COMPOSITION AND LAND APPLICATION OF HOLDING POND SLURRY

Contents

List of Tables

List of Figures

List of Supplementary Tables

Sample Collection of Holding Pond Slurry

To help guide adaptive manure management decisions, samples of manure slurry from the C&H ponds were collected periodically over the 5-year monitoring for analysis. A foot valve liquid manure sampler was used to collect samples of slurry from the top 6 inches of slurry, pond bottom, and from the entire depth of pond profile (Figure 1). Additional information on manure sampling is described in the Extension Fact Sheet, given as supplementary information at the end of this section (Supplementary File 1). The distribution of chemical constituents with lagoon depth is given in Figure 2. This information was shared with C&H's owners as part of the adaptive manure management discussions.

Figure 1. Foot valve manure sampler as used to collect samples from the C&H ponds.

Collection and analysis of manure samples from the holding ponds, representing the top water, bottom slurry, and entire profile, generated chemical profiles typical of other holding ponds associated with hog production. That is, N and P concentrations of the manure increased with water depth (Figure 2). However, P concentrations increased at a greater rate than N. The result of the relatively greater increase in P than N with pond depth is that the N:P ratio is greater for surface liquid than bottom slurries. Consequently, the higher N:P ratio of the surface water is closer to the ratio of these nutrients required by pastures on the C&H Farm.

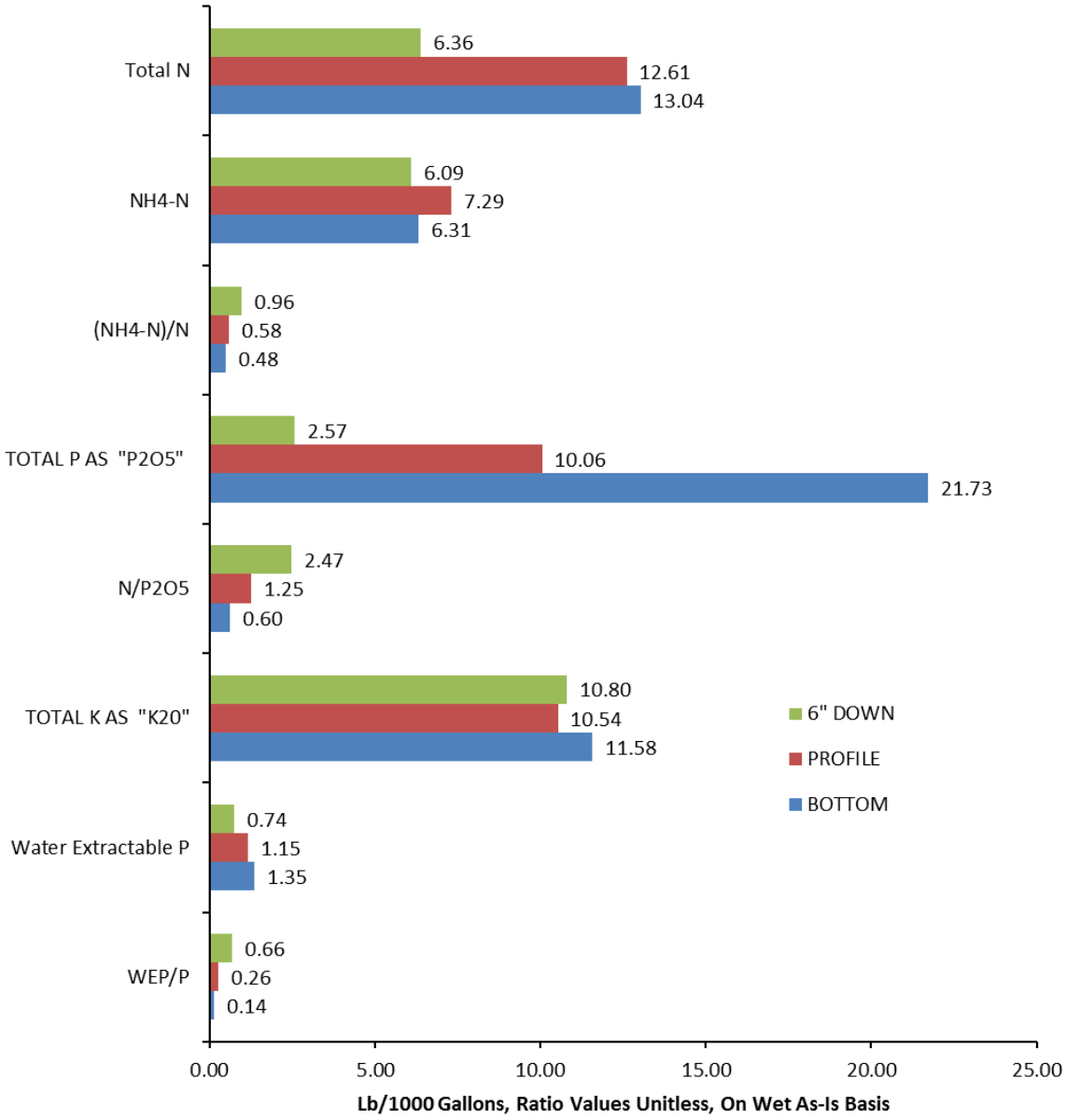

Figure 2. Distribution of N, P_2O_5, and K_2O with depth in the holding ponds, sampled on September 24, 2013

Land application of top water from the pond to farm pastures will more likely meet both the N and P needs of the pasture and avoid application of P surplus to plant needs. The higher concentration and lower N:P ratio of bottom slurries, will lend application of that slurry in a manure banking approach, where the slurry would be applied on alternate years to fields more distant from Big Creek. Even without the addition of mechanical and/or chemical separation approaches, the observed natural gravity separation of slurry and its constituents, provides opportunities for farm nutrient management to more closely match manure nutrients to crop nutrient needs.

