Extraction Oil and Gas

Excavation Procedure for Nashland #1 Re-entry

May 10, 2021

Nashland #1 (an orphan well) is located underneath the West wastewater lagoon at Hirsch Dairy. The well is needing to be accessed and re-plugged. This Re-Entry Plan provide steps that will be taken to protect the integrity of the lagoon, groundwater, and allow the operator to continue to operate the dairy operation in compliance with the applicable and Colorado Department of Public Health and Environment (CDPHE) and Weld County regulations at the time of the executed agreement between Hirsch Dairy and Extraction Oil and Gas.

Steps in sequential order:

1. Obtain necessary State and County permits, including but not limited to construction storm water permits. Copies of these permits shall be provided to Hirsch Dairy prior to mobilizing to the property.
2. Implement stormwater permit plan elements.
3. Install retention berm (natural material) to area around existing casing to allow for rig access. The retention berm will be constructed to separate the process water and the well area. The retention berm will be compacted to reduce horizontal water movement through the berm (Attachment 1: Grading Plan and Cross Sections).
4. Strip and stockpile staging area to the south of pond area to allow for truck and materials staging due to limited space around existing well.
5. At minimum, 56 - 600 BBL Frac Tanks will be brought on site, totaling 1.4 million gallons or 4.3 acre-ft, the volume that was displaced by the installation of the retention berm for the re-plugging operation. The Frac Tanks will be placed south of the pond in between the topsoil stockpiles. A 1' berm will be placed around the Frac Tanks for secondary containment.
    a. Should the berm be moved closer to the well head, there will be excess capacity already on-site. Should the berm be slightly further away, additional frac tanks can be brought on-site to accommodate this. Additional frac tanks are readily available and they will be brought on-site prior to water being moved out of the re-plugging area.
    b. The 1' berm over an approximate 1.7-acre area is sufficient for 1.2 acre-ft of secondary containment (area of capacity minus the volume the tanks take up). To be conservative, secondary containment was designed for one fourth of the frac tanks of 1.1 acre-ft of storage (Attachment 2: Secondary Containment Calculations).
    c. Should the secondary containment need to be used, a hydro-vac will be available on-site to clean the wastewater out of the secondary containment and return it to the other frac tanks. The incident will be evaluated, and necessary repairs will be completed.
    d. If wastewater is returned to the pond, it will be returned at a low rate that should not cause erosion. The operator will observe the operation, and should erosion start to occur the pumping will be ceased immediately, if any sign of erosion starts to occur, temporary riprap will be placed.
6. If the existing lagoon gauge is located within the sectioned off part of the lagoon, it will be relocated to the other section of the wastewater pond. The temporary pumpdown has been

evaluated and is located at approximately 2.4 feet from bottom of pond (existing pumpdown is at approximately 2.8 feet). From the Hirsch Dairy Facility Management Plan (FMP), prepared by Paragon Consulting Group, Inc. (Paragon) the storm event is 6.7 acre-feet. The stage-storage relationship was estimated by AGPROfessionals from the grading plans provided by 609 Consulting, LLC (Attachment 3: Stage Storage Tables).

   a. Extraction Oil and Gas will provide daily readings of the pond levels and frac tank levels to Hirsch Dairy. If the pond goes over pumpdown or the dairy does not have the 6.7 acre-feet capacity remaining in the pond or frac tank, Hirsch Dairy will be notified. Extraction Oil and Gas will run the pump from the pond to the frac tank and/or from the frac tanks to the pond as desired by Hirsch Dairy. Hirsch Dairy will be responsible for managing the dairy under the Facility Management Plan (FMP) and Nutrient Management Plan (NMP).
   b. The goal to complete this procedure will be prior to irrigation season or after irrigation season to allow Hirsch Dairy to get maximum yield from his field. Should irrigation water arrive during the process of the operation, Extraction Oil and Gas will work with Hirsch Dairy to transfer water as needed to the Frac Tanks. It will be the responsibility of Hirsch Dairy to maintain stormwater capacity and land apply at agronomic rates as set forth in their NMP. The content in the frac tanks and the lagoon is the same and should have already been sampled in accordance with the NMP.

7. Remove wastewater inside of sectioned off area using hydro-vac. Water will be pumped into the on-site frac tanks.
   a. A temporary 6” trash pump will be on-site to transfer the process water to the frac tanks to maintain the temporary pumpdown as described above.
   b. It is estimated that approximately 21,600 gallons per day of process water is flowing into the ponds (from Paragon Consulting Group). A 6” pump is estimated at 23-34 bbls/minute (966 gpm). To be conservative, 25% reduction in the optimum pumping was used. The 25% reduction is approximately 725 gpm. This capacity would pump the daily process water into the frac tanks in approximately 30 minutes.
   c. A back-up 4” trash pump will be kept on-site if the 6” trash pump goes down or gets plugged. The 4” trash pump can pump at 10-11 bbls/minute (420 gpm). A 25% reduction is 315 gpm, which can transfer the process water to the frac tanks in approximately one hour.
8. Remove sediment and solids from the well area. The existing clay liner near the existing well head will be removed only after all the sediments and solids have been removed. (Possible change once suitable subgrade is located below existing clay liner.)
   a. Excavation equipment will push existing sediment and solids to hydro-vac for removal. Loader or excavator will be used to load out solid material for transport off site. Transport may involve stockpiling excavated material onsite for future use by the landowner depending on prior agreement between the excavating contractor and landowner. If the landowner does not want to reuse the excavated material, it will be hauled to the nearest landfill. If any solids are land applied, the on-site nutrient management plan will be followed, and nutrient samples taken.
   b. Once the sediment and solids are removed, Paragon Consulting Group will be notified in writing at least five business days before the existing liner is to be removed so they can observe the removal of the existing liner.

    c. The clay liner will only be removed in the area where the well head will be accessed.
9. Install and compact new road base on excavated pond area to allow for stable surface conditions for Rig move in. Additional stabilization might be needed.
    a. This step is an option only if needed. Once the existing clay liner is excavated, a decision will be made by the Extraction company representative as to whether the existing subgrade is suitable for rig access.
10. Excavate around existing well casing to allow for welder to attach new surface head to casing.
    a. This step is an option only if needed due to existing casing height from new subgrade.
11. Rig moves into location.
    a. Due to limited space on location during rig operations, equipment will move off location unless needed to assist with rig and truck movement into and out of location.
    b. During the entire process, visual inspections of the area will be conducted to ensure berm stability and prevent any manure/wastewater from entering the working area. Should manure or wastewater come in contact with the working area, work will immediately be stopped, and pumping or scraping will remove any manure/wastewater. The area where manure/wastewater entered the working area will be repaired and recompacted.

