National Fish and Wildlife Foundation
Final Programmatic Report

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Project Name: Optimizing Manure Nutrient Utilization

Recipient Organization/Agency: UW-Madison

1) Summary of Accomplishments

1. We evaluated the ISS manure separation (ultra-filtration, UF) technology in a CAFO (confined animal feeding operation: 3,000 dairy cow) context, measured the variability of nutrient composition in the separated manure fractions (***1st Stage Solids***, and ***2nd Stage UF permeate*** and ***2nd Stage UF Concentrate*** (retentate), and developed 3 types of nutrient management plans to use these 3 main manure fractions: one for the ***UF permeate*** to be irrigated and/or hose drag applied (gallons); one for the ***UF Concentrate*** slurry which was dragline/hose injected (gallons); and, one for the solids which were applied to fields (and/or sold) as solids (tons).

2. We developed the cost of separation and application for each of these separated manure fractions. We were then able to link these costs to total volumes spread on fields at different distances to calculate the costs of application and efficiency of the movement of nutrients.

3. We spent a great deal of time interfacing this new technology with environmental compliance agencies (WI DNR) encouraging them to allow producers to be able to apply the ***UF permeate*** with center pivot rather than with trucks, tractors, tankers and/or dragline hoses.

4. The innovative manure separation technology as well as the new manure management concepts improved nutrient management and farm profitability.

2) Project Activities & Results

Project Objectives:

1. **Develop a practical manure sampling protocol to evaluate the nutrient content and uniformity of nutrients in raw manure and separated manure products at various stages in the manure enterprise (e.g., at separation, storage, and application).**

Activities and Results:

Our original (**BASE: 2006-2009, Before Separation**) measurement protocol was to sample manure every 4 hours as agitated pit manure was being applied to fields. This allowed us to build upon work we had previously done on the farm in a precision agriculture (PA), manure Nutrient Management Planning (NMP) research project. Thus for each separated product we sampled the manure being applied every four hours and related this information to the position in the field that the manure was being applied to so we could determine the nutrient applications in a site-specific way. We then were able to “back fill” N to meet crop removal NMP criteria using commercial fertilizer. We summarize this agitated pit manure nutrient composition (pounds/1,000 gallons) and variability (coefficient of variation (CV) = standard deviation/mean = 1 standard deviation relative to the mean (%)) for the **BASE: 2006-2009, No Separation**. (See **TABLE 1**). This TABLE provides our **BASE: Before Separation** manure composition and variability reference point.

- This Table indicates that agitated pit manure can be quite variable (CV > 20%), especially its P (CV = 51%) and S (CV = 42%) components. The N:P ratio is roughly 2:1, indicating that agitated pit manure can be a good source N (7.2 pounds N/1,000 gallons 1st and 2nd year), especially if soil test P is not a limiting factor (3.6 pounds P/1,000 gallons 1st and 2nd year).
- Using average manure compositions from these more frequent (every 4 hours) samples, especially after major system/management changes (number/composition of cows, change in ration, etc.), is recommended as individual samples can be quite variable.

NOTE that at the end of 2008 and 2009 we started the calibration of the ISS manure separation system and encountered several technical difficulties that prompted us to request a No Cost Extension to this CIG. We sampled raw manure and the separated products as they were separated and sent to the storage lagoons. We summarize these **Preliminary (Separator Calibration)** manure nutrient composition and variability data for 2008-2010 (See **TABLE 2**). **TABLE 3** provides a more detailed summary/analysis comparing the PRELIMINARY separated manure fractions (separation outputs) to Raw Manure without Sand (input manure feedstock to the separation system). **TABLE 2** and **TABLE 3** provide a Preliminary (Separator Calibration) separated manure composition/variability reference point. NOTE, these tables (**2** and **3**) are ***At Separation***, **NOT** ***As Applied*** (**TABLES 1, 4. 5,** and **6** are ***As Applied***).

