GROUNDWATER ASSESSMENT
MARSHALL STEAM STATION
FGD LANDFILL, Phase 1, Cell 1
PERMIT NO. 1809

Prepared for:
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8320 East NC Highway 150
Terrell, NC 28682
Project Number 2371.13

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JULY 12, 2012

REPORT VERIFICATION

PROJECT: **GROUNDWATER ASSESSMENT**
MARSHALL STEAM STATION
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PERMIT NO. 1809

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

Prepared by: William M. Miller Date: 7-12-12

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Professional Engineer Seal:

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APPENDIX A - Letter from North Carolina Department of Environment and Natural Resources. November 9, 2011. To Ed Sullivan, P.E., Duke Energy. DOC ID 15490.

Section 1
Introduction

The Marshall Steam Station Flue Gas Desulfurization (FGD) Landfill, Permit No. 1809, is located at the Marshall Steam Station in Catawba County and is owned and operated by Duke Energy Carolinas, LLC (Duke Energy).

In a letter dated November 9, 2011[1], to Mr. Ed Sullivan, P.E., of Duke Energy, the North Carolina Department of Environment and Natural Resources (NCDENR) Division of Waste Management (DWM) stated that exceedances of groundwater standards established in Title 15A North Carolina Administrative Code (NCAC) Subchapter 2L .0202 Groundwater Quality Standards (2L standards) were reported in groundwater samples collected from groundwater monitoring well MS-8 and surface water sampling location SW-1 during the March 22, 2011, sampling event. The letter is included as Appendix A.

The NCDENR letter stated that chromium and iron were reported at concentrations greater than their respective 2L standards in the groundwater sample collected from MS-8 and that iron and manganese were reported greater than the 2L standards in the surface water sample collected at SW-1 during this event. Monitoring well MS-8 is located at the compliance boundary and surface water sampling location SW-1 is a groundwater seep located beyond the compliance boundary. NCDENR also stated that industrial landfills are required to comply with the 2L standards at the compliance boundary in accordance with 15A NCAC 13B .0503 (2)(d)(iv).

In addition, the NCDENR letter stated that concentrations of chromium and iron were reported at concentrations above their respective 2L standards in groundwater monitoring wells MS-10, MS-15, and MS-16. These wells are located at the review boundary.

NCDENR stated that based on these exceedances, Duke Energy shall submit a groundwater assessment work plan to the DWM. The assessment work plan, dated February 9, 2012, was prepared by Altamont Environmental Inc. (Altamont) on behalf of Duke Energy and was approved by the DWM on February 20, 2012.

HDR Engineering Inc. of the Carolinas (HDR) has prepared this assessment on behalf of Duke Energy. This document presents the results of the assessment of groundwater exceedances at groundwater monitoring wells MS-8, MS-10, MS-15, MS-16 and at the surface water location SW-1.

[1] North Carolina Department of Environment and Natural Resources. Division of Waste Management. November 9, 2011, Monitoring Well MS-8 and SW-1 Assessment. Duke Energy – Marshall Steam FGD Landfill. DOC ID 15490.

Section 2
Background

2.1 Site and Landfill Description

Marshall Steam Station (Marshall) is owned and operated by Duke Energy. Marshall is a four-unit, coal-fired generating facility with a generating capacity of approximately 2,070 megawatts. Marshall is the second largest coal facility owned by Duke Energy in the Carolinas and generates enough electricity to power approximately 2 million homes. Since it began commercial operation in 1965, Marshall has been among the most efficient power plants in the nation.

The plant is located in Catawba County on Lake Norman (Figure 1). The FGD landfill is located northwest of the power plant and west of the Marshall ash basin as shown in Figure 1. In general, the topography of the landfill site slopes from the west-northwest to the east towards the Marshall ash basin.

The landfill is permitted to receive FGD residue (gypsum), clarifier sludge, fly ash, bottom ash, asbestos waste, construction and demolition waste, and mill rejects (pyrites). The clarifier sludge is generated from the FGD wastewater treatment system.

Only Cell 1 of the landfill is in operation and is approximately 18 acres in area. The landfill was constructed with an engineered liner system consisting of a leachate collection and removal system, a high-density polyethylene (HDPE) geomembrane, and a geosynthetic clay liner installed underneath the HDPE geomembrane. Contact stormwater and leachate are collected in a lined stormwater basin at the south end of Cell 1 and then piped to the ash basin. The landfill began receiving waste on February 7, 2007, and is currently receiving waste.

2.2 Site Geology and Hydrogeology

The Marshall site is located in the Piedmont Physiographic Province of North Carolina within the King's Mountain Belt. The rocks in the area were formed during the Precambrian era and metamorphosed during the Paleozoic era and consist of schist, gneiss, diorite, and granite. The soils that overlie the bedrock in the area have generally formed from the in-place weathering of the parent bedrock. The fractured bedrock is overlain by a mantle of unconsolidated material known as regolith. The regolith, where present, includes the soil zone, a zone of weathered, decomposed bedrock known as saprolite, and alluvium. Saprolite, the product of chemical and mechanical weathering of the underlying bedrock, is typically composed of clay and coarser granular material up to boulder size, and may reflect the texture of the rock from which it was formed.[2]

[2] A Master Conceptual Model for Hydrogeological Site Characterization in the Piedmont and Mountain Region of North Carolina, North Carolina Department of Environment and Natural Resources, Harry LeGrand, Sr. 2004.

In Piedmont aquifer systems, the soil-saprolite and underlying fractured bedrock form a composite water-table system. Generally, the surficial aquifer receives recharge from the infiltration of precipitation which then feeds the fractures in the underlying bedrock aquifer. Groundwater generally occurs within the saprolite under unconfined conditions.

A transition zone may occur at the base of the regolith between the soil-saprolite and the unweathered bedrock. This transition zone of partially weathered rock is a zone of relatively high permeability compared to the overlying soil-saprolite and the underlying bedrock.

2.3 Description of Monitoring System

The monitoring system at the FGD landfill consists of nine groundwater monitoring wells and one surface water sampling location listed below.

Monitoring Wells:	MS-8	MS-13
	MS-9	MS-14
	MS-10	MS-15
	MS-11	MS-16
	MS-12	
Surface Water Sampling Location:	SW-1	

The locations of the groundwater monitoring wells and surface water sampling location are shown in Figure 2. Well MS-8 is located north of the landfill and is described in the *Groundwater Sampling and Analysis Plan*[3] (SAP) as the background monitoring well for the site. Surface water sample location SW-1 is located at a groundwater seep and the analytical results are compared to 2L standards.

[3] Marshall Steam Station Flue Gas Desulfurization (FGD) Residue Landfill Phase 1, Cell 1 Permit No. 18-09 Groundwater Sampling and Analysis Plan, August 19, 2011.

2.4 SITE GROUNDWATER FLOW

Generalized groundwater surface contours for the site are shown in Figure 3. These contours were developed using groundwater elevations measured at the wells on March 13, 2012.

Groundwater flow in the area of the landfill is generally from areas of higher topography located to the north and west of the landfill, toward the Marshall Ash Basin, located to the east of the landfill. To a lesser extent, some component of groundwater flow is expected toward the surface water drainage feature containing surface water sample location SW-1.

2.5 Groundwater Quality Monitoring

In accordance with the SAP, groundwater monitoring is performed semiannually in March and September. Sampling results are submitted to DENR within 90 days of sampling.

The initial groundwater sampling event at the landfill was performed on September 25, 2006. The initial placement of waste in the landfill occurred on February 7, 2007. The most recent groundwater monitoring event was conducted on March 13, 2012.[4]

The March 2012 sampling event report presented the exceedances of the 2L standards measured during the March 2012 sampling event. Exceedances of the 2L standards were reported at locations MS-15, MS-16, and SW-1. No exceedances of the 2L standards were reported at locations MS-8 and MS-10.[5]

Exceedances were reported at MS-15 for chromium, at MS-16 for iron, and at SW-1 for iron and manganese. The locations and the sample results in excess of the 2L standards during the March 2012 sampling event are provided below.