Excavation Procedure and Relining of Pond for Nashland #1 Re-entry

12. Removal of installed road base in excavated pond area.
    a. If Step 9 was executed, then this step will be required, if not this step will be skipped.

    Removal will include stripping installed road base, load out and export. Export materials can be hauled to the nearest landfill or stockpiled on site pending the landowners possible use of the material.
13. Install new liner to cover entire disturbed and excavated pond area where the liner was damaged or removed. Either clay or bentonite will be used to repair the excavated liner area.
    a. If a clay liner is installed:
        i. The clay will have a permeability and proctor test completed by a professional engineer that meets the seepage rate of $1x10^{-6}$ cm/sec as required by the CDPHE Ag Program. The test results will be submitted to Hirsch Dairy.
            1. The lab results will provide specification for optimum moisture, compaction, and thickness of the clay liner to be installed and will be stamped by a Professional Engineer.
            2. The permeability and proctor testing report will be sent to Paragon Consulting Group and Hirsch Dairy at least 10 business days before commencing installation. A written reinstallation schedule will be provided to Paragon Consulting Group at least 10 business days before starting work.
            3. Once the new clay liner finish grade matches the existing clay liner and correct compaction percentages are achieved, the edge of the new clay liner and the edge of the existing clay liner will be scarified together and

re compacted to the correct moisture and compaction percentage to ensure a proper seal of the new clay to the existing clay.

4. A third-party Geotechnical Engineering Company will verify thickness, compaction and installation.
    a. Options for local Geotech firms include Earth Engineering Consultants (EEC) or Soilogic.

b. If clay liner material is not available or the work area does not allow for proper compaction of the clay liner, bentonite will be brought in to be used for the new section of liner.

14. Should the existing pond berm have been damaged, the area will be patched, repaired with approved liner material, and re-certified in the same manner as the well area. This is not anticipated.
15. The retention berm around well casing will be removed, and pond returned to full capacity.
16. Replace stripped topsoil in staging area.
17. Final regrade of affected areas will be completed.
    a. Entire affected area will be clean, free of debris and finish graded to match conditions that existed prior to mobilization off location. Extraction Oil and Gas will photograph the area pre- and post-construction to verify the area has been cleared.
    b. Once the wastewater has been land applied or placed back into the lagoon out of the frac tanks, the solids left in the frac tank will either be relocated off-site or provided to Hirsch Dairy for Land Application. The frac tanks will be removed. The secondary containment will be removed a regraded back to original grades and soil conditions/type.

Additions:

Due to certain unknowns about existing conditions, the sequential procedure may change or fluctuate. At this time, the depth of saturated sediment under the clay liner is unknown, therefore the quantity of material to be excavated is to be determined upon initial excavation.

The excavating portion of this project will be broken down into four phases.

- Phase 1 will consist of removal of all materials needed to gain access to the well.
- Phase 2 will be an optional phase consisting of the needed procedures to make the subgrade safe and suitable for rig operations.
- Phase 3 will consist of deconstruction and removal of any materials imported to stabilize the subgrade for rig operations.
- Phase 4 will consist of repairing the clay liner, replacing the retention berm, replacing stripped topsoil in staging area, final grade and cleanup of location.

Record documentation and recertification of the liner material will be stamped by a Colorado Professional Engineer and provided to CDPHE Ag Program and Hirsch Dairy.

For the Health and Safety of the Owner, Contractor and anyone working around manure or wastewater impoundments, it is important for each worker to be trained and properly equipped for confined spaces and working in areas with the potential of hydrogen sulfide and methane gas. Concentrations change over time and understanding how much gas is in the manure storage pit before each entry is important to prevent injury or death. A monitoring plan should be implemented by the operator prior to beginning the procedure. The plan should be developed and implemented by Extraction Oil and Gas. AGPRO is not responsible for the Health and Safety Plan. Technical Guidance Document for Identifying Hazardous Gas is Attachment 4.

Materials List*:

- 500 linear feet of retention berm to section off working area around well.
- 1800 Cu. Yds. (+/-) of new certified 80% clay material to patch clay liner. The clay will have a permeability and proctor completed on the soil with compaction requirements.
- 800 Cu. Yds. of road base to stabilize subgrade for rig operations.
- Fill dirt to fill subgrade level back up to bottom of clay liner.

*Currently, due to unknown existing conditions, the quantities are estimates. It is unknown how deep the saturation goes below the clay liner, therefore the depth of over excavation below the existing clay liner is unknown as well. Once the excavation process has started, decisions based on existing conditions will be discussed and agreed upon by Patriot Excavating and the Extraction representative on the best course of action to make the area suitable and safe for rig operations.

Comments:

- At this time, it is believed that the most efficient option to add additional wastewater capacity is the use of frac tanks.
    - The frac tanks used will be compliant with the specifications required by the state of Colorado. The frac tanks will hold, at minimum, the same volume of water that was displaced by the re-plugging operation.
    - With the frac tanks, the dairy will continue to have the same volume of wastewater storage. The dairy will be able to continue to operate without any disturbance to his operation.
- Upon agreement with the landowner, it would be ideal to completely drain the pond near the end of crop irrigation season.
    - With lower water levels the transportation of wastewater will be lower, and the excavation of sediment, solids, and existing clay liner can be completed without damage done to the surrounding clay liner.
- It is believed that the sub grade under the existing clay liner will be semi-stable and with minor compaction will be suitable for rig operations. However, stabilization equipment and road base are available if the sub grade is not suitable.
- In the event of substantial rainfall during rig operations, dewatering measures will be discussed, agreed upon and in place to make sure the subgrade remains stable and suitable for continued rig operations until project completion.
- Along with the frac tanks, water diversion will be installed with proper sloping, to direct water to the perimeter of the working area for pumping and dewatering purposes.
- Pumps will be on location and set in designated spots for immediate access in the event of substantial rainfall.
- As an extra precaution, rig mats may also be installed to further stabilize the working area and protect the undisturbed clay liner.
- Once rig operations are complete and the pad material is removed (if applicable), new certified clay will be installed. The use of Geosynthetic Clay Liner would not be ideal unless it was used on the entire pond area. Compaction and testing of new certified clay to patch the clay liner will ensure no leaks are present or anticipated.

