Landfill Gas Monitoring Plan

Lincoln County Landfill, Phase 4

Crouse, Lincoln County, North Carolina

DIN 25600

Prepared for

Lincoln County
Solid Waste Division
Crouse, North Carolina

Prepared by:

Municipal Engineering Services Company, P.A.
PO Box 97
Garner, NC 27529
Corporate License Number: C-0281
MESCO Project Number: G15141.6

Pre-Construction Plan Submitted: November 3, 2015

Steven R. Gandy, Ph.D., P.E.
Senior Project Manager

Jonathan Pfohl
Environmental Specialist

Municipal Services
P.O. BOX 97 GARNER, N.C. 27529
(919) 772-5393

Engineering Company, P.A.
P.O. BOX 349 BOONE, N.C. 28607
(828) 262-1767

LICENSE NUMBER: C-0281

DIN 25600
Approved by SWS 2/8/2016

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The North Carolina Solid Waste Management Rules 15A NCAC 13B require that a Landfill Gas Monitoring Plan be submitted in the application for the Permit to Construct a new Subtitle D solid waste landfill. This landfill gas monitoring plan has been prepared for the proposed Phase 4 municipal solid waste landfill (MSWLF) for Lincoln County, North Carolina. The site is located at 5291 Crouse Road in Crouse, North Carolina (Figures 1 and 2).

The information in this plan is designed to assist the Division of Solid Waste Management, the Operations Personnel and it's agents in evaluation of potential subterranean migration of explosive gas (methane) before it leaves the property or accumulates within structures. Included in this plan are sections concerning landfill gas monitoring, monitoring well construction, sampling procedures, record keeping and reporting requirements and contingency plan. Monitoring procedures shall be performed in accordance with the Division's rules and policies which can generally be referenced on their website. This plan is intended to conform to the NCDENR Solid Waste Section Landfill Gas Monitoring Guidance attached as Appendix B and referenced here within as SWS Guidance Document.

1.0 Background

North Carolina Solid Waste Management Rules 15A NCAC 13B require quarterly monitoring of methane gas (at MSW landfills) to ensure that methane does not exceed the lower explosive limit (LEL) in the soil at the facility property boundary or 25 percent of the lower explosive limit within facility structures. If the concentration exceeds the specified limits, steps must be taken to ensure the protection of public health and a remediation plan must be implemented immediately.

A LFG monitoring plan is necessary to ensure that these performance standards are met. LFG monitoring has reportedly been performed at this facility on a quarterly basis in compliance with Rule .1626 (4)(b).

This Landfill Gas Monitoring Plan’s objective is to provide clear guidelines and procedures for field personnel when performing explosive gas monitoring. This plan applies specifically to the proposed Phase 4 lined landfill at the Lincoln County Landfill. Facility conditions or unforeseen variables may warrant deviation from standard procedures in which case alternative sampling procedures will conform to the most current NC Solid Waste Section guidelines and industry Standards.

2.0 Site Geology and Hydrogeology

Lincoln County landfill Phase 4 is located in the NC Inner Piedmont Belt (Inner Piedmont). The hydrogeologic terrain of the site is one of massive and foliated crystalline rocks mantled by a thick regolith. The subsurface conditions in the Phase 4 expansion area consist of residual soils and partially weathered rock (PWR) which has formed by in-place weathering of the parent bedrock. The residual soils grade with depth into an indistinct transition zone which consists of PWR and saprolite that overlie the underlying bedrock. Neither PWR nor bedrock is suspected to influence LFG migration at this facility since it is beneath the water table at the site which serves as the lower LFG confining feature. The hydrogeology of Phase 4 is discussed in greater detail in the Design Hydrogeologic Study submitted to the SWS under separate cover.

The uppermost aquifer around Phase 4 has been identified to be within the unconsolidated regolith. The unsaturated residuum has an average porosity of 41% and a mean permeability of 1.42E-5 cm/sec. The unsaturated saprolite has an average porosity of 43% and a mean permeability of 4.32 E-4. The vertical LFG migration potential extent is the water table that ranges from 0 to 37.41 feet below ground surface, which is the deepest groundwater has ever been identified near Phase 4. Groundwater generally mirrors topography, and a groundwater surface map of the uppermost aquifer from groundwater elevations recorded on July 24, 2015 is shown on Figure 3.

The SWS Guidance Document accurately states that subsurface gas typically migrates above the groundwater table and is restricted laterally by streams. The southern property boundary is the northern bank of Indian Creek which is classified by the USGS as a perennial stream. Unnamed tributaries of Indian Creek are located east and west of the proposed Phase 4 landfill. Although the unnamed tributaries are classified as intermittent on USGS topographic maps, they are both believed to have consistent base flow year round. The topography between Phase 4 and the western property line is very flat with a shallow water table which is classified as a flood plain below approximately 789 ft msl as shown on Figure 4. The shallow water table and base flow may act as hydraulic barriers to potential horizontal LFG migration beyond the property boundaries.

3.0 Landfill Gas Monitoring

3.1 Landfill Gas Wells

3.1.1 Landfill Gas Well Locations

In addition to proposed lined Phase 4 the entire solid waste management facility consists of three existing lined units (Phases 1, 2 & 3), an unlined unit (Area"E"), and construction and demolition (C&D) landfill units (Phases 1 & 2). The LFG monitoring system in place beyond Phase 4 is not pertinent to this monitoring plan; thus, effectiveness was not evaluated in formation of this plan. LFG will continue to be monitored site-wide per the area's respective monitoring plan. Phase 4 will be monitored during the same established quarterly schedule; typically March, June, September and December.

Phase 4 is proposed to be monitored by three wells (MMW-3, MMW-4 and MMW-5). MMW-3 and MMW-4 monitor the east side and MMW-5 monitors the west side. Monitoring wells are not proposed south of Phase 4 because Indian Creek serves as the property boundary and an effective hydraulic barrier to potential LFG migration. In the unlikely event property lines change, the landfill gas monitoring plan will be revised accordingly. No additional monitoring locations are proposed at the facility. Well locations are shown on Figure 5.

The locations of monitoring points in this new LFG monitoring plan were chosen following careful consideration of spatial relationship between property boundaries, hydraulic barriers and both on and off-site structures.

3.1.2 Landfill Gas Well Construction Specifications

Landfill gas wells will be installed very similar to a water monitoring well except they terminate above seasonal high groundwater and a valve with a sample port is affixed to the top. Wells will be installed per SWS Guidance Document with the exception they may be 1" nominal PVC and protective cases may be made of aluminum (non-sparkable) rather than steel. A schematic of a typical landfill gas monitoring well is shown on Figure 6. Survey and well construction information of the proposed LFG well construction are shown on Table 1. All constructed wells will be equipped with a stopcock ball valve bushed to the well casing, quick connect coupling threaded into the well cap or an equivalent device that allows air flow to be controlled at the wellhead as shown on Figure 7.

3.2 Structure Monitoring

The inside of two on-site structures (Scale House and Maintenance Shop) located 0.86 miles north of Phase 4 will be monitored quarterly for LFG accumulation in accordance with the *Guidance Document*. The leachate pump station should be monitored each and every time entered. All on-site habitable structures are shown on Figure 6.

3.3 Landfill Gas Monitoring Frequency

LFG monitoring will be performed and documented on at least a quarterly basis (four times annually approximately three months apart). Monitoring per this plan will be initiated during the first scheduled quarterly event following waste disposal into Phase 4. Monitoring frequency will not be decreased without pre-authorization by the SWS.

3.4 Landfill Gas Monitoring Procedure

3.4.1 Equipment

Instrumentation must be capable of accurately reading percent methane, percent oxygen and percent carbon dioxide. Instruments shall be calibrated according to manufacturer's specifications prior to performing monitoring. Calibration gas must not be expired and consist of ratios of CO2 to CH4 of either 15%/15% or 35%/50%. Although other instrument(s) may be available which meet these requirements that would also be deemed acceptable, the most common instrument is a Landfill Gas Analyzer manufactured by LANDTEC which includes models such as GEM500, GEM2000 and GEM5000. Stopcock valves on monitoring wells should remain in a closed position until instrument tubing is tightly sealed.

3.4.2 Monitoring Procedure

LFG monitoring will be performed by personnel that understand the principles of operation and use instruments per manufacturer's instructions. LFG monitoring shall be performed in general accordance with procedures outlined in the most current NC SWS issued Landfill Gas Monitoring Guidance Document with steps listed below.

Any accumulation of landfill gas in the landfill gas monitoring wells is likely the result of landfill gas migration. The following procedure are the recommended steps for performing landfill gas monitoring of a well, but always read and follow the manufacturer's instructions because each instrument will be different.

Step 1– Calibrate the instrument according to the manufacturer's specifications. In addition, prepare the instrument for monitoring by allowing it to properly warm up as directed by the manufacturer. Make sure the static pressure shows a reading of zero on the instrument prior to taking the first sample.

Step 2– Purge sample tube for at least one minute prior to taking reading. Connect the instrument tubing to the landfill gas monitoring well cap fitted with a stopcock valve or quick connect coupling.

Step 3– Open the valve and record the initial reading and then the stabilized reading. A stable reading is one that does not vary more than 0.5 percent by volume on the instrument's scale.

Step 4- Record the stabilized readings, times and barometric pressure.

Step 5– Turn the stopcock valve to the off position and disconnect the tubing.

Step 6– Proceed to the next landfill gas monitoring well and repeat Steps 2 – 5.