Slurry Properties

Median values of physical and chemical properties of the manure slurry in the holding ponds determined at various times over the 5-year monitoring are presented in Table 1. These values represent samples collected September 24, 2013; April 10, 2014; October 28, 2014; April 16, 2015; January 15, May 27, and July 27, 2016; February 2, 2018; and February 8, February 20, and June 12, 2019.

An increasing linear relationship between total N, total P, total K, and water-extractable P concentrations and the increasing percent solids content of the slurry was observed (Figure 3). These nutrient concentrations are selected as they are required by plants for growth and are used to determine agronomic-based nutrient fertilizer applications. Water-extractable P is of interest due its key role in P Index calculations and determination of acceptable manure application rates. In addition, the ratio of total N:P_2O_5, total P_2O_5:Ca, and water extractable P and P_2O_5 concentration decreased exponentially with increasing percent solids content of slurry (Figure 4).

These trends reflect the variation in manure nutrient concentrations between ponds and depth within the ponds. C&H Farm management is aware of these variations and the nutrient management opportunities they present when making decisions regarding: which pond to pump from; whether the pond will be agitated; the depth at which to pump from; and which field to make the application. These factors coupled with the total number and size of application fields with the frequency in which each field receives a manure application, play a significant role in meeting the crop's nutrient fertility needs, while minimizing the potential for soil P accumulation and associated risk of P runoff.

Table 1. Median concentration of constituent property of manure sampled from the top 6 inches, bottom layer, and profile of holding ponds 1 and 2 on the C&H Farm between September 2013 and July 2019.

Property	Pond 1			Pond 2		
	Top 6 inches	**Bottom layer**	**Profile**	**Top 6 inches**	**Bottom layer**	**Profile**
pH	7.9	7.5	7.6	8.1	7.9	8.1
Electrical conductivity, µS/cm	13,905	10,710	12,780	10,275	10,475	8,371
Solids, %	0.8	11.9	3.62	0.5	4.3	2.2
Chloride, mg/L	360	409	467	338	409	483
Total N, mg/L	1,692	5,078	2,590	1,213	2,890	962
Ammonium-N, mg/L	1,323	1,437	1,146	859	938	536
Nitrate-N, mg/L	0.035	0.035	0.035	0.153	0.035	0.05
Total P, mg/L	180	5,070	1,492	114	458	216
Water-extractable P, mg/L	78	476	187	79	162	90
Total K, mg/L	1,383	1,593	1,408	1,109	1,180	1,123
Total Ca, mg/L	103	6,070	1,342	45	409	156
Total Mg, mg/L	30	2,368	365	6	177	67
Total S, mg/kg	60	1,076	169	23	133	87
Total Fe, mg/L	14	2,290	248	12	1,336	1,156
Total Mn, mg/L	0.6	102	11.5	0.0	9.8	4.6
Total Zn, mg/L	2.6	218	33.2	0.3	18.5	8.33

Property	Pond 1			Pond 2		
	Top 6 inches	Bottom layer	Profile	Top 6 inches	Bottom layer	Profile
Total Cu, mg/L	0.5	27.6	4.4	0.0	2.9	1.53
Total Na, mg/L	340	368	349	246	250	295