Certifications

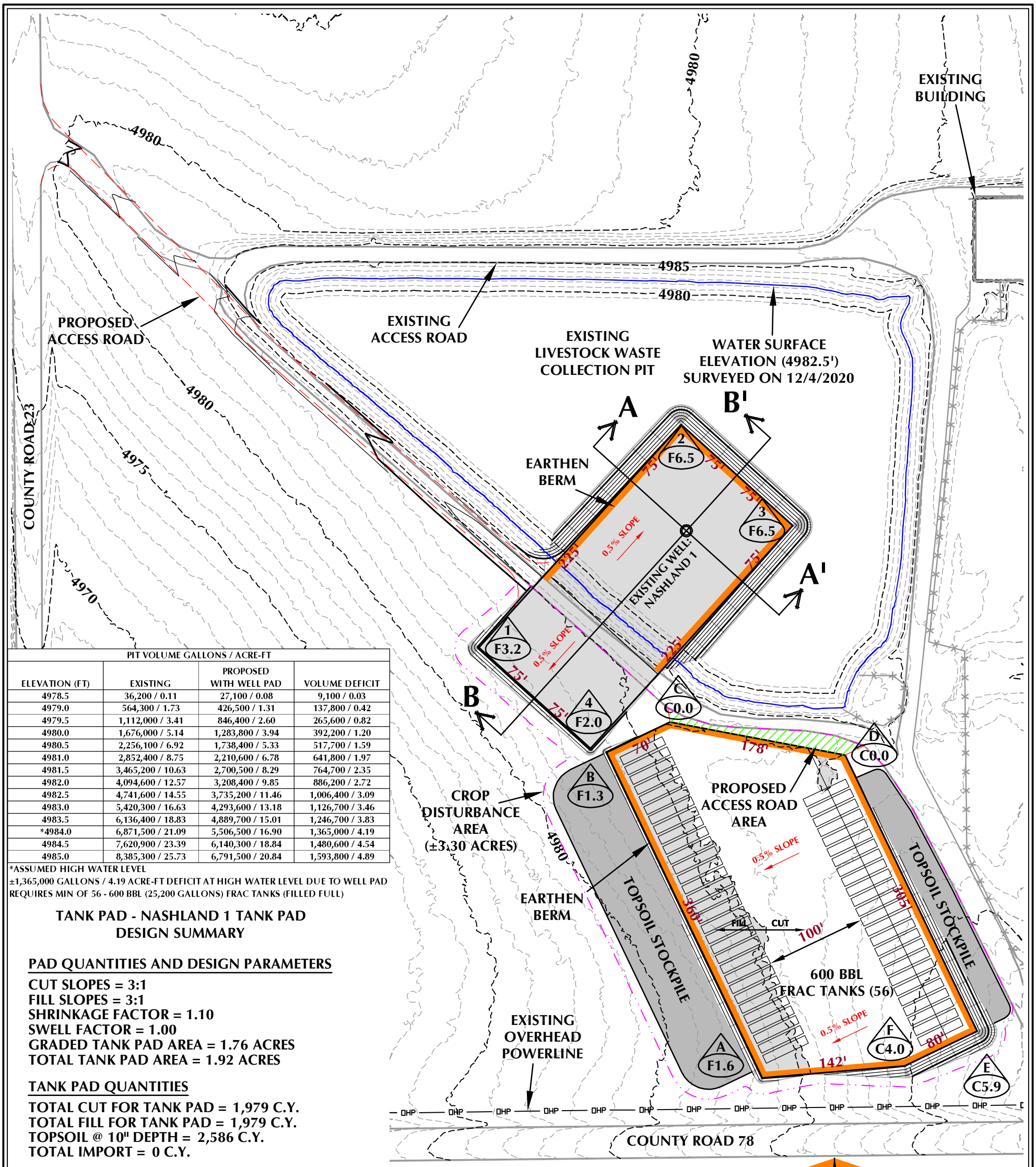
This procedure to be completed at Hirsch Dairy was reviewed and meets or exceeds the requirements in CDPHE-Ag Program's Regulation 81 as it relates to Confined Animal Feeding Operations (CAFOs) and liner certification compliance. Grading Plans, Stormwater Plans, well capping procedures were provided and certified by others.

Chad TeVelde, P.E.

AGPROfessionals

Attachment 1

Grading Plan and Cross Sections



PIT VOLUME GALLONS / ACRE-FT			
ELEVATION (FT)	EXISTING	PROPOSED WITH WELL PAD	VOLUME DEFICIT
4978.5	36,200 / 0.11	27,100 / 0.08	9,100 / 0.03
4979.0	564,300 / 1.73	426,500 / 1.31	137,800 / 0.42
4979.5	1,112,000 / 3.41	846,400 / 2.60	265,600 / 0.82
4980.0	1,676,000 / 5.14	1,283,800 / 3.94	392,200 / 1.20
4980.5	2,256,100 / 6.92	1,738,400 / 5.33	517,700 / 1.59
4981.0	2,852,400 / 8.75	2,210,600 / 6.78	641,800 / 1.97
4981.5	3,465,200 / 10.63	2,700,500 / 8.29	764,700 / 2.35
4982.0	4,094,600 / 12.57	3,208,400 / 9.85	886,200 / 2.72
4982.5	4,741,600 / 14.55	3,735,200 / 11.46	1,006,400 / 3.09
4983.0	5,420,300 / 16.63	4,293,600 / 13.18	1,126,700 / 3.46
4983.5	6,136,400 / 18.83	4,889,700 / 15.01	1,246,700 / 3.83
*4984.0	6,871,500 / 21.09	5,506,500 / 16.90	1,365,000 / 4.19
4984.5	7,620,900 / 23.39	6,140,300 / 18.84	1,480,600 / 4.54
4985.0	8,385,300 / 25.73	6,791,500 / 20.84	1,593,800 / 4.89

*ASSUMED HIGH WATER LEVEL
±1,365,000 GALLONS / 4.19 ACRE-FT DEFICIT AT HIGH WATER LEVEL DUE TO WELL PAD
REQUIRES MIN OF 56 - 600 BBL (25,200 GALLONS) FRAC TANKS (FILLED FULL)

TANK PAD - NASHLAND 1 TANK PAD DESIGN SUMMARY

PAD QUANTITIES AND DESIGN PARAMETERS

CUT SLOPES = 3:1
FILL SLOPES = 3:1
SHRINKAGE FACTOR = 1.10
SWELL FACTOR = 1.00
GRADED TANK PAD AREA = 1.76 ACRES
TOTAL TANK PAD AREA = 1.92 ACRES

TANK PAD QUANTITIES

TOTAL CUT FOR TANK PAD = 1,979 C.Y.
TOTAL FILL FOR TANK PAD = 1,979 C.Y.
TOPSOIL @ 10" DEPTH = 2,586 C.Y.
TOTAL IMPORT = 0 C.Y.