- ***These Tables were discussed extensively in our earlier CIG/Phase Reports.***

During the 2012 Crop Year (Fall of 2011, Spring and Summer of 2012) we were able to extensively sample and measure the **FINAL (Calibrated Separator)** manure nutrient composition and variability ***As Applied*** for comprehensive NMP regulatory purposes. We summarize these **FINAL (Calibrated Separator)** manure composition and variability ***As Applied*** in **TABLE 4**.

- ***This table is new to our CIG reporting.***

TABLE 5 provides a disaggregated nutrient composition and variability summary across **BASE: Before Separation**, **<u>Preliminary</u>: 2008:2010** (Separator Calibration), and **<u>FINAL</u>: 2012 Crop Year** (Calibrated Separator) scenarios. RECALL, while **<u>BASE</u>** and **<u>FINAL</u>** are ***As Applied***, **<u>Preliminary</u>** is ***At Separation***. Here, the sharp reduction in the variability of separated manure fractions compared to agitated pit manure is evident. As well, average composition and CV differences in separated manure fractions between **<u>Preliminary</u>** and **<u>FINAL</u>** reflect both ISS technology calibrations and changes in manure separation feedstock: ration changes (e.g., use of more corn gluten, potential annual/seasonal changes in stored feeds, etc.), changes in herd size and/or composition (adding dry cow manures), and seasonal rainfall/cooling (sprinkler) water dilutions. These changes indicate that measurement protocols need to account for any substantive changes in manure separation feedstock.

- ***This table is new to our CIG reporting.***

TABLE 6 summarizes the contrast of **BASE** ***(Before Separation)*** and **FINAL** ***(Calibrated Separation)*** **As Applied** nutrient composition and variability as well as the application (TOTAL POUNDS, % TOTAL Pounds) from the 2012 **FINAL** ***(Calibrated Separation)*** manure nutrients, aggregated by field and manure fraction.

- ***This table is new to our CIG reporting. It also provides the most succinct summary of our CIG.***

Discussion: TABLES 4, 5 and 6

The 2012 application of separated manure nutrients reduced the weighted average (across all manure fractions) CV (variability) for all nutrients (DM and NPKS (CV) ***As Applied***, compared to **BASE** ***(Before Separation)***:

- 2nd Stage ***UF Concentrate*** accounted for over half of total applied NPKS manure nutrients with often substantive reductions in applied nutrient variability.
  - Reductions: 3.1X (DM); 2.7X (P); 1.9X (K).
- 1st stage ***Solids*** accounted for 70% of total applied DM, often with substantive reductions in applied nutrient variability.
  - Reductions: 10X (DM); 1.9X (1st Year N); 2.1X (P); 3.3X (K).

Variability of total P applied was reduced 3X: CV reduced to 17.2% (**FINAL**) versus 51.4% (**BASE**). This demonstrates substantive potential improvement in reducing P losses through Precision Ag with separated manure NMP.

- 69% of total applied manure P was applied as 2nd Stage ***UF Concentrate*** with 2.7X less variability (more accuracy) than **BASE** ***(Before Separation)***!!!
- 19% of total applied manure P was applied as 2nd Stage ***UF Permeate: BLEND*** with ~7X less variability (more accuracy) than **BASE** ***(Before Separation)***!!!

Variability in total applied manure K was reduced 2.3X (CV was reduced from 28.8% to 12.8%).

- In contrast, the reduced variability of applied N and S was somewhat less dramatic:
  - 1.5X (1st Year N), 1.3X (1st and 2nd Year N) and 1.4X (S), respectively.

While weighted average variability (CV) of total applied manure N under **2012 Crop Year Separation** (~15%) was roughly comparable to **BASE** ***(Before Separation)*** (~20%):

- Both ***UF Permeates (TARGET*** and ***BLEND***) provided *substantive reductions* (~**4X** and ~**8X**, respectively) in applied manure N variability.
  - Again, these ***UF Permeates*** (especially ***UF Permeate: TARGET***) "tea waters" are likely to capture large portions the soluble manure N (and K) and can be "spoon fed" during the growing season under optimal irrigation (water and nutrient management) strategies.
- **NOTE:** CV's for applied N of 3% (***UF Permeate: BLEND*** **)** to 5% **(*UF Permeate: TARGET***) versus ~20% (**BASE** ***(Before Separation)***, agitated pit manures) provide much tighter (more precise) statistical bounds (Confidence Intervals) for Precision Ag, applied manure NMP, improved agronomic profitability and enhanced environmental performance.

