semiannual monitoring of groundwater elevation, flow rates, and flow gradients.
- Semiannual evaluation and statistical comparison of constituent concentrations in groundwater in the shallow and deep zones of the aquifer to the GWPS established for the site in Table A of the permit.
- Annual sampling and analysis for Appendix IX constituents at one of six POC wells. Annual monitoring is completed at a different POC well each year.

- Evaluating corrective action effectiveness and determining if additional corrective action measures should be implemented.

In addition to the tasks above, the corrective action effectiveness evaluation includes the following tasks associated with monitoring the iSOC system:

- Measuring the long-term effectiveness of both intrinsic bioremediation and the oxygen diffusion system by semiannual monitoring of treatment effectiveness wells (TE-1, TE-2, and TE-3) for acetone.
- Monitoring of oxidation reduction potential (ORP) wells (ORP-1, ORP-2, and ORP-3), and monitoring wells MW-7, MW-19, MW-51, and MW-52 for water levels, dissolved oxygen (DO) and ORP.

E.6.2 Proposed Groundwater Monitoring Plan Modifications

Following a comprehensive review of the established program requirements and evaluation of data collected in accordance with the permit, UCC proposes the following modifications to the groundwater monitoring program within this permit renewal application:

- Update and optimize the sampling locations to ensure the monitoring objectives are achieved while minimizing unnecessary samples, reduced from current monitoring list (refer to Section E.6a).
- Collect groundwater samples annually (refer to Section E.6b.1) and analyze for constituents that are documented to exceed or have the potential to exceed the GWPS or were known to have been disposed of in the landfill (Table A-1; refer to Section E6.b.2).
- Analyze samples from the POC wells for Table A constituents every other year (biennially; refer to Section E.6b.3).
- Analyze samples at one POC well per year for Appendix IX constituents such that each POC well is analyzed for Appendix IX constituents every 6 years (refer to Section E.6b.3).
- Update the statistical evaluation procedures to be consistent with current procedures outlined by EPA in its Unified Guidance (EPA 2009d; refer to Section E.6b).
- Update groundwater monitoring and corrective action effectiveness report contents to be consistent with updated sampling frequency and statistical procedures.
- Eliminate sampling designed to monitor the effectiveness of the iSOC oxygen curtain remediation system after the system is shut down. Shut down of the iSOC system is proposed in Section E.9d.2.

E.6a Description of Wells [40 CFR 270.14(c)(6)(ii); 264.97(a),(b),(c)]

40 CFR 270.14(c)(6) does not apply because hazardous constituents have been detected in groundwater at the facility. The requirements of 40 CFR 264.97(a), (b), and (c) are addressed in the subsections below.

E.6a.1 Groundwater Monitoring Wells

There are presently 43 groundwater monitoring wells associated with SWMU 1 (Table 7). Site wells have been classified into the following categories based on their associated monitoring objectives.

- Background – The background well monitors background conditions in the surficial aquifer.
- POC – POC wells are located on the downgradient edge of the closed landfill to monitor conditions in the surficial aquifer.
- TCS wells (also called point of exposure wells) – TCS wells are located adjacent to Todd Creek and monitor conditions prior to potential discharge to the creek.

- Interior (Non-POC) wells – These locations are used to monitor constituent concentrations over time and provide additional insight into groundwater conditions.
- iSOC performance monitoring wells – These wells are monitored specifically to evaluate the performance of the iSOC system.

E.6a.2 Monitoring Well Network

The purpose of the well network is to monitor the following:

- New releases from the closed landfill cells
- Concentrations of constituents at POC wells relative to the GWPS and TCTL
- Concentrations of constituents at TCS wells relative to criteria protective of Todd Creek
- Changes in concentrations of COC plumes over time
- Changes in groundwater flow directions and gradients over time
- Effectiveness of corrective action systems

Groundwater in the surficial aquifer (uppermost aquifer at the site) is the potential medium of concern. Groundwater quality in the surficial aquifer is generally evaluated in monitoring wells screened up to 32 feet bgs (shallow zone) and from 40 to 55 feet bgs (deep zone) within the surficial aquifer. In addition, two monitoring wells are screened at a deeper interval (84 to 102 feet bgs) to monitor the lower portion of the aquifer (Table 2). The surficial aquifer underlying the landfill has been impacted by dissolved and percolated material from buried wastes at the closed landfill. Constituents in the shallow zone of the surficial aquifer have the potential to reach the deep zone because of a downward hydraulic gradient between the shallow and deep groundwater zones. Groundwater in both the shallow and deep zones flows northward and eventually discharges to Todd Creek.

This plan proposes to optimize the number of groundwater monitoring wells sampled as part of the groundwater monitoring program. As part of the optimization process, UCC conducted a review of current and historical groundwater monitoring data (Table 4), evaluated MK trends for the past 16 years (Table 3), and reviewed isoconcentration contour plume maps of select COCs (Figures 14 through 25). Plume extents are discussed in Section E.5. Based on this evaluation, the monitoring well network was refined to include only locations that are necessary to meet monitoring objectives and comply with requirements of 40 CFR 264.97. The locations of the monitoring wells proposed for sampling are shown on Figure 27. Well construction details are summarized in Table 2 and Appendix B. Table 7 lists the wells, grouped by purpose, along with the rationale for inclusion or elimination from the monitoring program. The following sections provide additional information regarding the basis for the monitoring program.

E.6a.3 Background Well

MW-1 is hydraulically upgradient of the landfill (Figure 27) and has been designated as the site background groundwater monitoring well in the current permit and no change is proposed. MW-1 is screened in the shallow zone of the surficial aquifer. MW-1 is sampled during each monitoring event to assess background conditions in the shallow and deep zones of the surficial aquifer. Although not officially designated as a background monitoring well, deep zone well MW-37 is collocated with MW-1 and is used for monitoring of the upgradient deep zone groundwater.

E.6a.4 Point of Compliance Wells

POC wells (MW-6, MW-7, MW-8, MW-34, MW-38, and MW-39) are designated in the current permit and are screened in the shallow zone located between the landfill and Todd Creek. All six POC wells will be sampled during each monitoring event. UCC is not proposing any changes to the POC wells.

E.6a.5 Todd Creek Sentinel Wells

The current monitoring program includes monitoring at ten TCS monitoring locations. UCC proposes continuing to sample eight of these (four shallow zone and four deep zone; Figure 27) and discontinue sampling at two locations (MW-25 and MW-51). TCS wells monitor concentrations downgradient of the POC wells and are representative of groundwater potentially discharging into Todd Creek. This represents a reduction in the wells sampled in the deep zone. TCS wells MW-25 and MW-51 are recommended for removal from the groundwater monitoring program because they are not necessary to meet monitoring objectives based on the rationale detailed in Table 7. The wells selected for removal will not be abandoned at this time.

E.6a.6 Interior (non-POC) Wells

The current monitoring program includes monitoring at 19 interior (non-POC) locations. UCC proposes to continue sampling at 18 interior wells (6 shallow zone and 12 deep zone; Figure 27) and to discontinue sampling at one location (MW-49). These wells provide information on concentration trends within the interior of the closed landfill. This represents the removal of one well that was used specifically for monitoring the iSOC system. The remaining wells are sufficient to determine landfill cell leachate characteristics and plume migration.

E.6a.7 iSOC Performance Monitoring Wells

The iSOC system is recommended for a trial shutdown as discussed in Section E.9d. Wells TE-1, TE-2, and TE-3 are associated with monitoring the effectiveness of the former air sparge system and will no longer be monitored. Once the system is shut down, the treatment effectiveness wells for the iSOC system (ORP-1, ORP-2, and ORP-3) will no longer be monitored.

E.6b Proposed Sampling and Statistical Analysis Procedures for Groundwater Data [40 CFR 270.14(c)(7)(vi); 264.97(d),(e),(f); 264.99(c)-(g)]

For groundwater sampling, UCC adheres to the standards and procedures set forth in EPA Region 4, SESD, Field Branches Quality System and Technical Procedures (https://www.epa.gov/quality/quality-system-and-technical-procedures-lsasd-field-branches), as updated. The typical procedures currently in use are described in this section.

Water levels are collected following the EPA procedure set forth in EPA Region 4, SESD, Field Branches Quality System and Technical Procedures for groundwater level and well depth measurements. Prior to sampling, groundwater levels will be measured and recorded using an electronic water level indicator graduated in 0.01-foot increments. Groundwater levels and total depth will be measured from a marked reference point on the top-of-casing to the nearest 0.01 foot and checked with previous measurements, if available, and note any anomalies. The water level indicator will be decontaminated between each monitoring well utilizing a non-phosphate laboratory-grade soap and deionized water.

Field measurement and sampling procedures will adhere to the following EPA procedures:

- Field DO Measurement, April 12, 2017
- Field pH Measurement, July 23, 2020
- Field Measurement of Oxidation Reduction Potential, December 17, 2021
- Field Specific Conductance Measurement, May 5, 2020
- Field Temperature Measurement, March 14, 2018
- Field Turbidity Measurement, July 27, 2017
- Groundwater Sampling, April 26, 2017

- Packing, Marking, Labeling and Shipping of Environmental and Waste Samples, February 23, 2020

Groundwater will be purged and sampled by low-flow procedures utilizing a peristaltic pump using dedicated Teflon® lined tubing. The dedicated Teflon® line tubing is secured and stored inside each respective well casing between sampling events. Prior to connecting the peristaltic pump to the dedicated Teflon® tubing; initial depth to groundwater will be measured. The dedicated Teflon® tubing will be inspected for deficiencies prior to usage and replaced if there is notable damage. The peristaltic pump will then be connected to the dedicated Teflon® tubing and purged at a suitable pumping rate (approximately 200 to 500 milliliters per minute) to prevent drawdown.

Measurement of water quality parameters will be collected utilizing a multi-parameter water-quality sonde (temperature/pH/specific conductivity/ORP/turbidity/DO) meter coupled with flow-through-cell for measurements. A supplemental turbidity meter will be used if the down-hole multi-parameter water-quality sonde does not measure turbidity. Except for turbidity, all indicator field parameters will be measured every 3 to 5 minutes (or after each volume of the flow-through cell has been purged) and continue until stabilization goals have been established.

The well is considered stable and ready for sample collection when three consecutive readings are within the following limits:

- **Turbidity** within +/- 10% for values greater than 5 nephelometric turbidity units [NTUs] or if three turbidity values are less than 5 NTUs, consider the values stabilized.
- **DO** within +/- 10% for values greater than 0.5 mg/L or if three DO values are less than 0.5 mg/L, consider the values stabilized.
- **Specific Conductance** within +/- 3%
- **Temperature** within +/- 3%
- **pH** within +/- 0.1 unit
- **ORP** within +/- 10 millivolts (mV)

Purging will continue until stabilization is met or a minimum of three well volumes are purged. Once parameters are stabilized, groundwater samples will be collected by diverting flow out of the unfiltered discharge tubing into an appropriately labeled sample container. Laboratory provided bottleware may or may not have preservation material. Care will be taken to not displace any laboratory provided preservation material from the provided bottles. Upon filling bottleware, the samples will be placed immediately in a cooler with wet ice. All samples will be shipped and delivered under a Chain-of-Custody.

The following preferred analytical procedures are described based on the existing sampling program; however, the extent of sampling may change based on the approval of reductions of sampling at the site:

Analysis	Analytical Method or SOP	Quantity of Containers per Sample	Container Type	Preservation Method
Table A Constituents				
Table A VOCs + Chloromethane	SW-846 8260C	3	40-mL VOA	Hydrochloric Acid Cool to 4°C
Table A Metals (ICPMS) Table A Metals (ICP)	SW-846 6020A SW-846 6010C	1	250-mL HDPE	Nitric Acid Cool to 4°C
Fluoride	SM 4500-F-C-2011	1	500-mL HDPE	Unpreserved Cool to 4°C
Total Cyanide	SW-846 9012B	1	250-mL HDPE	Ascorbic Acid and Sodium Hydroxide Cool to 4°C
Sulfide	EPA 376.2	1	250-mL HDPE	Zinc Acetate and Sodium Hydroxide Cool to 4°C
Table A SVOCs and Methyl Phenols	SW-846 8270D	2	250-mL amber glass	Unpreserved Cool to 4°C
Table A Herbicides	SW-846 8270D SIM	2	1-L amber glass	Unpreserved Cool to 4°C
Formaldehyde	SW-846 8315A	1	250-mL clear glass	Unpreserved Cool to 4°C
Aldicarb	EPA 531.1	1	40-mL VOA	MCAA/Sodium Thiosulfate Cool to 4°C
Appendix IX Sampling				
APPIX VOCs + APPIX VOCs (Methacrylonitrile)	SW-846 8260C	5	40-mL VOA	Hydrochloric Acid Cool to 4°C
APPIX Metals (ICPMS) APPIX Metals (ICP)	SW-846 6020A SW-846 6010C	1	250-mL HDPE	Nitric Acid Cool to 4°C
Fluoride	SM 4500-F-C-2011	1	500-mL HDPE	Unpreserved Cool to 4°C
Total Cyanide	SW-846 9012B	1	250-mL HDPE	Ascorbic Acid and Sodium Hydroxide Cool to 4°C
Sulfide	EPA 376.2	1	250-mL HDPE	Zinc Acetate and Sodium Hydroxide Cool to 4°C
APPIX SVOCs and Methyl Phenols	SW-846 8270D	4	250-mL amber glass	Unpreserved Cool to 4°C
APPIX OC Pesticides	SW-846 8081B			
Polychlorinated Biphenyls (PCBs)	SW-846 8082A			
APPIX Herbicides	SW-846 8270D SIM	6	1-L amber glass	Unpreserved Cool to 4°C
Dinoseb	SW-846 8151A			
Organophosphate Pesticides	SW-846 8141B			
Formaldehyde	SW-846 8315A	1	250-mL clear glass	Unpreserved Cool to 4°C

Analysis	Analytical Method or SOP	Quantity of Containers per Sample	Container Type	Preservation Method
Carbamates	EPA 531.1	1	40-mL VOA	MCAA/Sodium Thiosulfate Cool to 4°C
Water Quality – iSOC™ performance monitoring				
Table A Metals and Iron (ICPMS) Table A Metals (ICP)	SW-846 6020A SW-846 6010C	1	250-mL HDPE	Nitric Acid Cool to 4°C
Nitrite – Nitrogen, Nitrite	EPA 353.2	2	50-mL HDPE	Unpreserved Cool to 4°C
Sulfate	EPA 300.0			
Nitrogen, Nitrate-Nitrite Nitrate Calculation-Nitrogen, Nitrate	EPA 353.2	1	40-mL VOA	Sulfuric Acid Cool to 4°C
Ferrous Iron	SM-3500	1	250-mL glass with Septa	Hydrochloric Acid Cool to 4°C
Total Organic Carbon	SW-846 9060A	5	40-mL VOA	Phosphoric Acid
Alkalinity	SM230B-2011	1	250-mL plastic	Unpreserved Cool to 4°C

Notes:
Inductively Coupled Plasma / Mass Spectrometry – ICPMS
Inductively Coupled Plasma – ICP
Existing bottle counts and bottleware are based on the existing laboratory procedures and may change.