Deviation from procedures outlined in this plan may be warranted depending on facility conditions or unforeseen variables. Any variance from the methodology contained in the current SWS *Guidance Document* will be consistent with industry standards and be described in the associated LFG monitoring report.

4.0 Regulatory Limits

In accordance with Rule 15A NCAC 13B, landfill gas readings will be recorded quarterly and results will be kept in the facility operating records. Lincoln County will follow all operational requirements for MSWLF facilities; ensuring the measured concentration of methane gas does not exceed the lower explosive limit (100% LEL or 5% by volume) at the facility boundary and (25% LEL or 1.25% by volume) in structures. LFG records will be submitted to the SWS in the event that stabilized methane levels exceed these limits or upon SWS request.

5.0 Record Keeping and Reporting

5.1 Monitoring Data Form

LFG monitoring event results shall be recorded on a Landfill Gas Monitoring Data Form. The monitoring data form should contain at least the information outlined in the *SWS Guidance Document* as shown on the example in Appendix I.

5.2 Monitoring Reports

A landfill gas monitoring report consisting of at a minimum the completed Landfill Gas Monitoring Report Form and a site drawing showing the location of each monitoring location shall be drafted shortly following every quarterly monitoring event. In the event that stabilized LFG levels are detected above regulatory standards, records will be submitted to the SWS.

5.3 Permanent Record Keeping

Landfill gas monitoring records including monitoring plans, monitoring reports and remediation plans will be retained at the facility in an operating record and updated as the information becomes available. Reports will be sent to the SWS only in the event methane is detected above allowable limits or per request.

6.0 Contingency Plan

If stabilized methane levels are detected above regulatory compliance levels, additional well(s) will be installed closer towards the property boundary in order to determine the LFG extent. If stabilized methane readings are detected above regulatory limits at the facility boundary or within any buildings, remedial actions will be implemented per Rule 15A NCAC 13B .1626(4)(c). The specific remedial actions taken to abate LFG migration will be chosen based on site specific circumstances and consistent with industry protocols.

7.0 Certification of Professional Engineer

This LFG monitoring plan pertains to the Lincoln County Phase 4 lined landfill. The landfill gas monitoring plan for this facility has been prepared under the direct supervision of a qualified engineer who is licensed to practice in the State of North Carolina. The plan has been prepared based on first-hand knowledge of site conditions and familiarity with North Carolina solid waste rules and industry protocol. This certification is made in accordance with North Carolina Solid Waste Regulations, indicating this Landfill Gas Monitoring Plan should provide early detection of methane migration through the vadose zone, so as to be protective of public health. No other warranties, expressed or implied, are made.

Signed Steven R. Brandy PhD PE

Printed Steven R. Brandy, PhD, P.E.

Date 11/3/15

NORTH CAROLINA PROFESSIONAL SEAL 31020 ENGINEER STEVEN R. BRANDY

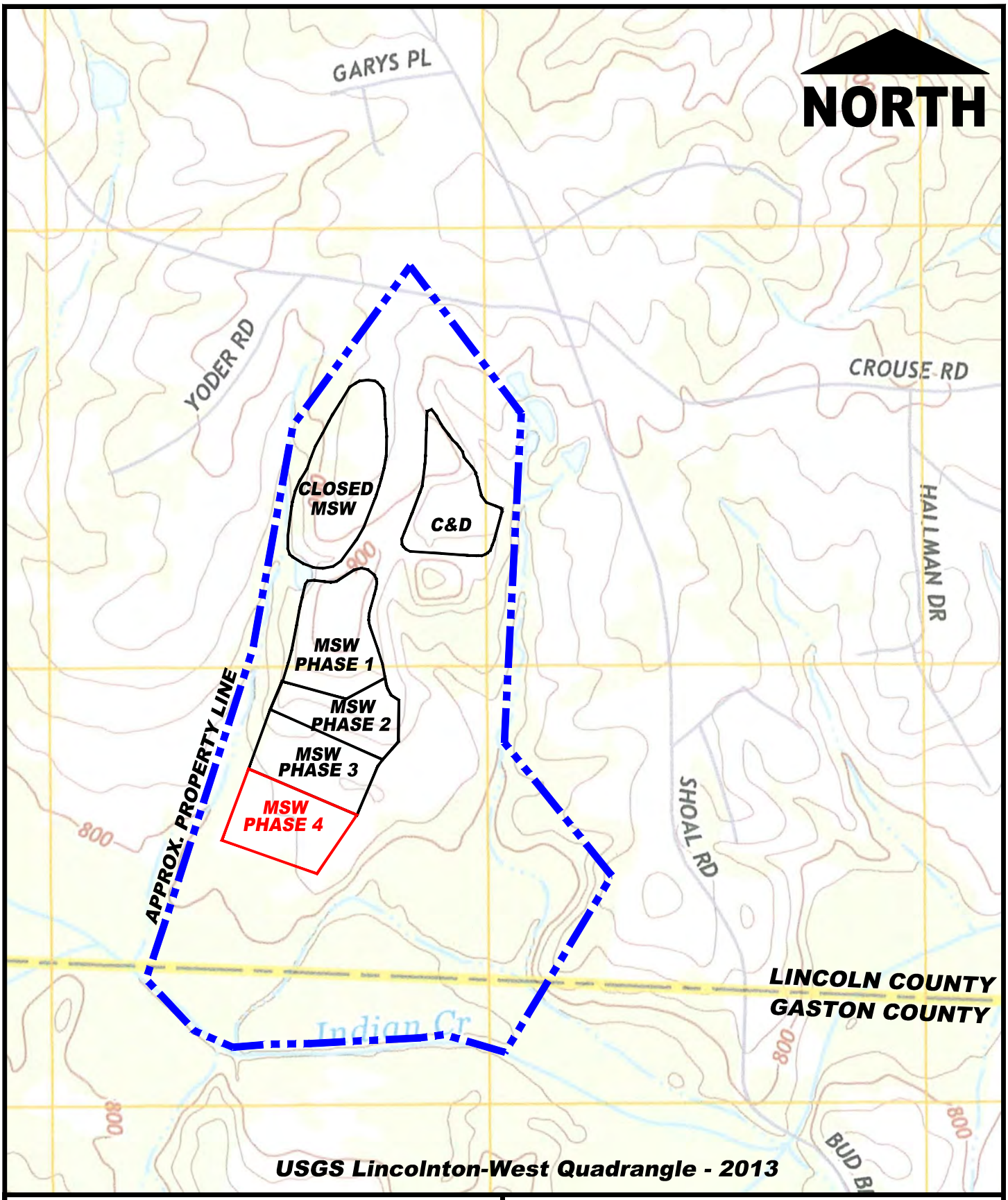
Tables

Table 1
Survey and Well Construction Data

Well ID	Date	Northing	Easting	Land Surface	Sand Interval	Screen Interval	Groundwater seasonal high		Locked Steel Protective Case and concrete pad	PVC Well Diameter	Valve Installed	Screened Lithology
				(ft-msl)	(ft-bls)	(ft-bls)	(ft-msl)	(ft-bls)				
MMW-3	9/20/94	616007.81	1299115.86	798.00	3-16	3-16	790.00	8	Yes	1”	Yes	Soil
MMW-4	9/7/05	615456.90	1297912.11	819.42	4.5-30	5-30	789.42	30	Yes	2”	Yes	Soil
MMW-5	9/21/94	616044.81	1297096.85	801.67	3-8	3-8	793.67	8	Yes	1”	Yes	Soil

Notes:
ft-msl = Feet-mean sea level
ft-bls = Feet-below land surface
Dimensions from well tags on August 25, 2015.
MMW-3 and MMW-4 coordinates from survey performed on May 6, 2015.

Figures



Municipal Services Engineering Company, P.A.