Hence, Precision Ag manure NMP and reduced nutrient (N) variability from manure separation can be used to minimizing nitrate leaching.

While we hoped to demonstrate substantive potential improvement in reducing N losses through Precision Ag with separated manure NMP using ***UF Permeate: TARGET*** via center pivot with optimal irrigation software. Unfortunately, however, we had substantive regulatory constraints (industrial spray field/monitoring well issues) that prohibited us from accomplishing this objective.

- **Table 6** indicates that about 1/5th (21%) of 2012 total applied manure N was applied via ***UF Permeates***:
  - 2% ***TARGET*** and 19% ***BLEND***.
- With ~**4X** (***TARGET***) and ~**8X** (***BLEND***) reductions in applied manure N variability compared to agitated pit manure (**<u>BASE</u>** ***(Before Separation)***).

It is unfortunate that regulatory concerns over such a relatively small amount of total applied manure N (~20% of total applied N but ~45% of total applied volume), with radically improved precision (reduced variability and optimized application via center pivot) compared to "standard" BMPs -- NMP with agitated pit manure (**<u>BASE</u>** ***(Before Separation)***) **–** prevented us from more fully demonstrating the economic and environmental performance potential of manure separation.

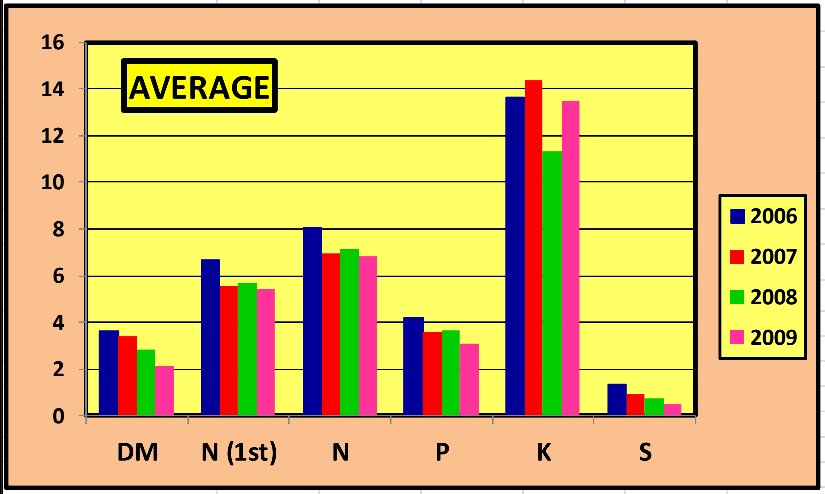
- Though, to be fair, empirical verification of these parameters (20% of total applied manure N, radically reduced nutrient variability, etc.) was not available until after **<u>FINAL</u>:** ***2012 Crop Year*** data were available and analyzed.

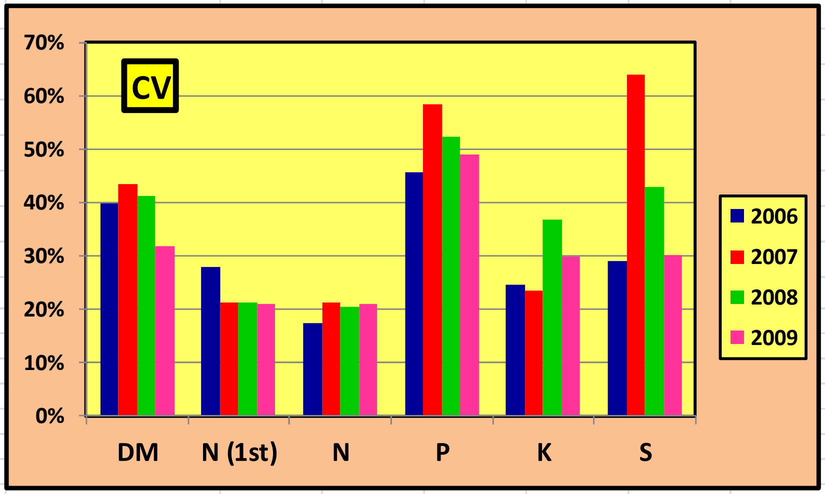
SUMMARY TABLES

TABLE 1. BASE 2006-2009 AGITATED PIT MANURE SUMMARY: 1st and 2ND YEAR MANURE NUTRIENT COMPOSITION AS APPLIED (Pounds/1,000 Gallons)