Parameter	Well ID	Result	Units	15A NCAC 2L Standard
Chromium	MS-15	21.5	µg/L	10
Iron	MS-16	1,107	µg/L	300
	SW-1	334	µg/L	
Manganese	SW-1	68	µg/L	50

The analytical results at MS-8 for chromium and iron were below the 2L standards. The analytical result for iron at MS-10 was below the 2L standards.

[4] These results were presented in a report titled Semiannual Groundwater Monitoring Report, Marshall Steam Station, FGD Residue Landfill, Phase 1, Cell 1, Permit No.1809, March 2012 Sampling Event, June 6, 2012, prepared by Altamont Environmental, Inc.

[5] All sampled locations except MS-15 reported exceedances for pH. The Altamont report stated that the pH values were consistent with historic readings at these locations.

Section 3
Waste Characteristics – FGD Residue

As stated earlier, the landfill is permitted to receive FGD residue (gypsum), clarifier sludge, fly ash, bottom ash, asbestos waste, construction and demolition waste, and mill rejects (pyrites). The clarifier sludge is generated from the FGD wastewater treatment system. The majority of the waste placed in the landfill is the FGD residue (gypsum) generated by the scrubber system at Marshall.

As described in the Site Suitability Report,[6] the typical composition and characteristics of the material produced by the scrubber system at Marshall is:

Typical FGD Residue Parameters

Gypsum ($CaSO_4 \cdot H_2O$)	93% to 95%
Sulfite ($CaSO_3$)	0.35%
CO_3	1.3%
CaF_2	0.2%
Inerts	2.5% to 3.5%
Fly ash Content	0.5% to 0.8%
pH	6.0 to 8.3
Unit Weight	76 lb/ft^3 to 97 lb/ft^3
Specific Gravity	2.35
Moisture	10% to 12%

3.1 Leachate Characteristics

A leachate sample was collected at the landfill on March 13, 2012. The sample was collected at the outlet end of the leachate collection system piping where the header pipe drains to the stormwater basin.

The sample was analyzed using the same laboratory methods and procedures that are used for analyzing the groundwater samples collected during the semiannual groundwater monitoring. The analytical results from the leachate sample are provided in Table 1.

As expected, with the waste stream in the landfill being largely gypsum, the constituent with the highest concentration in the leachate analytical results was sulfate, followed by chloride, iron, boron, and manganese. Table 2 presents the leachate analysis results sorted by magnitude of analytical results.

[6] Duke Power Marshall Steam Station Catawba County, N.C., Flue Gas Desulfurization (FGD) Residue Landfill Permit Application, Site Suitability Information, August 3, 2003, Volume 1.

As shown below, the leachate contains high concentrations of sulfate, chloride, and boron. Chromium was reported at a much lower concentration.

Constituent	Leachate Analytical Result
Sulfate	2,500,000 µg/L
Chloride	780,000 µg/L
Iron	269,000 µg/L
Boron	24,900 µg/L
Manganese	8,330 µg/L
Chromium	18.2 µg/L

Concentrations of constituents in the waste stream leachate depend on a number of factors including the mineral phases present, the Eh-pH of the leaching solution, the abundance of the mineral present, and other factors. The leachate results present the relative concentrations of the constituents and provide an indication of the relative concentrations of the constituents that would be expected to be present in groundwater if impacted by the landfill.

For this assessment, the constituents exceeding the 2L groundwater standards in the monitored locations were iron, manganese, and chromium. One assessment method identified in the assessment work plan was to evaluate the results from the sample locations for constituents attributed to FGD waste. Sulfate is a component of gypsum and, as shown in Table 2, sulfate is the leachate constituent with the highest concentration.

The relative concentrations of sulfate to iron, manganese, and chromium are useful in determining whether or not the exceedances of groundwater 2L standards could be attributed to the landfill or to naturally occurring background conditions.

The relative concentrations of sulfate to iron, manganese, and chromium are as follows:

Ratio of Concentrations:

Sulfate to Iron $\frac{2{,}500{,}000\ \mu g/L}{269{,}000\ \mu g/L} = 9.3:1$

Sulfate to Manganese $\frac{2{,}500{,}000\ \mu g/L}{8{,}330\ \mu g/L} = 300:1$

Sulfate to Chromium $\frac{2{,}500{,}000\ \mu g/L}{18.2\ \mu g/L} = 137{,}000:1$

Section 4
Assessment of Groundwater Exceedances

The assessment of the groundwater exceedances of the 2L standards at locations MS-8, MS-10, MS-15, MS-16, and SW-1 was performed as stated in the proposed assessment work plan. In general, the assessment work plan consisted of the following:

a. Review site groundwater flow and hydrogeologic reports to determine if groundwater flow from the landfill is towards MS-8.

b. Evaluate if the sources of exceedances at MS-8, MS-10, MS-15, MS-16, and SW-1 are naturally occurring and are from sediment or other particulate matter by performing one or more of the following:

    1. Evaluate historic concentrations compared to date of initial waste placement.
    2. Evaluate exceedances against background well results.
    3. Evaluate exceedances against turbidity values.
    4. Evaluate sampling flow rates.
    5. Evaluate sample results for constituents attributed to FGD leachate.
    6. Collect and analyze filtered and non-filtered samples.
    7. Redevelop well and clean pump if steps above do not resolve issue.

The exceedances of 2L standards at MS-8, MS-10, MS-15, MS-16, and SW-1 were for iron, manganese, and chromium. The initial groundwater sampling event at the site was performed on September 25, 2006, prior to the initial placement of waste, which occurred on February 7, 2007. The September 25, 2006 sampling event found values that exceed the current 2L standards for iron, manganese, and chromium at these locations indicating that these constituents were naturally occurring in concentrations in excess of the 2L standards.

4.1 Assessment of Groundwater Exceedances at Monitoring Well MS-8

Note that the analytical results at MS-8 for iron and chromium for the sampling performed on March 13, 2012, were below the 2L standards. However, since previous sample results were in excess of the 2L standards, the following assessment is provided.

4.1.2 Review Site Groundwater Flow and Hydrogeologic Reports

Monitoring well MS-8 is located to the north if the landfill approximately 234 feet from the waste boundary. MS-8 was installed on September 9, 2006. The well installation records, well depth, and screen interval are described in the SAP. The well screen was installed in the saprolite layer at a depth of 38 to 48 feet below ground surface (bgs). MS-8, as described in the SAP, was the monitoring well used as the background monitoring well. The boring log indicates that partially weathered rock lies immediately below the bottom of the well screen.

As described in the SAP, MS-8 is located along Steam Plant Road. A topographic or surface water divide runs along Steam Plant Road, with the ground surface sloping generally to the south east along the east side of the road and sloping to the west along the west side of the road.
HDR reviewed the hydrogeologic report prepared for the initial permit application.[7] The estimated seasonal high (ESH) groundwater contours for the site were presented in Sheet 3 of 7 of the hydrogeologic report. The ESH groundwater contours were developed during the pre-construction period.

Figure 4 shows the pre-construction ESH groundwater contours, provided by Duke Energy, superimposed on a figure portraying the constructed landfill footprint. The pre-construction, ESH groundwater contours present the same generalized direction of groundwater flow as shown on the March 2012 groundwater contours and the historic groundwater contours at the site.

Based on the groundwater flow direction at the site represented by both the pre-construction and current groundwater contours and the flow direction inferred from those contours, monitoring well MS-8 is not located where groundwater flowing beneath the landfill would flow to the well location. The well does not appear to be truly upgradient from the landfill, but would represent background water quality conditions at the site.

4.1.3 Evaluate if the Sources of Exceedances are Naturally Occurring and are from Sediment or Other Particulate Matter

The initial placement of waste in the landfill occurred on February 7, 2007. The initial groundwater sampling event at the landfill was performed on September 25, 2006. Table 3 presents the groundwater sampling results for MS-8 for iron, chromium, and turbidity. Note that the initial sampling event occurred before waste placement into the FGD landfill and the results from that sampling event indicated iron and chromium concentrations were above the 2L standards.