NOTE:

1. EXISTING UTILITIES DISPLAYED ON THE GRADING PLAN ARE FOR REFERENCE PURPOSES ONLY. PRIOR TO CONSTRUCTION OR EARTHWORK, CONTRACTOR WILL BE RESPONSIBLE TO CALL FOR LOCATES: (800) 922-1987
2. ASSUMED BOTTOM OF PIT ELEVATION 4978.5'
3. ASSUMED PIT HIGH WATER LEVEL 4984.0'
4. ASSUMED PIT SPILL ELEVATION 4985.1'

EARTHEN BERM (TYP.)
1,125 LINEAR FEET = 125 C.Y. (TANK PAD)
500 LINEAR FEET = 55 C.Y. (WELL PAD)

WELL NAME:	C/F
NASHLAND 1	F6.9

WELL PAD - NASHLAND 1 DESIGN SUMMARY

WELL PAD QUANTITIES AND DESIGN PARAMETERS

EXISTING GRADE @ CENTER OF WELL PAD = 4978.5'
FINISHED GRADE ELEVATION = 4985.4'
CUT SLOPES = 3:1
FILL SLOPES = 3:1
SHRINKAGE FACTOR = 1.10
SWELL FACTOR = 1.00
GRADED WELL PAD SURFACE AREA = 1.03 ACRES
TOTAL WELL PAD AREA = 1.34 ACRES

WELL PAD QUANTITIES

TOTAL CUT FOR WELL PAD = 14 C.Y.
TOTAL FILL FOR WELL PAD = 10,585 C.Y.
TOPSOIL @ 10" DEPTH = 468 C.Y.
TOTAL IMPORT = 10,571 C.Y.

WELL PAD LEGEND

- EXISTING WELL LOCATION
- PROPOSED WELL LOCATION
- EXISTING CONTOURS (1' INTERVAL)
- PROPOSED CONTOURS (1' INTERVAL)
- EPL — EXISTING PIPELINE
- PPL — PROPOSED PIPELINE
- EXISTING FENCE
- PUE — PROPOSED UNDERGROUND ELECTRIC LINE
- EARTHEN BERM

HORIZONTAL 0 50' 100' 1" = 100'
2' CONTOURS

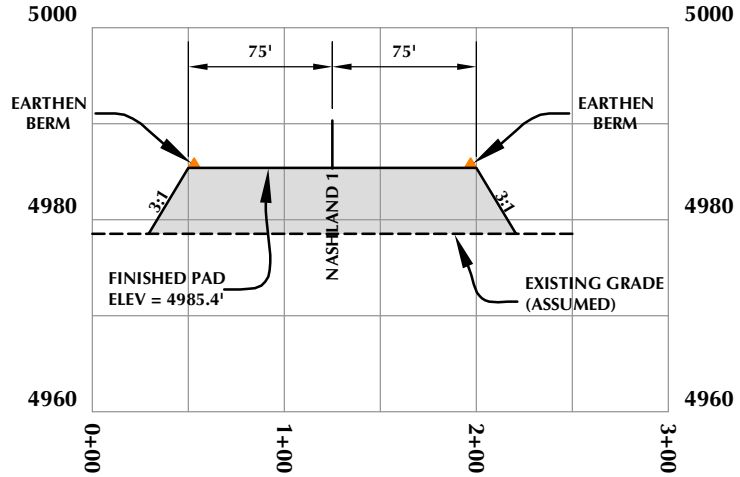
WELL PAD - NASHLAND 1

WELL PAD - GRADING PLAN
NASHLAND 1
LOCATED IN SECTION 24
T7N, R67W, 6TH P.M.
WELD COUNTY, COLORADO

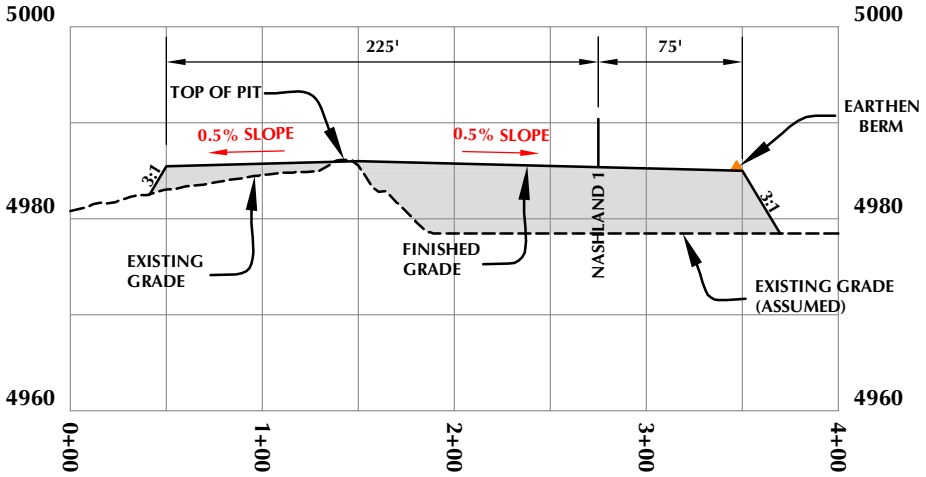
EXTRACTION Oil & Gas
370 17th Street
STE 5300
Denver, Colorado 80203

609 CONSULTING, LLC
LOVELAND OFFICE
6706 North Franklin Avenue
Loveland, Colorado 80538
Phone 970-776-4331
SHERIDAN OFFICE
1095 Saberton Avenue
Sheridan, Wyoming 82801
Phone 307-674-0609