AVERAGE	DM	N (1st)	N	P	K	S
2006	3.6	6.7	8.1	4.2	13.7	1.4
2007	3.4	5.6	7.0	3.6	14.3	1.0
2008	2.8	5.7	7.1	3.6	11.3	0.8
2009	2.2	5.4	6.8	3.1	13.5	0.5
AVERAGE	3.0	5.9	7.2	3.6	13.2	0.9

COEFFICIENT OF VARIATION	DM	N (1st)	N	P	K	S	Number Samples
2006	40%	28%	17%	46%	25%	29%	34
2007	43%	21%	21%	58%	24%	64%	60
2008	41%	21%	21%	52%	37%	43%	53
2009	32%	21%	21%	49%	30%	30%	53
AVERAGE	39%	23%	20%	51%	29%	42%	200





N (excluding 2006) stable around 7 pounds/1,000 gallons.
P stable (excluding 2006) around 3.3 pounds/1,000 gallons
K stable around 13.3 pounds/1,000 gallons
S stable (excluding 2006) around 0.7 pounds/1,000 gallons

N measurements are relatively stable (CV = 18%) across samples.
P measurements vary 2.5 times more than N (CV = 48%)!!!
K measurements are relatively stable (CV = 23%) across samples.
S measurements vary about the same as DM (~30%) across the samples.

TABLE 2. FALL 2008 thru Spring 2010 Separated Manure Nutrient Composition AT SEPARATION (Pounds/1,000 gallons): Separator Calibration

	1st and 2nd Year Credits (Pounds/1,000 gallons)							
AVERAGE	DM	N-1st	N	P	K	S	NH4-N	C:N
Raw w/o Sand	3.76	7.82	9.89	4.08	14.33	0.84	8.65	6.7
PRESS SOLIDS (TONS)	27.29	2.87	3.64	1.61	3.62	0.88	1.63	37.5
UF Permeate (Tea Water)	1.01	3.51	4.43	0.26	13.71	0.52	6.32	1.8
UF Concentrate	4.66	10.07	13.24	7.46	13.76	1.03	8.70	6.4
3rd Stage	1.96	5.17	6.69	2.64	11.10	0.50	8.10	4.2

COEFF of VARIATION	DM	N-1st	N	P	K	S	NH4-N	C:N	OBS
Raw w/o Sand	9.7%	15.2%	12.1%	16.0%	22.0%	34.2%	18.0%	15.7%	41
PRESS SOLIDS (TONS)	24.3%	13.1%	10.1%	22.5%	18.5%	45.0%	20.5%	13.8%	40
UF Permeate (Tea Water)	14.6%	20.6%	16.9%	27.9%	30.9%	38.8%	29.3%	22.2%	29
UF Concentrate	19.2%	24.9%	15.6%	30.8%	17.4%	35.4%	21.3%	16.6%	25
3rd Stage	8.8%	11.4%	5.9%	14.5%	13.6%	12.8%	6.0%	10.6%	7