E.6b.1 Monitoring Frequency

UCC proposes collecting groundwater samples annually rather than semiannually. Annual sampling is sufficient to detect changes in groundwater conditions and ensure there is adequate time to implement additional corrective actions, should they be needed, before there are any impacts to human health or the environment. This conclusion is supported by the following;

- Based on the 2022 groundwater monitoring report (Arcadis 2023) and review of groundwater data since 2006 (when standard low-flow sampling methodology was implemented) to 2022, indicates that groundwater plumes at the site are stable or decreasing. The analysis included a MK statistical evaluation as well as review of isoconcentration maps for selected COCs as presented in Section E.5.
- There is an environmental covenant in place prohibiting the installation of water supply wells at the facility.
- There are no groundwater supply wells at the facility or within 1,000 feet of SWMU 1.
- The groundwater in the shallow zone of the surficial aquifer flows northward toward Todd Creek with average groundwater velocities of 48 ft/yr in the shallow zone and 59 ft/yr in the deep zone (Arcadis 2023). Based on these flow rates and ignoring natural attenuation factors, any changes in COC concentrations in POC wells would not reach TCS wells in the period between sampling events.

Given the flow rate and the distance to the nearest potential receptors, annual monitoring has been determined to be a conservative monitoring frequency that would allow adequate time to identify and address changes that could impact potential receptors and achieves the objectives of 40 CFR 264, Subpart F.

Depth to groundwater measurements will be collected in all wells that are part of the annual monitoring program and will be used to establish the groundwater flow direction and velocities in the surficial aquifer and support development of potentiometric surface maps in the aquifer.

E.6b.2 Target Analyte List

The GWPS listed in Table A of the existing permit is proposed to remain unchanged.

Currently, UCC is sampling for 37 analytes listed in Table A of the existing permit (Table 6). UCC is proposing to continue monitoring 17 of these constituents and to discontinue monitoring 20 of these constituents. This shortened list is designated as Table A-1 (Table 9). Note that constituents proposed for removal will remain in the new release monitoring program per Section E.6b.3. UCC proposes monitoring for Table A-1 constituents at the frequency specified in Section E.6b.1 and locations identified in Section E.6a that have been demonstrated to have the potential to exceed their respective GWPS or provide additional information based on the well location and trends. UCC conducted an evaluation of groundwater data from the groundwater monitoring program to identify constituents that do not have the potential to exceed their respective GWPS based the following:

- COCs that have not been detected at concentrations exceeding the laboratory RL in the last 3 years.
- COCs with detected concentrations in the past 3 years but that had concentrations less than the GWPS and have a decreasing or stable MK trend.

Based on this analysis the 16 constituents listed below met one of these criteria for removal.

Herbicides	Metals	SVOC	VOC
▪ Dichlorophenoxyacetic acid (2,4-D)	▪ Antimony	▪ 1,4-Dichlorobenzene	▪ Acetonitrile
▪ 2,4,5-T		▪ Dibenzofuran	▪ Dichloromethane
▪ 2,4,5-Trichlorophenoxy propionic acid (Silvex)		▪ 2-Chlorophenol	▪ Methylacrylonitrile
▪ 4-Chloroaniline		▪ Fluorene	▪ Methyl ethyl ketone
▪ Aldicarb		▪ Phenanthrene	
		▪ Phenol	

- Of these, 4-chloroaniline was retained for analysis because the laboratory RL exceeded the GWPS and aldicarb, 2,4,5-T, and dichloromethane were retained because they were historically disposed of at the site; however, aldicarb has not been detected since 2012 and is recommended for monitoring at select wells (all POC wells; TCS wells MW-20 and MW-21; and interior wells MW-16, MW-22, and MW-46) only.
- The Table A constituent list was then further reviewed against constituent concentrations from 2006 (when standardized low-flow procedures were implemented) to 2022 to determine if there were any additional constituents that did not have the potential to exceed their GWPS. Based on this data review, an additional nine constituents (listed below) were identified that did not have the potential to exceed their GWPS:

VOCs	Metals	General Chemistry
▪ Acetone	▪ Nickel	▪ Cyanide
▪ Ethylbenzene	▪ Chromium	▪ Fluoride
▪ Xylene	▪ Selenium	
	▪ Zinc	

- Of these, acetone was retained because it was previously disposed of in the landfill.
- In general, these constituents had upward MK statistical trends that were based on limited detections or detections that were orders of magnitude below the GWPS.

The rationale for the constituents selected for the monitoring program is provided in Table 8. The modified list of constituents proposed for annual sampling is designated as Table A-1 and provided in Table 9. In addition to monitoring temporal and spatial COC trends, geochemical field parameters, including conductivity, DO, ORP, and pH will be monitored.

E.6b.3 New Release Monitoring

New release monitoring specified in Section III.D.6 of the post-closure permit (Georgia EPD 2017) that indicates UCC will conduct sampling and analysis for the constituents listed in Appendix IX of 40 CFR Part 264 (Appendix IX) each year will continue. In accordance with Section III.D.6 of the permit, an annual sample will be collected from one of six POC wells on a rotating basis such that each POC well is sampled every 6 years. The POC well sample will be analyzed for all constituents in Appendix IX. If an Appendix IX constituent not identified in Table A is detected, then UCC will have the option to resample the well within 1 month of receiving the results per Section III, Condition III.D.6 in the post-closure permit (Georgia EPD 2017). If the second analysis confirms the presence of the newly detected constituent, the permittee may, at the time of the next sampling event required by Condition III.D.2, sample the well that the newly detected Appendix IX constituent was detected in, the nearest downgradient well, and any additional downgradient wells to which groundwater may have traveled (based upon the evaluation required by Conditions III.D.3 and III.D.4) and analyze for the new Appendix IX constituent. If the new Appendix IX constituent is not identified in any of these wells, the permittee is relieved of the requirement to add the new constituents to Table A. However, if the Appendix IX constituent is identified in any of these wells, then the constituent will be added to Table A (Table 6) and Table A-1 (Table 9), and a GWPS (either the maximum contaminant level [MCL] or calculated alternate concentration limit [ACL]) and TCTL for the newly detected constituent will be generated and added to Table A and Table A-1 of the Permit after review and approval by the Georgia Environmental Protection Division (Georgia EPD).

In addition, the six POC wells will be analyzed every other year for all Table A constituents (Table 6). The purpose of this sampling is to identify potential releases with sufficient time to allow for the release to be addressed before Todd Creek is impacted (Section E.9d.3).

E.6b.4 Data Analysis and Statistical Analysis

The objective of the procedures for statistically evaluating the data generated from the analysis of groundwater samples is to determine if there are new releases. The procedures are described below:

- Calculate background groundwater concentration values for each analyte.
- Compare background values to established risk-based ACLs to determine if an alternate GWPS needs to be developed based on background conditions.
- Determine if the concentration for any constituent in any well has increased to the point that suggests that the site COCs could be impacting groundwater. Such an increase is called a “statistically significant increase.” This plan has been prepared according to procedures outlined by EPA in its Unified Guidance (EPA 2009d).

The following discusses the data conditioning required to process and prepare data for the statistical analyses, determination of data set normality, the statistical approach used in the background evaluation, and the site data comparison strategy.

Arcadis prepared the data and statistical analysis section.

E.6b.5 Data Conditioning

E.6b.5.1 Field Duplicate Samples

Each monitoring well is sampled once per sampling event. The exception to the single sampling is a duplicate sample, which is collected from one well during each sampling event for quality assurance/quality control purposes only. The concentrations of the parameters in the duplicate sample will not be included in the background data set for statistical evaluation.

E.6b.5.2 Data Validation and Qualified Data

The usability of the available analytical data for groundwater will be confirmed prior to statistical evaluation. The data used will meet EPA quality assurance requirements and is validated manually following the most recent versions of National Functional Guidelines (EPA 2017). Estimated concentrations (those results denoted with the "J" qualifier) will be treated as quantified detected concentrations for the purposes of statistical analysis and will be included in the data sets. No data rejected through data validation will be included in the data sets.

E.6b.5.3 Censored Data

If the data set contains nondetections, these values will be replaced by concentrations equal to one-half of the method detection limit. If the rate of detection is less than 85%, then an estimation using the Kaplan-Meier method will be applied. In data sets with more than 50% nondetections, non-parametric methods will be used.

Nondetected values with method detection limits greater than the maximum detected concentration in a well constituent data set will not be included in the data evaluation.

E.6b.6 Determination of Normality

Many of the tests in this statistical analysis plan are predicated on the normality of the data set, therefore, when necessary, data sets will be tested to demonstrate normality. The Shapiro-Wilk Test for Normality will be used for data sets with sample sizes up to 50 (EPA 2009d; Shapiro and Wilk 1965). The test will be run at the 5% critical level. For data sets with a sample size greater than 50, the Shapiro-Francia Test for Normality will be used (EPA 2009d; Shapiro and Francia 1972).

If a data set does not pass a test of normality, data will be transformed following the ladder of powers. The ladder of powers is a sequence of transformations: square root, square, cube root, cube, logarithmic transformation, x^4, x^5, and x^6 (Helsel and Hirsch 2002; Box and Cox 1964). All points in the untransformed data set will be changed by one of these operations and the new data set will be tested to determine if the transformed data meet the criterion of normality. If the test fails, the original data will be transformed using the next transformation in the ladder. Transformations will be attempted in the order of the ladder of powers until normality is achieved, or until all of the options are exhausted. In the latter case, non-parametric tests will be necessary.

E.6b.7 Background Evaluation

This section describes the statistical methods that will be used to evaluate background values of naturally occurring constituents in groundwater. When the background value for a naturally occurring constituent is present in groundwater at concentrations greater than the GWPS, it is appropriate to use the background value in lieu of the GWPS. The background values will be updated every 5 years to account for potential changes in background groundwater conditions. A decision tree summarizing the process is provided as Figure 28.

E.6b.7.1 Background Data Set

Shallow zone monitoring well MW-1 is located hydraulically upgradient of the landfill (Figure 27) and has been designated as the background monitoring well for shallow groundwater and comparison to the POC monitoring wells (installed in shallow zone). Historically, MW-1 has been sampled for Table A constituents on the same schedule as the remaining wells.

E.6b.7.2 Outlier Analysis

An outlier analysis can help identify potential outliers that may not be representative of the true background population. Including outliers in a background data set could lead to Type I (false positive) or Type II (false negative) errors (EPA 2002b). Type I errors may also occur with the exclusion of data points from a background data set; when extreme values are inappropriately eliminated from the background data set, this tends to bias the mean and variance low.

Well constituent pairs with a rate of detection less than 50% and a detection count less than or equal to four will not be analyzed for outliers. An outlier analysis will be conducted for MW-1 according to the steps outlined in the *Data Quality Assessment: Statistical Methods for Practitioners* (EPA 2006a) as follows:

1. If the rate of detection for a well constituent pair is less than 50% but the detection count is greater than four, then Tukey’s interquartile range (IQR) test (EPA 2009d; Tukey 1977) will be used.
2. Normal quantile-quantile plots will be inspected to identify potential outliers and isolated results that are separate from most of the data, as indicated by visible large gaps and deviation from concentration trends.
3. Distribution testing will be performed on well constituent data sets with visually identified potential outliers removed. Statistical tests require data sets be normally distributed or to be normalized by a transformation. If the data set is not normally distributed or cannot be normalized, then Tukey’s IQR test will be used.
4. Data sets that pass step three (i.e., are normally distributed or can be normalized by a transformation) will then be subjected to a statistical test. Dixon’s test (EPA 2009d; Barnett and Lewis 1994) will be used when the sample size is less than 25, and Rosner’s test (EPA 2009d; Rosner 1975) will be used when the sample size is equal to or greater than 25. Observations identified as statistical outliers at 5% significance will be documented but will not be removed from the background data set solely based on a statistical outlier test. No observations will be removed without agency concurrence.

A summary of the outlier process is included on Figure 28.

E.6b.7.3 Calculating Background Values

Following the outlier analysis and determination of the data distribution, statistical methods will be used to calculate the upper bound limits of the background population. All historical data will be included when calculating the background value for each well constituent pair in MW-1.

Following EPA Unified Guidance (2009), the 95% upper tolerance limit with 95% coverage (95-95UTL) will be used to represent background. The 95-95UTL represents the statistic, such that 95% of observations (current and future) from the target population will be less than or equal to the 95-95UTL with a confidence coefficient or 0.95. A 95-95UTL represents a 95% upper confidence limit of the 95th percentile of the data distribution (population). A 95-95UTL is designed to simultaneously provide coverage for 95% of the potential observations (current and future) from the background population (or comparable to background) with a confidence coefficient of 0.95.

For data sets with greater than 15% nondetections, the Kaplan-Meier method will be used. If there are more than 50% nondetections, a non-parametric method will be used. For highly censored data sets, the highest detected value will be used as the non-parametric 95-95UTL. For totally censored data sets (data sets composed exclusively of nondetections), the GWPS would then be the MCL or ACL that is available for the analyte. If there is no other GWPS available, then the double quantification rule will be applied. The double quantification rule (EPA 2009d) states the following:

> "*A confirmed exceedance is registered if any well constituent pair in the '100% nondetect' group exhibits quantified measurements (i.e., at or greater than the reporting limit) in two consecutive sample and resample events.*"

E.6b.7.4 Selecting Groundwater Protection Standards

Background values (95-95UTL) for each well constituent pair will be compared to the applicable GWPS. If the 95-95UTL exceeds the applicable GWPS, then the background value will replace the GWPS for the applicable well constituent pair. If the background value is less than the GWPS, then the GWPS will be retained and used for comparison to site groundwater data.

E.6b.8 Site Data Comparison Strategy

This section describes the statistical methods that will be used to evaluate groundwater concentrations in each of the site wells to determine if concentrations of Table A and Table A-1 constituents exceed the applicable GWPS. In addition, this section describes the statistical methods used to determine whether concentrations of Table A and Table A-1 constituents exceed the applicable TCTL (as defined in Section E.9d.3.2) concentrations in the POC wells. The statistical comparison will be performed in accordance with 40 CFR 264.97(h) and the EPA Unified Guidance (EPA 2009d). A decision tree outlining the statistical comparison of site data sets to applicable GWPS and TCTL is provided on Figure 29.