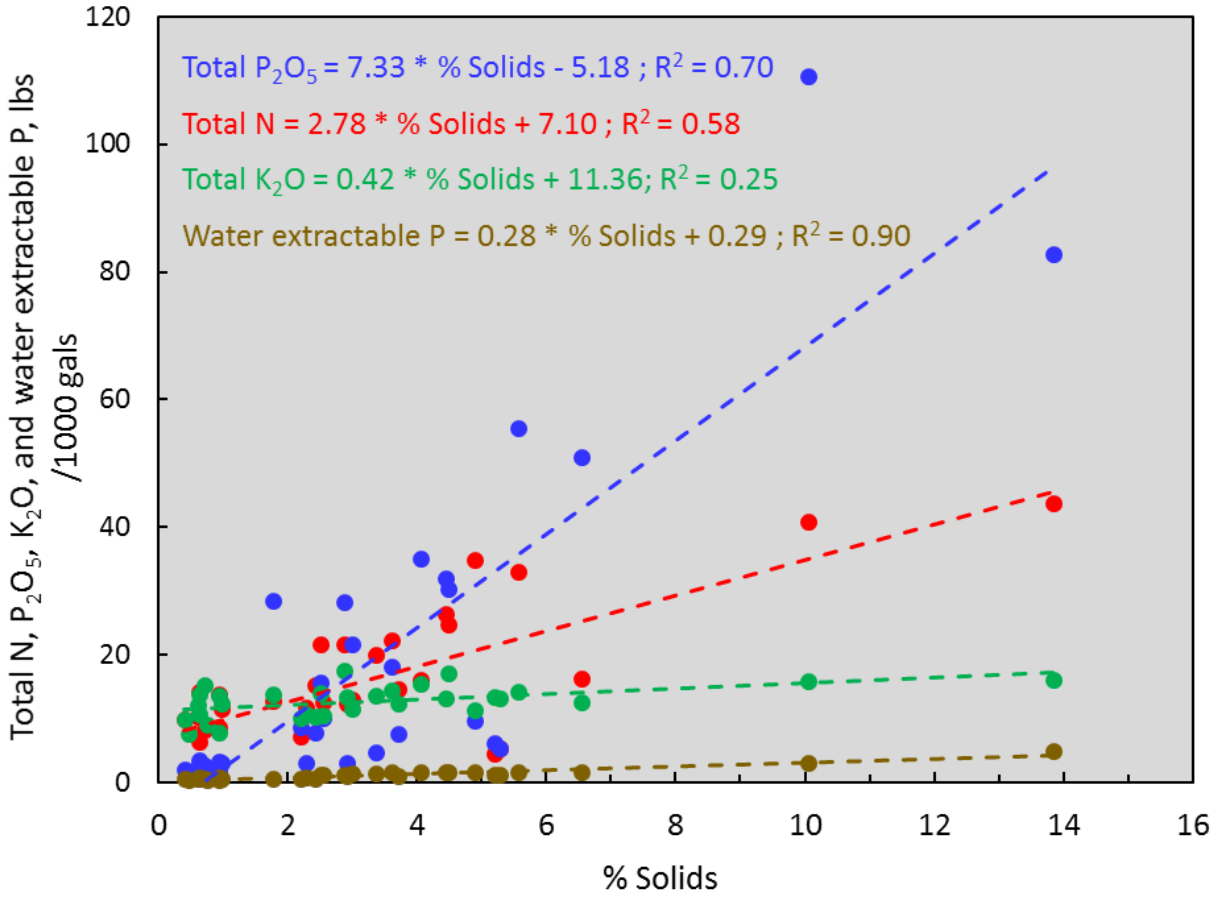

Figure 3. Relationship between total N, P, K and water-extractable P concentration and the percent solids content of swine slurry (all samples collected from ponds 1 and 2) from the C&H Farm operation.

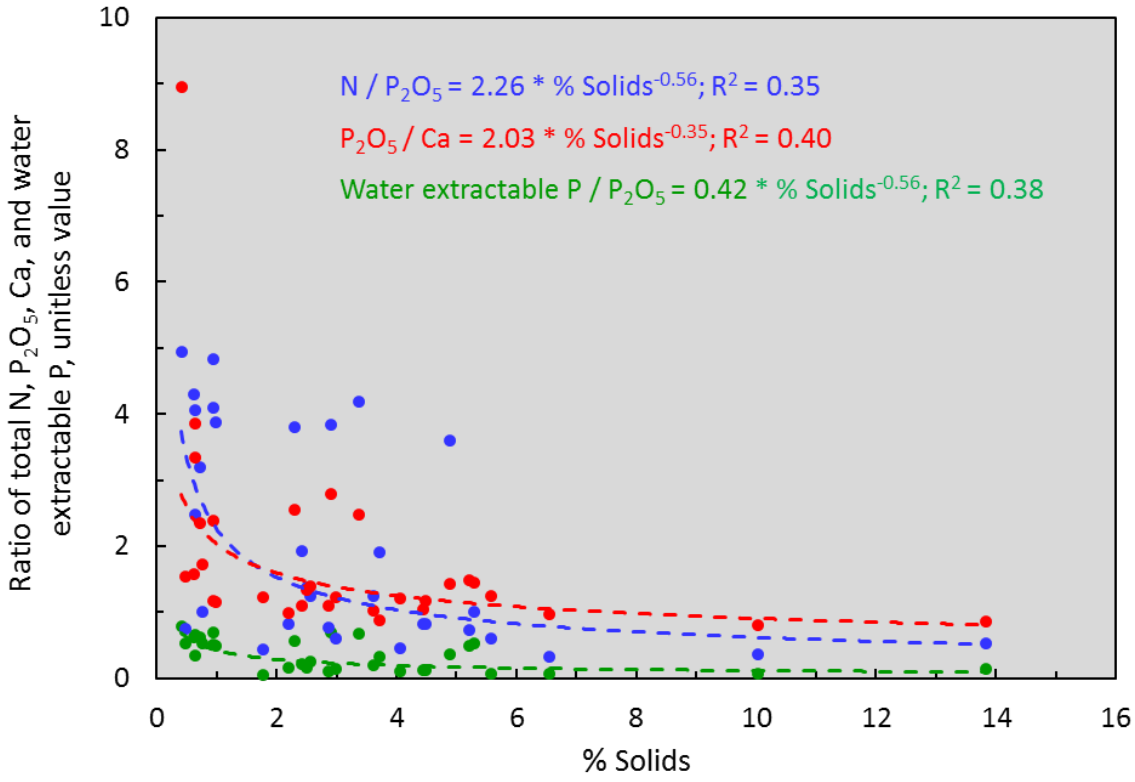

Figure 4. Relationship between the total N and P, total P and calcium, and total P and water extractable P concentration ratio and percent solids content of swine slurry (all samples collected from ponds 1 and 2) from the C&H Farm operation.

Land Application of Slurry

Fields permitted to receive manure slurry listed in the original approved Nutrient Management Plan for the C&H Farm, and are given in Table 2. Land application of slurry from holding ponds 1 and 2 of the C&H Farm are given in Supplementary Tables S1 to S7 for 2013 to 2018, respectively. These values are reported in the annual logs provided by C&H Farm owners to ADEQ each year. Annual land application of slurry to each field over the monitoring period was determined and presented in Table 3.

The average annual slurry application rate was consistent among years (2014 to 2018) ranging from 4,478 gals/ac in 2016 to 3,433 gals/ac in 2017 (Table 4). Thus, there was little change in land application and thereby, the amount of P and N applied in slurry to the monitored watershed between up and downstream sample collection sites.

The total application slurry, P, and N from the C&H Farm to permitted fields in the monitored watershed is given in Table 5. In terms of water volume, the amount of slurry applied in inches of liquid each year to each Feld was between 0.00 and 0.27 inches (Table 6).

Table 2. Fields permitted to receive manure slurry from the C&H operation. Fields bolded in red are monitored by BCRET.