P.O. BOX 97 GARNER, N.C. 27529
(919) 772-5393

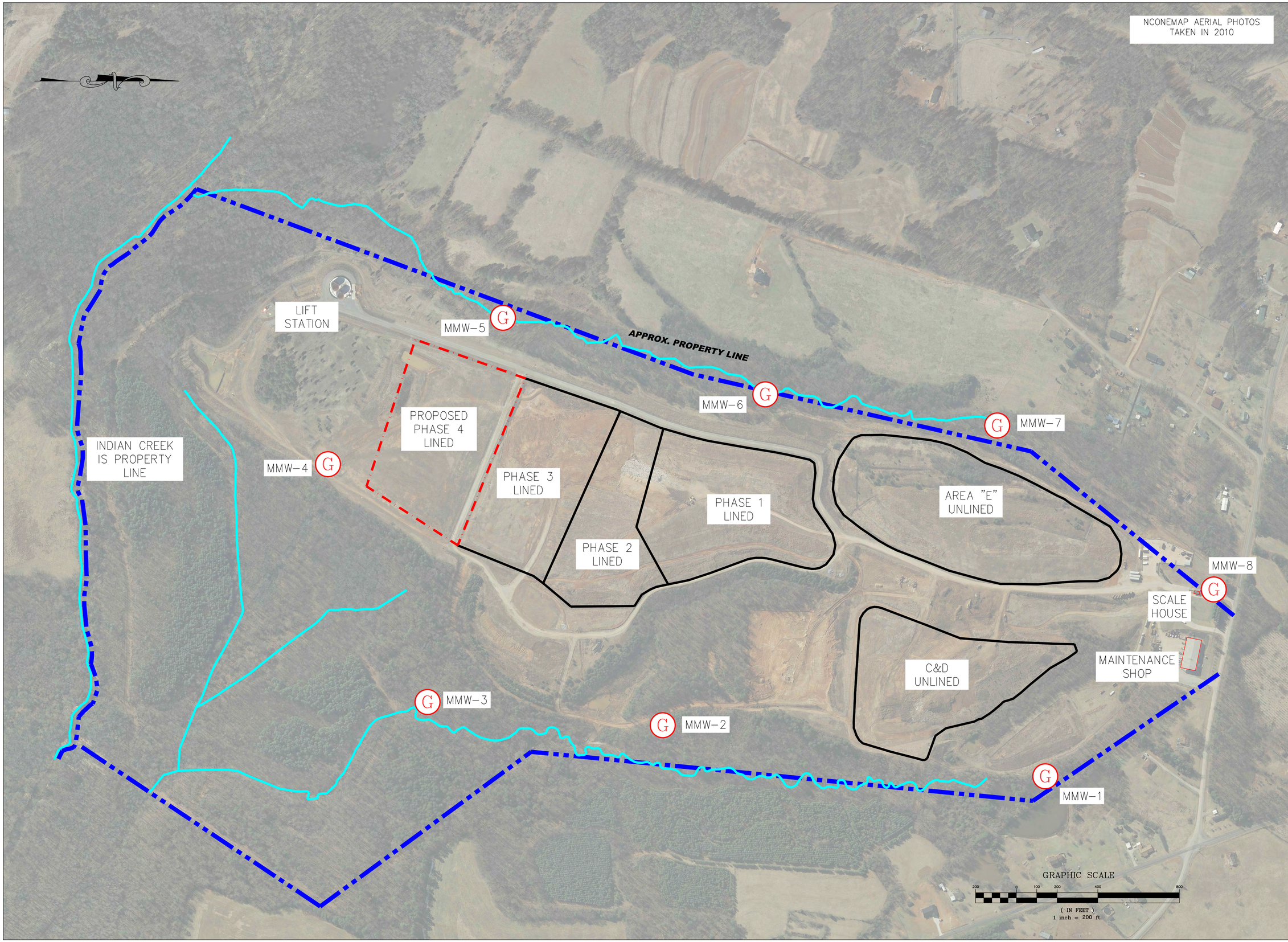
P.O. BOX 349 BOONE, N.C. 28607
(828) 262-1767

LICENSE NUMBER: C-0281

FIGURE 1
SITE LOCATION (USGS TOPO)

Lincoln County Landfill, Phase 4
Crouse, North Carolina

SCALE:	DATE:	PROJECT NO.:
1" = 1000'	8/10/2015	G15041



Municipal Engineering Services Company, P.A.

P.O. BOX 97 GARNER, N.C. 27529
(919) 772-5393

P.O. BOX 349 BOONE, N.C. 28607
(828) 262-1767

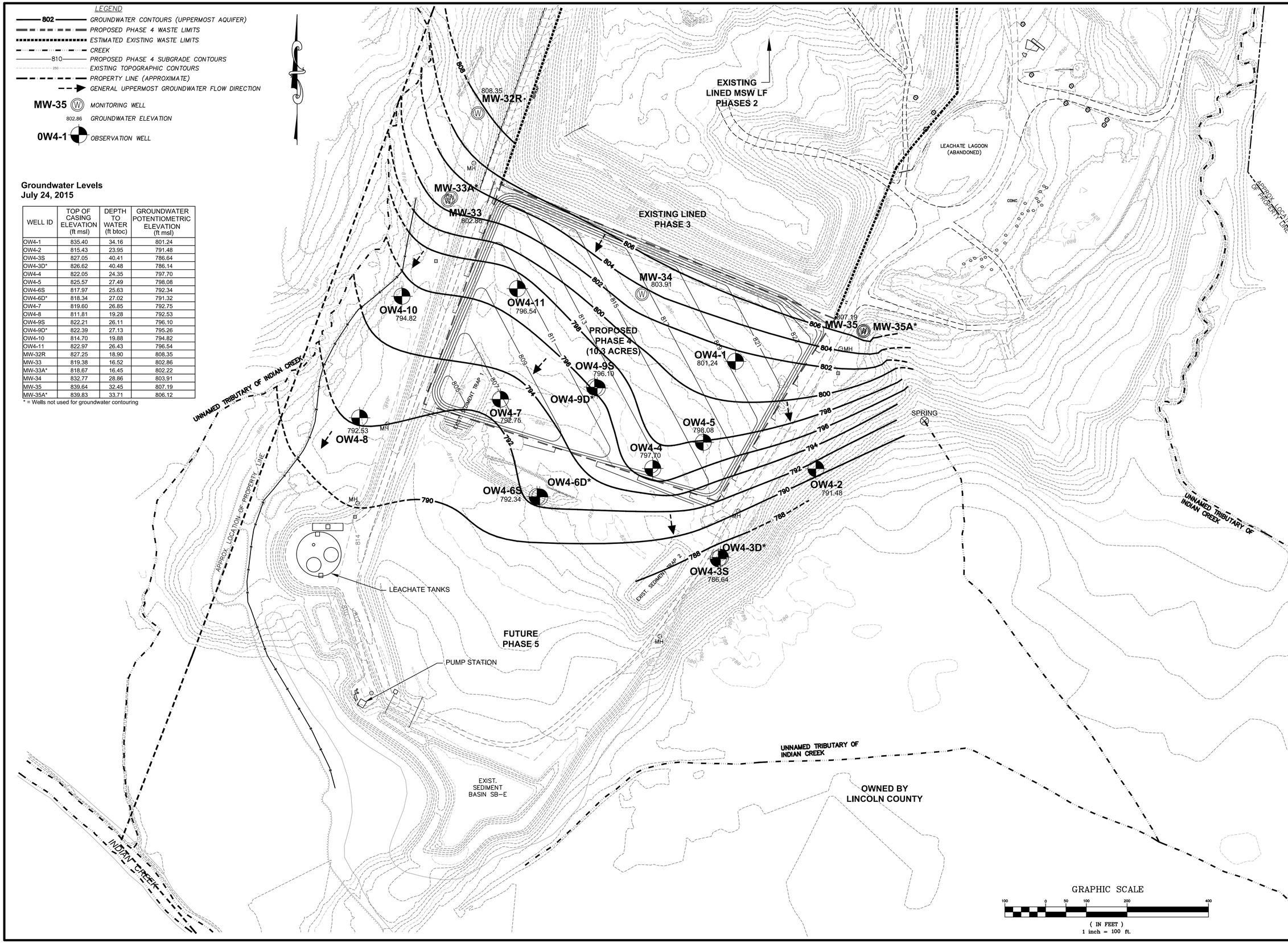
LICENSE NUMBER: C-0281

MUNICIPAL SOLID WASTE LANDFILL FACILITY
LINCOLN COUNTY
CROUSE, NORTH CAROLINA

DATE	BY	REV.	DESCRIPTION

SITE LOCATION AERIAL

SCALE:	1" = 200'
DATE:	10-12-2015
DRWN. BY:	R.MOSS
CHKD. BY:	W. SULLIVAN
PROJECT NUMBER	G15141.6
DRAWING NO.	
SHEET NO.	FIG. 2



Groundwater Levels
July 24, 2015

WELL ID	TOP OF CASING ELEVATION (ft msl)	DEPTH TO WATER (ft btoc)	GROUNDWATER POTENTIOMETRIC ELEVATION (ft msl)
OW4-1	835.40	34.16	801.24
OW4-2	815.43	23.95	791.48
OW4-3S	827.05	40.41	786.64
OW4-3D*	826.62	40.48	786.14
OW4-4	822.05	24.35	797.70
OW4-5	825.57	27.49	798.08
OW4-6S	817.97	25.63	792.34
OW4-6D*	818.34	27.02	791.32
OW4-7	819.60	26.85	792.75
OW4-8	811.81	19.28	792.53
OW4-9S	822.21	26.11	796.10
OW4-9D*	822.39	27.13	795.26
OW4-10	814.70	19.88	794.82
OW4-11	822.97	26.43	796.54
MW-32R	827.25	18.90	808.35
MW-33	819.38	16.52	802.86
MW-33A*	818.67	16.45	802.22
MW-34	832.77	28.86	803.91
MW-35	839.64	32.45	807.19
MW-35A*	839.83	33.71	806.12

* = Wells not used for groundwater contouring

Municipal Services Engineering Company, P.A.
P.O. BOX 97, GARNER, N.C. 27529 (919) 772-5393
P.O. BOX 349 BOONE, N.C. 28607 (828) 262-1767
LICENSE NUMBER: C-0281

MUNICIPAL SOLID WASTE LANDFILL FACILITY
LINCOLN COUNTY
CROUSE, NORTH CAROLINA

DATE	BY	REV.	DESCRIPTION

GROUNDWATER SURFACE
JULY 24, 2015

SCALE:	1" = 100'
DATE:	10-13-2015
DRWN. BY:	R.MOSS
CHKD. BY:	S.GANDY
PROJECT NUMBER	G15041
DRAWING NO.	SHEET NO. FIGURE 3

Municipal Services Engineering Company, P.A.