The iron results at MS-8 have ranged from an initial value of 9,665 µg/L in September 2006 to a maximum of 22,000 µg/L in September 2010. The March 13, 2012 sample iron results were 294 µg/L, below the 2L standard and the lowest to date. The chromium results have ranged from 25.7 µg/L in September 2006 to a maximum of 82.0 µg/L in September 2010. The chromium results for the March 2012 sampling were the lowest measured with the lab reporting no results detected above 3.9 µg/L.

The turbidity values range from an initial value of 27.8 NTU in September 2006 to a high of 363.0 NTU in September 2010. The September 2010 sampling event also measured the highest iron and chromium concentrations. The turbidity measured in the March 13, 2012 event was 9.4 NTU, the lowest recorded. The March 2012 sampling event also recorded the lowest iron and chromium concentrations.

[7] Duke Power Marshall Steam Station Catawba County, N.C., Flue Gas Desulfurization (FGD) Residue Landfill Permit Application, Site Suitability Information, Hydrogeologic Study, S&ME Project No. 1264-02-578, August 29, 2003, Volume 2

Figure 5 shows the historic analytical results for iron at MS-8 plotted with the measured turbidity values on the secondary axis. Figure 6 shows the historic analytical results for chromium at MS-8 plotted with the measured turbidity values on the secondary axis. In Figure 5, there does not appear to be a visual correlation between the iron and turbidity results. However, there does appear to be a general trend of decreasing values for both iron and turbidity. Figure 6 indicates a visual relationship between the chromium results and the turbidity values, with the relative changes in chromium results tracking closely with turbidity values.

Based on review of the analytical results, the date of initial waste placement, groundwater flow direction, and the turbidity data, the source of the iron and chromium exceedances reported to date in MS-8 appear to be related to turbidity introduced from naturally occurring sources and are not related to impacts associated with the FGD landfill.

4.2 Assessment of Groundwater Exceedances at Monitoring Well MS-10

Note that the analytical results for iron at MS-10 for the sampling performed on September 27, 2011, and on March 13, 2012, were below the 2L standards. However, since previous sample results were in excess of the 2L standards, the following assessment is provided.

The assessment of groundwater exceedances of the 2L standards for iron at monitoring well MS-10 was performed as stated in the proposed assessment work plan.

As shown in Figure 2, monitoring well MS-10 is located approximately 90 feet to the northwest of the waste boundary. The well was installed as part of the landfill siting program in December 2002.

As described in the well installation records included in the SAP, the well screen was installed to intercept the shallow aquifer. The 10-foot screen was installed at approximately 10 feet to 20 bgs. The groundwater contours developed from the March 13, 2012, groundwater elevations indicate the well is upgradient from the landfill with groundwater flow in the direction away from the well location and towards the landfill.

As shown in Table 3, the iron results for MS-10 were the highest during the initial sampling event prior to waste placement and have generally decreased over time to values below the 2L standard (e.g. 28 µg/L and 97 µg/L measured in September 2011 and March 2012, respectively). The turbidity results have also generally decreased from a high of 81.0 NTU in September 2006 to 4.2 NTU and 9.6 NTU measured in September 2011 and March 2012, respectively.

Based on review of the data, the source of the iron exceedances reported to date in MS-10 are related to turbidity introduced from naturally occurring sources and are not related impacts from the FGD landfill.

4.3 Assessment of Groundwater Exceedances at Monitoring Well MS-15

As shown in Figure 2, monitoring well MS-15 is located approximately 100 feet to the east of the waste boundary, near the southeast end of the landfill, and to the east of Steam Plant Road. The well was installed as part of the landfill siting program in December 2002 as well B-4 and was later renamed as well MS-15.

As described in the well installation records included in the SAP, the well screen was installed to intercept the shallow aquifer. The 10-foot screen was installed at approximately 49 feet to 59 feet bgs. A review of the boring log for boring B-4 in the hydrogeologic report prepared for the initial permit application shows that the bottom of the well screen was installed at the approximate elevation of auger refusal.

The groundwater contours developed from the March 13, 2012, groundwater elevations show the well to be downgradient from the landfill.

As shown in Table 3, the analytical result for chromium in MS-15 was 19 µg/L in the September 2006 sample event, prior to initial waste placement in February 2007. In February 2007, the 2L standard for chromium was 50 µg/L. On January 1, 2010, the 2L standard for chromium was changed to 10 µg/L. As shown in Table 3, the analytical results for chromium at MS-15 have exceeded the 2L standard since the March 2010 sample event (i.e., since the standard was lowered).

The chromium result from the March 13, 2012, sampling event was 21.5 µg/L and is the highest measured to date. The minimum chromium value measured was 12 µg/L in March 2007.

The turbidity measured during sampling has ranged from a high of 34.0 NTU in March 2007 to a low of 1.6 NTU in March 2011. There does not appear to be a relationship between the chromium and the turbidity values measured at MS-15.

As shown in Table 1, the values for chromium and sulfate measured in the leachate sample were 18.2 and 2,500,000 µg/L, respectively. Section 0 presented the ratio of sulfate concentration to chromium concentration in the leachate as 137,000:1.

The sulfate results in MS-15 from the March 13, 2012, sample event were 1,134 µg/L, and the chromium concentrations were 21.5 µg/L. The ratio of the concentrations of sulfate to chromium at MS-15 in the March 13, 2012, sample results is approximately 53:1.

The leachate concentrations of sulfate are over 2,000 times greater than those measured in MS-15, while the concentrations of chromium are essentially the same as in the leachate. Based on the absence of elevated sulfate concentrations in MS-15 and the fact that there was a measured value of chromium in excess of the current 2L standard prior to waste placement, HDR believes that the chromium exceedances measured to date in MS-15 are naturally occurring and are not related to impacts from the landfill.

4.4 Assessment of Groundwater Exceedances at Monitoring Well MS-16

As shown in Figure 2, monitoring well MS-16 is located approximately 100 feet to the east of the waste boundary along the east side of the landfill. MS-16 was installed in December 2006.

As described in the well installation records included in the SAP, the well screen was installed to intercept the shallow aquifer. The 10-foot screen was installed at approximately 38 feet to 48 feet bgs. A review of the boring log shows that the bottom of the well screen was installed in material described as partially weathered rock by using a hollow stem auger.

The groundwater contours developed from the March 13, 2012, groundwater elevations show the well to be downgradient from the landfill.

Table 3 presents the groundwater sampling results for iron and turbidity for MS-16. Note that the initial sampling results for iron were above the 2L standard. This sampling event occurred before waste placement in February 2007. The turbidity values range from an initial value of 1,000.0 NTU in September 2006 to a low of 14.5 NTU in March 2011. The recent March 13, 2012, sampling event measured a value of 22.1 NTU. The September 2006 sampling event measured the highest iron concentration at 57,572 µg/L. The lowest iron concentration was measured during the September 2011 sampling event at 359 µg/L.

Figure 7 shows the plotted historic analytical results for iron at MS-16 with the measured turbidity values on the secondary axis. Figure 7 shows a visual relationship between the iron results and the turbidity values, with the relative changes in iron results tracking closely with turbidity values.

Based on review of the analysis results and the turbidity data, the source of the iron exceedances reported to date in MS-16 appear to be related to turbidity introduced from naturally occurring sources and are not related impacts from the FGD landfill.

4.5 Assessment of Groundwater Exceedances at Surface Water Sample Location SW-1

As shown in Figure 2, surface water sample location SW-1 is located approximately 520 feet to the south of the waste boundary. The sampling location is located where seepage emerges from the ground and flows into an adjacent ephemeral stream. SW-1 is located downgradient from the landfill.