Field	Area	Soil unit †	Field slope ‡			Flood freq. ¶
			Min.	Max.	Rep.	
	acres		---------- % ----------			
1	**7.3**	**Noark very cherty silt loam**	**3**	**8**	**5**	**None**
2	6.0	Noark very cherty silt loam	8	20	14	None
3	13.6	Razort loam	0	3	2	Occasional
4	6.8	Noark very cherty silt loam	8	20	14	None
7	64.3	Razort loam	0	3	2	Occasional
8	8.6	Spadra loam	2	5	1.5	None
9	35.5	Spadra loam	0	3	2	Occasional
10	29.3	Spadra loam	2	5	2.5	None
11	14.2	Noark very cherty silt loam	8	20	14	None
12	**11.4**	**Spadra loam**	**0**	**3**	**2**	**Occasional**
13	50.9	Noark very cherty silt loam	8	20	14	None
14	8.1	Noark very cherty silt loam	8	20	14	None
15	37.5	Noark very cherty silt loam	8	20	14	None
16	15.2	Spadra loam	0	3	2	Occasional
17	31.9	Spadra loam	3	8	5	None

† NRCS soil mapped unit.

‡ Minimum, maximum, and representative field slopes from NRCS soil survey.

¶ NRCS flooding designation as none and occasional.

Table 3. Volume and nutrients applied in slurry from the C&H operation to permitted fields for 2014 to 2018. Fields bolded in red are monitored by BCRET.

Field	Slurry applied	Number apps	Average application rate †	Nutrients applied	
				P	N
	gallons		gals/acre	---------- lbs ----------	
2013					
15	36,000	1	3,000	30	38
2014					
1	**46,000**	**2**	**3,538**	**221**	**925**
2	22,600	1	3,767	108	454
3	118,100	3	4,374	567	2,374
4	28,800	3	3,388	138	579
7	396,200	4	3,221	1,902	7,964
8	25,000	1	2,778	120	503
9	103,800	2	2,966	498	2,086
10	249,200	5	3,894	1,196	5,009
11	51,000	1	3,000	245	1,025
12	**48,000**	**1**	**4,848**	**230**	**965**
13	453,550	11	3,004	2,177	9,116
14	73,000	2	3,174	350	1,467
15	434,400	15	2,896	2,085	8,731
16	56,000	1	6,222	269	1,126
17	294,750	13	2,807	1,415	5,924
2015					
1	**12,000**	**1**	**1,429**	**58**	**241**
2	39,000	1	6,500	187	784
3	0	0	0	0	0
4	18,000	1	2,500	86	362

Field	Slurry applied	Number apps	Average application rate †	Nutrients applied	
				P	N
	gallons		gals/acre	---------- lbs ----------	
7	696,000	1	7,516	5,498	10,579
8	21,000	1	2,442	101	422
9	186,000	1	5,239	893	3,739
10	483,000	2	7,918	2,318	9,708
11	0	0	0	0	0
12	**93,000**	**2**	**4,079**	**446**	**1,869**
13	300,000	1	5,894	1,440	6,030
14	36,000	1	4,444	173	724
15	0	0	0	0	0
16	63,000	1	4,145	302	1,266
17	418,000	2	6,552	2,006	8,402
2016					
1	**78,000**	**2**	**4,643**	**641**	**1,143**
2	48,000	2	4,000	420	727
3	108,000	2	2,000	945	1,636
4	57,000	2	3,958	478	844
7	0	0	0	0	0
8	84,000	2	4,884	735	1,273
9	420,000	2	5,915	3,091	5,821
10	303,000	2	4,967	2,672	4,610
11	132,000	2	3,882	1,072	1,922
12	**156,000**	**2**	6,842	1,073	2,093
13	264,000	2	**2,593**	**3,311**	**4,928**
14	75,000	1	9,259	135	653
15	261,000	2	870	2,555	4,206

Field	Slurry applied	Number apps	Average application rate †	Nutrients applied	
				P	N
	gallons		gals/acre	---------- lbs ----------	
16	93,000	1	6,118	1,460	2,009
17	462,000	2	7,241	2,583	5,645
2017					
1	**60,000**	**2**	**3,571**	**1,818**	**1,459**
2	48,000	2	4,000	1,447	1,133
3	105,000	2	1,944	3,170	2,496
4	54,000	2	3,750	1,634	1,303
7	756,000	3	2,721	22,892	18,317
8	57,000	2	3,314	1,733	1,414
9	346,000	3	3,249	10,468	8,341
10	243,000	3	2,656	7,326	5,731
11	63,000	1	3,706	1,915	1,562
12	**90,000**	**2**	**3,947**	**2,714**	**2,124**
13	281,000	3	1,840	8,472	6,630
14	60,000	2	3,704	1,812	1,430
15	318,000	2	1,060	9,592	7,526
16	90,000	1	5,921	2,691	2,016
17	390,000	2	6,113	11,733	9,082
2018					
1	**57,000**	**2**	**3,393**	**1,613**	**1,231**
2	51,000	2	4,250	1,443	1,102
3	108,000	2	2,000	3,056	2,333
4	57,000	2	3,958	1,613	1,231
7	639,000	2	3,450	18,084	13,802
8	78,000	2	4,535	2,207	1,685

Field	Slurry applied	Number apps	Average application rate †	Nutrients applied	
				P	N
	gallons		gals/acre	---------- lbs ----------	
9	361,000	2	5,085	10,216	7,798
10	288,000	2	4,721	8,150	6,221
11	57,000	1	3,353	1,613	1,231
12	**105,000**	**2**	**4,605**	**2,972**	**2,268**
13	204,000	1	4,008	5,773	4,406
14	60,000	2	3,704	1,698	1,296
15	273,000	2	910	7,726	5,897
16	66,000	1	4,342	1,868	1,426
17	339,000	2	5,313	9,594	7,322

† Average slurry application rate is total applied / applied acres in a given field

Table 4. Average application rate of slurry from the C&H operation to permitted fields for each monitoring year. Fields bolded in red are monitored by BCRET.