E.6b.8.1 Site Data Set

Monitoring of site groundwater will be performed at background, POC, retained TCS and retained non-POC wells at the frequencies specified in Section E.6b.1 for constituents specified in Section E.6b.2. Information regarding the background, POC, TCS, and non-POC wells (shallow and deep) is provided in Table 2. The locations are depicted on Figure 27 and discussed below.

E.6b.8.2 Initial Screening and Comparison to Applicable Screening Levels

The site data set will initially be screened to identify well constituent pairs with concentrations less than the applicable RL during the most current sampling event. The identified well constituent pairs will not be evaluated further.

Well constituent pairs with detected concentrations in the most current sampling event will be compared to the applicable GWPS at all wells and to the applicable TCTL only at POC wells. If the detected concentrations do not exceed the applicable GWPS or TCTL, then there is no statistical exceedance. If the detected concentration in a non-POC well exceeds the applicable GWPS, then the well constituent pair will be documented as an exceedance and no further action will be required. If the detected concentration in a

POC well exceeds the applicable GWPS or TCTL, then the statistical methods outlined in the following sections will be used to determine if the exceedance is a statistical exceedance.

E.6b.8.3 Outlier Analysis

An outlier analysis will be performed to help identify potential outliers that may not be representative of the true population. Including outliers in the data set could lead to Type I (false positive) or Type II (false negative) errors (EPA 2002b).

Well constituent pairs with a rate of detection less than 50% and a detection count less than or equal to four will not be analyzed for outliers. An outlier analysis will be conducted on POC well data that exceed the GWPS or TCTL according to the steps outlined in the *Data Quality Assessment: Statistical Methods for Practitioners* (EPA 2006a) as follows:

1. If the rate of detection for a well constituent pair is less than 50% but the detection count is greater than four, then Tukey's IQR test (EPA 2009d; Tukey 1977) will be used.
2. Normal quantile-quantile plots will be inspected to identify potential outliers and isolated results that are separate from most of the data, as indicated by visible large gaps and deviation from concentration trends.
3. Distribution testing will be performed on well constituent data sets with visually identified potential outliers removed. Statistical tests require data sets be normally distributed or to be normalized by a transformation. If the data set is not normally distributed or cannot be normalized, then Tukey's IQR test will be used.
4. Data sets that pass step three (i.e., are normally distributed or can be normalized by a transformation) will then be subjected to a statistical test. Dixon's test (EPA 2009d; Barnett and Lewis 1994) will be used when the sample size is less than 25, and Rosner's test (EPA 2009d; Rosner 1975) will be used when the sample size is equal to or greater than 25. Observations identified as statistical outliers at 5% significance will be documented but will not be removed from the data set solely based on a statistical outlier test. No observations will be removed without agency concurrence.

A summary of the outlier process is included on Figure 28.

E.6b.8.4 Calculation of 95 Percent Upper Confidence Limits

The confidence interval around the mean is designed to estimate the true average of the underlying population, while accounting for variability in the data. EPA Unified Guidance (2009) recommends calculating upper confidence levels (UCLs) from compliance well data and comparing the UCLs to fixed standards, such as GWPSs or TCTLs, in corrective action monitoring programs. POC well constituent pairs identified in Section E.6b.7.2 as exceeding applicable GWPS or TCTL will be evaluated using UCLs in accordance with EPA Unified Guidance (2009) and as summarized below.

Prior to calculating UCLs, the data set must be checked for normality to determine which UCL is appropriate to represent the true average of the data set. The normality of the data set will be determined as described in Section E.6b.5. If the data are not found to be normally distributed, then a transformation will be applied using the ladder of powers. The resulting UCL is back-transformed using the inverse of the applied transformation. It should be noted that UCLs computed on transformed data are not built around the arithmetic mean of the data set, but on an alternative central tendency. For example, lognormal data have their geometric mean as their central tendency, and square root normal data have the root mean squared as their central tendency.

Calculating UCLs also requires a data set of preferably more than eight (EPA 2009d); therefore, UCLs will be calculated using the most recent 12 sample concentrations to meet this requirement and capture current groundwater conditions.

The UCLs for data sets with normal distributions and data normalized by a transformation will be calculated using the following one-tailed confidence interval equation:

$$UCL_{1-\alpha} = \bar{x} + t_{1-\alpha,n-1} \times \frac{s}{\sqrt{n}}$$

where α is the significance level (in this case, 0.05), $\bar{x}$ is the mean, s is the standard deviation, n is the size of the data set, and $t_{1-\alpha,n-1}$ is obtained from a Student's t-table with (n-1) degrees of freedom.

Well constituent pairs that are not normally distributed and that cannot be normalized will be represented by a non-parametric UCL. The median is taken as the central tendency and rank order statistics are used to compute the UCL. The data are ranked in order of concentration and a non-parametric statistical interval is built around the median. This method uses the concept that a randomly selected measurement in a sample of n concentration measurements has a certain probability of falling above a given value. This probability should follow a binomial distribution. Therefore, one can determine the rank of the value that would come closest to having a probability that matched the desired level of confidence. It follows that the cumulative binomial distribution can be computed from the values of Bin(x; n,p), which is the probability of x or fewer successes occurring in n trials with success probability p.

$$Bin(x;n,p) = \sum_{i=0}^{x} \frac{n!}{i!\,(n-i)!}\, p^{i} 1 - p^{n-1}$$

Recall that the main difference between parametric and non-parametric methods is that the confidence level can be selected for the former, and it can only be approximated for the latter. The value whose rank comes closest in probability to the desired confidence level becomes the non-parametric UCL (EPA 2009d, p. 21-14 to 21-20). For a data set with 12 members, the UCL is the fourth-highest value.

E.6b.8.5 Mann-Kendall Trend Analysis

The MK test will be used for POC well constituent pairs with UCL values greater than the applicable GWPS or TCTL. Results of the MK analysis will be documented and further evaluation using linear regression performed for POC well constituent pairs with decreasing trends.

As described in the EPA Unified Guidance (EPA 2009d), the MK test "is a non-parametric test for linear trend, based on the idea that a lack of trend should correspond to a time series plot fluctuating randomly about a constant mean level, with no visually apparent upward or downward pattern." The test compares each data point to every successive measurement and determines if the change is positive or negative (the magnitude of change/slope is not considered). A data point followed by a data point with a higher concentration is given a score of +1. Conversely, a data point followed by one with a lower concentration is given a score of -1. Two identical values are given a score of 0. A test statistic is then computed based on the sum of the assigned scores. A positive test statistic implies an increasing trend through time, whereas a negative test statistic implies a decreasing trend through time.

The test statistic is compared to a critical value based on a chosen confidence level (1 – α) in order to accept or reject the null hypothesis of no trend (i.e., equal numbers of positive and negative differences) (EPA 2009). A 95% confidence level was chosen (α = 0.025 on each tail); therefore, probability values for the test statistic that are less than 0.025 indicate a statistically significant increasing or decreasing concentration trend.

Nondetected results will be handled following Section 17 of Unified Guidance (EPA 2009d), which recommends substituting a common value that is less than the minimum detection. The common values substituted in this evaluation will be one-half of the minimum method detection limit in the data set. If one-half of the minimum detection limit is greater than the minimum detected value, then one-half of the minimum detected value will be used.

E.6b.8.6 Linear Regression Analysis

Linear regression analysis will be used to estimate the time required to reach the applicable GWPS or TCTL for POC well constituent pairs with decreasing trends identified using the MK test. Results of the linear regression analysis will be documented and discussed.

Linear regression is the most common way to measure a linear trend and is used to assess whether the population mean has significantly increased or decreased (EPA 2009d). Linear regression is performed by plotting concentration versus time and calculating a rate constant (i.e., attenuation rate) using the slope of the line. If a negative slope is present, the slope can be used to estimate the time required to reach a remediation goal. The correlation coefficient, R^2, is a measure of how well the linear regression fits the site data; values close to one are considered a good fit, while values close to zero are considered to be a poor fit. The p-value of the correlation provides a measure of the level of significance of the statistical test. Correlations are accepted as significant for p-values less than or equal to an assigned confidence level (typically 0.05) and not significant for p-values greater than the assigned confidence level (EPA 2002b).

The statistical technique requires that the regression residuals (the difference between each concentration measurement and its predicted value from the regression equation) are approximately normal in distribution, homoscedastic (equal in variance at different times and for different mean concentration levels), and statistically independent. Further, a minimum of 8 to 10 measurements is required. Significant skewness or the presence of outliers can bias or invalidate the results of a trend test based on linear regression. Standard linear regression methods do not account for nondetects or missing data values at selected sampling events; therefore, linear regression should be used for data sets with few if any nondetects. When the assumptions of linear regression cannot be verified at least approximately, a non-parametric trend method should be considered instead (EPA 2009d).

E.6b.9 Reporting

A groundwater monitoring report including an evaluation of results and the associated technical analysis will be provided annually. Groundwater elevations will be calculated from depth to water measurements obtained during sampling events. Potentiometric surface maps will be generated from these measurements for the surficial aquifer. Additionally, plume maps for COCs with GWPS or TCTL exceedances at three or more wells will be prepared and evaluated to determine if there are changes in the plume extent. These observations and an evaluation of the results and statistical analysis will be provided in an annual report submitted to Georgia EPD, as also described in Section E.9e.

E.7 [Not Assigned]

Not applicable.

E.8 [Not Assigned]

Not applicable.

E.9 Corrective Action Program [40 CFR 270.14(c)(8); 264.99(j); 264.100]

Components of the Corrective Action Program for the closed landfill (SWMU 1) are discussed in Section E.6 and in the following sections.

E.9a Characterization of Contaminated Groundwater [40 CFR 270.14(c)(8)]

The characteristics of the contaminated groundwater are described in Section E.5 of this permit application.

E.9b Concentration Limits [40 CFR 270.14(c)(8)(ii); 264.94; 264.100(a)(2)]

The GWPS for the site are based on Table 1 from 40 CFR 264.94 where applicable or ACLs based on the human health risk assessment (HHRA) (CH2M 2011) conducted for the closed landfill. The GWPS were developed for potable water use and are listed in Table A in the current permit (included as Table 6). The GWPS are proposed to remain unchanged. The GWPS are used for comparison to site routine groundwater monitoring data and determination of whether corrective actions need to be considered.

UCC also developed target levels protective of potential exposures at Todd Creek (TCTLs) for determining if corrective action is necessary. The target levels are based on a human health and ecological risk assessment (included in Appendix G and summarized in Section E.9d.3.2) that are protective of recreational human receptors and ecological receptors for groundwater potential discharges to Todd Creek. The TCTLs are provided in Table 5.

E.9c Alternate Concentration Limits [40 CFR 270.14(c)(8)(ii); 264.94(b); 264.100(a)(2)]

No new alternative concentration limits are being proposed at this time.

E.9d Corrective Action Plan [40 CFR 270.14(c)(8)(iii); 264.100(b); 264.101]

Corrective actions related to SMWU 1 are discussed in the following section. A Corrective Action Plan for munitions and explosives of concern (MEC) within SWMUs 8 and 9 is included as Appendix D. Past and present corrective actions for the facility are described in Section J. Specifically, ongoing corrective actions related to the SWMU 8 Drum Removal Area and Rocket Test Pit are detailed in Sections J.1.9.1 and J.1.9.2, respectively.

E.9d.1 Todd Creek Streambank Monitoring and Contingency Plans

E.9d.1.1 Current Conditions

This section describes the current conditions and information about the Todd Creek streambank erosion. It also summarizes information about Todd Creek near the landfill area.

E.9d.1.1.1 Todd Creek Characteristics

Todd Creek is a meandering, tidally influenced creek, which is a tributary of the Satilla River that abuts the northern property boundary of the site. The creek is hydraulically connected with the Satilla River via Floyd Basin and Floyd Creek (Figure 30).

Currents within Todd Creek in the project vicinity are largely due to tidal action as water levels rise and fall, causing flood and ebb currents as water flows through the creek channels and over the marsh flats. The ebb is the outgoing phase, when the tide drains away from the shore; and the flood is the incoming phase when water rises again. Typically, currents are greater toward the outer streambank of the meander and smaller along the inside streambank. The variation in flow between the inner streambank and the outer streambank drives the formation of meanders, with the larger currents cutting back the outer streambank and the lower currents resulting in deposition on the inner streambank of the bend. The erosion at the project site appears in part because of this natural process of meander formation. There is a fairly strong correlation between high tide water surface elevation and peak water velocities that occur during ebb tides near the western end of the site. This is largely because of the amount of water that drains into the channel from the flooded marsh flat as the tide recedes, influencing water velocity.

The peak velocities in Todd Creek occur during ebb flow with notably smaller velocities during peak flood. During the flood tide, the rising tide begins to inundate the marsh flats, resulting in flow out of the channel onto the marsh flat, limiting the flow and flow velocities inside the channel. Conversely, during the falling tide, water flows off the marsh flats, adding water to the channel, resulting in increased peak water velocities. Previous studies conducted for the site (Appendix E) included an evaluation of tidal variations and current velocities in Todd Creek adjacent to the landfill area. Results of velocity measurements using acoustic doppler current profiles along the western portion of the site (near ECM-3 and ECM-4) show the flood velocity is limited to approximately 2 feet per second during high tide compared to peak ebb flows, which are roughly doubled, up to 4 feet per second.

Waves at a given site can be a combination of locally generated wind waves and waves that propagate in from outside the local area. Under normal conditions, the waves approaching the site are limited to small wind waves that are generated within the short fetches associated with the sections of Todd Creek adjacent to the site. In addition to locally generated wind waves, wave energy from the Atlantic Ocean can enter the Satilla River and propagate up toward the project site. The size of these waves will be reduced because of the processes of diffraction and refraction as they propagate toward the site and will be limited in size by waves breaking on the shallower marsh flats.

However, under conditions that generate a considerable storm surge, the fetch over which waves are generated will increase significantly as the water floods the marsh flats. Storm surges can occur in the coastal plains in this region during passage of significant storms, specifically tropical storms and hurricanes. The relatively shallow offshore bathymetry and low topography, particularly surrounding the mouth of the Satilla River, do not provide an effective barrier from storm surge and wave energy propagating over land and up the river.

Water surface elevations for the site are based on the tidal datums from the St. Simons Island Lighthouse Station (Station Identification 8677344). A comparison of water surface elevation data from a 2017 site survey and the St. Simons Island Lighthouse demonstrated that water elevation at St. Simons Island tracked closely with those collected at the site for much of the record. Table 10 lists the tidal datums from St. Simons Island Lighthouse for the most recent tidal epoch (based on data collected between 1999 and 2008) (National Oceanic and Atmospheric Administration 2018). Bathymetric data collected in 2017 show bottom elevations of Todd Creek ranging from 3 to -31 feet North American Vertical Datum of 1988 (NAVD88) with an average bottom elevation of 14.8 feet NAVD88.