Table 3 shows the sample results at SW-1 for iron, manganese, turbidity, and sulfate. As with the other monitoring locations, SW-1 was sampled in September 2006 prior to waste placement in February 2007. The highest value for iron at SW-1 was measured during the September 2006 event. The most recent sampling event, March 13, 2012, measured the lowest iron concentration

at 334 µg/L. Turbidity values have ranged from a high of 88.9 NTU to a low of 13.0 NTU in the recent March 13, 2012, sampling event. There does not appear to be a relationship between the analytical results for iron and turbidity. The highest analytical result for manganese was 447 µg/L during the March 2011 sampling event. The result from the September 2006 (pre-waste placement) event was 418 µg/L. The result for the recent March 13, 2012, event was 68 µg/L. There does not appear to be a relationship between the analytical results for manganese and turbidity.

As shown in the leachate sample analytical results presented in Table 1 and discussed in Section 0, sulfate concentration in the leachate was 2,500,000 µg/L – by far the highest concentration of the constituents analyzed in the leachate.

The sulfate result at SW-1 for the pre-waste placement sample event, September 25, 2006, was 5,110 µg/L. Since that sampling event, the sulfate results have ranged from a maximum of 9,520 µg/L to a minimum of 3,705 µg/L reported for the March 13, 2012, event.

Other than the initial, pre-operational sampling event, the maximum iron results in SW-1 occurred during March 16, 2010 event. For that event, the ratio of the concentration of sulfate to the maximum concentration of iron was:

$$\text{Sulfate to Iron} \qquad \frac{6{,}280\ \mu g/L}{2{,}680\ \mu g/L} = 2.3:1$$

The maximum results for manganese in SW-1 occurred during March 22, 2011 event. For that event, the ratio of the concentration of sulfate to the maximum concentration of manganese was:

$$\text{Sulfate to Manganese} \quad \frac{7{,}600\ \mu g/L}{447\ \mu g/L} = 17.0:1$$

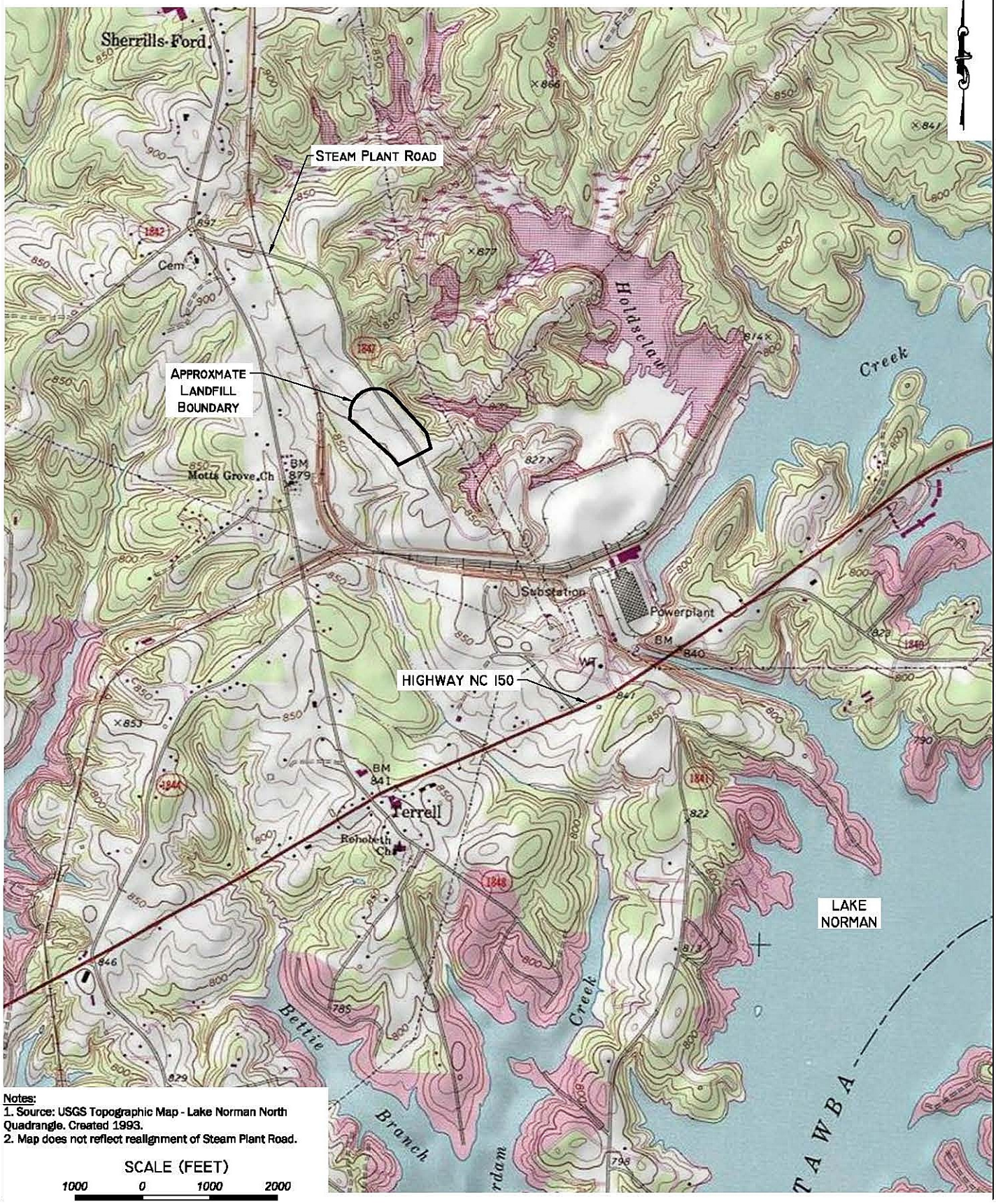
From Section 0: Ratio of Concentrations in Leachate:

Sulfate to Iron: 9.3:1
Sulfate to Manganese: 300:1

At SW-1, both the ratio of sulfate to iron and the ratio of sulfate to manganese are less than similar ratios of these constituents in the leachate sample.

Based on the absence of elevated sulfate concentrations and the fact that there were results for iron and manganese in excess of the 2L standards prior to waste placement, HDR believes that the iron and manganese exceedances measured to date in SW-1 are naturally occurring and are not related to impacts from the FGD landfill.

FIGURES



Notes:
1. Source: USGS Topographic Map - Lake Norman North Quadrangle. Created 1993.
2. Map does not reflect realignment of Steam Plant Road.

SCALE (FEET)
1000 0 1000 2000

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SITE LOCATION MAP
MARSHALL STEAM STATION
FGD RESIDUE LANDFILL
PHASE 1, CELL 1
PERMIT NO. 1809