Field	Average annual slurry application						
	2013	2014	2015	2016	2017	2018	Total
	gals/ac						
1		**3,538**	**1,429**	**4,643**	**3,571**	**3,393**	**19,889**
2		3,767	6,500	4,000	4,000	4,250	27,020
3		4,374	0	2,000	1,944	2,000	12,382
4		3,388	2,500	3,958	3,750	3,958	21,065
7		3,221	7,516	0	2,721	3,450	20,290
8		2,778	2,442	4,884	3,314	4,535	21,543
9		2,966	5,239	5,915	3,249	5,085	26,945
10		3,894	7,918	4,967	2,656	4,721	28,987
11		3,000	0	3,882	3,706	3,353	16,729
12		**4,848**	**4,079**	**6,842**	**3,947**	**4,605**	**29,185**
13		3,004	5,894	2,593	1,840	4,008	20,807
14		3,174	4,444	9,259	3,704	3,704	29,142
15	3,000	2,896	0	870	1,060	910	14,472
16		6,222	4,145	6,118	5,921	4,342	32,098
17		2,807	6,552	7,241	6,113	5,313	33,631
Average	3,000	3,592	3,911	4,478	3,433	3,482	354,185

Table 5. Total volume and nutrients applied in slurry from the C&H operation to permitted fields from 2013 to 2018. Fields bolded in red are monitored by BCRET.

Field	Slurry applied	Number apps	Nutrients applied	
			P	N
	gallons		---------- lbs ----------	
1	**253,000**	**9**	**4,350**	**4,999**
2	208,600	8	3,606	4,200
3	439,100	9	7,738	8,839
4	214,800	10	3,950	4,319
7	2,487,200	10	48,376	50,662
8	265,000	8	4,896	5,296
9	1,416,800	10	25,167	27,785
10	1,566,200	14	21,663	31,279
11	303,000	5	4,845	5,741
12	**492,000**	**9**	**7,435**	**9,319**
13	1,502,550	18	21,173	31,112
14	304,000	8	4,168	5,570
15	1,289,400	22	21,988	26,398
16	368,000	5	6,590	7,842
17	1,903,750	21	27,331	36,375

Table 6. Total volume as inches of slurry applied from the C&H operation to permitted fields for each monitoring year. Fields bolded in red are monitored by BCRET.

Field	Slurry applied						
	2013	2014	2015	2016	2017	2018	Total
	inches						
1		**0.13**	**0.05**	**0.17**	**0.13**	**0.12**	**0.61**
2		0.14	0.05	0.15	0.15	0.16	0.64
3		0.16	0.00	0.07	0.07	0.07	0.38
4		0.12	0.05	0.15	0.14	0.15	0.61
7		0.12	0.05	0.00	0.10	0.13	0.40
8		0.10	0.05	0.18	0.12	0.17	0.62
9		0.11	0.05	0.22	0.12	0.19	0.69
10		0.14	0.24	0.18	0.10	0.17	0.84
11		0.11	0.00	0.14	0.14	0.12	0.51
12		**0.18**	**0.24**	**0.25**	**0.15**	**0.17**	**0.98**
13		0.11	0.05	0.10	0.07	0.15	0.47
14		0.12	0.05	0.34	0.14	0.14	0.78
15	0.01	0.11	0.00	0.03	0.04	0.03	0.22
16		0.23	0.05	0.23	0.22	0.16	0.89
17		0.10	0.24	0.27	0.23	0.20	1.03
Total		1.98	1.19	2.47	1.90	2.12	9.67
Rainfall		25.13	28.83	15.5	14.57	23.17	107.2

Supplementary File 1: Sampling Liquid Manure U of A Fact Sheet

UNIVERSITY OF ARKANSAS
DIVISION OF AGRICULTURE
Cooperative Extension Service

Sampling Liquid Manure

Karl VanDevender, Ph.D., P.E.
Professor, Extension Engineer

Liquid animal manure sampling can be an important management tool. Proper sampling provides the producer with nutrient analysis results that can be used in a sound farm fertilization program. Nutrient analysis of manure, in conjunction with soil sampling, helps determine how much manure should be applied to fields to maintain adequate fertility while minimizing potential environmental problems such as ground and surface water pollution. However manure applications should not exceed the maximum application rates in a manure management plan until sufficient data can be collected to justify revising the plan.

When to Sample

Liquid animal manure should be sampled for nutrient analysis as close to land application time as possible. This helps ensure that the reported nutrient content accurately reflects what is being applied to the land. If the manure is sampled as it is being land applied, the results will not be available to govern present application rates. It does, however, provide information for future land applications of animal manure, if the manure management remains fairly constant over time.

How to Collect a Liquid Manure Sample

During Land Application

The easiest way to collect liquid animal manure samples is to collect the manure as it is being land applied. This approach ensures what is sample reflects what is applied. Randomly place catch pans in the field to collect the liquid manure as it is land applied by an irrigation system or honey wagon. Flexible rubber feed pans work well. Immediately after the manure has been applied, collect the manure from the catch pans, combine in a bucket to make one composite sample and mix well by stirring. This bucket will be the source of the manure sent for analysis.

From a Storage Facility

If collecting liquid animal manure samples during land application is not possible, collect the samples from the storage facility. Liquid animal manure storage facilities have a tendency for the manure to stratify with the solids settling to the bottom and the liquids remaining on top. It is also not uncommon for some solids to form a floating crust. This stratification affects the manure nutrient concentrations in the storage facility. The nitrogen and potassium will be more concentrated in the top liquid, while the phosphorus will be more concentrated in the settled solids. This stratification of nutrient concentrations increases the challenge of getting samples that represent what will be applied to a particular field. If the liquids from the top and middle of the profile will be applied, only this material should be sampled. If the settled solids will be applied, then they should be sampled. However, if the manure is to be agitated before pumping, as has been the traditional recommendation, the sample should contain representative proportions of manure from the top, middle, and bottom. The idea is to collect a sample of an entire column of manure to represent the manure after agitation.