SCALE: 1"=100'	DATE: 12/15/20	SHEET NO:
REVISED: JFE 5/10/21		1 1 OF 3



CROSS SECTION A-A'



CROSS SECTION B-B'

WELL PAD CROSS SECTIONS

NASHLAND 1
LOCATED IN SECTION 24
T7N, R67W, 6TH P.M.
WELD COUNTY, COLORADO

EXTRACTION Oil & Gas
370 17th Street
STE 5300
Denver, Colorado 80203

609 CONSULTING, LLC

LOVELAND OFFICE
6706 North Franklin Avenue
Loveland, Colorado 80538
Phone 970-776-4331

SHERIDAN OFFICE
1095 Saberton Avenue
Sheridan, Wyoming 82801
Phone 307-674-0609

HORIZONTAL 0 50' 100' 1" = 100'
VERTICAL 0 10' 20' 1" = 20'

SCALE: 1"=100'	DATE: 12/23/20	SHEET NO: 2
REVISED: JFE 5/10/21		2 OF 3

Attachment 2

Secondary Containment Calculations

NASHLAND #1 | REPLUGGING | 02/12/2021

Secondary Containment calculation

Berm height = 1 foot

area of secondary containment = 75510 sq.ft = 1.7 acre x 1 FT
= 1.7 ACRE-FT

tank volume at 1' = 425 cu.ft x 56 tanks = 23,800 cu ft
(600 BBL)
= 0.55 Acre-ft
assume dimension → 50' x 8.5'

volume available for secondary containment
1.7 ACRE-FT - 0.55 ACRE-FT = 1.15 ACRE-FT

TO BE CONSERVATIVE → SECONDARY CONTAINMENT FOR 1/4 OF TANKS

1 TANK = 25,200 GALLONS (600 BBL)

14 TANKS = 352,800 GALLONS = 1.08 ACRE-FT
(1/4 OF 56 TANK)

SITE ADEQUATE 1.15 ACRE-FT > 1.08 ACRE-FT ✓

TYP. REQUIREMENTS 110% OF LARGEST TANK.

1.1 x 25,200 GAL = 27,720 GAL = 0.08 ACRE-FT

Attachment 3

Stage Storage Tables

AGPROfessionals
DEVELOPERS OF AGRICULTURE

Hirsch Dairy

West Pond - Extraction Oil and Gas

Elev (ft)	Gauge Reading (ft)	Proposed Volume (w/ well pad) (ac-ft)	
4978.5	**0.0**	0.1	
4979	**0.5**	1.3	
4979.5	**1.0**	2.6	
4980	**1.5**	3.9	
4980.5	**2.0**	5.3	
4980.9	**2.4**	6.5	Pumpdown
4981	**2.5**	6.8	
4981.5	**3.0**	8.3	
4982	**3.5**	9.9	
4982.5	**4.0**	11.5	
4983	**4.5**	13.2	Freeboard
4983.5	**5.0**	15.0	
4984	**5.5**	16.9	
4984.5	**6.0**	18.8	
4985	**6.5**	20.8	TOB

*Volumes taken from Well Pad-Grading Plan from 609 Consulting LLC

AGPROfessionals
DEVELOPERS OF AGRICULTURE

Hirsch Dairy

West Pond Existing

Elev (ft)	Gauge Reading (ft)	Proposed Volume (w/ well pad) (ac-ft)	
4978.5	**0.0**	0.1	
4979	**0.5**	1.7	
4979.5	**1.0**	3.4	
4980	**1.5**	5.1	
4980.5	**2.0**	5.9	
4981	**2.5**	8.8	
4981.3	**2.8**	9.9	Pumpdown
4981.5	**3.0**	10.6	
4982	**3.5**	12.6	
4982.5	**4.0**	14.6	
4983	**4.5**	16.6	Freeboard
4983.5	**5.0**	18.8	
4984	**5.5**	21.1	
4984.5	**6.0**	23.4	
4985	**6.5**	25.7	TOB

*Volumes taken from Well Pad-Grading Plan from 609 Consulting LLC

Attachment 4

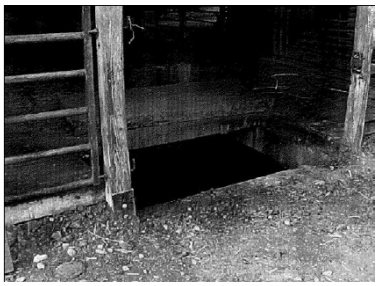
Technical Guidance for Identifying Hazardous Gas

GREAT PLAINS
Center for Agricultural Health
www.GPCAH.org

Manure Storage Pit Dangers: Identifying Hazardous Gases

Technical Guidance for Selection and Use of Monitors to Assess Air Hazards

People entering manure pits without taking proper precautions are at risk of dying from high exposures to hydrogen sulfide gas. Guidance on manure pit operations from ASABE specify the need to monitor these spaces prior to entry. This alert provides general guidance on why and how to monitor.



Access to manure pit where two died after entering a manure pit, Iowa FACE 2005 IA 024, 025.

Do not enter manure storage areas without ventilating and measuring gas concentrations.

Four Midwestern farmers died in July 2015 from gas exposures when entering manure pits:

- Palo Alto County, Iowa: Son entered manure pit to make repairs, and father entered to rescue him. Both died July 25, 2015. http://www.siouxlandmatters.com/story/d/story/palo-alto-co/38089/L8vsp-TP00OoWIs_n4MX-g
- Chippewa County, Wisconsin: Son entered manure pit to retrieve equipment, and father entered to rescue him. Both died July 2, 2015. http://www.jsonline.com/news/wisconsin/2-wisconsin-men-die-after-falling-into-manure-pit-b99532179z1-311646871.html

People cannot smell hazardous concentrations of hydrogen sulfide (H_2S) and methane (CH_4), but concentrations may be high enough to decrease oxygen or paralyze breathing. Concentrations change over time, and understanding how much gas is in the manure storage pit before each entry is important to prevent death. Monitors for measuring gas concentrations are available and should be used prior to entry into any manure storage area.