DATE
July 12, 2012

FIGURE
1

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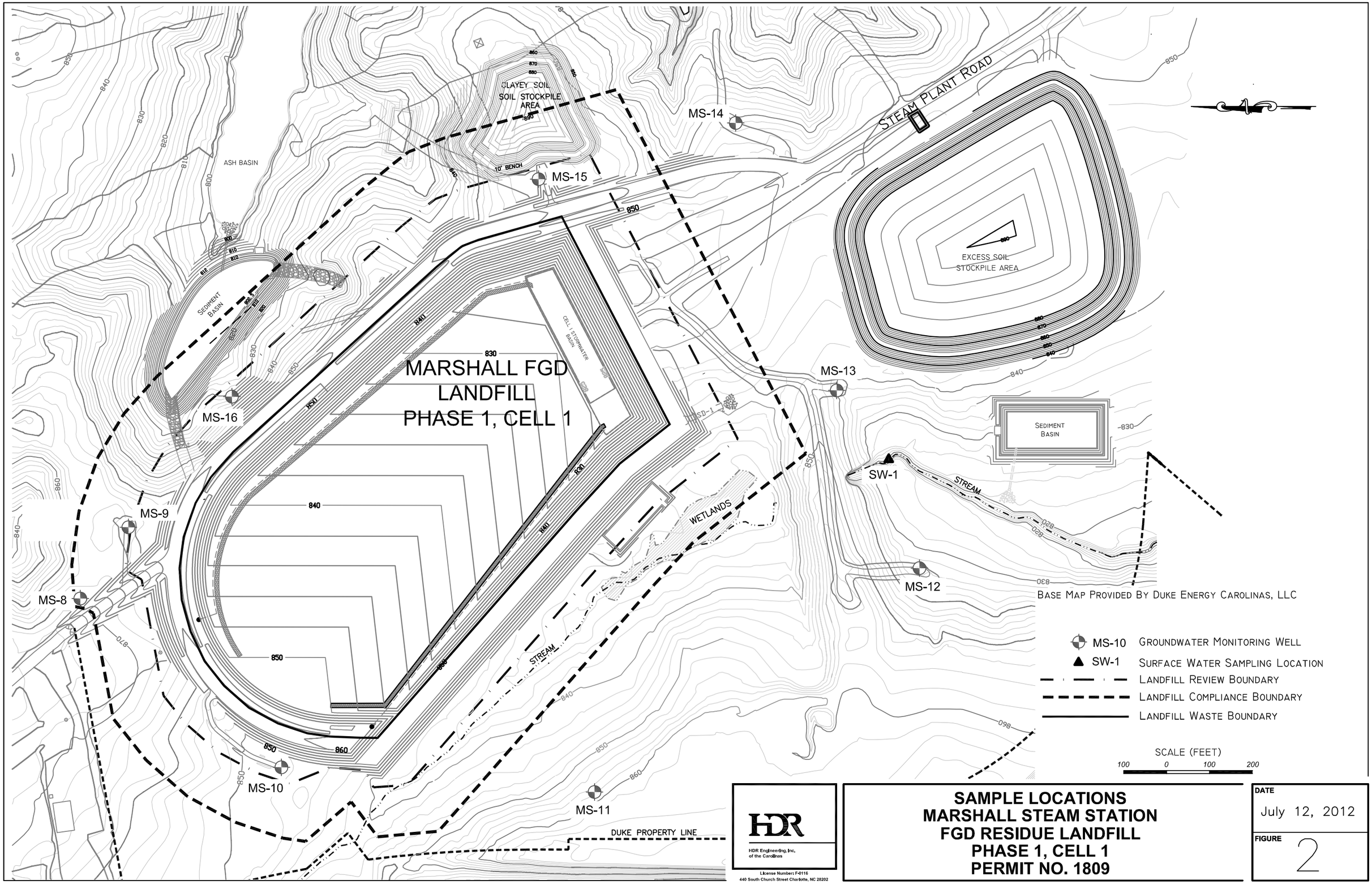

HDR

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SAMPLE LOCATIONS
MARSHALL STEAM STATION
FGD RESIDUE LANDFILL
PHASE 1, CELL 1
PERMIT NO. 1809

DATE
July 12, 2012

FIGURE
2

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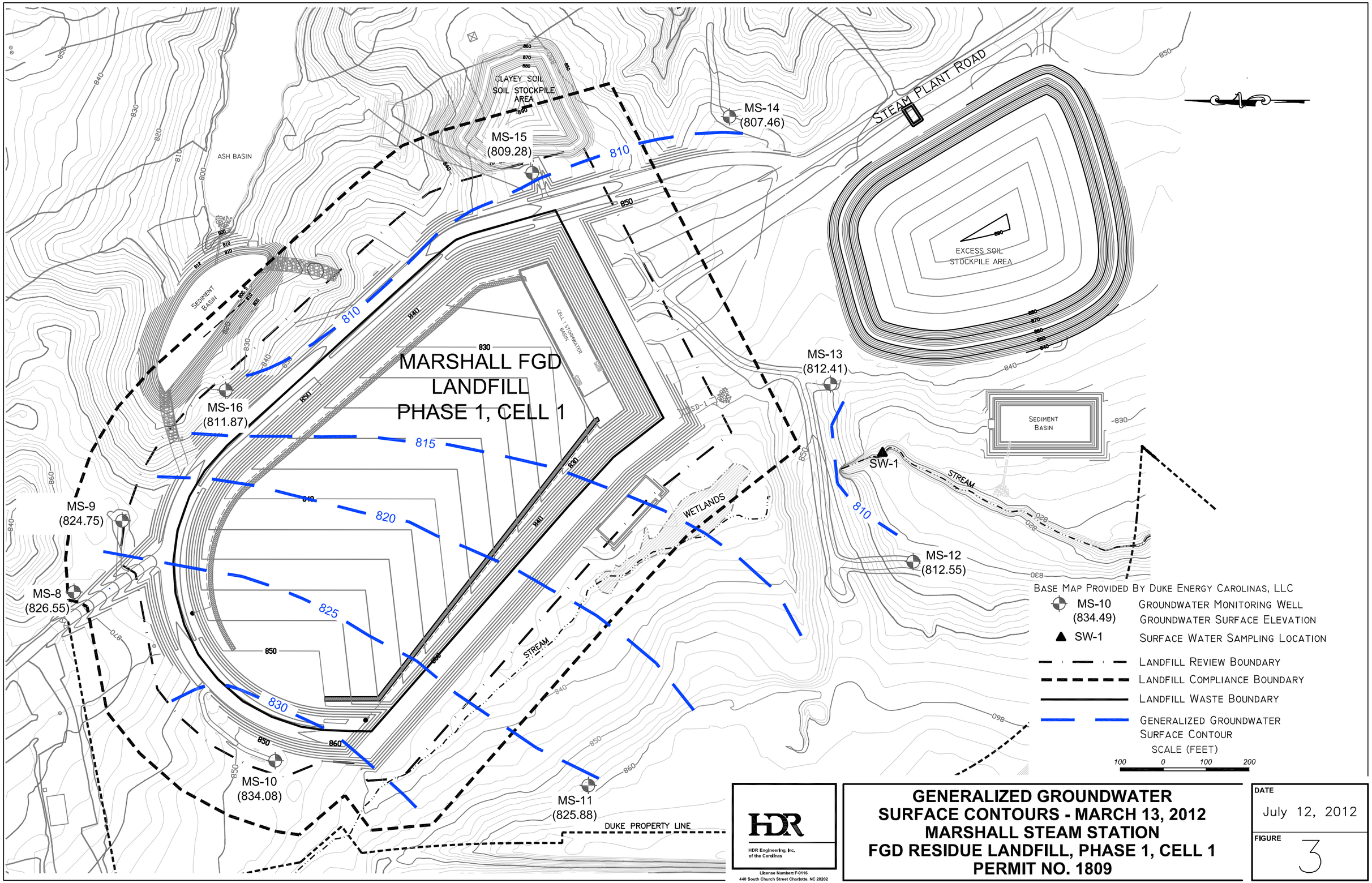

HDR

HDR Engineering, Inc.
of the Carolinas

License Number: F-0116
440 South Church Street Charlotte, NC 28202

GENERALIZED GROUNDWATER SURFACE CONTOURS - MARCH 13, 2012
MARSHALL STEAM STATION
FGD RESIDUE LANDFILL, PHASE 1, CELL 1
PERMIT NO. 1809