If agitating the manure prior to sampling is not possible, an alternative approach is to make a sampler to collect the required sub-samples. The sub-samples are then mixed to represent the manure after agitation. The easiest to construct is simply a container such as a cup, attached to the end of a pole. Liquids from the manure surface can be simply scooped up. To collect liquids from the middle depths, or settled solids, the container is held up side down, trapping air, until the desired sampling depth is reached. Then the container is rotated, releasing the air and collecting the sample. When collecting a sample of the entire profile of the manure, sub-samples are collected and mixed in a bucket.

- over -

A sampler design that automatically collects a sample of the entire profile uses 10 foot, 1 ½ inch PVC pipe with a PVC ball valve at the bottom. The handle of the ball valve is replaces with a lever arm about 2 feet long. The free end of the lever arm is attached to the end of a 10 foot, 1 inch PVC pipe. The lever arm and smaller pipe allow the ball valve to be operated while holding to top of the sampler. To use the sampler the valve is opened and the sampler is inserted (in a line, not and arc) into the manure. When the foot of the valve is at the bottom of the settled solids, it is closed. Then the sample of the entire manure profile can be removed from the manure and placed in a bucket.

Sketch of Cup Sampler

Sketch of Foot Valve Sampler

Whichever sampler is used, at least 8 locations around the manure storage unit should be sampled and mixed in a bucket to serve as a final composite sample. This bucket will be the source of the manure sent for analysis

Getting the Sample Analyzed

After thoroughly mixing the final composite sample, fill a one liter plastic bottle half full. These bottles may be obtained from your county Extension office. Never fill the bottle more than half full to allow for gas expansion of the sample and to prevent the bottle from exploding. Keep the samples as cool as possible until you can take them to your county Extensions office for shipping to the University of Arkansas lab for analysis. There you will get assistance in filling out an information sheet on your manure sample. There is a fee to have the sample analyzed. While the sample can be sent to a private lab, the fees are often higher. If you are required by the Arkansas Department of Environmental Equality (ADEQ) to sample your liquid animal manure as part of your Regulation No. 5 permit, make sure that you inform the individual helping you with the paperwork so the correct set of analyses can be performed. In addition to the analyses to determine the fertilizer value of manure, it is recommended to analyze for the amount of phosphorus in the manure that is water soluble. Water soluble phosphorus is needed to evaluate the potential environmental risk associated with phosphorus application rates specified in manure management plans. Having good farm based information should help planners develop plans tailored to and individual farm.

Key Points to Remember

The important things to remember in collecting a liquid animal manure sample are:

- Collect a sample that best represents the nutrient content of the manure in that storage facility and what will be applied. If only the top water is to be applied it should be sampled. If the storage unit will be agitated prior to application the sample should contain material from the entire depth profile.
- Only fill the sample bottle ½ full.
- Keep the sample cool prior to shipping.
- Ship the sample to the lab as soon as possible.

Handout, April 27, 2010

Supplementary Tables

Table S 1. Volume and nutrients applied in slurry from the C&H operation to permitted fields in 2013. Fields bolded in red are monitored by BCRET.

Field	Slurry applied	Area	Application rate	Nutrients applied		Application rate	
				P	N	P	N
	gallons	acres	gals/acre	------- lbs -------		------ lbs/ac ------	
15	3,000	12	250	30	38	2.5	3.2

Table S 2. Volume and nutrients applied in slurry from the C&H operation to permitted fields in 2014. Fields bolded in red are monitored by BCRET.

Field	Slurry applied	Area	Application rate	Nutrients applied		Application rate	
				P	N	P	N
	gallons	acres	gals/acre	------- lbs -------		------ lbs/ac ------	
1	**18,000**	**6**	**3,000**	**86**	**362**	**14.4**	**60.3**
1	**28,000**	**7**	**4,000**	**134**	**563**	**19.2**	**80.4**
2	22,600	6	3,767	108	454	18.1	75.7
3	18,000	6	3,000	86	362	14.4	60.3
3	38,500	6	6,417	185	774	30.8	129.0
3	61,600	15	4,107	296	1,238	19.7	82.5
4	3,000	1	3,000	14	60	14.4	60.3
4	12,000	4	3,000	58	241	14.4	60.3
4	13,800	3.5	3,943	66	277	18.9	79.3
7	133,000	29	4,586	638	2,673	22.0	92.2
7	67,200	15	4,480	323	1,351	21.5	90.0
7	87,000	19	4,579	418	1,749	22.0	92.0
7	109,000	60	1,817	523	2,191	8.7	36.5

Field	Slurry applied	Area	Application rate	Nutrients applied		Application rate	
				P	N	P	N
	gallons	acres	gals/acre	------- lbs -------		------ lbs/ac ------	
8	25,000	9	2,778	120	503	13.3	55.8
9	72,800	25	2,912	349	1,463	14.0	58.5
9	31,000	10	3,100	149	623	14.9	62.3
10	60,000	15	4,000	288	1,206	19.2	80.4
10	18,000	6	3,000	86	362	14.4	60.3
10	51,000	14	3,643	245	1,025	17.5	73.2
10	67,200	15	4,480	323	1,351	21.5	90.0
10	53,000	14	3,786	254	1,065	18.2	76.1
11	51,000	17	3,000	245	1,025	14.4	60.3
12	**48,000**	**9.9**	**4,848**	**230**	**965**	**23.3**	**97.5**
13	33,000	11	3,000	158	663	14.4	60.3
13	57,500	19	3,026	276	1,156	14.5	60.8
13	87,000	29	3,000	418	1,749	14.4	60.3
13	44,800	14	3,200	215	900	15.4	64.3
13	58,000	19	3,053	278	1,166	14.7	61.4
13	27,500	9	3,056	132	553	14.7	61.4
13	28,750	9	3,194	138	578	15.3	64.2
13	12,000	4	3,000	58	241	14.4	60.3
13	14,200	5	2,840	68	285	13.6	57.1
13	62,800	22	2,855	301	1,262	13.7	57.4
13	28,000	10	2,800	134	563	13.4	56.3
14	45,000	15	3,000	216	905	14.4	60.3
14	28,000	8	3,500	134	563	16.8	70.4
15	3,000	1	3,000	14	60	14.4	60.3
15	6,000	2	3,000	29	121	14.4	60.3