P.O. BOX 97 GARNER, N.C. 27529
(919) 772-5393

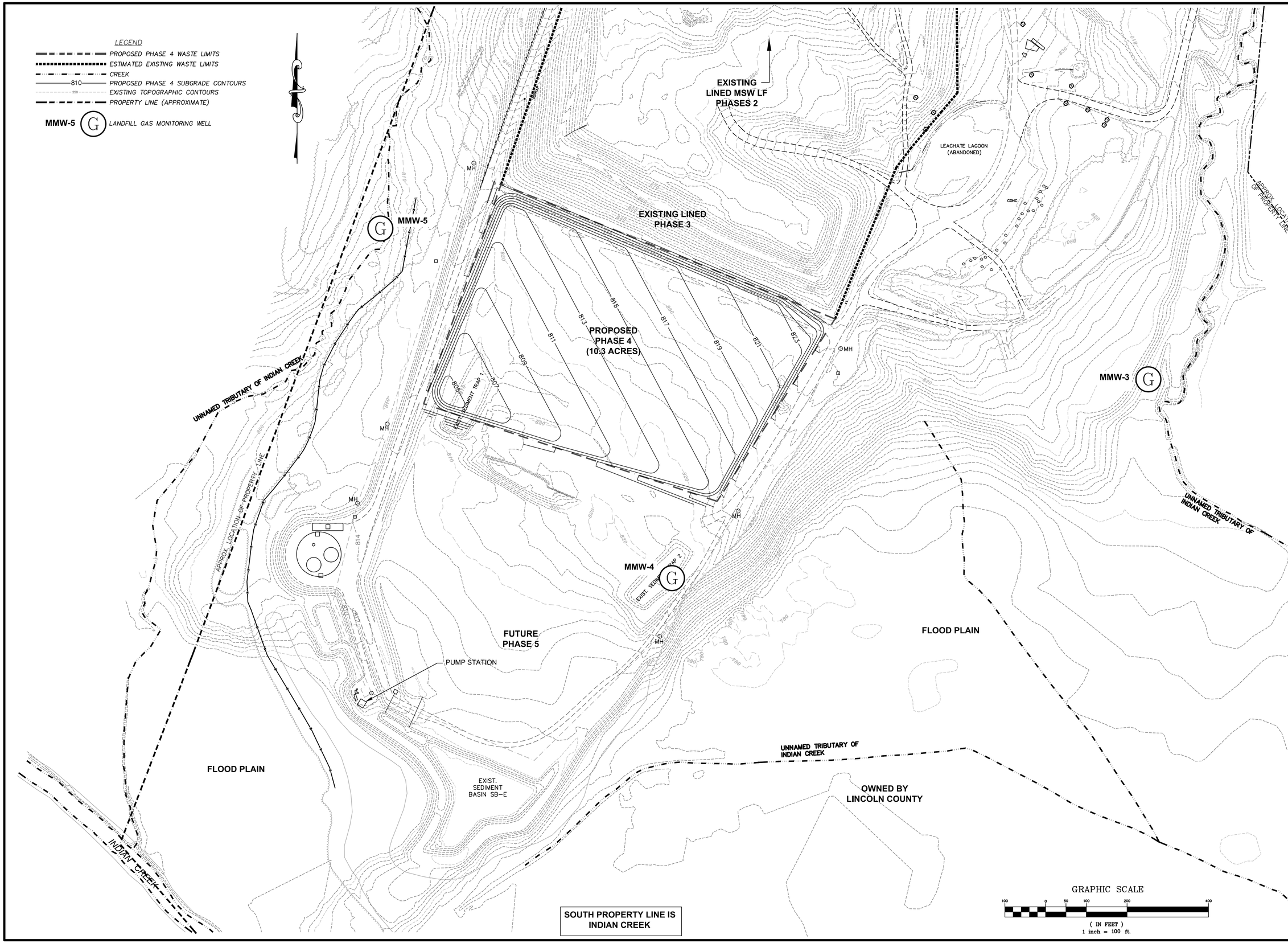
P.O. BOX 349 BOONE, N.C. 28607
(828) 262-1767

LICENSE NUMBER: C-0281

FIGURE 4
FLOOD PLAIN (NCFMP)

Lincoln County Landfill, Phase 4
Crouse, North Carolina

SCALE:	DATE:	PROJECT NO.:
NOT TO SCALE	8/10/2015	G15041



Municipal Services Engineering Company, P.A.

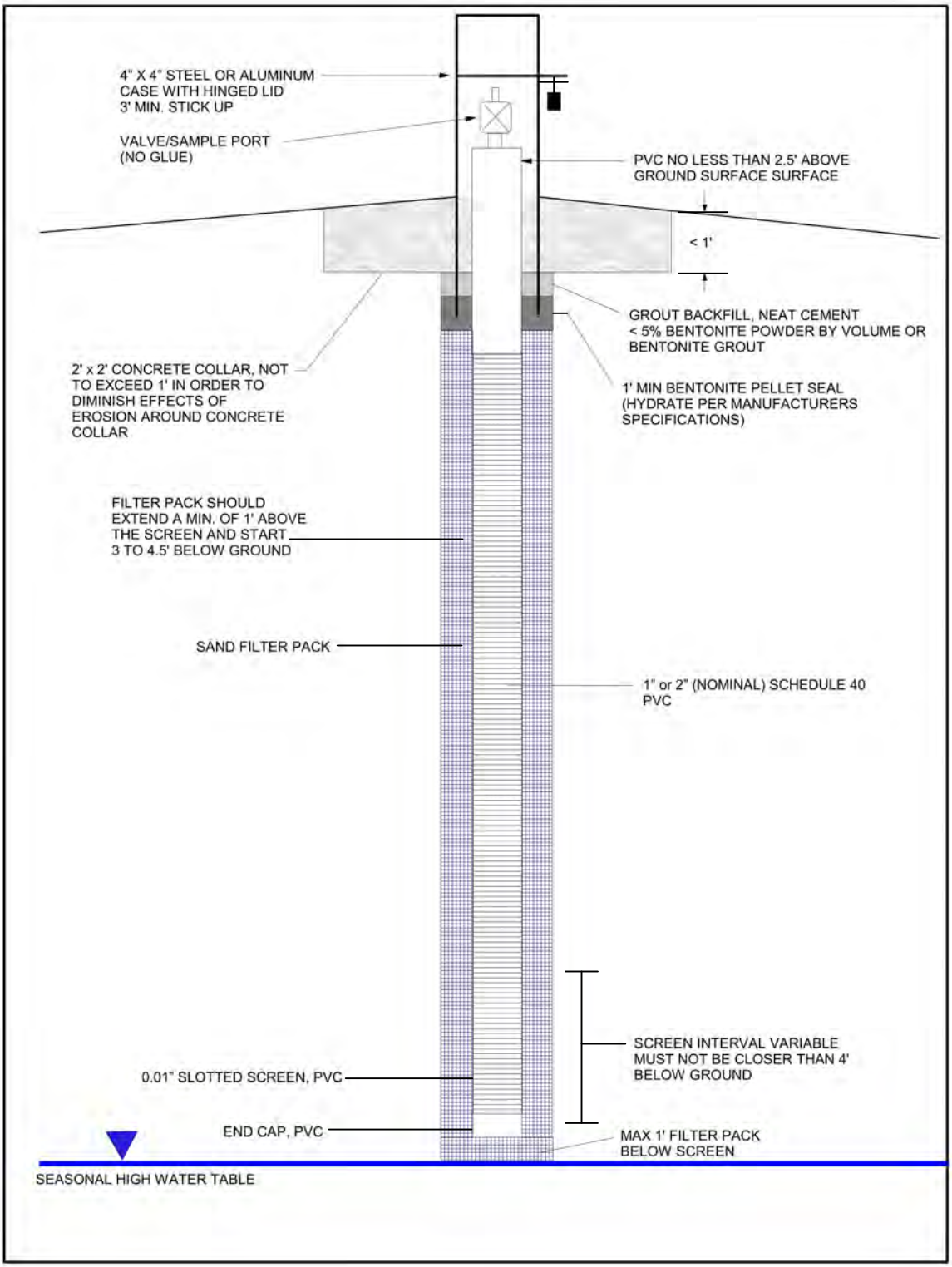
P.O. BOX 97, GARNER, N.C. 27529 (919) 772-5393
P.O. BOX 349 BOONE, N.C. 28607 (828) 262-1767
LICENSE NUMBER: C-0281

MUNICIPAL SOLID WASTE LANDFILL FACILITY
LINCOLN COUNTY CROUSE, NORTH CAROLINA

DATE	BY	REV.	DESCRIPTION

PHASE 4 LANDFILL GAS MONITORING PLAN

SCALE:	1" = 100'
DATE:	10-13-2015
DRWN. BY:	R.MOSS
CHKD. BY:	S.GANDY
PROJECT NUMBER	G15041
DRAWING NO.	SHEET NO. FIGURE 5



Municipal Services Engineering Company, P.A.

P.O. BOX 97 GARNER, N.C. 27529
(919) 772-5393

P.O. BOX 349 BOONE, N.C. 28607
(828) 262-1767

LICENSE NUMBER: C-0281

FIGURE 6

TYPICAL LANDFILL GAS WELL SCHEMATIC

Lincoln County Landfill, Phase 4
Crouse, North Carolina

SCALE:	DATE:	PROJECT NO.:
NOT TO SCALE	8/10/2015	G15041

Ball Valve
(Bushed onto Well Casing)

OR
Quick Connect Coupling
(Threaded into Cap)

OR
Equivalent

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(919) 772-5393

P.O. BOX 349 BOONE, N.C. 28607
(828) 262-1767

LICENSE NUMBER: C-0281

FIGURE 7
VALVE DETAIL

Lincoln County Landfill, Phase 4
Crouse, North Carolina

SCALE:	DATE:	PROJECT NO.:
NOT TO SCALE	8/10/2015	G15041

Appendix A

NC Division of Waste Management – Solid Waste Section

Landfill Gas Monitoring Data Form

Notice: This form and any information attached to it are "Public Records" as defined in NC General Statute 132-1. As such, these documents are available for inspection and examination by any person upon request (NC General Statute 132-6).