DATE
July 12, 2012

FIGURE
3

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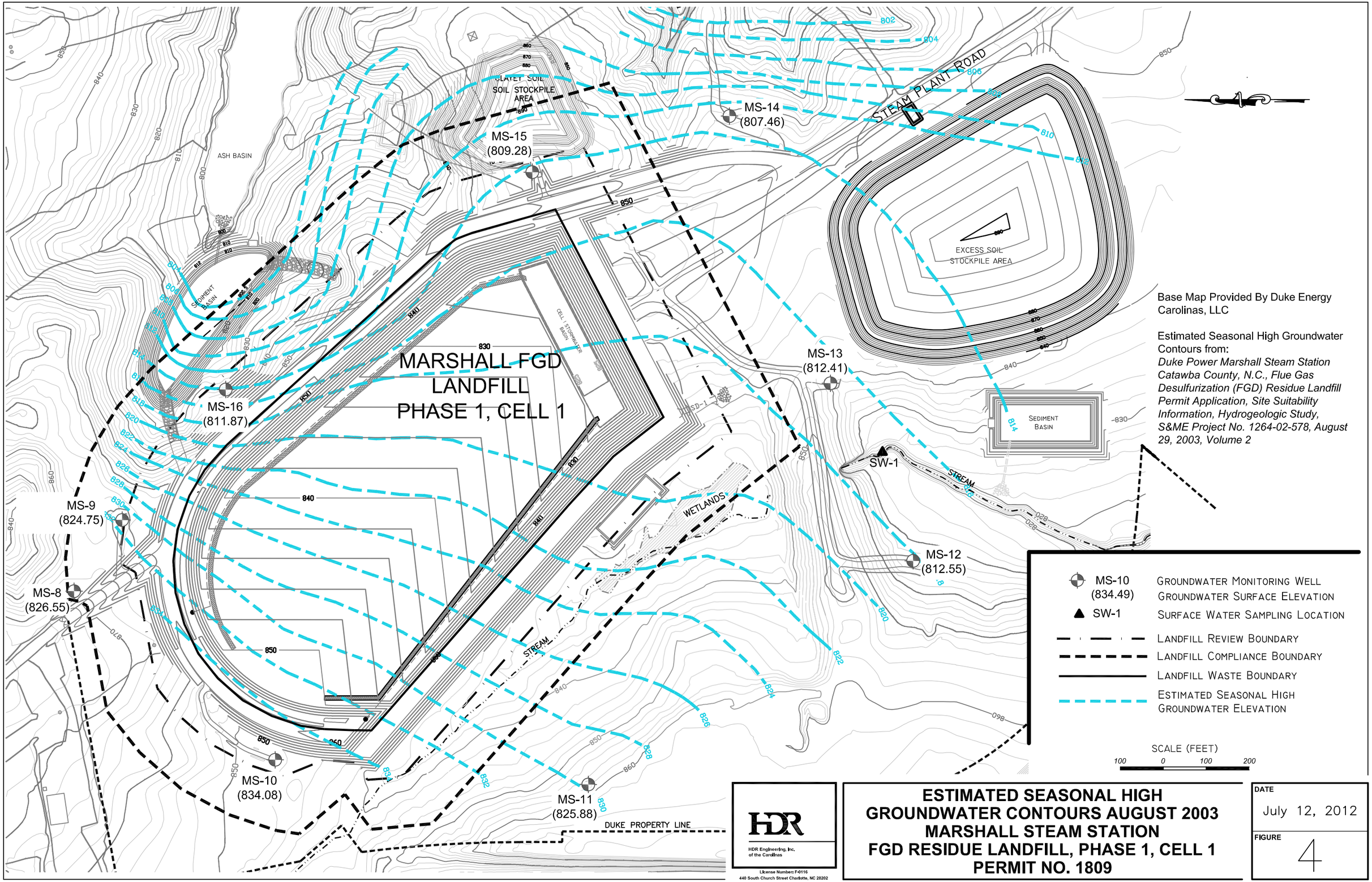

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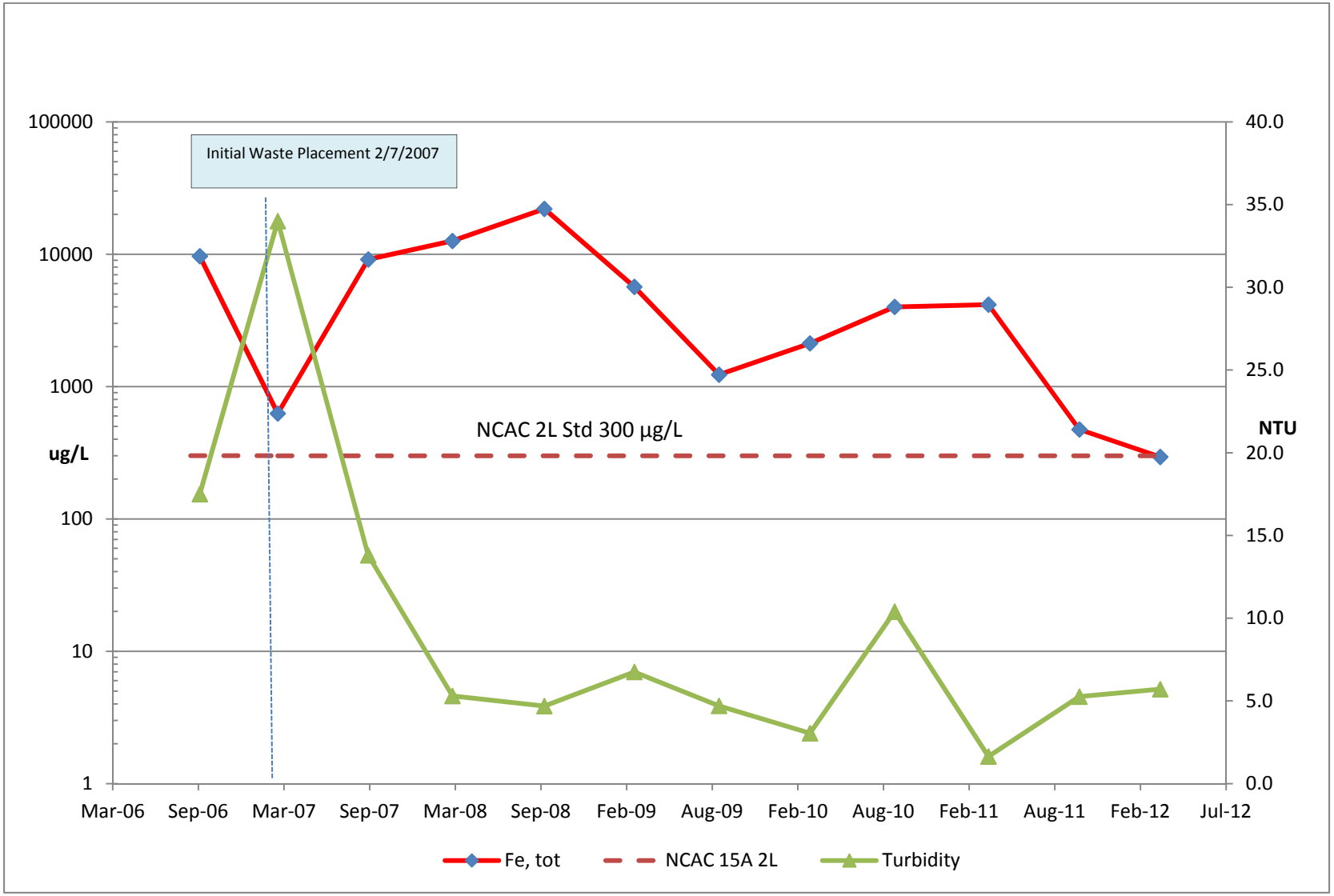
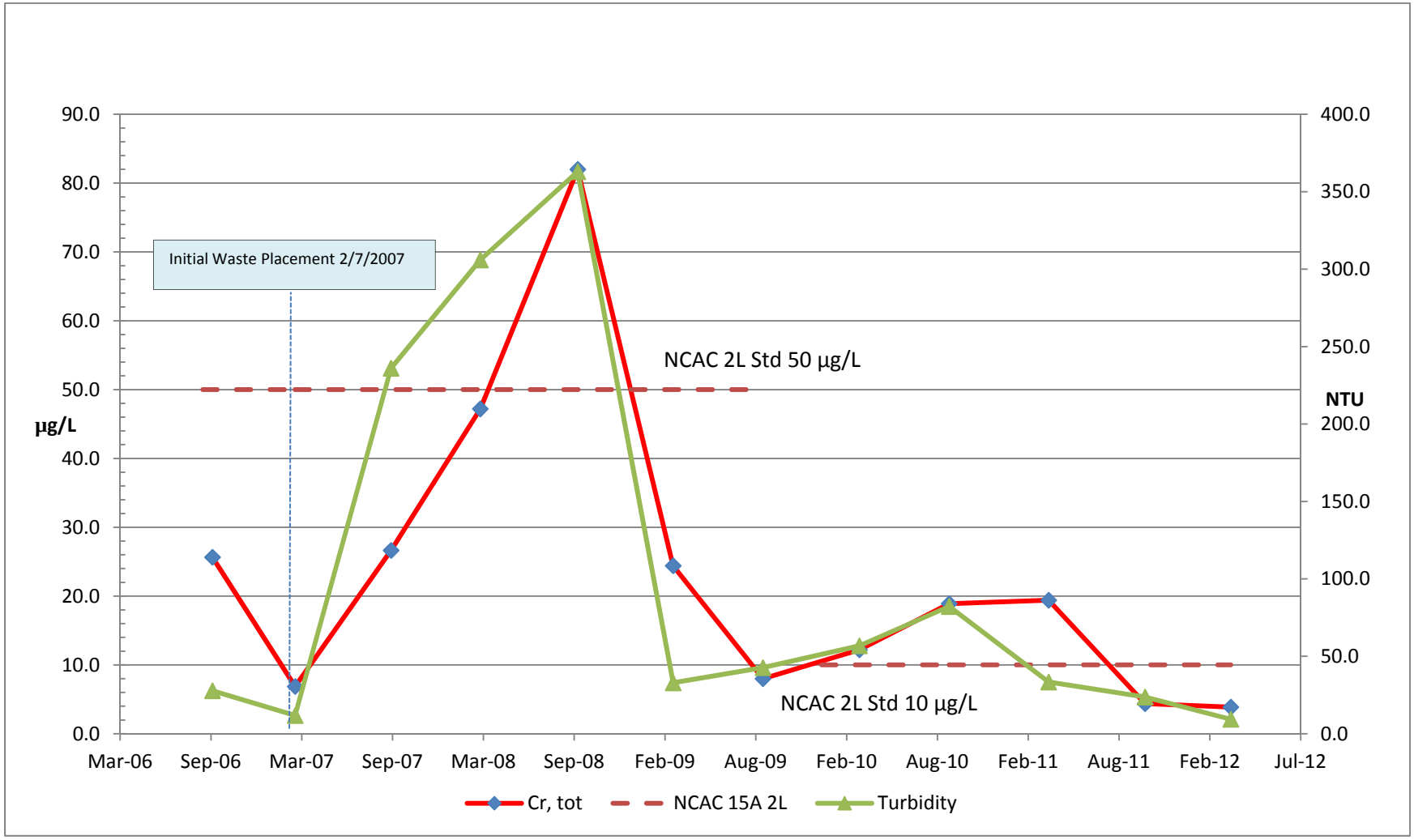
Figure 5 – Monitoring Well MS-8
Iron (Total) vs. Turbidity
Duke Energy Carolinas Marshall Steam Station
FGD Residue Landfill, Phase 1, Cell 1--Permit No. 1809