Field	Slurry applied	Area	Application rate	Nutrients applied		Application rate	
				P	N	P	N
	gallons	acres	gals/acre	------- lbs -------		------ lbs/ac ------	
15	24,000	9	2,667	115	482	12.8	53.6
15	18,000	7	2,571	86	362	12.3	51.7
15	36,000	13	2,769	173	724	13.3	55.7
15	42,000	14	3,000	202	844	14.4	60.3
15	45,000	15	3,000	216	905	14.4	60.3
15	25,400	9	2,822	122	511	13.5	56.7
15	16,800	6	2,800	81	338	13.4	56.3
15	16,800	6	2,800	81	338	13.4	56.3
15	11,200	4	2,800	54	225	13.4	56.3
15	8,200	3	2,733	39	165	13.1	54.9
15	90,000	29	3,103	432	1,809	14.9	62.4
15	57,500	20	2,875	276	1,156	13.8	57.8
15	34,500	12	2,875	166	693	13.8	57.8
16	56,000	9	6,222	269	1,126	29.9	125.1
17	6,000	2	3,000	29	121	14.4	60.3
17	30,000	10	3,000	144	603	14.4	60.3
17	3,000	10	300	14	60	1.4	6.0
17	30,000	5	6.000	144	603	28.8	120.6
17	21,000	7	3.000	101	422	14.4	60.3
17	36,000	12	3,000	173	724	14.4	60.3
17	25,000	9	2,778	120	503	13.3	55.8
17	22,400	8	2,800	108	450	13.4	56.3
17	16,800	6	2,800	81	338	13.4	56.3
17	11,800	4	2,950	57	237	14.2	59.3
17	18,000	6	3,000	86	362	14.4	60.3

Field	Slurry applied	Area	Application rate	Nutrients applied		Application rate	
				P	N	P	N
	gallons	acres	gals/acre	------- lbs -------		------ lbs/ac ------	
17	46,000	16	2,875	221	925	13.8	57.8
17	28,750	10	2,875	138	578	13.8	57.8

Table S 3. Volume and nutrients applied in slurry from the C&H operation to permitted fields in 2015. Fields bolded in red are monitored by BCRET.

Field	Slurry applied	Area	Application rate	Nutrients applied		Application rate	
				P	N	P	N
	gallons	acres	gals/acre	------- lbs -------		------ lbs/ac ------	
1	**12,000**	**8.4**	**1,429**	**58**	**241**	**6.9**	**28.7**
2	39,000	6.0	6,500	187	784	31.2	130.7
4	18,000	7.2	2,500	86	362	12.0	50.3
7	696,000	92.6	7,516	5,498	10,579	59.4	114.2
8	21,000	8.6	2,442	101	422	11.7	49.1
9	186,000	35.5	5,239	893	3,739	25.1	105.3
10	174,000	30.5	5,705	835	3,497	27.4	114.7
10	309,000	30.5	10,131	1,483	6,211	48.6	203.6
12	**33,000**	**11.4**	**2,895**	**158**	**663**	**13.9**	**58.2**
12	**60,000**	**11.4**	**5,263**	**288**	**1,206**	**25.3**	**105.8**
13	300,000	50.9	5,894	1,440	6,030	28.3	118.5
14	36,000	8.1	4,444	173	724	21.3	89.3
16	63,000	15.2	4,145	302	1,266	19.9	83.3
17	178,000	31.9	5,580	854	3,578	26.8	112.2
17	240,000	31.9	7,524	1,152	4,824	36.1	151.2

Table S 4. Volume and nutrients applied in slurry from the C&H operation to permitted fields in 2016. Fields bolded in red are monitored by BCRET.

Field	Slurry applied	Area	Application rate	Nutrients applied		Application rate	
				P	N	P	N
	gallons	acres	gals/acre	------- lbs -------		------ lbs/ac ------	
1	**42,000**	**8.4**	**5,000**	**76**	**365**	**9.0**	**43.5**
1	**36,000**	**8.4**	**4,286**	**565**	**778**	**67.3**	**92.6**
2	24,000	6.0	4,000	43	209	7.2	34.8
2	24,000	6.0	4,000	377	518	62.8	86.4
3	54,000	27.0	2,000	97	470	3.6	17.4
3	54,000	27.0	2,000	848	1,166	31.4	43.2
4	30,000	7.2	4,167	54	261	7.5	36.3
4	27,000	7.2	3,750	424	583	58.9	81.0
8	42,000	8.6	4,884	76	365	8.8	42.5
8	42,000	8.6	4,884	659	907	76.7	105.5
9	252,000	35.5	7,099	454	2,192	12.8	61.8
9	168,000	35.5	4,732	2,638	3,629	74.3	102.2
10	150,000	30.5	4,918	270	1,305	8.9	42.8
10	153,000	30.5	5,016	2,402	3,305	78.8	108.4
11	72,000	17.0	4,235	130	626	7.6	36.8
11	60,000	17.0	3,529	942	1,296	55.4	76.2
12	**99,000**	**11.4**	**8,684**	**178**	**861**	**15.6**	**75.6**
12	**57,000**	**11.4**	**5,000**	**895**	**1,231**	**78.5**	**108.0**
13	60,000	50.9	1,179	108	522	2.1	10.3
13	204,000	50.9	4,008	3,203	4,406	62.9	86.6
14	75,000	8.1	9,259	135	653	16.7	80.6
15	111,000	150.0	740	200	966	1.3	6.4
15	150,000	150.0	1,000	2,355	3,240	15.7	21.6

Field	Slurry applied	Area	Application rate	Nutrients applied		Application rate	
				P	N	P	N
	gallons	acres	gals/acre	------- lbs -------		------ lbs/ac ------	
16	93,000	15.2	6,118	1,460	2,009	96.1	132.2
17	336,000	31.9	10,533	605	2,923	19.0	91.6
17	126,000	31.9	3,950	1,978	2,722	62.0	85.3

Table S 5. Volume and nutrients applied in slurry from the C&H operation to permitted fields in 2017. Fields bolded in red are monitored by BCRET.