A monitoring plan should be incorporated into a confined-space program that identifies how to assess the air quality prior to entering a manure storage pit. This alert provides farmers with specific information on the hazards of manure gases, information on how to select monitoring equipment, procedures to use to safely monitor the air quality prior to entering spaces containing or previously containing manure, and how to interpret readings to ensure a safe entry. This alert *supplements* the brief hazard alert "Manure Storage Pit Dangers: Hazard Gas Awareness" to provide technical information to farmers to implement a monitoring program.

*This alert provides technical guidance to help agricultural workers understand how to **safely evaluate the air quality** in manure storage pits for safe entry into manure pits.*

Everyone who works in or around manure storage tanks /pits / lagoons should understand manure gas hazards.

Do not enter **manure storage areas until they are adequately ventilated and concentrations are verified to be safe.**

"Holding your breath" is not an acceptable strategy to safely enter into hazardous environments.

The following pages provide general guidance on how to select and use gas monitors to evaluate whether a manure pit is safe for entry.

GREAT PLAINS
Center for Agricultural Health
www.GPCAH.org

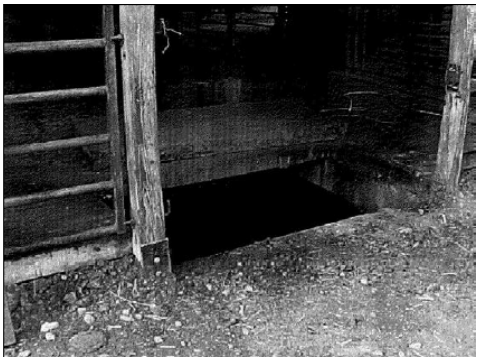
Manure Storage Pit Dangers: Identifying Hazardous Gases

Technical Guidance for Selection and Use of Monitors to Assess Air Hazards

What are the hazards?

Methane and hydrogen sulfide gases are generated naturally in all anaerobic manure pits.

Hydrogen sulfide (H_2S) has a rotten egg odor at low concentrations, but as concentration increases, people can no longer smell this compound (olfactory fatigue). At and above concentrations of 100 ppm, severe eye and lung irritation begins and pulmonary edema (a potentially fatal lung condition) may occur. Most importantly, at high concentrations (800 ppm and above), the respiratory system is paralyzed and the exposed person loses consciousness, with typically fatal outcomes. Concentrations well above 1000 ppm have been measured during manure agitation (ASABE, standard EP470.1).



Access to manure pit where two died after entering a manure pit, Iowa FACE 2005 IA 024, 025 (http://www.public-health.uiowa.edu/face/Reports/PDF-Reports/2005IA024-025.pdf)

Methane (CH_4) is also generated in manure pits. It cannot be smelled, but can be released in manure pits in concentrations that are combustible. When methane concentrations are between 5% (50,000 ppm) and 15% (150,000 ppm) and an ignition source is present (such as a pilot light, cigarette, shorting electrical wires, open torches), an explosion can occur. At these high concentrations, there is also a risk of reduced oxygen in the air: for every increased 4% of methane, the percent oxygen decreases by approximately 1%. When oxygen levels reduce from 20.9 to 19.5% (at sea level), people will not have enough oxygen. In oxygen-deficient atmospheres, a worker's pulse and breathing rate may increase and they may begin to feel nauseous. Impaired thinking, reduced coordination, and fatigue develop, and workers may faint: these safety hazards may lead to death in a manure pit.

How do know if these gases are present?

Workers should presume that these gases are present at hazardous concentrations in all manure pits. If entry into the pit is needed, a specific plan for entering is needed. This plan is referred to as a "confined space entry" program, which identifies the risks of entering a manure pit and outlines the steps for a safe entry.

See the following web sites for chemical-specific hazard information on gases common to manure pits:

Oxygen deficiency:
http://www.airproducts.com/~/media/Files/PDF/company/safetygram-17.pdf
LEL:
http://www.fireengineering.com/articles/2010/08/hazmat-atmospheric-monitors.html
Carbon monoxide:
http://ephtracking.cdc.gov/showCoRisk.action
https://www.osha.gov/Publications/3282-10N-05-English-07-18-2007.html
Hydrogen sulfide:
https://www.osha.gov/SLTC/hydrogensulfide/hazards.html
https://www.osha.gov/Publications/hydrogen_sulfide.html
Carbon dioxide:
http://www.epa.gov/ozone/snap/fire/co2/appendixb.pdf

Examples of a written confined space programs are provided at the end of this alert, for reference.

Monitors are available to test the air quality inside the manure pit. Monitors are available to measure a single gas or to measure multiple gases at the same time ("multi-gas monitors"). Identifying the presence of oxygen is important as well as identifying whether the methane is at explosive concentrations. The best monitor to select is a multi-gas monitor that has sensors for oxygen (O_2), hydrogen sulfide (H_2S), and methane or explosion (LEL or Lower Explosive Limit). Since these monitors typically have the capability for monitoring four gases at once, we recommend farmers select carbon monoxide (CO) as the fourth gas sensor, which comes in handy in the winter when gas-fired heaters may generate hazardous concentrations in livestock buildings. Ammonia (NH_3) sensors are also available, but these are expensive to purchase and calibrate, and a separate single-gas monitor is recommended for testing ammonia.

Inexpensive monitors can detect gases and indicate dangerous concentrations.

How does the monitor measure methane?

Direct reading monitors specific for combustible gases are available to measure whether methane gases are present in the air. These devices can be expensive ($600-1200 each), and units require calibration to ensure accurate readings. You should select a meter that is "intrinsically safe" so that it does not introduce a spark that might ignite the methane in the area you are testing. Rental companies (details at end of alert) can provide calibrated monitors, but it make take several days to receive rented monitors: plan to secure monitors before undertaking activities that might release methane. These meters provide readouts that will indicate the presence of methane (as LEL) to let you know if the indoor environment has a problem. Evacuate the building if you see %LEL increase when wearing / using these monitors.

If you are using an LEL monitors with catalytic (or "pellistor") sensors, oxygen is required for the LEL sensor to work properly. If there is insufficient oxygen, the LEL sensor will underestimate the risk of explosion. *If oxygen is lower than 20.9%*, presume that the *LEL risk is higher* than the monitor indicates, and do not enter the area.

What does %LEL mean?

The reading on most combustion meters indicate the gas concentration relative to its ability to combust or explode. Meters indicate the gas concentration in percent of the lower explosive limit (%LEL). Normal air should read 0% LEL.