Facility Name: Lincoln County Landfill (Crouse) **Permit Number:** 55-03

Date of Sampling: _____ **NC Landfill Rule (.0500 or .1600):** 0.1600

Name & Position of Sample Collector: _____

Type & Serial Number of Gas Meter: _____ **Calibration Date of Gas Meter:** _____

Date & Time of Field Calibration: _____

Type of Field Calibration Gas (15/15 or 35/50): _____ **Expiration Date of Field Calibration Gas Canister:** _____

Pump Rate of Gas Meter: _____

Ambient Air Temperature: _____ **Barometric Pressure:** _____ **General Weather Conditions:** _____

Instructions: Under "Location or LFG Well" identify the monitoring wells or describe the location for other tests (e.g., inside buildings). A drawing showing the location of test must be attached. Report methane readings in both %LEL and % methane by volume. A reading in percent methane by volume can be converted to %LEL as follows: % methane by volume = %LEL/20

Location or LFG Well ID	Sample Tube Purge (Sec)	Time Reading Taken	Time Pumped in (Sec.)	Initial % LEL	Stabilized % LEL	Stabilized % CH4 by Volume	% O2	% CO2	Notes
MMW-1									
MMW-2									
MMW-3									
MMW-4									
MMW-5									
MMW-6									
MMW-7									
MMW-8									
Scale House									
Maintenance Shop									

Certification

To the best of my knowledge, the information reported and statements made on this data submittal and attachments are true and correct. I am aware that there are significant penalties for making any false statement, representation, or certification including the possibility of a fine and imprisonment.

SIGNATURE _____ TITLE _____

Appendix B

NORTH CAROLINA DEPARTMENT OF ENVIRONMENT AND NATURAL RESOURCES

DIVISION OF WASTE MANAGEMENT

SOLID WASTE SECTION

LANDFILL GAS MONITORING GUIDANCE

NOVEMBER 2010

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SECTION 1 - Introduction

North Carolina Solid Waste Management Rules 15A NCAC 13B require quarterly monitoring of methane gas (at MSW landfills) and quarterly monitoring of methane and other explosive landfill gases (LFG) (at C&D and other landfills) to ensure that landfill gas does not exceed the lower explosive limit (LEL) at the facility property boundary or 25 percent of the lower explosive limit in facility structures. If the concentration exceeds the specified limits, steps must be taken to ensure the protection of public health and a remediation plan must be implemented immediately. A landfill gas monitoring plan is necessary to ensure that these performance standards are met and this guidance document was developed to assist in establishing a standardized procedure for the monitoring of landfill gas.

Background

Organic matter in landfills begins to decompose almost immediately after being placed in a disposal site. Putrescible wastes such as food products and sewage sludges begin to break down by biological processes very rapidly whereas paper, cardboard or cellulose based materials are slower to decompose. However, when conditions become favorable, most organic matter will decompose. The decomposition process typically goes through several stages that depend on conditions such as pH, temperature, and moisture content. The final stage results in the production of methane and although the rate of production may vary, most landfills produce methane.

Landfill Gas Generation

Landfill gas is a natural by-product of the anaerobic decomposition of organic waste in a landfill. The composition, quantity and rate of landfill gas generation are dependent on the types of waste that are decomposing and the level of microbial activity within the wastes. The decomposition of biodegradable waste begins with aerobic decomposition which lasts until the oxygen in the landfill is depleted. The anaerobic phase then begins, resulting in landfill gas production.

There are four stages of landfill gas composition: the first stage is characterized by elevated nitrogen levels and occurs when the landfill is new. The second stage is characterized by elevated carbon dioxide levels and occurs for a relatively short period of time after the initial stage is complete. The third and fourth stages are characterized by elevated methane concentrations and represent the active life of a landfill and the post-closure time frame.

Landfill gas is generally composed of 50-55% methane (CH4); 45-50% carbon dioxide (CO2); less than 5% nitrogen (N2); and less than 1% non-methane organic compounds. These individual gases generally remain co-mingled and do not naturally separate. The Solid Waste Section (SWS) Rules typically focus on methane (CH4) and its explosive properties due to public safety issues. Hydrogen sulfide (H2S) is also of particular concern in landfills and is typically recognized by its rotten egg odor. H2S is immediately dangerous to life and health at concentrations of 100 parts per million (ppm).

Landfill Gas Migration

The production of landfill gas creates a positive pressure within the landfill that forces the gas to migrate. Landfill gas migrates from place to place by diffusion and pressure gradient and will follow the path of least resistance. Subsurface gas typically migrates above the groundwater table and is restricted laterally by streams. Porous soils lying above the bedrock can serve as pathways to transmit large volumes of gas. Underground off-site migration is common and can be facilitated by the presence of pipelines, buried utility corridors or trenches located within or adjacent to the landfill boundaries. Movement depends on soil type and moisture, and migration distances of 1,500 feet have been observed. Barometric pressure also influences movement. Falling barometric pressure allows methane to migrate out of the landfill and into surrounding areas.

SECTION 2 - Factors Influencing Landfill Gas Generation and Migration

Factors that affect landfill gas generation and migration through the subsurface include the following:

Waste Composition
The production of landfill gas is directly related to the amount of organic matter present in waste. The bacteria that break down the waste require small amounts of specific minerals such as calcium, potassium, magnesium and other micronutrients. Bacteria are able to thrive and produce landfill gas if the minerals/micronutrients are present. If the minerals/micronutrients are not present or if substances that inhibit bacterial growth exist, landfill gas production will occur at a reduced rate. Some forms of organic matter such as cellulose break down quickly whereas matter such as lignin breaks down more slowly. The rate at which landfill gas is produced depends on the proportions of each type of organic matter present in the waste.

Moisture Content
Landfills with higher moisture content generate higher concentrations of landfill gas in earlier stages of development (such as during leachate recirculation). Moisture accelerates the methanogenic process.

Temperature
Landfill bacteria are temperature dependant. They are able to survive and function below the freezing point, but they also function well at temperatures up to 65°C. Anaerobic bacteria produce small amounts of heat and may not be able to maintain the temperature of a shallow landfill when external temperatures decrease, so LFG generation may exhibit seasonal variations. Saturated landfills may not achieve ideal temperatures because the bacteria do not generate sufficient heat to raise the temperature of the excess water. Higher temperatures promote volatilization and chemical reactions with the waste so the trace gas component of landfill gas tends to increase with higher landfill temperatures.

Age of Landfill
Typically, landfills have an increasing generation of landfill gas for a number of years until closure at which time landfill gas generation reaches a peak and begins to subside. An evaluation of the age of the landfill and use of a landfill gas generation curve can be helpful in determining the likelihood of significant landfill gas concentrations from the landfill.

Landfill Cap
The type or presence of landfill cover can influence landfill gas generation and migration. Although a low permeability cap will reduce moisture and landfill gas generation over the longer term, initially, the installation of a landfill cap could drive landfill gas migration further from the landfill in the subsurface without proper ventilation (either passive or active). This is especially true in the case of unlined (unvented) landfills.

Water Table
Landfill gas movement in unlined landfills may be influenced by groundwater table variations. A rising water table could cause displacement and force upward movement of landfill gas.

Man-made and Natural Conduits
Structures such as drains, trenches, and buried utility corridors can act as conduits for landfill gas migration. Geologic features including fractured bedrock, porous soil, and permeable strata also provide conduits for landfill gas migration

Landfill Liner Conditions
The presence of a Subtitle-D (or equivalent) landfill liner has the capability to limit the lateral migration of landfill gas in the subsurface. Unlined landfills have no barrier to prevent lateral landfill gas migration in the subsurface.

Weather Conditions
Barometric pressure and precipitation have significant effects on landfill gas migration. Increased barometric pressure yields decreased landfill gas venting from the subsurface, until the pressure within the subsurface is greater than the atmospheric (barometric) pressure. Conversely, as the barometric pressure decreases, the landfill will vent the stored gas until pressure equilibrium is reached. Capping of a landfill can influence the effect of barometric pressure on landfill gas migration. Generally, a more permeable landfill cap will allow greater influence by barometric pressure than a less permeable landfill cap.

SECTION 3 – Current Solid Waste Section Rules Pertaining to Landfill Gas Monitoring

Web link to the 15A NCAC 13B rules - http://portal.ncdenr.org/web/wm/sw/rules

15A NCAC 13B

.0101- DEFINITIONS
.0101 (14) "Explosive gas" means Methane (CH4)
.0101(25) "Lower explosive limit" (LEL) means the lowest percent by volume of a mixture of explosive gases which will propagate a flame in air at 25 degrees Celsius and atmospheric pressure.

.0503 - SITING AND DESIGN REQUIREMENTS FOR DISPOSAL FACILITIES
.0503(2) A site shall meet the following design requirements:

(a) The concentration of explosive gases generated by the site shall not exceed:

(i) twenty-five percent of the limit for the gases in site structures (excluding gas control or recovery system components); and

(ii) the lower explosive limit for the gases at the property boundary;

.0543 - CLOSURE AND POST-CLOSURE REQUIREMENTS FOR C&DLF FACILITIES
.0543(e) Post-closure criteria.