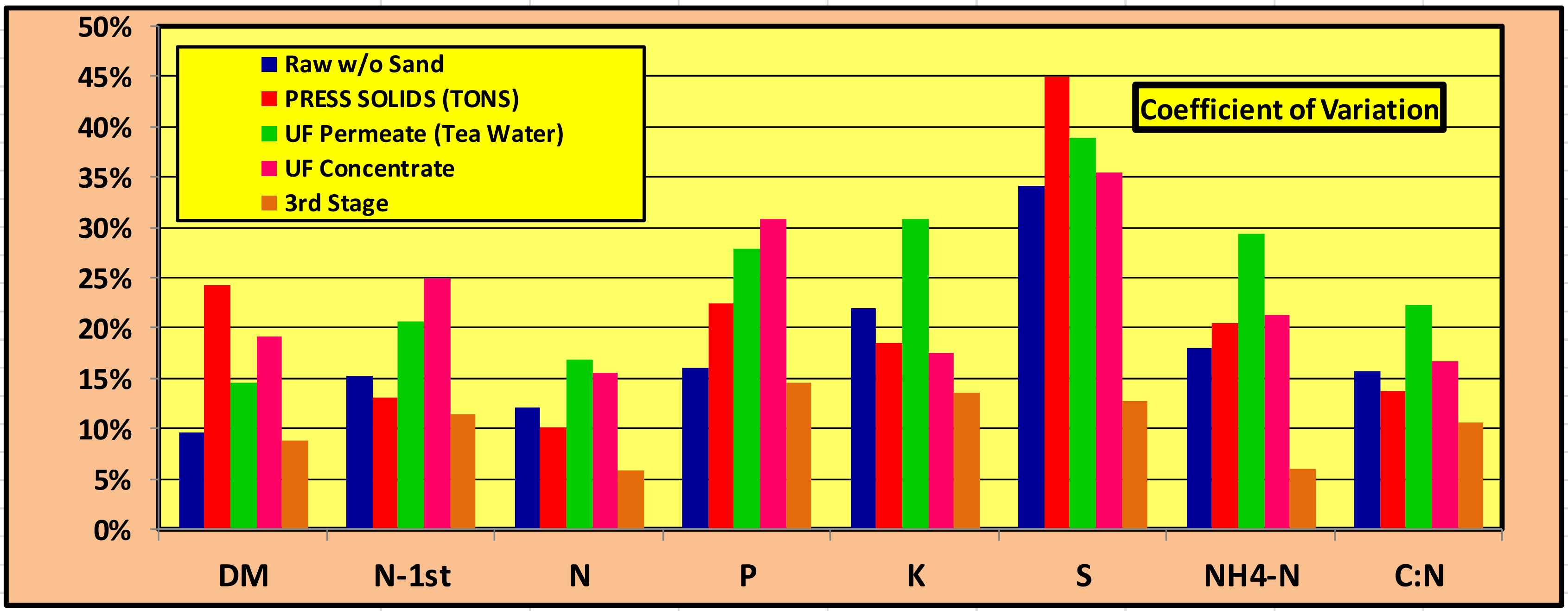


TABLE 3. Comparison of Nutrient Composition of Manure Fractions AT SEPARATION

PRELIMINARY (Separator Calibration): Fall 2008 - Spring 2010

Raw without sand (BASE)

	DM	N	P	K	S
Year 1					
Average	3.758	7.824	3.427	12.455	0.703
Coeff Variability (CV)	13.1%	15.2%	19.2%	26.6%	35.1%
Year 2					
Average	3.759	9.890	4.079	14.334	0.841
Coeff Variability (CV)	9.7%	12.1%	16.0%	22.0%	34.2%
Change versus Raw with Sand: Year 2					
Average	-7.899	-2.983	-1.396	-3.781	-0.993
% change	-67.8%	-23.2%	-25.5%	-20.9%	-54.1%
Coeff Variability (CV)	-24.4%	2.4%	-0.4%	6.6%	-15.0%
% change	-71.6%	24.3%	-2.6%	43.4%	-30.5%

Summmary: Raw w/o versus Raw with Sand

DM: Decrease Average ~2/3 (-68%), decreases CV = -72%
N: Decrease AVG -23%, Increase CV +24%
P: Decrease AVG -26%, Decrease CV slightly (-3%)
K: Decrease AVG -21%, Increase CV +44%
S: Decrease AVG -54%, Decrease CV -31%

Sand separation reduces all manure nutrient compositions, decreases the variability on DM, P (slightly) and S, while increasing the variability of N and K.