During an investigation conducted in 2017, six surface sediment samples were collected for soil testing and classification of the sediment material within Todd Creek. Sediment along the actively eroding western portion of the site, show predominately medium- to fine-grained sand with smaller portions of silt and clay. Sediment collected from areas that appear to be depositional included greater percentages of silts and clays with less fine-grained sand.

E.9d.1.1.2 Streambank Conditions

Todd Creek has a normal wetted channel width that varies between about 250 and 400 feet. The southern streambank is composed of a steep bluff that is generally 20 feet high above the normal creek water level, consisting of loose sand with some layers of finer-grained materials. There is some live vegetation on the slopes, but areas of active slope recession are not vegetated. UCC implemented a streambank stabilization project on portions of the southern streambank in 2021. The project consisted of regrading of the streambank slopes, adding of stone protection, and revegetating streambank in two areas (ECM-1 and ECM-4). The northern streambank is bordered by adjacent marshlands. Figure 31 is a site map of the area showing the key site features.

The channel alignment and normal water velocities create cutting actions that are eroding segments of the bluff. In addition, wave action from tropical storms and hurricanes can also result in erosion of the streambank. Generally, the erosional areas are located on the western portion of the site area (approximately from the northernmost portion of the streambank to data collection [DC] reference line DC-2) and the far eastern portion of the site (proximal to DC-1). Near the center of the site (approximately east of the northernmost portion of the streambank to ECM-1), a vegetated intertidal zone has developed, extending from about 50 to 100 feet from the toe of the bluff before dropping off to stream depths. This central intertidal area appears to be a depositional area, providing some protection of the bluff behind it against erosion from waves and currents.

Figure 32 is a conceptual site model for the western streambank conditions of native streambank in the area around ECM-3. Bluff erosion at the site is driven by two primary mechanisms. One is daily erosion and bedload transport resulting from stream and tidal current velocities that cut the streambank within the normal water level fluctuations. Currents within Todd Creek near SWMU 1 are largely due to tidal action as water levels rise and fall, causing flood and ebb currents as water flows through the channel and over the marsh flats (CH2M 2008b). Daily erosion near the site appears to be due, in part, to the natural process of meander migration. The channel's thalweg alignment and typical flow velocities create cutting actions that are eroding segments of the bluff. This daily erosion of soil at and below the water line causes the overlying bluff soil to collapse periodically and fill in the eroded areas. This cycle of erosion and collapse is repeated and causes gradual but steady recession of the bluff (Jacobs 2019).

The second mechanism is episodic events, which can induce wind-driven wave actions that also affect higher elevations of the streambank. At high tides, when the marsh to the north is inundated, the fetch for wind from the northeast increases significantly to 4 or 5 miles. The potential for wave growth over the tidal flats is somewhat limited by the relatively shallow water depth over the marsh flats at these high tides. However, under low-frequency, high-intensity storm events (e.g., hurricanes and "nor'easters"), the combination of a storm surge and high tides can result in greater wave action at the site. Investigations estimate the 100-year still water elevation to be 10.3 feet NAVD88 with 100-year return period wave heights of more than 4 feet in the area (Jacobs 2019).

Streambank bluff monitoring data collected over the past 27 years have created a robust data set and a strong understanding of recession rates at the site's monitoring transects (Figures 33 and 34). Recession of the top of the southern bluff has been monitored since 1996 (about 27 years). Recession rates calculated from site monitoring data (feet of streambank lost per year from 1996 to 2023) are consistent with long-term streambank recession rates developed in 2008 from historical shoreline surveys completed in 1908 and 1939 (Appendix F). These data indicate that the rate of streambank recession can be approximated by a simple regression of the data and that this rate has been relatively consistent over the past several decades at each transect (Figures 33 and 34 and Appendix F).

The recession measurements, cumulative recession, and cumulative recession rates have been charted and are presented in Appendix F. In summary, these data indicate:

- The maximum observed rate of recession at an ECM with native streambank is at ECM-3. The long-term cumulative recession rate for the 27-year period for ECM-3 is 2.00 ft/yr with the largest single measured collapse being approximately 9.43 feet in 2022 after Tropical Storms Ian and Nicole.
- The maximum observed rate of recession at the data collection (non-ECM) points is at DC-2, where the long-term recession rate for the 6-year period is 2.64 ft/yr with the single largest streambank collapse of 8.71 feet in 2017 after Hurricane Irma.
- The long-term cumulative recession rates at native streambanks ECM-0 and ECM-2 for the monitoring period are 0.48 and 0.16 ft/yr, respectively.
- Prior to streambank stabilization work in 2021 at ECM-1 and ECM-4, the recession rates were 0.09 and 3.16 ft/yr, respectively. The largest streambank collapse at these transects was 8.13 feet at ECM-4 in 2017 after Hurricane Irma.

Detailed analyses of wind, waves, water levels, and historical erosion observations were performed in 2007 (CH2M 2011).

E.9d.1.2 Streambank Stabilization Project

Since 1996, UCC has monitored the southern streambank of Todd Creek near the RCRA landfill quarterly and submitted reports to the Georgia EPD. Section E.9d.1.3.1 describes the current streambank monitoring program for the site. Data generated from the monitoring program indicate the highest rate of recession has occurred on the western side of the monitored area around transect ECM-4 and DC-2, as noted in Section E.9d.1.1.2. As a result of erosion nearing the Primary Contingency trigger pins in the areas of ECM-1 and ECM-4, UCC implemented a streambank stabilization project as an interim action to protect portions of the southern streambank in 2021. The objective of the streambank stabilization system was to address erosional areas near ECM-1 and ECM-4 from both daily and episodic wave action, resist damages by normal tidal fluctuations, and provide wave protection during 2- to 5-year return period storms to maintain the existing natural buffer zone between the landfill and Todd Creek. Figure 31 shows the streambank stabilization areas and key site features.

UCC installed stabilization measures along 540 feet of streambank near ECM-1 and 465 feet of streambank near ECM-4 (Figure 31). The fieldwork component of the streambank stabilization activities was completed between March 15 and August 26, 2021, with landscape restoration completed on October 8, 2021. Streambank stabilization consisted of a combination of bank grading, stone toe protection, stone keys, stone revetment, and revegetation that mitigates erosional mechanisms while minimizing impacts to Todd Creek and the environment (Jacobs 2022d). Table 11 summarizes each of these design elements, and Figures 35 and 36 provides plan and cross-sectional view of the system installed at ECM-1 and ECM-4, respectively. The following activities were conducted to achieve the project objectives:

- Installing a streambank stabilization system at ECM-1 and ECM-4 that consists of slope grading, stone toe protection, stone keys, stone revetment, and revegetation.
- Stockpiling removed streambank material at a location onsite.
- Restoring and landscaping the construction area by installing coir matting, seeding, and planting shrubs and trees.

Stone toe protection is well suited for high-energy environments with a self-launching component that allows the structure to adapt to future channel conditions. The stone toe slows tidal current velocities near the shoreline and decreases current and wave energies. The terrace reduces wave energy and surface runoff while encouraging sediment deposition to reduce significant erosion forces. However, terraces are not successful in high wave energy environments, which is why the terrace surface is protected with stone.

Stone revetments provide erosion protection in high-energy environments by dissipating incident wave energy on the slope and should withstand storm surge conditions. Guidelines from the Stevens Institute (Stevens Institute of Technology 2016) suggest revetments can withstand moderate to high wave conditions (greater than 3 feet), variable currents (greater than 8 feet per second), and storm surges greater than 3 feet. Live vegetation planted landward of the riprap revetment further stabilizes the upper streambank slope. The stone toe and vegetated terrace improves fish and aquatic invertebrate habitats. Additionally, the vegetation enhances site aesthetics.

The installed streambank stabilization is largely hardscape, has minimal risk of failure, and is suitable for high-energy environments. If necessary, future stabilization of the streambanks along Todd Creek can be used where both bi- and unidirectional velocities and local wave energy are expected to be moderate to high. The system performance will be monitored and maintained and will be evaluated to determine the effectiveness of the system and inform future work, as described in Section E.9d1.3.2 and Appendix N.

E.9d.1.3 Streambank Monitoring Program

Recession of the bluff along the southern bank of Todd Creek adjacent to SWMU 1 has been monitored since 1996. Initial measurements were collected at transects extending from the northern landfill fence line (baseline) to the streambank through well locations MW-17, MW-20, and MW-24 (later renamed ECM reference line ECM-1, ECM-2, and ECM-3, respectively). Measurement locations were expanded in 2012 to include ECM-4 and expanded again in 2017 to include ECM-0 and two DC reference lines located upstream and downstream of landfill (DC-1 and DC-2, respectively) (Figure 31).

The *Todd Creek Bank Stabilization Plan* incorporated into the amended Post-Closure Care and Corrective Action Permit HW-063(D) (dated June 7, 2017) established multiple trigger pins on each of the ECM reference lines. The trigger pins were set at the following distances from the baseline:

- Primary design trigger pin (115 feet from the baseline): Primary Contingency Plan design and permitting must be initiated no later than the point in time which is concurrent with bank erosion reaching the 115-foot trigger pin.
- Primary contingency complete pin (100 feet from the baseline): Corrective action activities described in the approved Primary Contingency Plan must be completed prior to or concurrent with bank erosion reaching the 100-foot trigger pin.
- Secondary design trigger, 5 feet past the 100-foot trigger pin (95 feet from the baseline): The Secondary Contingency Plan must be evaluated/designed.
- Secondary contingency complete pin (85 feet from the baseline): Corrective action activities described in the approved Secondary Contingency Plan must be completed prior to or concurrent with bank erosion reaching the 85-foot Trigger Pin.

E.9d.1.3.1 Present Monitoring and Inspection Program

The current streambank monitoring and inspections consist of quarterly measurements from the top of bluff to a series of interim marking pins to record cumulative bluff recession and cumulative recession rates for each reference line. Streambank measurements also are performed following tropical storms and hurricanes. Appendix F contains bluff recession data for the site through 2023.

In addition to the top of bluff measurements, the streambank is inspected for possible undercutting of the top of bluff and presence of groundwater seeps from the sides of the streambank. These inspections are performed concurrent with the quarterly streambank measurements using an uncrewed aerial vehicle (UAV) equipped with a camera.

E.9d.1.3.2 Proposed Monitoring and Inspection Program

UCC proposes updating the current monitoring program to provide a more robust data set for future decision making and incorporating site changes associated with implementation of the streambank stabilization project completed in 2021. UCC proposes updating the current monitoring program to include the following:

- Periodic visual inspections of the native streambank and streambank stabilization areas.
- Continued collection of distance measurements to the top of the bluff along ECM and DC reference lines where there is native streambank. Distance measurements will be collected from the top of bluff to the baseline and the trigger pins along transects ECM-0, ECM-2, and ECM-3 to determine if primary contingency triggers (as defined in Section E.9d.1.4.1 of the permit renewal application) have been reached.
- Photogrammetric surveys along Todd Creek streambank between DC-1 and DC-2. The surveys will collect aerial photos of the streambank to produce an ortho mosaic figure and three-dimensional model.
- Eliminate distance measurements of the top of the bluff along transects ECM-1 and ECM-4 where the streambank stabilization measures have eliminated the presence of an erosional bluff between the trigger pins and Todd Creek. Instead, utilize the successive photogrammetric survey datasets for topographic comparisons of the streambank stabilization measures to determine whether the stone toe protection, stone keys, or stone revetment have eroded and to determine if maintenance is needed or if secondary contingency triggers (as defined in Section E.9d.1.4.2) have been reached.

A Monitoring and Maintenance Plan (MMP) for Todd Creek is included in Appendix N. It applies to both stabilized and native streambank areas along Todd Creek adjacent to the landfill. The main objective of monitoring and maintenance along Todd Creek streambank is to protect the landfill from erosion of the streambank. The MMP details how monitoring of erosion and bank recession rates will be completed, indicates how often and under what conditions inspections will occur, outlines the evaluation process for monitoring data collected, and defines when maintenance is triggered.

E.9d.1.3.2.1 Storm Event Monitoring

As detailed in the Todd Creek MMP (Appendix N), a site inspection will be conducted following a storm event where water levels in the Todd Creek/Satilla River basin are greater than 2 feet above the mean high water (MHW) at National Oceanic and Atmospheric Administration (NOAA) tidal measurement stations: Kings Bay MSF Pier (Station ID: 8679598) or San Fernandina Beach (Station ID: 8720030). The measurement stations selected are those closest to the UCC site that record data for retrieval.

The metrics for triggering an inspection following a storm are based upon the following.

- The design of the streambank stabilization project calls for inspections following storms that have the potential to cause damage. The top of the stone revetment at the streambank stabilization areas is at an elevation of 11 feet (NAVD88) which is 8.4 feet above the MHW elevation (2.6 feet NAVD88) at the site. Considering a worst-case potential storm-induced wave height of 4 feet (CH2M 2008b) a trigger of > 2 feet above MHW represents a conservative trigger level for possible storm-induced wave action to occur above the revetment.

- Review of site-specific recession data over the past 27 years indicates there is general correlation between the larger recession measurements and tropical storms that pass proximal to the site. Though the site-specific data set comparing tidal and wave measurements from storms with recession data is somewhat limited, storm surges of more than 2 feet and sustained winds greater than 20 knots appear to show a relationship to larger streambank recession events (Appendix F).

E.9d.1.3.2.2 Monitoring Frequency

Routine Todd Creek streambank monitoring will be conducted quarterly for the first year following renewal of the Post-Closure Care and Corrective Action Permit HW-063(D). If the accuracy of the photogrammetric measurements is verified during the first year (as detailed in the Todd Creek MMP included in Appendix N), it will be recommended that measurements continue using only the photogrammetric measurements. If accuracy cannot be verified within the first year, manual measurements will continue following the first year. UCC will send a request for approval of the monitoring method and frequency to Georgia EPD following the first year of measurements, which will include a summary of the data collected and the accuracy of the photogrammetric measurements.

Based on evaluation of the site recession data, it is anticipated reducing the frequency of streambank measurements and photogrammetry from quarterly to an annual basis combined with inspections following storm events (as described in Section E.9d.1.3.2.1) is sufficient for decision making purposes.

E.9d.1.4 Todd Creek Contingency Plan

UCC is proposing to replace the current contingency plan with an updated contingency plan based on current site conditions. This section provides the updated contingency plan.