(1) Following closure of each C&DLF unit, the owner and operator must conduct post-closure care. Postclosure care must be conducted for 30 years, except as provided under Subparagraph (2) of this Paragraph, and consist of at least the following:

(C) maintaining and operating the gas monitoring system in accordance with the requirements of Rule .0544 of this Section; and

(2) The length of the post-closure care period may be:

(A) decreased by the Division if the owner or operator demonstrates that the reduced period is sufficient to protect human health and the environment and this demonstration is approved by the Division; or

(B) increased by the Division if the Division determines that the lengthened period is necessary to protect human health and the environment.

.0544 - MONITORING PLANS AND REQUIREMENTS FOR C&DLF FACILITIES
.0544(d) Gas Control Plan

(1) Owners and operators of all C&DLF units must ensure that:

(A) the concentration of methane gas or other explosive gases generated by the facility does not exceed 25 percent of the lower explosive limit in on-site facility structures (excluding gas control or recovery system components);

(B) the concentration of methane gas or other explosive gases does not exceed the lower explosive limit for methane or other explosive gases at the facility property boundary; and

(C) the facility does not release methane gas or other explosive gases in any concentration that can be detected in offsite structures.

(2) Owners and operators of all C&DLF units must implement a routine methane monitoring program to ensure that the standards of this Paragraph are met.

(A) The type of monitoring must be determined based on soil conditions, the Hydrogeologic conditions under and surrounding the facility, hydraulic conditions on and surrounding the facility, the location of facility structures and property boundaries, and the location of all offsite structures adjacent to property boundaries.

(B) The frequency of monitoring shall be quarterly or as approved by the Division.

(3) If methane or explosive gas levels exceeding the limits specified in Subparagraph (d)(1) of this Rule are detected, the owner and operator must:

(A) immediately take all steps necessary to ensure protection of human health and notify the Division;

(B) within seven days of detection, place in the operating record the methane or explosive gas levels detected and a description of the steps taken to protect human health; and

(C) within 60 days of detection, implement a remediation plan for the methane or explosive gas releases, place a copy of the plan in the operating record, and notify the Division that the plan has been implemented. The plan must describe the nature and extent of the problem and the proposed remedy.

(4) Based on the need for an extension demonstrated by the operator, the Division may establish alternative schedules for demonstrating compliance with Parts (3)(B) and (3)(C) of this Paragraph.

(5) For purposes of this Item, "lower explosive limit" means the lowest percent by volume of a mixture of explosive gases in air that will propagate a flame at 25 C and atmospheric pressure.

.0566 - OPERATIONAL REQUIREMENTS FOR LAND CLEARING/INERT DEBRIS (LCID) LANDFILLS

.0566(13) The concentration of explosive gases generated by the facility shall not exceed:

(a) Twenty-five percent of the lower explosive limit for the gases in facility structures.

(b) The lower explosive limit for the gases at the property boundary.

.1626 – OPERATIONAL REQUIREMENTS FOR MSWLF FACILITIES

.1626(4) Explosive gases control.

(a) Owners or operators of all MSWLF units must ensure that:

(i) The concentration of methane gas generated by the facility does not exceed 25 percent of the lower explosive limit for methane in facility structures (excluding gas control or recovery system components); and

(ii) The concentration of methane gas does not exceed the lower explosive limit for methane at the facility property boundary.

(b) Owners or operators of all MSWLF units must implement a routine methane monitoring program to ensure that the standards of (4)(a) are met. A permanent monitoring system shall be constructed on or before October 9, 1994. A temporary monitoring system shall be used prior to construction of the permanent system.

(i) The type and frequency of monitoring must be determined based on the following factors:

(A) Soil conditions;

(B) The hydrogeologic conditions surrounding the facility;

(C) The hydraulic conditions surrounding the facility; and

(D) The location of facility structures and property boundaries.

(ii) The minimum frequency of monitoring shall be quarterly.

(c) If methane gas levels exceeding the limits specified in (4)(a) are detected, the owner or operator must:

(i) Immediately take all necessary steps to ensure protection of human health and notify the Division;

(ii) Within seven days of detection, place in the operating record the methane gas levels detected and a description of the steps taken to protect human health; and

(iii) Within 60 days of detection, implement a remediation plan for the methane gas releases, place a copy of the plan in the operating record, and notify the Division that the

plan has been implemented. The plan shall describe the nature and extent of the problem and the proposed remedy.

(iv) Based on the need for an extension demonstrated by the operator, the Division may establish alternative schedules for demonstrating compliance with (4)(c)(ii) and (iii) of this Rule.

(d) For purposes of this Item, "lower explosive limit" means the lowest percent by volume of a mixture of explosive gases in air that will propagate a flame at 25°C and atmospheric pressure.

.1626(10) Recordkeeping requirements.

(a) The owner or operator of a MSWLF unit must record and retain at the facility, or an alternative location near the facility approved by the Division, in an operating record the following information as it becomes available:

(iii) Gas monitoring results and any remediation plans required by Item (4) of this Rule;

.1627 – CLOSURE AND POST CLOSURE REQUIREMENTS FOR MSWLF ACTIVITES

.1627(d) Post-Closure Criteria

(1) Following closure of each MSWLF unit, the owner or operator shall conduct post-closure care. Post-closure care shall be conducted for 30 years, except as provided under Subparagraph (2) of this Paragraph, and consist of at least the following:

(D)-Maintaining and operating the gas monitoring system in accordance with the requirements of Rule .1626 of this Section.

(2) The length of the post-closure care period may be:

(A) Decreased by the Division if the owner or operator demonstrates that the reduced period is sufficient to protect human health and the environment and this demonstration is approved by the Division; or

(B) Increased by the Division if the Division determines that the lengthened period is necessary to protect human health and the environment.

(3) Following completion of the post-closure care period for each MSWLF unit, the owner or operator shall notify the Division that a certification, signed by a registered professional engineer, verifying that post-closure care has been completed in accordance with the post-closure plan, has been placed in the operating record.

NOTES:

Based on the referenced rules above, the following words / phrases are presently in the Solid Waste Section rules pertaining to methane and explosive landfill gas.

Rule .0101(14) states: *"Explosive gas means Methane (CH)"*.
Rule .0503 (2)(a) refers to *"explosive gases"*.
Rule .0544(d) refers to *"Gas Control Plan"*
Rule .0544(d)(1) refers to *"methane or other explosive gases"*.
Rule .0544(d)(2) refers to "*methane monitoring program*"
Rule .0544(d)(3) refers to *"methane or explosive gas levels*"
Rule .0566 (13) refers to *"explosive gases"*.
Rule .1626 (4) refers to *"explosive gases control"*
Rule .1626(4)(a-b) refers to "*methane monitoring"* and "*methane monitoring program"*.

Monitoring Goals

Landfill design and landfill gas monitoring regulations in North Carolina require that there not be an exceedance of 100% of the Lower Explosion Limit (LEL) (equivalent to 5% methane) at the property boundary, or 25% LEL in on-site structures. These regulations were developed over time to protect the health and safety of the citizens of North Carolina and the U.S. from the asphyxiation and explosive hazards of landfill gas.

NC Rule History

A review of NC landfill guidance documents and regulations from 1972 to the present indicates that from 1972 through 1982, there was no mention of design requirements regarding the control of landfill gas, nor were there any landfill monitoring requirements for landfill gas. In 1982, the regulations were changed to require that sanitary landfill design prevent landfill gas concentrations of 100% LEL at the property boundary line and 25% inside on-site structures. Although a design requirement was added, no design requirement was established to determine if the design requirement was being met. In 1993 with the establishment of .1600 rules, requirements for designs to limit landfill gas levels to below 100% at the property boundary line and 25% in on-site structures and monitoring of landfill gas concentrations around the perimeter of the landfill and inside on-site structures were adopted.

SECTION 4 – Landfill Gas Incidents and Explosions

Hazards Involving Landfill Gas

Landfill fires may or may not be directly caused by landfill gas. The primary concern with these fires is air contamination from the resulting smoke; however they also present a variety of additional problems. In addition to concerns with containing and extinguishing landfill fires, potential reactions involving unknown chemicals in the landfill can cause uncertain hazards. Discarded consumer products in a landfill, such as pesticides, paints, solvents, cleaners, and other material can be the source of chemical releases. Heat from the fire can cause chemicals to volatilize, breakdown, and enter the environment. Also to be considered is the presence of other combustible gases in addition to methane. Whenever an environmental investigation of a landfill is prompted by odorous compounds or explosive gases, the presence of toxic substances should also be investigated. One example is hydrogen sulfide (H2S) that can cause asphyxiation and is flammable. An analysis should include alkyl benzenes, sulfur compounds, vinyl chloride, and methane, and other products associated with industrial wastes, construction and debris waste, and normal organic and inorganic waste.

Fires and explosion hazards become a concern when gases collect in confined spaces. Buildings, basements, and pits are typically regarded as confined spaces. However, landfill gases also collect in and migrate to cracks in the landfill cover, leachate “springs”, cracks in adjacent structures, paved parking areas, etc. Fires can occur on the surface and underground. Surface fires involve recently buried waste near the surface in an aerobic decomposing layer, typically 1 to 4 feet below ground. These fires can be intensified by subsurface landfill gas and spread throughout the landfill. Subsurface fires occur deeper within the landfill, involve material buried for months or years, and can burn for days and months.