Raw with Sand

	DM	N	P	K	S
Year 1					
Average	11.925	10.298	4.844	16.442	1.728
Coeff Variability (CV)	36.8%	11.0%	17.8%	17.6%	65.0%
Year 2					
Average	11.658	12.872	5.475	18.115	1.834
Coeff Variability (CV)	34.1%	9.7%	16.5%	15.3%	49.1%

Virtually all manure nutrients applied to fields at partner dairy are from Manure w/o Sand. This comparison (Raw w/o versus Raw with Sand) measures the impacts of the sand separation for applied manures, the BASE manure "fraction" for the remaining nutrient composition|variability analysis.

Cleaned Sand

	DM	N	P	K	S
Year 1					
Average	87.559	0.510	1.616	0.586	1.088
Coeff Variability (CV)	2.5%	39.0%	38.7%	80.6%	53.8%
Year 2					
Average	87.582	0.572	1.843	0.699	1.165
Coeff Variability (CV)	2.9%	15.1%	27.9%	21.6%	36.5%
Change versus Raw w/o Sand: Year 2					
Average	83.824	-9.318	-2.236	-13.635	0.324
% change	2230.2%	-94.2%	-54.8%	-95.1%	38.6%
Coeff Variability (CV)	-6.8%	3.0%	11.9%	-0.4%	2.3%
% change	-69.8%	25.0%	73.9%	-1.7%	6.7%

Summmary: Cleaned Sand versus Raw w/o Sand

DM: increase ~22X, decrease CV -70%
N: decrease -94%%, increase CV +25%
P: decrease -55%, increase CV +74%
K: decrease -95%, ~ no change in CV -2%
S: increase +39%, increase in CV +7%

Cleaned sand removes massive (sand) solids and contains some N|P|K (0.5%, 1.6%, 0.6%) and substantive S (1.1%, a 39% increase over the BASE manure w/o Sand).

Press Solids

	DM	N	P	K	S
Year 1					
Average	27.986	2.875	1.406	3.132	0.779
Coeff Variability (CV)	25.4%	13.1%	26.5%	27.6%	44.7%
Year 2					
Average	27.293	3.639	1.608	3.623	0.884
Coeff Variability (CV)	24.3%	10.1%	22.5%	18.5%	45.0%
Change versus Raw w/o Sand: Year 2					
Average	23.534	-6.251	-2.471	-10.711	0.043
% change	626.1%	-63.2%	-60.6%	-74.7%	5.1%
Coeff Variability (CV)	14.6%	-2.0%	6.4%	-3.4%	10.8%
% change	150.0%	-16.5%	40.1%	-15.7%	31.6%

Summmary: Press Soilds versus Raw w/o Sand

DM: increase ~6.3X, increase CV ~1.7X
N: decrease -63%, decrease CV -17%
P: decrease -60%, increase CV +40%
K: decrease -75%, decrease CV -16%
S: increase +5%, increase in CV +32%

Manure w/o sand is pressed to generate a liquid fraction for the UF process. The resulting Press Solids have substantively (>60%) reduced N|P|K levels and increased DM|S (+6X|+5%). While variability of N|K are reduced (~16%), P|S variablity increases >30%.

UF Permeate (tea water)

	DM	N	P	K	S
Year 1					
Average	1.006	3.507	0.223	12.527	0.440
Coeff Variability (CV)	15.6%	20.6%	27.9%	34.3%	37.9%
Year 2					
Average	1.010	4.425	0.262	13.710	0.515
Coeff Variability (CV)	14.6%	16.9%	27.9%	30.9%	38.8%
Change versus Raw w/o Sand: Year 2					
Average	-2.748	-5.464	-3.817	-0.624	-0.326
% change	-73.1%	-55.3%	-93.6%	-4.4%	-38.7%
Coeff Variability (CV)	4.9%	4.8%	11.9%	8.9%	4.6%
% change	50.2%	39.7%	74.0%	40.6%	13.6%

Summmary: UF Permeate (tea water) versus Raw w/o Sand

DM: decrease -73%, increase CV +50%
N: decrease -55%, increase CV +40%
P: decrease -94%, increase CV +74%
K: small decrease (-4%), increase CV +41%
S: decrease -39%, increase in CV +14%

"Tea Water" is the liquid|permeate fraction from the UF process that is particularly interesting for its N|K with reduced P components. While P is reduced 94% from the BASE manure, its variablity increases 74%, as does N|K variablity (~40%).