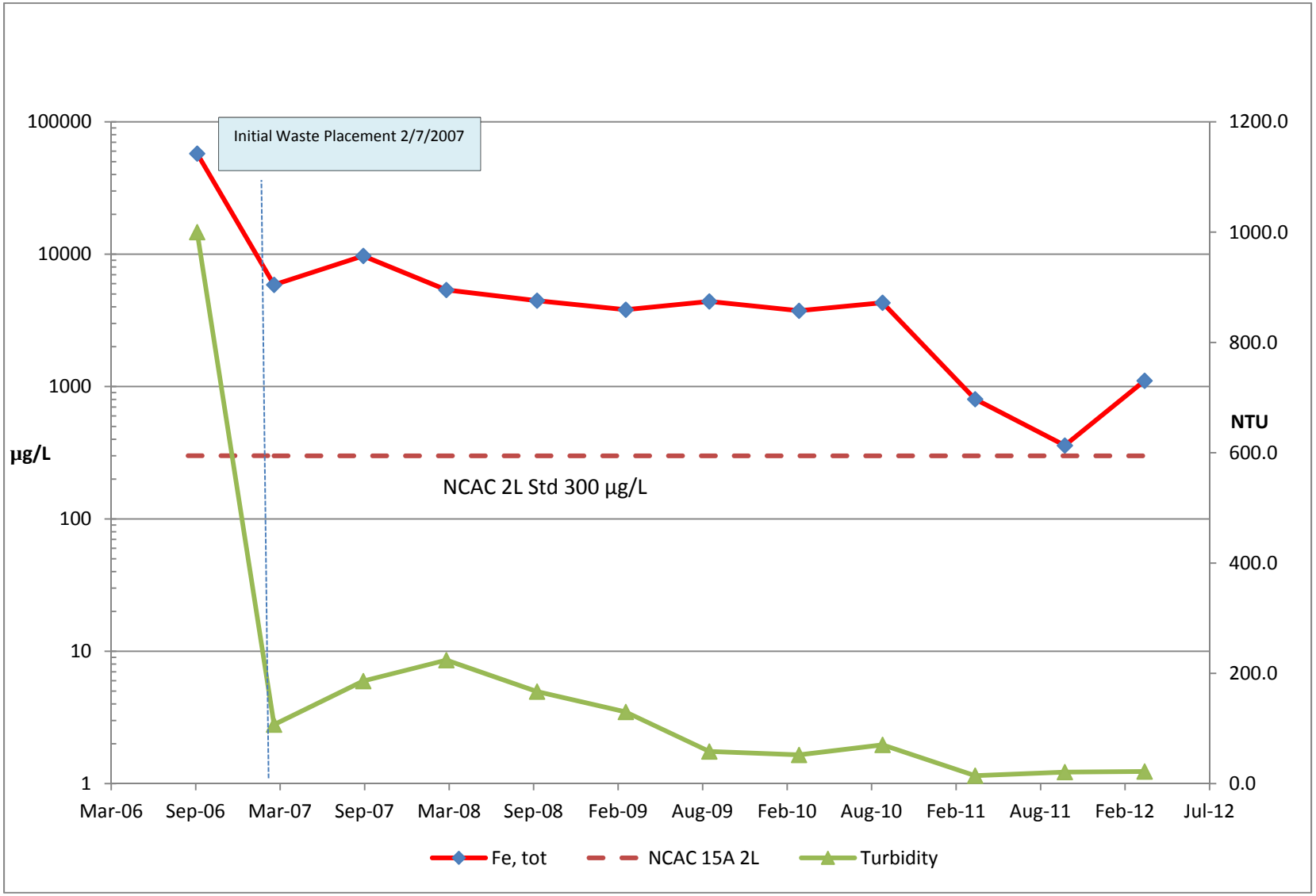
Data provided by Duke Energy.

Figure 6– Monitoring Well MS-8
Chromium (Total) vs. Turbidity
Duke Energy Carolinas Marshall Steam Station
FGD Residue Landfill, Phase 1, Cell 1--Permit No. 1809



Data provided by Duke Energy.

Figure 7– Monitoring Well MS-16
Iron (Total) vs. Turbidity
Duke Energy Carolinas Marshall Steam Station
FGD Residue Landfill, Phase 1, Cell 1--Permit No. 1809



Data provided by Duke Energy.