E.9d.1.4.1 Primary Contingency

The Primary Contingency for protection of the landfill from erosion of the Todd Creek streambank is streambank stabilization measures consisting of a combination of bank grading, stone toe protection, stone keys, stone revetment, and revegetation that mitigates erosional mechanisms while minimizing impacts to Todd Creek and the environment (Jacobs 2022d). This approach was selected as the Primary Contingency based on the following considerations:

- Successful construction of the streambank stabilization project in 2021 at ECM-1 and ECM-4. The efficacy of the design was tested in 2022 when Tropical Storms Ian and Nicole passed over the site on September 29 and October 10, respectively. The post-storm inspection indicated that there was minimal stone loss from the streambank stabilization project areas and no streambank recession identified. In comparison, substantial recession was documented in areas of native streambank along Todd Creek (Appendix F).
- The design for the 2021 streambank stabilization project was acceptable to site stakeholders and was preferrable to the Primary Contingency (groin system) specified in the 2011 site permit (CH2M 2011).
- The design for the 2021 streambank stabilization project was successfully permitted by the U.S. Army Corps of Engineers and Georgia Department of Natural Resources (Jacobs 2019).

Routine monitoring of the native streambank will be completed in accordance with Section E.9d.1.3.2 and Section 3 of the Todd Creek MMP (Appendix N). The primary contingency will be constructed in areas of native streambank when triggered by streambank loss along ECM-0, ECM-2 and ECM-3. Design and permitting of the primary contingency will be initiated no later than the point in time which is concurrent with streambank erosion reaching the 115-foot trigger pin (Design Initiation Trigger Pin; Figure 31). Along transects ECM-0, ECM-2 and ECM-3, construction of the primary contingency will be completed prior to or concurrent with streambank erosion reaching the 100-foot trigger pin (Primary Contingency Pin; Figure 31).

At ECM-1 and ECM-4 where streambank stabilization measures were constructed in 2021, monitoring and maintenance activities will be completed in accordance with the Todd Creek MMP (Appendix N).

E.9d.1.4.1.1 Primary Contingency Design

The streambank stabilization plan described below consists of streambank grading, installing a stone toe protection, placing a riprap revetment to above the 100-year return period elevation, and revegetating the streambank.

The primary purpose of the design is to address daily and episodic erosion on the southern streambank of Todd Creek. The stabilization system will resist damage from normal tidal fluctuations and provide streambank protection during moderate storms to help maintain the existing natural buffer zone between the landfill and Todd Creek. The stabilization system will include the following elements:

- Streambank regrading and slope transition;
- Placement of a nonwoven geotextile filter fabric underlying the bedding layer;
- Installation of an 8-inch-thick bedding layer (Georgia Department of Transportation [GDOT] Type 467 stone);
- Installation of a stone toe protection (GDOT Type 3 riprap [D50 = 9 inches]);
- Installation of stone keys at the upstream and downstream extents of each stabilization area and intermediate stone keys as needed;
- Installation of a 1.5-foot-thick riprap revetment layer (GDOT Type 3 riprap);
- Restoring the site and landscaping the streambank above the riprap revetment to a 25-foot buffer beyond the top of bluff.

UCC may modify the details of the final design of the stone toe protection, riprap revetment, and slope regrading contingency based on performance data obtained from monitoring of the streambank stabilization project areas to enhance its performance. Figure 37 provides a representative plan view and cross-section showing these elements of the stabilization system. The following sections describe the elements of the streambank stabilization design in greater detail.

Streambank Regrading and Slope Transition

Existing streambanks along Todd Creek within the extents of streambank stabilization work area will be regraded at a 2H:1V (horizontal:vertical) slope. Above the stone toe protection, the continuous streambank slope will incorporate a level terrace to provide a work platform that is not influenced by tides for construction activities and potential long-term maintenance needs. The terrace will be installed with a finished surface elevation above the mean higher high water (MHHW) level (2.97 feet North American Vertical Datum of 1988 [NAVD88]; Table 10). The terrace will be 15 feet wide perpendicular to the slope. The 2H:1V slope regrading will continue from the landward extent of the terrace to the existing top of bluff elevation. At the eastern and western extents of the stabilization area, the graded streambank slope will be tied into the adjacent existing streambanks at a 2H:1V or flatter slope.

Riprap Bedding and Filter Layer

The filter layer and bedding layer placed on the regraded streambanks will consist of a nominal 12-ounce-per-square-yard nonwoven geotextile filter fabric overlain by 8 inches of bedding stone. The geotextile will serve as the filter layer to limit migration of the existing fine-grained sand through the bedding stone and riprap revetment stone. The use of a geotextile filter fabric is recommended over the use of graded filters considering the savings in earthwork volumes, imported material volumes, and quality control measures associated with the placement of multiple aggregate layers.

The recommended riprap bedding stone for the Type 3 riprap will consist of GDOT Type 467 stone, as recommended by GDOT Standard Specifications (GDOT 2013). The bedding stone will provide protection to the nonwoven geotextile during riprap placement and provide ballast to the geotextile to keep it in place before and during placement of the riprap. The geotextile will be placed from the bottom elevation of the stone toe protection at -5 feet NAVD88, below the mean lower low water elevation (-4.23 feet NAVD88; Table 10), extending up the slope to the top of the riprap revetment at 11 feet NAVD88. The same combination of filter layer and bedding layer will be used under the stone key elements.

Stone Toe Protection

Hydraulic modeling results and fluvial stone sizing equations were used to size the riprap and potential scour depth that serve as inputs to the design of the stone toe protection. Based on the calculated stone size and locally available cost-effective material, GDOT Type 3 riprap was selected for use in the riprap revetment. Use of GDOT Type 3 riprap will provide adequate protection for daily tidal currents at the site and limited protection from moderate and severe storms. Some damage to the riprap revetment may be expected during severe storms involving wave action on the streambank. Storm damage is expected to be limited to the riprap revetment, somewhat mitigated by the ability of the revetment to resist over-steepening of the streambank's slope that would otherwise be caused by normal tidal current erosion, and graded slope transitions.

Stone will be placed longitudinally along the toe of the streambank stabilization measures (not at the toe of streambank slope or channel thalweg), covering the range of expected tidal erosion. Stone toe protection will be placed at an elevation of -5.0 feet NAVD88 to extend below mean lower low water elevation of -4.23 feet NAVD88 (Table 10). The top elevation of the stone toe protection will be at elevation 1.0 feet NAVD88. The stone toe will consist of GDOT Type 3 riprap installed at a 2H:1V slope overtop a layer of bedding stone.

When erosive conditions in Todd Creek cause scour holes to form adjacent to the stone toe protection, a portion of the stone toe is designed to self-launch and line the advancing edge of the scour hole with riprap, limiting further slope erosion. The launchable volume of stone installed as part of the stone toe protection is designed to provide continuous streambank protection like riprap revetments and allow for riprap material loss during underwater installation, while also providing sufficient stone for self-launching to protect the estimated scour depth.

Stone Keys

The stone keys, which are an extension of the stone toe protection, will be installed from the landward side of the stone toe protection and terminate into the top of bluff, angled away from the toe of slope at a 30- to 45-degree angle with respect to the dominant flow direction. The stone keys will provide a source of self-launching material that can provide protection against flanking erosion in the same manner that the stone toe protection can self-launch to line scour holes at the toe of the slope. Because of the similar design intent, the stone keys are designed to contain the same volume of streambank stone per linear foot of key as the stone toe protection contains per linear foot of streambank (2.4 cubic yards per linear foot).

The stone keys will consist of GDOT Type 3 riprap installed in an excavated embankment trench. The trench will be lined with a geotextile filter before installing a layer of bedding stone along the bottom of the trench and streambank stone up to the adjacent surface grade at a 2H:1V or flatter slope.

Riprap Revetment and Terrace

GDOT Type 3 riprap will be placed along the streambank at 1.5 feet thick (measured perpendicular to the surface of the stone bedding layer) from the top of the stone toe protection at elevation 1.0 feet NAVD88 to above the 100-year return period elevation at 11.0 feet NAVD88. Above the stone toe protection, a 15-foot-wide terrace will be installed above the MHHW with a finished surface elevation of 4.5 feet NAVD88 to provide an access path for future maintenance.

Site Restoration and Landscape Plan

Shrubs will be planted on the 2H:1V slope above the top of the riprap revetment (11.0 feet NAVD88) and from the new top of streambank to a 25-foot buffer beyond the top of the bluff. Shrubs will consist of 3-gallon containerized wax myrtle, sparkleberry, saw palmetto, yaupon holly, or red bay planted 12 to 15 feet on-center.

Finished earthen slopes above the top of the riprap revetment (11.0 feet NAVD88) will be protected from wind and rainfall erosion by a biodegradable erosion control mat, Rolanka BioD-OCF or equivalent. This product is composed of a 0.25-inch-thick coir fiber mattress stitched between two jute woven nets. The BioD-OCF product was selected for this area based on recommended usage with sandy soils.

Transition areas adjacent to the primary streambank stabilization measures, where the grading will transition from the 2H:1V specified slopes to match the existing topography of the adjoining bluffs, will be protected from tidal current, wind, and rainfall erosion by a combination of two biodegradable erosion control mats, Rolanka BioD-OCF (or equivalent) as the inner layer and Rolanka BioD-Mat 70 (or equivalent) as the outer layer. The Rolanka BioD-OCF product is as described above. The Rolanka BioD-Mat 70 is composed of a woven bristle coir mat with 48% open areas and was selected for this application based on the recommended usage for installation on steep slopes (up to and steeper than 1:1), resistance to flow velocities up to 12 feet per second, and typical 5- to 7-year effective lifespan. The combination of the two products will provide effective erosion control for these challenging locations, while supporting growth of temporary and permanent vegetation.

Trees will be planted from the new top of streambank to a 25-foot buffer beyond the top of the bluff. Trees will consist of 2-inch caliper red maple, laurel oak, bald cypress, slash pine, or southern magnolia planted approximately 30 to 40 feet on-center.

E.9d.1.4.1.2 Permitting for Primary Contingency

To implement the primary contingency, permits and authorizations are required by federal, state, and local regulatory agencies. Anticipated permits and approvals described in this section are summarized in Table 12. UCC will review the project at the time of execution and obtain all required permits.

E.9d.1.4.1.2.1 Joint Application Process

The U.S. Army Corps of Engineers (USACE) Section 404 Permit, Georgia Coastal Marshlands Protection Act (CMPA) permit (GADNR 2020), Georgia Revocable License, and Georgia Water Quality Certification will be applied for jointly using the Joint Application (GADNR 2018). The Joint Application process involves submitting the Joint Application to the USACE Savannah District, Georgia Department of Natural Resources (GADNR) Coastal Resources Division (CRD) Habitat Management Program (HMP), GADNR Real

Estate Unit, GADNR CRD Ecological Services, and GADNR and EPD Water Protection Branch per the instructions on the Joint Application.

E.9d.1.4.1.2.1.1 Clean Water Act Section 404 and Rivers and Harbors Act of 1899 Section 10

The project is within USACE Savannah District jurisdiction and requires an approved jurisdictional determination for waters of the United States. Implementation of the project could be authorized by a nationwide permit (NWP). Typically, an NWP takes 60 days to process from the time USACE deems the application complete.

E.9d.1.4.1.2.1.2 Georgia CMPA Permit and Revocable License

Camden County is one of six coastal counties within the Georgia Coastal Zone managed by the Georgia Coastal Management Program within GADNR CRD HMP. The HMP is responsible for executing leases and easements for state-owned water bottoms and issuing CMPA permits, Revocable License, and shore permits. The CMPA permit authorizes impacts to coastal resources, and the Revocable License authorizes construction in tidal water bottoms and can include a permanent easement request and stream/marsh buffer variance, if required.

E.9d.1.4.1.2.1.3 Coastal Zone Consistency Review

Coastal Zone Consistency means that the activity is designed to be consistent with the applicable enforceable policies, or environmental laws, of the State of Georgia. Under NOAA's Federal Consistency provisions (15 CFR 930), Federal agencies must determine if their proposed project directly affects Georgia's coastal zone. Cumulative and secondary effects must be included. The Georgia Coastal Management Program and Federal Consistency provisions are applicable in the 11 coastal counties, and a federal consistency certification must accompany all applications for federal permits.

E.9d.1.4.1.2.1.4 Stream Buffer Variance

GA EPD has 60 days after receipt of a complete buffer variance application to either provide comments to the applicant or propose to issue a variance. Once the proposal to issue the variance is issued, GA EPD will send out a public advisory to all citizens and groups who request to receive the advisories. The applicant will then publish one public notice in the newspaper in the county where the buffer disturbance will occur. The public advisory and public notice shall describe the proposed buffer encroachment, the location of the project, where the public can review site plans, and where comments should be sent. The public shall have 30 days from the date of publication of the public advisory and the public notice to comment on the proposed buffer variance. Camden County flood management office will be notified and able to comment on the stream buffer variance application that will be submitted.

E.9d.1.4.1.2.1.5 Biological Resources

Based on the review of the U.S. Fish and Wildlife Service's Information for Planning and Consultation website and the GADNR Biodiversity portal, no critical habitat has been identified within the project vicinity (U.S. Fish and Wildlife Service 2019; GADNR 2019). The likelihood of federally listed species to occur in the area is moderate, as habitat for aquatic species within the immediate project area exists. There is also potential for impacts to terrestrial species in the area to be cleared and graded, as well as the areas that will be used temporarily for site access and staging.

Federal species include the west Indian manatee (*Trichechus manatus*), green sea turtle (*Chelonia mydas*), leatherback sea turtle (*Dermochelys coriacea*), loggerhead sea turtle (Caretta *caretta*), Kemp's Ridley sea turtle (*Lepidochelys kempii*), shortnose sturgeon (*Acipenser brevirostrum*), Atlantic sturgeon (*Acipenser* *oxyrinchus oxyrinchus*), eastern indigo snake (*Drymarchon couperi*), and the Northern Atlantic right whale (*Eubalaena glacialis*). If construction occurs during the migratory bird nesting season (to be determined), a qualified biologist should conduct a preconstruction nesting bird survey within 7 days of construction. If active bird nests are identified, additional avoidance and minimization measures, such as avoidance buffers, or noise and visual barriers, may be recommended. Coordination with the GADNR Wildlife Resources Division is required for potential impacts to state-listed species.

The previous work included monitoring and management of the state-listed gopher tortoise, monitoring for manatees, and monitoring for the eastern indigo snake.

E.9d.1.4.1.2.1.6 National Pollutant Discharge Elimination System Permit for Stormwater Discharges from Construction Activities (General Permit No. GAR 100001)

Streambank stabilization is anticipated to be done from both a barge and from the upland area of the streambank. Any upland staging or access areas will be permitted under the most current National Pollutant Discharge Elimination System General Permit GAR 100001. After coordination with Camden County and Camden County review of the plans, forms for Land Disturbance Activity Permit will be submitted to the Camden County Planning and Development office. Camden County will submit the package to the Georgia Soil and Water Conservation Commission for review. A 60-day review period by Georgia Soil and Water Conservation Commission is anticipated following submission of the permit to Camden County. At least 14 days before the start of construction activities, any project in Georgia with land disturbance equal to or greater than 1.0 acre is required to submit a Notice of Intent to the Georgia EPD (Georgia EPD 2016). Permit application, including the Notice of Intent form, completed GAR10001 checklist, and one set of erosion and sediment control plans prepared and signed by a design professional licensed by the State of Georgia will be submitted to Georgia EPD.