Field	Slurry applied	Area	Application rate	Nutrients applied		Application rate	
				P	N	P	N
	gallons	acres	gals/acre	------- lbs -------		------ lbs/ac ------	
1	**48,000**	**8.4**	**5,714**	**1,459**	**1,190**	**173.7**	**141.7**
1	**12,000**	**8.4**	**1,429**	**359**	**269**	**42.7**	**32.0**
2	24,000	6	4,000	730	595	121.6	99.2
2	24,000	6	4,000	718	538	119.6	89.6
3	60,000	27	2,222	1,824	1,488	67.6	55.1
3	45,000	27	1,667	1,346	1,008	49.8	37.3
4	39,000	7.2	5,417	1,186	967	164.7	134.3
4	15,000	7.2	2,083	449	336	62.3	46.7
7	255,000	92.6	2,754	7,752	6,324	83.7	68.3
7	321,000	92.6	3,467	9,758	7,961	105.4	86.0
7	180,000	92.6	1,944	5,382	4,032	58.1	43.5
8	30,000	8.6	3,488	912	744	106.0	86.5
8	27,000	8.6	3,140	821	670	95.4	77.9
9	216,000	35.5	6,085	6,566	5,357	185.0	150.9
9	30,000	35.5	845	912	744	25.7	21.0
9	100,000	35.5	2,817	2,990	2,240	84.2	63.1
10	66,000	30.5	2,164	2,006	1,637	65.8	53.7
10	54,000	30.5	1,770	1,642	1,339	53.8	43.9
10	123,000	30.5	4,033	3,678	2,755	120.6	90.3
11	63,000	17	3,706	1,915	1,562	112.7	91.9
12	**45,000**	**11.4**	**3,947**	**1,368**	**1,116**	**120.0**	**97.9**
12	**45,000**	**11.4**	**3,947**	**1,346**	**1,008**	**118.0**	**88.4**
13	80,000	50.9	1,572	2,432	1,984	47.8	39.0

Field	Slurry applied	Area	Application rate	Nutrients applied		Application rate	
				P	N	P	N
	gallons	acres	gals/acre	------- lbs -------		------ lbs/ac ------	
13	60,000	50.9	1,179	1,824	1,488	35.8	29.2
13	141,000	50.9	2,770	4,216	3,158	82.8	62.1
14	36,000	8.1	4,444	1,094	893	135.1	110.2
14	24,000	8.1	2,963	718	538	88.6	66.4
15	168,000	150	1,120	5,107	4,166	34.0	27.8
15	150,000	150	1,000	4,485	3,360	29.9	22.4
16	90,000	15.2	5,921	2,691	2,016	177.0	132.6
17	144,000	31.9	4,514	4,378	3,571	137.2	111.9
17	246,000	31.9	7,712	7,355	5,510	230.6	172.7

Table S 6. Volume and nutrients applied in slurry from the C&H operation to permitted fields in 2018. Fields bolded in red are monitored by BCRET.

Field	Slurry applied	Area	Application rate	Nutrients applied		Application rate	
				P	N	P	N
	gallons	acres	gals/acre	------- lbs -------		------ lbs/ac ------	
1	**30,000**	**8.4**	**849**	**648**	**101.1**	**77.1**	**1**
1	**27,000**	**8.4**	**764**	**583**	**91.0**	**69.4**	**1**
2	27,000	6	764	583	127.4	97.2	2
2	24,000	6	679	518	113.2	86.4	2
3	54,000	27	1,528	1,166	56.6	43.2	3
3	54,000	27	1,528	1,166	56.6	43.2	3
4	30,000	7.2	849	648	117.9	90.0	4
4	27,000	7.2	764	583	106.1	81.0	4
7	255,000	92.6	7,217	5,508	77.9	59.5	7
7	384,000	92.6	10,867	8,294	117.4	89.6	7
8	27,000	8.6	764	583	88.8	67.8	8
8	51,000	8.6	1,443	1,102	167.8	128.1	8
9	171,000	35.5	4,839	3,694	136.3	104.0	9
9	190,000	35.5	5,377	4,104	151.5	115.6	9
10	159,000	30.5	4,500	3,434	147.5	112.6	10
10	129,000	30.5	3,651	2,786	119.7	91.4	10
11	57,000	17	1,613	1,231	94.9	72.4	11
12	**48,000**	**11.4**	**1,358**	**1,037**	**119.2**	**90.9**	**12**
12	**57,000**	**11.4**	**1,613**	**1,231**	**141.5**	**108.0**	**12**
13	204,000	50.9	5,773	4,406	113.4	86.6	13
14	30,000	8.1	849	648	104.8	80.0	14
14	30,000	8.1	849	648	104.8	80.0	14
15	150,000	150	4,245	3,240	28.3	21.6	15

Field	Slurry applied	Area	Application rate	Nutrients applied		Application rate	
				P	N	P	N
	gallons	acres	gals/acre	------- lbs -------		------ lbs/ac ------	
15	123,000	150	3,481	2,657	23.2	17.7	15
16	66,000	15.2	1,868	1,426	122.9	93.8	16
17	147,000	31.9	4,160	3,175	130.4	99.5	17
17	192,000	31.9	5,434	4,147	170.3	130.0	17