Combustion monitors provide readings in terms of %LEL. At 100% LEL, the concentration of the gas is at the lower explosive limit. If the gas is methane, the

Using Gas Monitors – Methane as % LEL (Lower Explosive Limit)

1. There must be sufficient oxygen in the environment for an LEL monitor to read correctly, so a multi-gas monitor that also reads oxygen is recommended.
2. Gas monitors should be calibrated, at least as frequently as is specified by the manufacturer's directions. Follow calibration procedures in a safe area, where concentrations are anticipated to represent clean air.
3. To make sure the sensors are working before needing to rely on them to protect you, bump test the monitor with gas to make sure the sensors can "see" the gas and the monitor alarms to give you warning. You can use the calibration gas to do this check (without putting the monitor in calibration mode).
4. If oxygen content *decreases* when using an LEL meter, the %LEL reading will be wrong: Respond to a LOW Oxygen reading as an indication of dangerous LEL and evacuate.

lower explosive limit is 5% in air, or 50,000 ppm. Therefore, when the monitor reads "10% LEL", this means that the methane concentration is approximately 5000 ppm
(calculated by: 0.10 x 50,000 ppm).

How do I respond to a reading of %LEL in a manure storage area?

Fire risk is *high* when the monitor indicates 10% LEL or greater. Confined space programs should specify "no entry" when 5% LEL is measured. Why this factor of safety? This is because you are only monitoring one area of the manure storage pit, and concentrations might be higher in other areas. If someone enters the pit and generates a spark in an area of high methane, an explosion can occur. The storage area should be ventilated (see ASABE S607) and the space retested prior to allowing entry.

Note that the meter only reads the concentration in the immediate vicinity of the monitor: if there is little air movement in the room, you may have pockets of air at dangerous concentrations. Hence, it is critical to have turned off electrical sources and prevent sparking (hitting metal on metal, electrical equipment cycling on/off) when testing these spaces.

How does a monitor measure hydrogen sulfide (H_2S)?

Direct reading monitors specific for hydrogen sulfide as a single gas component are available for $100-200, each. These units also require calibration to ensure accurate readings and testing to make sure the sensor is still working. Rental companies can provide calibrated monitors, but plan ahead to make sure you have monitors for manure pit activities, including pumping and entry. These meters provide readouts that will indicate the presence of hydrogen sulfide to let you know if the indoor environment has a problem.

Using Gas Monitors – Hydrogen Sulfide (H_2S)

1. Gas monitors should be calibrated, at least as frequently as is specified by the manufacturer's directions. Follow calibration procedures in a safe area, where concentrations are anticipated to represent clean air.
2. To make sure the sensors are working before needing to rely on them to protect you, bump test the monitor with gas to make sure the sensors can "see" the gas and the monitor alarms to give you warning. You can use the calibration gas to do this check (without putting the monitor in calibration mode).
3. When performing a bump check, evaluate how long it takes for the monitor to display the concentration that matches the one in your calibration gas. If this starts to take longer than it did last time (or longer than the manufacturer's book indicates), it is time to order a new sensor and replace it so you are ready the next time you need it.

Know the limitations of the sensor that you have. Traditional hydrogen sulfide sensors use metal oxide semiconductors or electrochemical sensors. Metal oxide sensors have *slower response times* (up to 120 seconds) and *may have difficulty responding to low concentrations* until a "bump" test (putting high concentration of hydrogen sulfide gas onto the sensor), although new nano-technology sensors may be improving these devices. Alternatively, traditional electrochemical sensors operate by measuring a voltage change from a chemical reaction between the sensor chemicals and hydrogen sulfide in the air: the voltage change is converted to concentration information in the monitor display. Note that these sensors *may take 30 seconds to respond* to hydrogen sulfide, and many *do not respond well in cold (-20^o C) temperatures*.

Hydrogen sulfide monitors have been typically set to alarm at 10 or 15 ppm. These are old concentration limits that were set by the American Conference of Governmental Industrial Hygienists (ACGIH) to protect workers over an 8-hour and 15-minute work duration, respectively. **Current exposure limits are now set at 1 and**

5 ppm, and it is appropriate to set alarms to these new limits. Note that OSHA regulations specify that workers not exceed 20 ppm at any time, with a 50 ppm exposure ceiling for 10 minutes if there is no other exposure occurs. These levels may not be protective of human health.

How do I get the sampler into the area I need to monitor?

To minimize the risk to the worker during monitoring, you need to make sure the sampler measures the air *before* a person has a chance to breathe the air. Stand outside the manure pit and place the monitor inside the air space of a manure pit. Take care not to get liquid onto or into the monitor, as this will foul the sensor and make it unusable.

Some monitors have an internal pump and allow you to put an extension wand on the end of the unit, with an approved tubing to go onto the end. This pump and tubing allows you to measure air far away from where you stand. If you don't have a monitor with a pump to draw air into the sampler, you can secure the monitor to the end of a long stick (for putting the monitor into a space laterally) or rope (if lowering the monitor into a space). When putting the monitor into the space, remain outside the space where the air is "clean". You want to be able to see the readout on the monitor when you are testing the air. If concentrations exceed the alarm levels, the unit will vibrate and the display will probably be flashing: this alarming will let you know *it is not safe to enter* without first ventilating the manure storage pit.

Once the area is tested while standing from the outside, if it is safe to enter, measure air quality in the path that you need to travel in order to do the job that makes you go into the pit. Follow testing methods for "stratified atmospheres", by testing in the direction of needed travel: check at least 4 feet in front of you, in the direction of travel, *and* 4 feet to each side when checking for safe entry.

Remember, however, that it takes TIME for the monitor to react to the chemical in the air and time for the pump to move the air from the pit onto the sensor. Therefore, sampling the air to make sure it is safe to breathe ***will take time***.

The time it takes to test air at each location in the manure storage pit should be a function of the sensor with the longest response time: check the manufacturer's manual for each sensor's response time. If using a pump system, *add to the sensor response time* the time it will take to pull air into the sensing area of the monitor. See the side box for an example of how to calculate the time it will take for the monitor to measure gas at a given location, using sample manufacturer's data in the operation manual.

The order of testing is important if you do not have a multi-gas monitor. Oxygen must be sampled for first, followed by combustible/flammables (methane as %LEL), followed by toxic chemicals (hydrogen sulfide).