The following have been identified for future repairs and maintenance to the streambank stabilization area. The streambank stabilization area is currently covered under the CMPA permit, which is valid until May 12, 2025. If future repairs and maintenance are needed, they will be covered by a USACE NWP 3a, with no notification to the USACE required in advance of the start of work. In the event of an emergency situation such as after a hurricane, USACE may allow certain maintenance or repairs related to the storm event to be conducted without a permit application being submitted to the USACE.

E.9d.1.4.2 Secondary Contingency Plan

A conceptual design of the secondary contingency will be developed following the Landfill Protection Assessment and Contingency Plan evaluation discussed in Section E.9d.1.5.2 and will consider data collected during streambank monitoring (defined in Appendix N) and the results of the landfill protection assessment. The final design and construction of the Secondary Contingency will be triggered as follows:

- For native streambank near transects ECM-0, ECM-2, and ECM-3 the trigger points are unchanged from the current permit:
  - Secondary Contingency design must be complete no later than the point in time that is concurrent with streambank erosion reaching 95 feet from the baseline (5 feet past the 100-foot Primary Contingency Complete Pin) (Figure 31).
  - Secondary Contingency corrective action activities must be complete no later than the point in time that is concurrent with streambank erosion reaching the Secondary Contingency Pin (85 feet from the baseline) (Figure 31).
- In the stabilization areas near ECM-1 and ECM-4 new trigger points are proposed as follows:

- Secondary Contingency design must be complete no later than the point in time that is concurrent with erosion reaching the landward edge of the terrace at the toe of the stone revetment (Secondary Design Complete Trigger Line) (Exhibit A).
- Secondary Contingency corrective action activities must be complete no later than the point in time that is concurrent with erosion reaching the top of the stone revetment (Secondary Installation Complete Trigger Line) (Exhibit A).

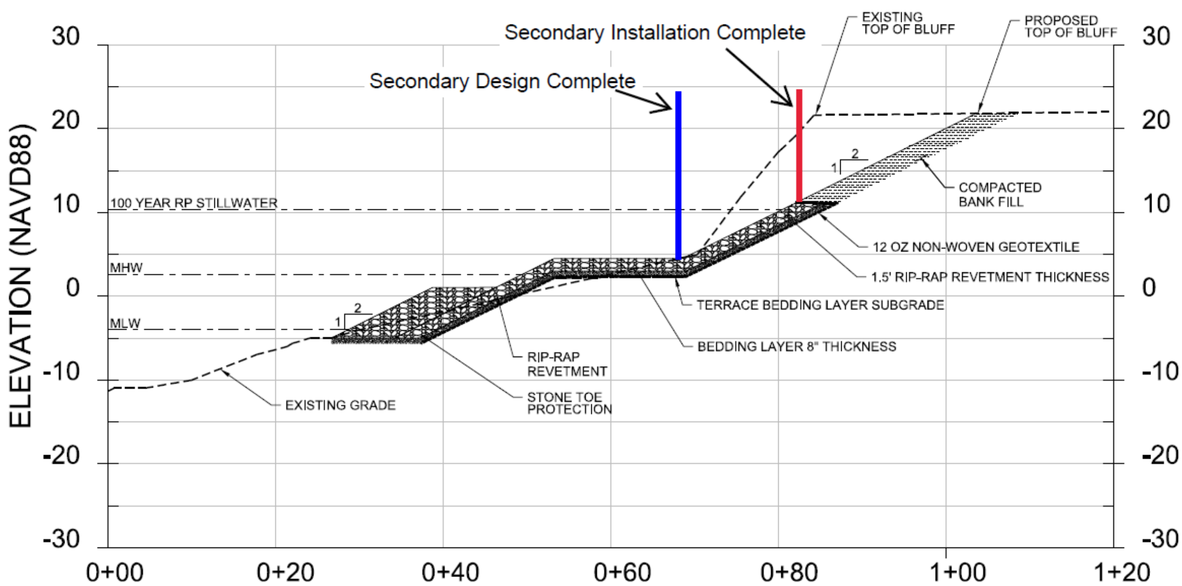

Exhibit A. Cross section of streambank stabilization measures with Secondary Contingency triggers

E.9d.1.5 Reporting

The following reports will be provided as part of the Todd Creek streambank monitoring program, landfill protection assessment and contingency planning.

E.9d.1.5.1 Streambank Monitoring Reports

A brief email summary of the results of each of the routine and post-storm visual inspections of the Todd Creek streambank will be submitted to Georgia EPD within 30 days of the inspection. For the stabilized areas (ECM-1 and ECM-4) the summary will indicate if any maintenance triggers have been exceeded and the nature/magnitude of the exceedance. For the native streambank (transects DC-1, DC-2, ECM-0, ECM-2, and ECM-3) the notification will include measurements of bank recession (from the baseline), and distance to the nearest trigger pin (where applicable).

The results of the routine and post-storm visual inspections and UAV surveys will also be provided to Georgia EPD on an annual basis by April 1 for the period of January through December of the previous calendar year. The annual reports will provide an evaluation of UAV photos and survey data collected and a summary of the results of the streambank monitoring and any maintenance performed as described in the Todd Creek MMP (Appendix N).

E.9d.1.5.2 Landfill Protection Assessment and Contingency Plan

A landfill protection assessment will be completed to evaluate the following:

- Determine the overall effectiveness of the streambank stabilization measures installed near ECM-1 and ECM-4.
- Assess regional geomorphology and migration of the Todd Creek channel over time.
- Consider impacts of rising sea levels and climate change on Todd Creek.
- Identify and evaluate long-term management approaches to protect the landfill from streambank erosion and migration.
- Develop alternatives and propose a conceptual design for a Secondary Contingency plan for protection of the landfill.
- If appropriate, develop proposed updates to the Primary Contingency plan.

The landfill protection assessment and contingency plan will be completed within 3 years of approval and issuance of the Post-Closure Care and Corrective Action Permit HW-063(D) based on the following:

- Field studies and research is anticipated to take 18 months to complete and may consist of a bathymetric survey, collection of surface and subsurface samples of stream sediment, and evaluation of stream geomorphology and historical aerial photo interpretation of stream migration extending upgradient and downgradient of the landfill. This includes time to research and obtain data from public sources on climate change and historical storms that have impacted the area.
- Data evaluation is anticipated to take 6 months to complete following field studies and research and may consist of evaluating bathymetric data, projecting stream migration over time, and updating existing hydraulic models for Todd Creek. This evaluation will consider data collected during routine and post-storm streambank monitoring.
- Reporting is anticipated to take 12 months to complete following data evaluation, will consist of an alternatives analysis and development of a Secondary Contingency plan, and if necessary, will include proposed updates to the Primary Contingency plan and the Todd Creek MMP.

The Landfill Protection Assessment and Contingency Plan report will be delivered to Georgia EPD for their review. Proposed contingency plans and updates to the Todd Creek MMP will be approved by Georgia EPD prior to implementation.

E.9d.2 Groundwater Corrective Action

The objective of active groundwater remediation is to address COCs that are above their specific target levels which are protective of human and ecological receptors for the site-specific water use scenario(s). Target levels for corrective actions are based on the human health and ecological risk assessments and potentially complete exposure pathways. An updated risk assessment for potential exposures to receptors at Todd Creek and associated target levels is documented in Section E.9d.3.2. As detailed in Section E.5, there are no COCs that pose unacceptable cancer risk or hazards based on current groundwater quality at the POC wells considering the long-term groundwater monitoring program and existing institutional controls. Nonetheless, an iSOC corrective action system was installed in December 2011 for the following purposes:

- Enhance natural attenuation in the surficial aquifer by creating an oxygenated zone to treat groundwater along the downgradient edge of the landfill so that GWPS are met at the POC wells.
- Provide an added measure of long-term protectiveness for potential downgradient receptors.

E.9d.2.1 Existing iSOC System

The iSOC corrective action system consists of 15 oxygen diffusion (OD) wells, each with an iSOC unit, and piping and equipment associated with the system. The following provide additional detail on the existing system.

The 15 diffusion wells were installed on approximately 20-foot centers in an east-west row along the northern site boundary to form a continuous oxygenated zone perpendicular to groundwater (and plume) flow direction (Figures 8 and 9). The wells are constructed of 2-inch-diameter polyvinyl chloride, installed to a depth of approximately 50 feet, and screened over the shallow and deep surficial aquifer. Figure 38 shows a typical construction detail for the wells.

Each well includes its own oxygen delivery unit that consists of a stainless-steel casing filled with a proprietary micro-porous hollow polymer fiber material. The unit is inserted into the diffusion well, and oxygen from a compressed gas cylinder is delivered to the unit through connected polyurethane tubing. The oxygen flow is controlled at the cylinder head with a design oxygen use rate of approximately 1 cubic foot per infusion well per day. The iSOC supersaturates the diffusion well with DO. The supersaturated DO curtain of water disperses around the well into the adjacent groundwater, with the intent of forming an enhanced bioremediation treatment zone to stimulate the degradation of the target constituents. Average DO measurements in the diffusion wells have ranged between 8.6 and 192.9 parts per million over the operational period of the system (Arcadis 2023) with the most recent (June 2022 to November 2022) being 11.8 parts per million.

Maintenance of the iSOC system consists of periodically changing spent oxygen cylinders and conducting quarterly inspection and maintenance of the iSOC water filters.

The corrective action system monitoring program includes routine data collection, and semiannual groundwater sampling of the monitoring well network (including iSOC system monitoring wells MW-7, MW-19, MW-49, and MW-50). Data collection activities include monthly and/or quarterly measurements collected from OD wells. Quarterly DO and ORP measurements are collected from the ORP wells (ORP-1, ORP-2, and ORP-3) and iSOC system monitoring wells (MW-7, MW-19, MW-49, and MW-50). The results from these routine sampling events are used to evaluate the effectiveness of the iSOC oxygen delivery system. Results of monitoring have been reported in semiannual effectiveness reports since installation of the system in 2011, with the most recent report being the 68th semiannual report (Arcadis 2023).

E.9d.2.2 Effectiveness Review

UCC conducted an evaluation to determine if the system was effective at achieving its stated purpose. For the evaluation, UCC assessed whether natural attenuation is occurring in a tiered analysis of four phases. The evaluation also consisted of the following:

- Reviewing DO data since starting the iSOC system in the iSOC wells and downgradient wells;
- Assessing the radius of influence of increased DO from the iSOC wells;
- Evaluating COC concentration trends to determine if there are any demonstratable effects on COC concentrations due to operation of the iSOC system;
- Comparing groundwater concentrations to target levels for groundwater discharge to Todd Creek;
- Reviewing geochemical conditions in the aquifer to determine if they support biodegradation of organic COCs.

A non-parametric analysis of variance method, the Kruskal-Wallis test, was applied to the data to test for differences in DO measurements between the OD wells (OD Wells 1 through 15), effectiveness wells (MW-7, MW-19, MW-49, and MW-50) located directly downgradient of the OD wells, and side-gradient wells (MW-6, MW-8, MW-38, and MW-39) (Figures 8 and 13). The Kruskal-Wallis method tests for differences among average population ranks equivalent to the medians, assuming observations in each group are identically and independently distributed apart from location. When observations represent very different distributions, the method is a test of dominance between distributions. The calculated probability (p-value) from the test was compared with a common significance level of 0.05. When the probability is below this level, a significant difference in the distribution of at least one of the data sets and the other data sets is suggested. A post-hoc test (multiple comparison test) was employed to determine which well groups were statistically different.

The well sets were selected for evaluation because the OD wells are known to be influenced by the iSOC, the side-gradient wells are known not to be influenced by the iSOC, and the effectiveness wells are the wells that are most likely to be influenced by the iSOC (located approximately 15 feet from the iSOC OD wells). The p-value of the Kruskal-Wallis test was less than 0.001, indicating DO levels are statistically different between the well groups. The results of the post-hoc test indicate there is a statistically significant difference in DO between the OD wells and the effectiveness wells and between the OD wells and side-gradient wells; however, there was no statistical difference between the effectiveness wells and the side-gradient wells. This suggests that the effectiveness wells are not influenced by the iSOC system.

Graphical presentations of the data were made using various statistical plotting methods to supplement the formal statistical comparison. Statistical plotting methods that were used include box-and-whisker plots (referred to as box plots), probability plots, and histograms.

Box plots show the central tendency, degree of symmetry, range of variation, and potential outliers of a data set. The upper value of the box represents the 75th percentile for the data, and the lower value of the box is the 25th percentile for the data. Thus, 50% of the data fall within the box. The top of the whisker represents the 75th percentile plus 1.5 times the IQR, where the IQR is the 75th percentile minus the 25th percentile. The bottom of the whisker is the 25th percentile minus 1.5 times the IQR. Any value outside this range is considered a potential statistical outlier, which is represented by a dot on the plot. The outlying concentrations of box plots only serve the definition of falling relatively far from the middle 50% of the data. If the data are drawn from a highly skewed distribution, or a symmetrical one with long tails, multiple outliers of this type are expected.

Various interpretations are possible by examining box plots. For example, if extensive overlap exists between the box plots from different data groups, then the measurements from each group, on average, are similar. Conversely, little overlap between data groups suggests that the measurements from the groups are, on average, different.

Normal probability plots show the ordered sample results versus the corresponding quantiles of a theoretical data distribution, such as the normal distribution, and is described as a quantile-quantile plot. A normal probability plot is used to evaluate the normality of the distribution of a variable (i.e., whether, and to what extent, the distribution of the variable follows the normal distribution). If the data are not normally distributed, they will deviate systematically from a straight line. Variability in the data will cause the data to scatter randomly around this line, but the data will still appear to follow a single straight line. Probability plots are useful when identifying and evaluating outlying observations. Overlapping probability plots can be used to compare the quantiles of different data sets against each other to help determine whether they come from the same population.

A histogram is a visual representation of the data collected into groups. The data range is divided into several bins or classes, and the data are sorted into the bins. A histogram is a bar graph conveying the bins and the frequency of data points in each bin. Histograms provide a visual method of accessing location, shape, and spread of the data; the shape of a histogram helps determine whether the distribution is symmetric or skewed. The visual impression of a histogram is sensitive to the number of bins selected. A large number of bins will increase data detail, while fewer bins will increase the smoothness of the histogram. Stacked histograms can be used to compare values between multiple groups of data.