The following is a brief summary of some incidents involving landfill gas migration from landfills:

2007 Four employees died as a result of exposure to high concentrations of hydrogen sulfide while attempting to repair a leachate pump at a C&D landfill in Superior, Wisconsin (Journal of Environmental Heath 2008).

1999 An 8-year old girl was burned on her arms and legs when playing in an Atlanta, Georgia playground. The area was reportedly used as an illegal dumping ground many years ago (Atlanta Journal-Constitution 1999).

1994 While playing soccer in a park built over an old landfill in Charlotte, North Carolina, a woman was seriously burned by a methane explosion (Charlotte Observer 1994).

1987 Offsite landfill gas migration is suspected to have caused a house to explode in Pittsburgh, Pennsylvania (EPA 1991).

1984 Landfill gas migrated to and destroyed one house near a landfill in Akron, Ohio. Ten houses were temporarily evacuated (EPA 1991).

1983 An explosion destroyed a residence across the street from a landfill in Cincinnati, Ohio. Minor injuries were reported (EPA 1991).

1975 In Sheridan, Colorado, landfill gas accumulated in a storm drain pipe that ran through a landfill. An explosion occurred when several children playing in the pipe lit a candle, resulting in serious injury.

1969 Methane gas migrated from an adjacent landfill into the basement of an armory in Winston-Salem, North Carolina. A lit cigarette caused the gas to explode, killing three men and seriously injuring five others (USACE 1984).

SECTION 5 - Landfill Gas Monitoring Wells

Locations

Landfill gas monitoring well locations will be site specific depending upon site geology, depth to groundwater, surface water features, on-site and off-site structures and sensitive receptors. The landfill gas monitoring wells must be spaced no more than 500 feet apart depending upon site specifics. A readily accessible, unobstructed path must be maintained so that landfill gas monitoring wells are always accessible using four-wheel drive vehicles. Regardless of site specifics, the permittee must obtain approval from the Solid Waste Section for the design and installation of any landfill gas monitoring well system.

Well Construction and Installation

Landfill gas monitoring wells are the same as groundwater monitoring wells with two exceptions. Landfill gas monitoring wells are installed just above the water table within the unsaturated zone and are equipped with a stopcock valve or a quick connect coupling on the cap, which allows for accurate landfill gas measurements. The stopcock valve must be equipped with flexible tubing and a barb connection that will fit the gas meter's inlet tube. The stopcock valve or a quick connect coupling must be closed between monitoring events. The landfill gas monitoring well must also be capped, locked, and labeled with a permanently affixed identification plate stating the well contractor name and certification number, date of well competition, total depth of well, screen length and well ID number. See detailed schematics of a landfill gas monitoring well (Figure 1).

The depth of each landfill gas monitoring well will be site specific depending upon depth to groundwater. Landfill gas monitoring wells must be constructed the same as groundwater monitoring wells as described in 15A NCAC Subchapter 2C. Typically landfill gas monitoring wells must be installed using 2" PVC piping and screen. The screen length, also site specific, must span the majority of the unsaturated zone while still allowing for proper well construction. A North Carolina Professional Geologist or Professional Engineer must be present to supervise the installation of all landfill gas monitoring wells. The exact locations, screened intervals, and nesting of the wells must be approved by the Solid Waste Section Hydrogeologist prior to landfill gas monitoring well installation. Each landfill gas monitoring well must be surveyed for location and elevation by a North Carolina Registered Land Surveyor. Within thirty (30) days of the completed construction of each new landfill gas monitoring well, the boring log and a diagram of each well including, but not limited to total depth, screened interval and distance above seasonal high water table must be submitted to the Solid Waste Section. The submittal must also include a scaled topographic map showing the location and identification of new, existing and abandoned landfill gas monitoring wells.

Nested and Clustered Landfill Gas Monitoring Wells

Nested and/or clustered landfill gas monitoring wells may be required in unsaturated zones of 45 feet or more to measure specific depths of the unsaturated zone. Initially, the installation of one long screen shall be sufficient. If a monitoring event shows an exceedance of the lower explosive limit, then the Solid Waste Section may require the installation of nested and/or clustered landfill gas monitoring wells.

Abandonment of Wells

An abandonment record must be submitted to the Solid Waste Section within 30 (thirty) days of the abandonment of a landfill gas monitoring well. The landfill gas monitoring well(s) must be overdrilled and sealed with grout in accordance with 15A NCAC 2C .0113(d) and certified by a North Carolina Professional Geologist or Professional Engineer.

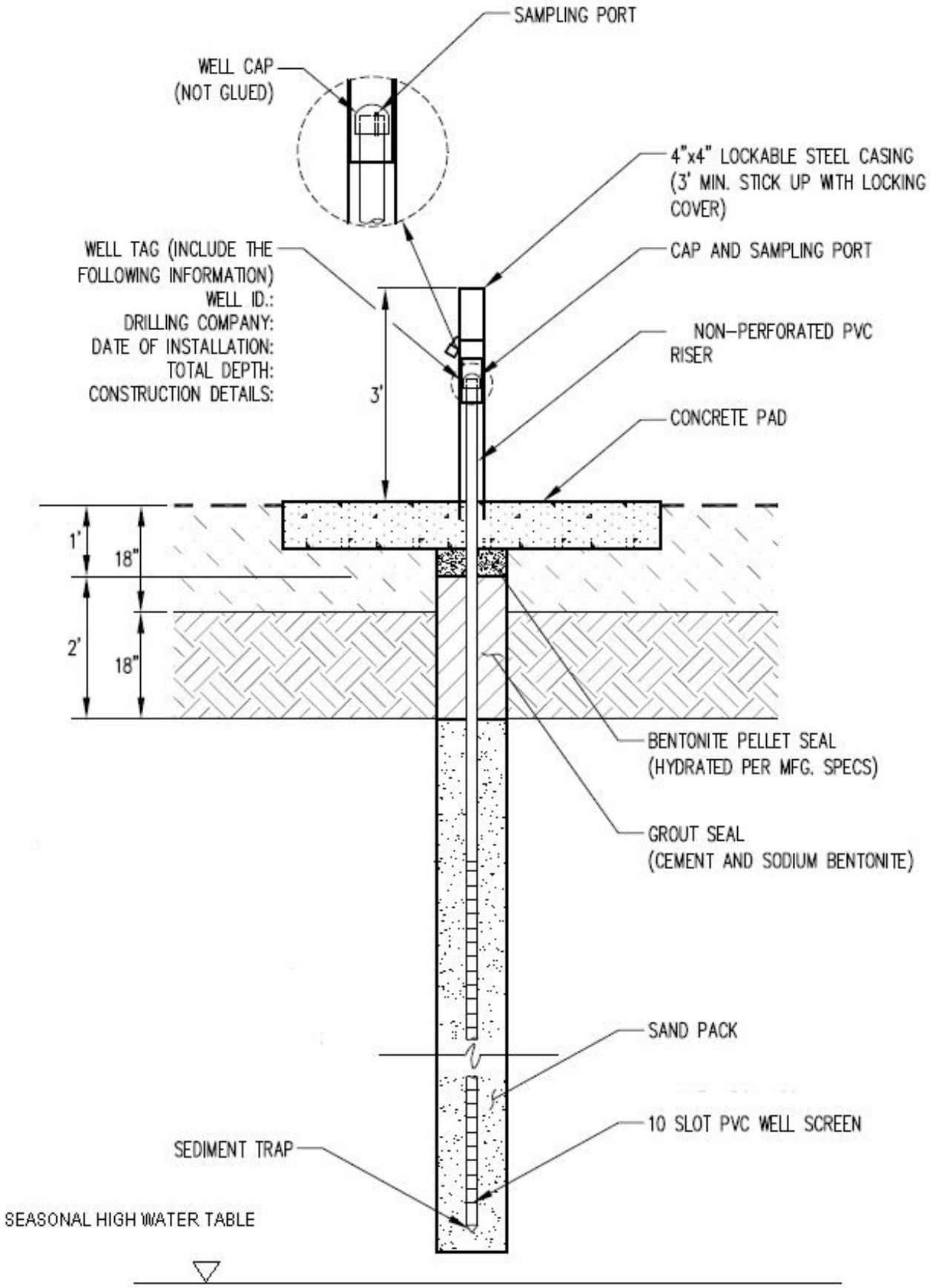
Professional Certification

The certification statement below must be signed and sealed by a North Carolina Professional Geologist or Professional Engineer and submitted with the Landfill Gas Monitoring Plan.

> The landfill gas monitoring plan for this facility has been prepared by a qualified geologist or engineer who is licensed to practice in the State of North Carolina. The plan has been prepared based on first-hand knowledge of site conditions and familiarity with North Carolina solid waste rules and industry standard protocol. This certification is made in accordance with North Carolina Solid Waste Regulations, indicating this Landfill Gas Monitoring Plan should provide early detection of any release of hazardous constituents to the uppermost aquifer, so as to be protective of public health and the environment. No other warranties, expressed or implied, are made.
>
> Signed _____
>
> Printed _____
>
> Date _____
>
> Not valid unless this document bears the seal of the above mentioned licensed professional.

In addition, the boring logs and/or well diagram must be signed and sealed with the stamp of a North Carolina Registered Land Surveyor.