TABLES

Table 1 - Field and Analytical Results
Leachate Sample Results
Marshall Steam Station
FGD Residue Landfill, Phase 1, Cell 1, Permit No. 1809

Sample Date: March 13, 2012

Laboratory Certificate Codes:
Duke Energy Carolinas Field #5193
Duke Energy Analytcial Laboratory #248

Field Sampling performed by Duke Energy Carolinas, LLC

Parameter	SWS ID	Units	Certificate Code	Leachate Sample Results	SWSL
Field pH	320	SU	5193	3.28	-
Field Specific Conductance	323	umho/cm	5193	5,417	-
Temperature	325	°C	5193	21.72	-
Top of Casing	328	feet	-	-	-
Depth to Water	318	feet	-	-	-
Water Elevation	319	feet	-	-	-
Well Depth	411	feet	-	-	-
Arsenic	14	µg/L	248	6.67	10
Barium	15	µg/L	248	23	100
Boron	428	µg/L	248	24,900	NE
Cadmium	34	µg/L	248	<2	1
Chloride	301	µg/L	248	780,000	NE
Chromium	51	µg/L	248	18.2	10
Copper	54	µg/L	248	60	10
Fluoride	312	µg/L	248	2,900	2,000
Iron	340	µg/L	248	269,000	300
Lead	131	µg/L	248	<2	10
Manganese	342	µg/L	248	8,330	50
Mercury	132	µg/L	248	<0.05	0.2
Nickel	152	µg/L	248	277	50
Nitrate as Nitrogen	303	µg/L	248	4,900	10,000
Selenium	183	µg/L	248	169	10
Silver	184	µg/L	248	<5	10
Sulfate	315	µg/L	248	2,500,000	250,000
Total Dissolved Solids	311	µg/L	248	4,680,000	NE
Zinc	213	µg/L	248	554	10

Notes:

1. Concentrations presented in micrograms per liter (µg/L) unless otherwise noted.
2. SWS ID is the Solid Waste Section Identification Number.
3. SWSL is the Solid Waste Section Limit. This limit (identified by NCDENR) is the lowest amount of analyte in a sample that can be quantitatively determined with suitable precision and accuracy.
4. Data obtained from Tim Hunsucker of Duke Energy Carolinas, LLC on July 5, 2012.

Table 2 - Leachate Sample Analytical Results
Sorted by Results Concentration
Marshall Steam Station
FGD Residue Landfill, Phase 1, Cell 1
Permit No. 1809

Sample Date: March 13, 2012

Field Sampling performed by Duke

Parameter	Units	Leachate Sample Results
Total Dissolved Solids	µg/L	4,680,000
Sulfate	µg/L	2,500,000
Chloride	µg/L	780,000
Iron	µg/L	269,000
Boron	µg/L	24,900
Manganese	µg/L	8,330
Nitrate as Nitrogen	µg/L	4,900
Fluoride	µg/L	2,900
Zinc	µg/L	554
Nickel	µg/L	277
Selenium	µg/L	169
Copper	µg/L	60
Barium	µg/L	23
Chromium	µg/L	18.2
Arsenic	µg/L	6.67
Silver	µg/L	<5
Cadmium	µg/L	<2
Lead	µg/L	<2
Mercury	µg/L	<0.05

Analytical results provided by Duke Energy.

Table 3 - Groundwater Monitoring Results MS-8, MS-10, MS-15, MS-16, SW-1
Duke Energy Carolinas, LLC/Marshall Steam Station
FGD Residue Landfill, Phase 1, Cell 1--Permit No. 1809

		Background Well											
	MS 8	**MS-8**	**MS-8**	**MS-10**	**MS-10**	**MS-15**	**MS-15**	**MS-16**	**MS-16**	**SW-1**	**SW-1**	**SW-1**	**SW-1**
	Cr, tot (ug/L)	**Fe, tot (ug/L)**	**Turbidity (NTU)**	**Fe, tot (ug/L)**	**Turbidity (NTU)**	**Cr, tot (ug/L)**	**Turbidity (NTU)**	**Fe, tot (ug/L)**	**Turbidity (NTU)**	**Fe, tot (ug/L)**	**Mn, tot (ug/L)**	**Turbidity (NTU)**	**SO4, tot (ug/L)**
NCAC 15A-2L	*50 / 10 **	*300*	*NA*	*300*	*NA*	*50 / 10 **	*NA*	*300*	*NA*	*300*	*50*	*NA*	*250,000*
September 25, 2006	25.7	**9665**	27.8	**2353**	81.0	19.3	17.5	**57572**	1000.0	**3816**	**418**	88.9	5110
March 6, 2007	6.9	**626**	11.8	**985**	27.0	11.5	34.0	**5874**	107.0	**2617**	33	43.9	7060
September 10, 2007	26.6	**9129**	236.0	165	11.1	15.6	13.8	**9709**	186.0	NS	NS	NS	NS
March 3, 2008	47.2	**12600**	306.0	**363**	15.5	20.5	5.3	**5370**	224.0	NS	NS	NS	NS
September 10, 2008	**82.0**	**22000**	363.0	70.5	4.1	12.9	4.7	**4460**	167.0	**866**	**105**	23.4	<5000
March 16, 2009	24.4	**5670**	32.9	283	14.6	12.8	6.8	**3810**	130.0	**2210**	22	62.3	9520
September 8, 2009	8.0	**1230**	42.7	169	12.2	16.4	4.7	**4400**	58.4	**1260**	**271**	23.1	<5000
March 16, 2010	**12.2**	**2120**	56.8	**597**	21.3	**16.4**	3.1	**3740**	52.1	**2680**	**70**	43.4	6280
September 8, 2010	**18.9**	**4000**	82.2	**322**	6.2	**14.4**	10.4	**4300**	70.4	NS	NS	NS	NS
March 22, 2011	**19.4**	**4160**	33.4	**631**	20.4	**15.9**	1.6	**803**	14.5	**2130**	**447**	32.8	7600
September 27, 2011	4.4	**474**	23.7	28	4.2	**19.7**	5.3	**359**	21.0	**624**	**75**	27.2	6420
March 13, 2012	3.9	294	9.4	97	9.6	**21.5**	5.7	**1107**	22.1	**334**	**68**	13.0	3705

* NCAC 15A-2L Standard for Chromium changed from 50 ug/L to 10 ug/L on January 1, 2010
Sep-06 sampling event was before initial waste placement. Initial wast eplacement occurred on February 7, 2007.
Bold values indicate exceedance of the applicable NCAC 15A-2L standard
NS indicates that no sample was collected.
Analytical results provided by Duke Energy.

APPENDICES

APPENDIX A

Letter from North Carolina Department of Environment and Natural Resources, November 9, 2011, To Ed Sullivan, P.E., Duke Energy DOC ID 15490.

North Carolina Department of Environment and Natural Resources
Division of Waste Management

Beverly Eaves Perdue
Governor

Dexter R. Matthews
Director

Dee Freeman
Secretary

November 9, 2011

Mr. Ed Sullivan, P.E.
Mail Code EC13K
PO Box 1006
Charlotte, NC 28201

RE: Monitoring Well MS-8 and SW-1 Assessment
Duke Energy – Marshall Steam FGD Landfill
Permit #18-09
Catawba County
DOC ID 15490

Dear Mr. Sullivan:

A review of groundwater analytical data from the FGD Landfill indicates exceedances of groundwater standards established in 15A NCAC 2L .0202 (2L Standards) during the March 22, 2011monitoring event. Chromium and iron have been reported at concentrations greater than the 2L Standards in groundwater samples collected from MW-8, while iron and manganese have concentrations above 2L in SW-1, which has been determined to be a groundwater seep. Monitor well MW-8 appears to be located at the compliance boundary. Industrial landfills are required to comply with the 2L standards at the compliance boundary in accordance with 15A NCAC 13B .503 (2)(d)(iv).

Duke Energy shall acquire the services of a North Carolina licensed professional geologist and submit a groundwater assessment work plan to the Solid Waste Section (Section) outlining how the reported metals contamination in MW-8 will be delineated. The Section will review the submitted work plan, approve, or request additional information or amendments before implementation. Please submit this work plan within 90 days of receiving this letter. The work plan may include, but not limited to an alternate source demonstration for the metals contamination. In addition, monitoring wells MS-10, MS-15 and MS-6 have chromium and iron concentrations above their respective 2L Standards and appear to be located at the review boundary, which triggers the need for assessment.

The Section solicits your cooperation and would like to remind you that it is your responsibility to comply with the requirements of the rules and statues since the rules are self-implementing. Please contact me at (919) 707-8253 or via email Elizabeth.werner@ncdenr.gov if you have any questions or concerns regarding this letter. Thank you in advance for your anticipated cooperation in this matter.

Sincerely,

Elizabeth S Werner
Hydrogeologist

cc: William M. Miller, PE, Altamont Environmental Inc.
Mark Poindexter, SWS
Ellen Lorscheider, SWS
Jason Watkins, SWS
Deb Aja, SWS
Central File