To supplement the formal statistical comparisons, overlapping probability plots comparing the quantiles of the DO levels in the three data sets against each other are provided on Figure 39. This figure also includes stacked histograms and side-by-side box plots comparing the DO levels. These graphical presentations of the data also indicate that DO levels are similar in the effectiveness wells and side-gradient wells. This further indicates that the iSOC system is not influencing conditions in the effectiveness wells.

The statistical difference in DO between the OD wells and the other well groups is expected given that oxygen is supplied directly to these wells. These data indicate that while the iSOC system does create an oxygenated zone within the OD wells, oxygenation of the aquifer is limited with no observable changes in DO in the immediately downgradient effectiveness wells.

E.9d.2.2.1 Natural Attenuation

One of the objectives of the iSOC system is to enhance natural attenuation in the surficial aquifer. To assess whether natural attenuation is occurring, UCC used the tiered analysis approach from the *Use of Monitored Natural Attenuation for Inorganic Contaminants in Groundwater at Superfund Sites* (EPA 2015), which updated and expanded on the Use *of Monitored Natural Attenuation at Superfund, RCRA Corrective Action, and Underground Storage Tanks Sites* (EPA 1999), to develop multiple lines of evidence. As discussed below, the tiered analysis is composed of the following four phases:

- Phase I: Demonstration that the groundwater plume is not expanding.
- Phase II: Determination that the mechanism and rate of the attenuation process are sufficient.
- Phase III: Determination that the capacity of the aquifer is sufficient to attenuate the mass of contaminant within the plume (and the stability of the immobilized contaminant is sufficient to resist re-mobilization for inorganic constituents).
- Phase IV: Design of a performance monitoring program based on an understanding of the mechanism of the attenuation process, and establishment of contingency remedies tailored to site-specific characteristics.

Phase I: Demonstrate Plume Stability

In the 1999 monitored natural attenuation (MNA) guidance, this tier is described as "*historical groundwater and/or soil chemistry data that demonstrate a clear and meaningful trend of decreasing contaminant mass and/or concentration over time at appropriate monitoring or sampling points.*" The objective of the Phase I analysis is to evaluate whether MNA should be eliminated from further consideration for sites where the groundwater plume is not stable or continuing to expand.

UCC evaluated the extent of select COC plumes in Section E.5 beginning with initial sitewide groundwater data at the site from 1986 (where available). COCs evaluated were those that had statistical exceedances in POC wells or had detections at three or more spatially distinct wells at concentrations exceeding the GWPS and consisted of: acetone, 2,4,5-T, p-cresol, formaldehyde, naphthalene, sulfide, and vanadium.

The overall conclusion from this evaluation is that over time COC plumes at the site have contracted in size and concentration or remained stable. None of the COCs was observed to have expanding plumes.

As part of groundwater compliance monitoring, the non-parametric MK test is used to evaluate statistical trends of Table A constituent concentrations. The data includes results from groundwater monitoring event beginning in 2006 and continuing to the most recent results from 2022. The analysis was completed for the upgradient background well, POC wells, and TCS wells.

POC Wells. Comparison of concentrations in the POC wells to the risk-based TCTLs developed in Section E.9d.3.2 indicates that all concentrations in the most recent sampling event (Arcadis 2023) were below the TCTL for potential exposures at Todd Creek. Per the *68th Semiannual Groundwater Compliance Monitoring Report* (Arcadis 2023) and as summarized below, the Table A constituents in the POC wells are in four categories relative to GWPS:

- Concentrations are less than their respective GWPS with decreasing trends or no statistical trends at all POC wells. These constituents consist of 23 of the 37 constituents monitored and is the largest group of constituents. These constituents are not shown in the summary table.
- Concentrations are greater than their respective GWPS at one or more of the POC wells, but all the wells all have either decreasing trends or no statistical trends. This category includes 2-methylnaphthalene, formaldehyde, and sulfide. Pyridine exceeds the GWPS at MW-07 and shows an increasing trend at MW-06 but does not have an increasing trend where it exceeds the GWPS.
- Concentrations are less than their respective GWPS at all POC wells, but there is an increasing trend at one or more of the POC wells. This category includes acetone, arsenic, barium, carbon disulfide, chromium, ethylbenzene, methylene chloride, and toluene. However, based on the September 2022 semiannual sampling data, the concentrations of these constituents were at least 65% lower than their respective GWPS or below laboratory detection limits.
- Concentrations are greater than their respective GWPS and have an increasing trend at one or more of the POC wells. This category includes naphthalene and vanadium. However, the September 2022 concentrations are less than or consistent with historical sampling results (e.g., the naphthalene concentrations at MW-07 and MW-34 are about 50% of their 1998 and 2002 concentrations, respectively). Furthermore, the naphthalene and/or vanadium concentrations generally decrease in the direction of groundwater flow as evidenced by the recent and historical results at the following well pairs: MW-06 and MW-23A, MW-07 and MW-20, and MW-34 and MW-17/42.

In summary, all Table A constituent monitoring at the POC wells was less than the respective TCTLs and the majority (27 of 37) of the Table A constituents have decreasing trends or no statistical trends. Of the remaining 10 constituents, only 2 (naphthalene and vanadium) had increasing concentration trends that are above the GWPS and both constituents are within plumes that are stable and not increasing in extent.

Table A Constituents with a GWPS Exceedance or Increasing Trend	Shallow POC Wells					
	MW-06	MW-07	MW-08	MW-34	MW-38	MW-39
2-Methylnaphthalene	NST	NST	--	▼	--	--
Acetone	▼	▼	NST	NST	▲	▼
Arsenic	▲	▼	▼	▼	▼	NST
Barium	NST	▼	NST	▼	▼	▲
Carbon disulfide	NST	▲	▲	▲	NST	▲
Chromium	NST	▲	NST	NST	▲	--
Ethylbenzene	▲	▲	--	NST	NST	--
Formaldehyde	NST	NST	NST	NST	▼	▼
Methylene chloride	▲	--	--	--	--	--
Naphthalene	NST	▲	NST	▲	NST	NST
Pyridine	▲	NST	--	--	--	--
Sulfide	NST	NST	NST	▼	▼	▼
Toluene	▲	▲	NST	NST	NST	NST
Vanadium	▲	▲	NST	▲	▲	▲

Notes:
NST = no significant trend; ▼ = decreasing trend; and ▲ = increasing trend
-- not detected
Greater than GWPS
Greater than GWPS and an increasing trend

Todd Creek Sentinel Wells. Per the *68th Semiannual Groundwater Compliance Monitoring Report* (Arcadis 2023) and as summarized below, the Table A constituents in the TCS wells are in four categories relative to the GWPS:

- Concentrations are less than their respective GWPS with decreasing trends or no statistical trends at all TCS wells. These constituents consist of 17 of the 37 constituents monitored and is the largest group of constituents. These constituents are not shown in the summary table.
- Concentrations are greater than their respective GWPS at one or more of the TCS wells, but the wells have decreasing trends or no statistical trends. This category includes sulfide.
- Concentrations are less than their respective GWPS at all TCS wells, but there is an increasing trend at one or more of the TCS wells. This category includes acetone, arsenic, barium, carbon disulfide, chromium, ethylbenzene, fluoride, methylene chloride, nickel, pyridine, selenium, toluene, xylenes, and zinc. However, based on the September 2022 semiannual sampling data, the concentrations of these constituents were at least 66% lower than their respective GWPS or below laboratory detection limits.
- Concentrations are greater than their respective GWPS and have an increasing trend at one or more of the TCS wells. This category includes formaldehyde, naphthalene, and vanadium. However, except for formaldehyde at MW-20 and vanadium at MW-42, the September 2022 concentrations are less than or consistent with historical sampling results.

In summary, only 3 of 37 constituents monitored had an increasing trend in a TCS well that exceeded the GWPS. These constituents (formaldehyde, naphthalene, and vanadium) were within plumes that were stable.

Table A Constituents with a GWPS Exceedance or Increasing Trend	Todd Creek Sentinel Wells								
	Shallow				Deep				
	MW-17	MW-20	MW-23	MW-42	MW-18	MW-21	MW-24	MW-25	MW-41
Acetone	▲	▼	NST	NST	▲	NST	NST	▼	▼
Arsenic	NST	▼	▲	▲	NST	NST	NST	NST	▲
Barium	NST	NST	NST	▼	▲	▲	▼	▲	NST
Carbon disulfide	NST	NST	NST	NST	▲	▲	▲	NST	▲
Chromium	▲	NST	--	NST	NST	NST	NST	NST	NST
Ethylbenzene	--	▲	NST	--	--	--	--	--	▼
Fluoride	--	NST	NST	NST	▲	▼	▲	NST	NST
Formaldehyde	▼	▲	▼	▼	NST	NST	NST	NST	▼
Methylene Chloride	NST	▲	NST	--	--	--	NST	--	NST
Naphthalene	▲	NST	NST	--	--	▲	NST	NST	NST
Nickel	▲	NST	NST	NST	--	--	--	--	NST
Pyridine	--	--	NST	--	--	--	--	--	▲
Selenium	▲	▼	▼	▲	NST	▼	NST	NST	▼
Sulfide	NST	▼	NST	▼	NST	NST	--	NST	NST
Toluene	NST	▲	▲	--	NST	NST	NST	NST	NST
Vanadium	▲	NST	▲	▲	▲	NST	NST	▲	▼
Xylenes	NST	▲	NST	NST	--	--	NST	NST	NST
Zinc	NST	NST	NST	NST	NST	NST	▲	NST	NST

Notes:
NST = no significant trend; ▼ = decreasing trend; and ▲ = increasing trend
-- not detected
Greater than GWPS
Greater than GWPS and an increasing trend

Phase II: Determine Mechanism and Rate of the Attenuation

In the 1999 MNA guidance, this tier is described as "*hydrogeologic and geochemical data that can be used to demonstrate indirectly the type(s) of natural attenuation processes active at the site, and the rate at which such processes will reduce contaminant concentrations to required levels.*"

Historically, DO, ORP, pH, nitrate/nitrite, total organic carbon (TOC), alkalinity, iron, and ferrous iron have been monitored at the site to assess whether the groundwater geochemistry is facilitating natural attenuation. Excluding the iSOC wells, the relatively low DO concentrations (that is, less than 1 mg/l) are indicative of conditions that are favorable for the anaerobic biodegradation of the organic COCs (e.g., acetone, ethylbenzene, formaldehyde, naphthalene, and toluene). DO is the most thermodynamically favored electron acceptor used by microbes for the biodegradation of organic carbon, whether natural or anthropogenic. The prevalence of anaerobic biodegradation suggested by the low DO concentrations is consistent with the other geochemical parameters that are routinely measured at the effectiveness wells; MW-7, MW-19, MW-49, and MW-50; as follows:

- ORP values, which generally range from -300 to -100 millivolts (mV), indicate strongly reducing conditions.
- Nitrate/nitrite concentrations, which are below detection limits, indicate strongly reducing conditions as the nitrate is used as an electron acceptor for anaerobic biodegradation of organic carbon via denitrification.

- Relatively elevated alkalinity at MW-7 (and increasing since 2012) and MW-19 is indicative of increased microbial activity. Increases in alkalinity result from the dissolution of rock driven by the production of carbon dioxide produced by the metabolism of microorganisms.
- Decreasing TOC concentrations at each of the monitoring wells since 2012 suggests an active microbial population as they are using the TOC as an electron donor, just like the contaminants.
- Though relatively low, the pH is within the range (6 to 8 standard units) where microbes capable of degrading organic contaminants can thrive.

Overall, though commonly slower than aerobic biodegradation, anaerobic biodegradation is likely responsible for the decreasing trends and overall plume stability observed at the site and discussed in Phase I.

As the organic COCs are biodegraded, and less of the natural DO is used as the electron acceptor to facilitate the redox reactions, the groundwater gradually becomes more aerobic in the direction of flow. While the inorganic COCs tend to mobilize under reducing conditions, they will oxidize and become immobile as the groundwater becomes more oxidizing toward Todd Creek. Consistent with the gradually oxidizing conditions, the ferrous iron concentrations at MW-7, MW-19, MW-49, and MW-50 have decreased slightly since 2012, which suggest that less of the natural (ferric) iron is reducing.

Phase III: Determine System Capacity and Stability

In the 1999 MNA guidance, this tier is described as "*data from field or microcosm studies (conducted in or with actual contaminated site media) which directly demonstrate the occurrence of a particular natural attenuation process at the site and its ability to degrade the contaminants of concern (typically used to demonstrate biological degradation processes only)*"

No microcosm studies nor microbial sampling has been conducted at the site.

Phase IV: Design of a Performance Monitoring Program and Identify Alternative Remedy

This phase in effect reflects recommendations in the 1999 MNA guidance, but consolidated into a single, additional phase. The iSOC-specific elements in the current monitoring program includes quarterly data collection from ORP-1, ORP-2, and ORP-3 and MW-7, MW-19, MW-49, and MW-50 to assess geochemical conditions (i.e., DO, ORP, pH, nitrate/nitrite, TOC, alkalinity, iron, and ferrous iron). Groundwater monitoring at the site is proposed be conducted annually to evaluate Table A-1 constituent concentrations at background, POC, and non-POC sampling locations. The monitoring program includes a network of wells that provide adequate areal and vertical coverage to verify that the groundwater plume(s) remains static or shrinks and the ability to monitor groundwater chemistry throughout the zones where contaminant attenuation is occurring. The monitoring program also includes an assessment of groundwater flow patterns so the monitoring network can be adjusted to evaluate the influence of potential flow changes within the plume.

E.9d.2.2.2 Effectiveness Review Conclusions

The effectiveness review determined that although DO concentrations have increased in the OD wells, the iSOC system does not increase DO concentrations in the POC wells that are immediately downgradient or side-gradient of the OD wells.

Therefore, it can be concluded that the concentration trends are driven by intrinsic natural attenuation and not from increased DO in groundwater from the iSOC system. Based on the evaluation of system performance data and groundwater monitoring results, it can be concluded that operation of the iSOC corrective action system is not necessary to protect human health and the environment for the following reasons:

- COCs in POC wells are below target concentrations protective of potential human receptors and ecological receptors in Todd Creek (TCTLs, as defined in Section E.9d.3.2), as discussed in Section E.5.
- Current and future potential exposures from drinking water are prevented by the absence of water wells and an environmental covenant that prevents the installation of new water supply wells at the site.
- Operation of the iSOC system does not appear to be influencing groundwater conditions near the POC wells, and concentration trends are no different than can be accounted for by intrinsic natural attenuation, which is facilitating plume stability or contraction.
- The groundwater monitoring program is sufficient to detect any future changes in groundwater conditions at the POC.