Figure 1 – Landfill Gas Monitoring Well Detail



SECTION 6 – Landfill Gas Monitoring Instrumentation

The person using the landfill gas monitoring instrument must understand the principles of operation and follow the manufacturer's instructions. This includes calibrating the instrument according to the manufacturer's specifications. Include the following on the top portion of the landfill gas monitoring form (See example below) : facility name, permit number, type and serial number of gas monitoring instrument, calibration date of the instrument, date and time of field calibration, type of gas used for field calibration (15/15 or 35/50), expiration date of field calibration gas canister, date of landfill gas monitoring event, name and position of sample collector, pump rate of instrument being used, ambient air temperature, and general weather conditions. Verification that the equipment was calibrated in accordance with the manufacturer's specifications is also required. When determining which field calibration gas to use, take into consideration the expected levels of methane in the landfill gas monitoring wells. If the methane levels are expected to be low, use the 15/15 gas canister (15% CO2/15% CH4). If the methane levels are expected to be high, use the 35/50 gas canister (35% CO2/50% CH4).

For every landfill gas monitoring well, please include the following: verification of sample tube purge prior to each sample taken (should be one minute), the time pumped in seconds (should be at least one minute), barometric pressure, time stabilized reading collected, percent lower explosive limit, percent methane by volume, percent oxygen, percent carbon dioxide, and any observations or comments.

The landfill gas monitoring data form (See example below) and results should be retained in the facility's operating record unless an exceedance has occurred and/or is requested by the Solid Waste Section.

Landfill gas monitoring readings from non-calibrated or inaccurately calibrated instruments are not reliable, and will therefore be rejected by the Solid Waste Section. Landfill gas monitoring readings collected with monitoring equipment that was not designed for landfill gas monitoring will also be rejected by the Solid Waste Section. There are several different landfill gas monitoring instruments on the market which may be used in order to obtain all of the information required by the Solid Waste Section.

Monitoring Times

Monitoring times are also important when conducting landfill gas monitoring. Proper landfill gas monitoring should include sampling during times when landfill gas is most likely to migrate. Landfill gas can migrate and accumulate not only in landfill gas monitoring wells; it can also migrate and accumulate in buildings and other structures. Because subsurface gas pressures are considered to be at a maximum during the afternoon hours, monitoring should be conducted in the afternoon or whenever the barometric pressure is low.

Scientific evidence also indicates that weather and soil conditions influence the migration of landfill gas. Barometric pressure and precipitation have significant effects on landfill gas migration. Increased barometric pressure generates decreased landfill gas venting from the subsurface, until the pressure within the subsurface is greater than the atmospheric (barometric) pressure. On the other hand, when the barometric pressure decreases, the landfill will vent the stored gas until a pressure equilibrium is reached. Capping of a landfill can influence the effect of barometric pressure on landfill gas migration. Generally, a more permeable landfill cap will allow greater influence by barometric pressure than a less permeable landfill cap. As a result, landfill gas monitoring should be conducted when the barometric pressure is low and soils are saturated. During the winter season when snow cover is just beginning to melt or when the ground is frozen or ice covered, landfill gas monitoring should be conducted when the barometric pressure is low.

Landfill Gas Sampling Procedures
Any accumulation of landfill gas in the landfill gas monitoring wells is the result of landfill gas migration. The following procedure is a recommended example for conducting landfill gas monitoring well sampling, but always read and follow the manufacturer's instructions because each instrument will be different.

Step 1 – Calibrate the instrument according to the manufacturer's specifications. In addition, prepare the instrument for monitoring by allowing it to properly warm up as directed by the manufacturer. Make sure the static pressure shows a reading of zero on the instrument prior to taking the first sample.
Step 2 – Purge sample tube for at least one minute prior to taking reading. Connect the instrument tubing to the landfill gas monitoring well cap fitted with a stopcock valve or quick connect coupling.
Step 3 – Open the valve and record the initial reading and then the stabilized reading. A stable reading is one that does not vary more than 0.5 percent by volume on the instrument's scale.
Step 4 - Record the stabilized reading including the oxygen concentration and barometric pressure. A proper reading should have two percent oxygen by volume or less. If levels of oxygen are higher, it may indicate that air is being drawn into the system giving a false reading.
Step 5 – Turn the stopcock valve to the off position and disconnect the tubing.
Step 6 – Proceed to the next landfill gas monitoring well and repeat Steps 2 – 5.

Landfill Gas Constituent Sampling and Analysis
Sampling of landfill gas to determine volume percentages/concentrations of each constituent can be accomplished through the use of canisters which are specifically designed for landfill gas analysis. Several analytical methods are available to determine the concentrations of a variety of constituents. Typically, landfill gas analysis of this type is performed to determine the non-methane organic compounds emission rate for Tier 2 testing under the Clean Air Act (Title V Subpart WWW 60.754). Isotropic identification of landfill methane can be accomplished to identify one source of methane from another. In this case, isotopes of carbon and hydrogen in the methane are analyzed to determine the methane source.

NC Division of Waste Management - Solid Waste Section

Landfill Gas Monitoring Data Form

Notice: This form and any information attached to it are "Public Records" as defined in NC General Statute 132-1. As such, these documents are available for inspection and examination by any person upon request (NC General Statute 132-6).

Facility Name: _____ Permit Number: _____

Date of Sampling: _____ NC Landfill Rule (.0500 or .1600): _____

Name and Position of Sample Collector: _____

Type and Serial Number of Gas Meter: _____ Calibration Date of Gas Meter: _____

Date and Time of Field Calibration: _____

Type of Field Calibration Gas (15/15 or 35/50): _____ Expiration Date of Field Calibration Gas Canister: _____

Pump Rate of Gas Meter: _____

Ambient Air Temperature: _____ Barometric Pressure: _____ General Weather Conditions: _____

Instructions: Under "Location or LFG Well" identify the monitoring wells or describe the location for other tests (e.g., inside buildings). A drawing showing the location of test must be attached. Report methane readings in both % LEL and % methane by volume. A reading in percent methane by volume can be converted to % LEL as follows: % methane by volume = % LEL/20

Location or LFG Well ID	Sample Tube Purge	Time	Time Pumped (s)	Initial %LEL	Stabilized %LEL	%CH4 by Volume	%O2	%CO2	Notes

If your facility has more gas monitoring locations than there is room on this form, please attach additional sheets listing the same information as contained on this form.

Certification
To the best of my knowledge, the information reported and statements made on this data submittal and attachments are true and correct. I am aware that there are significant penalties for making any false statement, representation, or certification including the possibility of a fine and imprisonment.

_____ _____
SIGNATURE TITLE

SECTION 7 - References

Agency for Toxic Substances & Disease Registry. "Landfill Gas Primer- An Overview for Environmental Health Professionals. 2001." http://www.atsdr.cdc.gov/HAC/landfill/html/toc.html (accessed February 24. 2010).

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Florida Department of Environmental Protection. Gas Management Systems, under Rule 62-701.530. http://www.dep.state.fl.us/waste/quick_topics/rules/default.htm (accessed February 24, 2010).

Missouri Department of Natural Resources, Flood Grant Team. "An Analysis of Landfill Gas Monitoring Well Design and Construction, 2007". http://www.clu-in.org/conf/itrc/directpush/prez/Missouri_Study.pdf (accessed February 24, 2010).

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Wisconsin Department of Natural Resources. Environmental Monitoring for Landfills, under Chapter NR 507.22. http://www.dnr.state.wi.us/org/aw/wm/information/wiacsss.htm (accessed February 24, 2010).

"Landfill Gas-an Overview" Landfill-gas.com. Web, 22, Feb. 2010 http://www.landfill-gas.com/webpage -LFG-overview.doc

SECTION 8 – Suggested Outline for a Landfill Gas Monitoring Plan

1. Introduction
   1.1. Background (project overview, site observations, NCDENR rules referenced)
   1.2. Site Geology with discussion of groundwater depth and flow (potentiometric surface map)
   1.3. Regulatory Limits
2. Landfill Gas Monitoring
   2.1. Landfill Gas Monitoring Well Locations (discussion of reasoning behind proposed locations, discussion of well construction, reference map showing proposed locations, reference table displaying well ID, well depth, screen interval and depth to groundwater)
   2.2. Structure and Ambient Sampling
   2.3. Landfill Gas Monitoring Frequency
3. Landfill Gas Sampling Procedures
   3.1. Detection Equipment Used (discussion of calibration procedures)
   3.2. Landfill Gas Sampling Procedure
4. Record Keeping and Reporting
   4.1. Landfill Gas Monitoring Data Form
   4.2. Sampling Reports
   4.3. Permanent Record Keeping
5. Contingency Plan
6. Certification of Professional Geologist or Professional Engineer
7. Certification of Registered Land Surveyor

Figures

Map displaying proposed landfill gas monitoring well locations

Potentiometric Surface Map

Diagram showing construction of stopcock valve or quick connect coupling on well cap

Diagram showing well construction of each landfill gas monitoring well

Table

Table displaying well ID, well depth, screen interval, depth to groundwater

Example of landfill gas monitoring data form

SECTION 9 – Checklist of Items to be Included in a Landfill Gas Monitoring Plan

1. Depth to groundwater discussion
2. Well locations
    a. Number of wells
    b. Well spacing
3. Instrumentation being used
    a. Calibration procedures
4. Sampling procedures as per the manufacture's instructions
5. Map of well locations
6. Table describing each well location
    a. Well ID
    b. Well depth
    c. Screen interval
    d. Depth to groundwater
    e. Subsurface lithology
7. Diagram of cap construction w/ stopcock valve or quick connect coupling
8. Diagram of well construction
9. Potentiometric surface map
10. Professional Geologist or Professional Engineer certification
11. Registered Land Surveyor certification