Example TIME Calculation for sampling:

1. Identify the maximum response time of sensor in the manual. For this device, the manual provides time to achieve 90% of final reading, when within normal temperature range (0-40°C), in:
    a. O_2: 30 sec
    b. LEL: 30 sec
    c. CO: 60 sec
    d. H_2S: 60 sec
    *Hence, max response time is **60 seconds**.*
2. Look up the sample time for the monitor's pump specs, based on sample line length:

Table 1-1. Device Specifications

TEMPERATURE RANGE	**NORMAL**	-20 to +50°C (-4 t
SAMPLE LINE TRANSPORT TIMES	25 feet 50 feet	10 seconds 20 seconds

25 feet: **10 seconds**

3. ***Total Time to Sample at each location*: 70 seconds**.

How do I interpret the monitor readings?

See the table below. The "High Alarm" typically results in louder alarm than the low, or first, alarm. If you don't have two alarm set points, choose the low alarm setting in the table. IDLH is the concentration that is "immediately dangerous to life and health," which is established by NIOSH (the National Institute of Occupational Safety and Health). The IDLH values identify concentrations that are ACUTELY hazardous (Danger!). If the monitor displays concentrations that are at or above the IDLH, *immediately leave the area*. The actions indicated are for the ***acute hazards to the person conducting monitoring***. To safely work in the area, concentrations need ***to be below the alarm set points***, as indicated.

	Set Alarm Levels*			
Contaminant	Low Alarm	High Alarm	IDLH	Notes
Oxygen, % (at sea level)	19.5	19	*No IDLH: Leave if reach 19.5%*	LEL may not read correctly if <19.5%. This presumes no O_2 generation sources.
LEL, %*♦	5	10	Asphyxiant; watch Oxygen% changes	Remove all workers, animals from room if pit > 50% LEL as methane (25,000 ppm)**
CO, ppm	25	50	1000	Headache at 100-400 ppm. If develop flu-like symptoms quickly; get out.
H_2S, ppm	1	5	100	Remove all workers, animals from room if pit gas > 80 ppm.**
NH_3, ppm	25	35	300	Eye irritation may prevent safe action above 140 ppm; lung irritation @ 100 ppm.
CO_2, ppm♦	5000	-	40,000 (4%) will displace oxgen	Remove all workers, animals from room if pit gas > 32,000 ppm.**

*Note: If you don't calibrate the LEL sensor with methane, you need to know the response to the calibration gas and how it relates to methane. For example, calibration with pentane typically gives you %LEL readings higher than the true LEL. Check the operation manual for the sensor and monitor you have.

♦If CO_2 and %LEL reach significant levels, it will displace oxygen. Watch changes in Oxygen % as an indicator of significant concentrations of these two contamiants combined.

** See ASABE S607 Table 7.

Who can I contact for more information?

The faculty and staff of the Great Plains Center for Agricultural Health are able to help you with monitoring questions. Contact CPH-GreatPlainsCenter@uiowa.edu for assistance. We are glad to provide hands-on training and education to groups of interested farmers, emergency responders, and agricultural outreach organizers to develop expertise to protect farmers and those working on the farm.

New Hazard Communication pictogram indicating health hazard.

Recommended sign to post near manure pit entry locations (ASABE EP470.1)

GREAT PLAINS
Center for Agricultural Health
www.GPCAH.org

Links to More Information

General Information on Manure Pit Hazards

NIOSH has been providing information to prevent asphyxiation in manure pits since 1990. See http://www.cdc.gov/niosh/docs/90-103/

The ASABE is a professional and technical organization dedicated to the advancement of engineering applicable to agricultural, food and biological systems. This organization has developed standards to recommend ventilation (S607) and operation (EP470.1) of manure storage pits with safety in mind. Their recommendations include monitoring spaces prior to entry.
ASAE EP470.1: https://elibrary.asabe.org/azdez.asp?JID=2&AID=39802&CID=s2000&T=2
ANSI/ASABE S607: https://elibrary.asabe.org/azdez.asp?JID=2&AID=36208&CID=s2000&T=2

General Confined Space Program Information

Michigan's Department of Licensing and Regulatory Affairs has provided a sample written program for permit-required confined space entry that can be customized for farming operations: *http://www.michigan.gov/documents/dleg/deleg_wsh_cet5330_346240_7.doc*.

OSHA has developed training program to outline the confined space program (although this is for another sector, the images aren't useful for agriculture, but the content is useful): https://www.osha.gov/Publications/2254.html

OSHA also provides assistance materials on confined spaces to all at: https://www.osha.gov/confinedspaces/index.html

Gas-Vapor Monitoring References

NIOSH Technical Report: Components for Evaluating Direct-Reading Monitors for Gases and Vapors http://www.agronext.iastate.edu/immag/manurevideos.html

OSHA Safety and Health Information Bulletin (SHIB 09-30-2013): Calibrating and Testing Direct-Reading Portable Gas Monitors https://www.osha.gov/dts/shib/shib093013.html

PennState Extension – Confined Space Manure Gas Monitoring Fact Sheet: http://extension.psu.edu/business/ag-safety/confined-spaces/manure/manure-pit-safety-fact-sheets/e-52

FACE Reports

These comprehensive investigations provide details of what happened that caused or contributed to worker fatalities associated with manure storage pit entry. As important as the sequence of events are, these contain recommendations to prevent these from happening in your operation.

Iowa farmer and employee died after collapse and attempted rescue in manure storage pit (http://www.public-health.uiowa.edu/face/Reports/PDF-Reports/2005IA024-025.pdf)

Iowa hog farmer dies from asphyxiation after manure pit agitation (http://www.public-health.uiowa.edu/face/Reports/PDF-Reports/Manure%20Pit%20Agitation.pdf)

Minnesota farm owner and son asphyxiated in manure waste pit (http://www.cdc.gov/niosh/face/In-house/full9229.html)

Minnesota hog farm co-owner and employee die of hydrogen sulfide poisoning in manure pit (http://www.cdc.gov/niosh/face/In-house/full9228.html)

Five family members in Michigan die after entering manure waste pit on dairy farm (http://www.cdc.gov/niosh/face/In-house/full8946.html

Equipment Rental Companies

Google search "Gas monitor rental" to identify monitor rental services. Ensure that the company will provide calibrated equipment, written certification of calibration in the shipment, and operation manual. Request they set the alarms to the limits you need prior to shipping.