E.9d.2.2.3 Proposal for Trial Shut Down of Existing iSOC System

UCC proposes a trial shutdown of the iSOC system and monitoring to verify that TCTLs are not exceeded in the POC wells after shutdown and that intrinsic natural attenuation is sufficient to protect human health and environment under site-specific conditions. The proposed monitoring and evaluation approach is described in Section E.9d.2.2.4.

E.9d.2.2.4 Monitoring and Evaluation of iSOC Trial Shut Down

UCC proposes conducting a trial shutdown of iSOC system for a period of 1 year and conducting monitoring to verify the conclusions of the iSOC effectiveness review. Groundwater monitoring would be conducted quarterly in the following effectiveness, downgradient wells, and side-gradient wells:

- Effectiveness wells: MW-7 (POC), MW-19, MW-49, MW-50
- Downgradient wells: MW-20 (TCS), MW-21 (TCS)
- Side-gradient wells: MW-38 (POC) and MW-39 (POC)

The locations of the wells are shown on Figure 8. The effectiveness wells will monitor changes immediately downgradient of the iSOC OD wells. Based on the groundwater flow velocity and distance from the OD wells these wells should see the effects of shutting down the iSOC within approximately 100 to 200 days. The downgradient and side-gradient wells are located beyond the influence of the iSOC and will allow comparison of the upgradient wells to potential overall trends in the aquifer.

Samples from the monitoring wells will follow the procedures and be analyzed using the methods described in the groundwater monitoring plan (Section E.6b). Wells listed above will be analyzed for Table A-1 constituents. Field parameters collected during sampling will consist of static water levels, pH, DO, and ORP. In addition, effectiveness wells MW-7, MW-19, MW-49, and MW-50 will also be analyzed for the following general chemistry parameters: nitrate/nitrite, sulfate, TOC, alkalinity, iron, and ferrous iron.

UCC will prepare a report on the results of the 1-year trial shutdown within 120 days following completion and receipt of laboratory analysis of the fourth quarterly samples. The report will include the following:

- Statistical analysis of trends of site COCs in the monitored wells following MK statistical analysis approach utilized in the groundwater monitoring plan (Section E.6b). Statistical trends of the effectiveness wells will be compared to trends in the downgradient and side-gradient wells.
- Evaluation of changes in groundwater geochemistry parameters following shut down of the iSOC.

- Verification of groundwater flow directions.

Based on the evaluation of the 1-year trial shutdown data UCC will:

- Restart and Continue iSOC Operations: Restart of the iSOC will be recommended if concentrations of biodegradable organic COCs in effectiveness wells exhibit statistically significant increasing trends that may exceed applicable TCTLs following shut down of the iSOC system. In this case, UCC will restart the system within 60 days of Georgia EPD approval unless directed otherwise by Georgia EPD.
- Leave iSOC Shut Down: Permanent shutdown of the iSOC will be recommended if concentrations of biodegradable organic COCs are below applicable TCTLs and are stable or decreasing and geochemical conditions in the aquifer remain favorable for biodegradation. In this case, UCC will make recommendations for continued monitoring in the report and will continue monitoring of the wells as described in this section pending Georgia EPD's review and approval of any changes. During the review period, UCC will not restart the iSOC system but will continue to maintain the equipment in operable condition. Pending review and approval of the report by Georgia EPD, the oxygen generation equipment would be removed for the site and wells and piping would be retained for possible future use.
- Continue Trial Shut Down: If the data are inconclusive, UCC may recommend that monitoring continue to further evaluate whether the iSOC should be returned to operations. In this case, UCC will not restart the system and will continue to monitor as described in this section during Georgia EPD's review of the report. If reductions to the monitoring approach are suggested, they will not be implemented without approval from Georgia EPD.
- Following completion of the trial shut down period, groundwater monitoring would be conducted annually in accordance with the landfill groundwater monitoring program. The need for future contingency actions would follow the Groundwater Contingency Plan (Section E.9d.3).

E.9d.3 Groundwater Contingency Plan

A groundwater contingency plan has been developed to address current or future releases from the hazardous waste landfill. Data collected by the groundwater monitoring plan in Section E.6 will be used to determine the need for implementing the contingency plan.

E.9d.3.1 Approach

UCC will utilize a risk-based approach to determine if current or future releases to groundwater have resulted in conditions that require active remediation to address COC concentrations above levels that are protective of human and ecological receptors for the site-specific water use scenario(s). Potential exposures are controlled as follows:

- Ingestion and Dermal Exposure to Groundwater – There are no groundwater supply wells at or near the site and an EC prohibits the use of groundwater at the site for non-remedial purposes.
- Vapor Intrusion to Indoor Air – No occupied buildings are present at the landfill and associated buffer area (inclusive of the area between the landfill and Todd Creek).

The only potential exposures under current and future water use scenarios are potential ecological and recreational user exposure routes at Todd Creek.

As discussed in Section E.5, there are currently no COCs that pose unacceptable cancer risk or hazards based on current groundwater quality at the POC wells. As a result, the long-term groundwater monitoring program and institutional controls are the most appropriate corrective action elements at this time. However, future groundwater monitoring data may identify a changed condition that indicates that an active remediation system is necessary to reduce concentrations of constituents and provide an added measure of long-term protectiveness to potential downgradient receptors. The purpose of this contingency plan is to identify conditions that would trigger the implementation of an active corrective action for groundwater and identify corrective action(s).

E.9d.3.2 Target Levels for Protection of Potential Exposures at Todd Creek

To determine whether active remediation may be required to protect human and ecological receptors at Todd Creek, UCC will screen groundwater concentrations at POC wells based on a set of TCTLs. The Georgia Instream Water Quality Standards (ISWQS) set for Todd Creek are the standards Georgia has determined to be protective of human health and the environment for the designated use of Todd Creek. This approach is supported by both federal guidance for RCRA Corrective Action and Georgia guidance for Hazardous Waste Response Sites that indicate the promulgated and enforceable standard should be used if there is one and a site-specific standard derived if there is not. The TCTLs for this purpose are based on Georgia ISWQS, where available. If a Georgia ISWQS is not available, target levels are based on calculated risk-based screening levels (SLs) for potential site-specific exposure scenarios of occasional recreational wading and fish/crab consumption. The SLs for recreational exposures were developed for adult and youth (6- to 16-year-old) receptors using the EPA's Regional Screening Level (RSL) calculator (EPA 2023) based on a target excess lifetime cancer risk of 1×10^{-6} and target hazard quotient of 1. The exposure parameter values were based on standard EPA values (EPA 2004c, 2011, 2014a, 2019) and site-specific assumptions based on observations made during the site reconnaissance with Georgia EPD on September 19, 2023. Surface water SLs based on fish and crab consumption were developed for adult and youth receptors. The surface water SLs were developed by calculating chemical-specific fish/crab consumption SLs using EPA's RSL calculator (EPA 2023) (based on a target excess lifetime cancer risk of 1×10^{-6} and target hazard quotient of 1) and combining the fish/crab consumption SLs with chemical-specific surface water-to-fish/crab BCF. The exposure parameter values were based on standard EPA values (EPA 2014a) and site-specific assumptions based on observations made during the site reconnaissance with Georgia EPD on September 19, 2023. Documentation for development of the SLs is provided in Appendix G.

The ecological risk assessment determined that, while there are complete exposure pathways for aquatic plants and animals in Todd Creek, risks to populations of creek receptors associated with exposure to groundwater-related constituents are unlikely to be significant (Appendix G). This conclusion is considered to be conservative because (1) dilution upon discharge was not taken into account, (2) the sample-specific concentration for a nondetected constituent was assumed to be equivalent to the detection limit (except in cases where there were too many nondetects to calculate a 95UCL), and (3) the groundwater concentrations detected at each location may not accurately represent the concentration likely to discharge to the creek (sample turbidity could have been elevated in some cases and attenuation/degradation would be likely to occur during migration toward the creek). Considering the 1,000-fold dilution factor only, estimated surface water exposure concentrations would be reduced by three orders of magnitude in the creek in a short time period after discharge.

Site-specific risk-based target levels for groundwater corrective action for protection of Todd Creek exposures (TCTLs) are listed in Table 5 for Table A constituents. All constituents that are part of the groundwater monitoring program have target levels with the exception of sulfide and acetonitrile because there are no human health toxicity data for those constituents nor are there Georgia ISWQS established.

E.9d.3.3 Process for Triggering Additional Corrective Action

The process for triggering design and implementation of groundwater corrective action is depicted on Figure 40 and defined for the following steps. The evaluation process will be conducted for each constituent monitored at each of the POC wells.

Step 1: Statistical Exceedance at POC Well

Concentrations of each monitored constituent at POC wells will be compared to the GWPS (Table 6) and the TCTL (Table 5). If a constituent has a statistical exceedance (as defined in the groundwater monitoring plan, Section E.6) then evaluation will proceed to Step 2 of the assessment process. Otherwise, groundwater monitoring will continue, as specified in Section E.6.

Step 2: Assessment of Exposure Scenario and Current Mitigation Measures

If the constituent has a statistical exceedance of either the GWPS or TCTL in a POC well, the potential exposure pathways will be identified to determine if the statistical exceedance is currently mitigated.

GWPS Statistical Exceedance: The GWPSs are based on the residential potable exposure use scenario. An institutional control is in place to mitigate this exposure pathway through an environmental covenant prohibiting groundwater use and residential use of the property. If a GWPS is exceeded, it will be verified that no drinking water wells have been installed and that there is no residential property use within the bounds of the groundwater COC plume. If this remains true, then no further action is required and monitoring will continue, as specified in Section E.6.

TCTL Statistical Exceedance: The TCTLs are based on potential exposures to humans or the environment at Todd Creek. If there is a statistical exceedance of a TCTL, it will be determined if there is an existing remedy in place to address the constituent. If a remedy is not in place, the evaluation will proceed to Step 3. Otherwise, groundwater monitoring will continue, as specified in Section E.6.

Step 3: Assess Data and Evaluate Remedial Alternatives

The first part of Step 3 will be to evaluate whether the exceedance has resulted in a potential for unacceptable exposures to human health or the environment. This step will incorporate consideration of available and relevant data appropriate for decision making. Data and information that may be considered as part of this step include, but are not limited to, the following:

- MK analysis of concentration trends in POC and nearby wells
- Linear regression analysis of decreasing trends, if present, in POC wells
- Evaluation of concentrations in downgradient TCS wells
- Resampling the statistically exceeding POC well, and potentially monitoring the exceeding POC well and downgradient TCS wells at an accelerated frequency
- Update risk assessment incorporating updated site-specific information and/or toxicity data, if available

If the existing data are insufficient to make a determination of whether or not there may be unacceptable risks to human health or the environment, then additional data may be collected to support decision making.

The results of this evaluation will be presented to Georgia EPD for approval to either continue monitoring or to proceed to Step 4.

Step 4: Design and Install Corrective Action

Final design and implementation of corrective action will be implemented in accordance with the corrective actions defined in Section E.9d.3.4.

E.9d.3.4 Corrective Action

Corrective action for groundwater will be implemented based on the properties of the constituent for which corrective action has been triggered. A primary corrective action approach has been identified for classes of constituents in Table A (Table 6) of which Table A-1 (Table 9) is a subset.

E.9d.3.4.1 Biodegradable Constituents Downgradient of iSOC OD Wells

The primary corrective action for constituents amenable to aerobic biodegradation downgradient of the iSOC OD wells (POC well MW-7 area) is reactivation and enhancement of the iSOC system. This approach is based on the scenario where concentrations have increased to levels where intrinsic natural attenuation in the aquifer is no longer sufficient to protect human health and the environment and supplemental oxygen would be sufficient to enhance biodegradation rates to achieve the remedial objective. If the iSOC system is already operating when increasing concentrations occur (indicating it is ineffective on the identified COC), then the primary contingency under E.9d.3.4.2 will be implemented.

E.9d.3.4.2 Biodegradable and/or Strippable Constituents

The primary corrective action for biodegradable and/or strippable constituents is air sparging (AS). The geologic conditions in the uppermost aquifer at the site are amenable to AS due to their permeable sandy nature with few low permeability zones. AS would be installed downgradient of the landfill cells between the cells and the existing landfill fence (Figure 42). The objective of the AS system would be to reduce concentrations of target constituents in groundwater to below the TCTLs in Table 5 prior to groundwater migrating beyond the landfill fence. The specific location, length, and depth of the installed system will be determined based on the location(s) where constituents triggered the need for active corrective action.

AS is a commonly applied technology for constituents that have physical properties that are amenable to aerobic biodegradation and/or volatilization from groundwater. The AS system would have the additional benefit of creating oxidizing conditions that would promote the redox-based immobilization of inorganic constituents (e.g., arsenic). Depending on the physical properties of the constituents being treated, the system may be designed to maximize volatilization or enhancement of oxygen (biosparging). The design of AS systems is relatively straightforward with off-the-shelf units available for lease or purchase for air injection and vapor treatment. AS may be implemented utilizing a series of vertical air injection wells, one or more horizontal directionally drilled injection wells, or an aeration trench. The AS system may include a vapor recovery system if it is determined that one is necessary based on the estimated emissions. The details of the system will be determined during the final design.

An Underground Injection Control permit will be required for the injection of air into the aquifer. An air permit may be required based on the estimated emissions from the system, though based on available data, it is unlikely an air permit will be necessary.

The largest limitation to installation of an AS system is the lack of available electrical power to the site.

E.9d.3.4.3 Other Constituents

Most of the constituents in Table A are amenable to aerobic biodegradation, volatilization, or redox reactions that would promote immobilization with increasingly oxidizing conditions. If the COC(s) triggering the need for corrective action are not amenable to these processes, then UCC will propose an alternative technology to the primary contingency. UCC will complete a feasibility study for groundwater corrective action within 180 days of issuance of the renewed permit HW-063(D) by Georgia EPD.

E.9e Corrective Action Effectiveness Reports

A Groundwater Compliance Monitoring Report and Corrective Action Effectiveness Report will be prepared and submitted to Georgia EPD annually as described in Section E.6b.9. The report will include the following:

- Statistical comparison of the hazardous constituent concentrations detected in groundwater in POC wells with the GWPS established under Condition III.B of the current permit (Table 6) and the TCTL described in Section E.9d.3.2 (Table 5).
- Statistical comparison of the POC and TCS well data with the historical monitoring data.
- Evaluation of hazardous constituent concentrations detected in non-POC wells relative to the GWPS and TCTL.
- Description of trends in groundwater quality.
- An assessment of groundwater flow rates and direction.

For the landfill cover the report will include a summary of landfill maintenance and inspections. While the iSOC system remains operational the report will assess the effectiveness of the corrective action consistent with the current monitoring approach as detailed in the 2011 permit renewal application (CH2M 2011).

Todd Creek streambank stabilization inspection and monitoring reporting is described in Section E.9d.1.5.