UF Concentrate

	DM	N	P	K	S
Year 1					
Average	4.478	10.073	5.738	11.867	0.842
Coeff Variability (CV)	27.4%	24.9%	42.2%	33.6%	49.5%
Year 2					
Average	4.660	13.238	7.463	13.763	1.026
Coeff Variability (CV)	19.2%	15.6%	30.8%	17.4%	35.4%
Change versus Raw w/o Sand: Year 2					
Average	0.901	3.348	3.384	-0.571	0.185
% change	24.0%	33.9%	83.0%	-4.0%	22.0%
Coeff Variability (CV)	9.5%	3.5%	14.7%	-4.5%	1.2%
% change	97.7%	29.3%	91.8%	-20.5%	3.4%

Summmary: UF Concentrate versus Raw w/o Sand

DM: increase ~2.4X (235%), increase CV +90%
N: decrease -30%, increase CV 1.8X (+182%)
P: increase 2.3X (+234%), increase CV +75%
K: decrease -93%, increase CV +86%
S: increase ~10X (+970%), decrease CV -40%

UF Concentrate, the UF co-product with "tea water", has increased DM|N|P|S and decreased K nutrients as well as variablity.

3rd Stage

	DM	N	P	K	S
Year 1					
Average	1.910	5.166	2.168	9.504	0.412
Coeff Variability (CV)	11.2%	11.4%	18.5%	15.7%	14.6%
Year 2					
Average	1.957	6.691	2.637	11.097	0.496
Coeff Variability (CV)	8.8%	5.9%	14.5%	13.6%	12.8%
Change versus Raw w/o Sand: Year 2					
Average	-1.801	-3.198	-1.442	-3.237	-0.345
% change	-47.9%	-32.3%	-35.3%	-22.6%	-41.1%
Coeff Variability (CV)	-0.9%	-6.2%	-1.5%	-8.3%	-21.4%
% change	-9.5%	-51.5%	-9.3%	-37.8%	-62.7%

Summmary: 3rd Stage versus Raw w/o Sand

DM: decrease ~70%, increase CV 4%
N: decrease ~50%, increase CV 9%
P: decrease ~90%, increase CV 2%
K: increase 24%, increase CV 6%
S: decrease 18%, increase in CV 2%

TABLE 4. 2012 CROP YEAR MANURE SEPARATION SUMMARY: 1^{ST} and 2^{ND} YEAR NUTRIENTS AS APPLIED (POUNDS)

	Total Acres	Total Manure (1,000 gallons)	DM	N-1st	N: 1^{st} and 2^{nd}	TOTAL N	P	K	S
1st STAGE SOLIDS (TONS)	443	7,935	230,386	19,195	25,578	63,957	20,799	49,114	6,464
		#/acre	520.4	43.4	57.8	144.5	47.0	110.9	14.6
		Share of TOTAL	69.6%	8.6%	8.9%	10.3%	10.4%	8.1%	23.2%
		Average CV	3.8%	12.3%	12.2%	12.2%	20.9%	8.8%	35.1%
2nd STAGE: UF CONCENTRATE	1,610	18,812	72,588	148,866	186,710	373,471	137,486	306,034	14,135
		#/acre	45.1	92.5	116.0	232.0	85.4	190.1	8.8
Share of TOTAL	65.4%	57.8%	21.9%	66.6%	65.2%	60.0%	68.8%	50.4%	50.6%
		Average CV	12.7%	19.7%	19.1%	21.6%	18.7%	15.2%	31.8%
2nd STAGE UF PERMEATE: TARGET	340	6,264	7,476	17,692	23,579	58,954	3,931	101,107	3,273
		#/acre	22.0	52.0	69.4	173.4	11.6	297.4	9.6
Share of TOTAL	13.8%	19.3%	2.3%	7.9%	8.2%	9.5%	2.0%	16.7%	11.7%
		Average CV	10.5%	5.3%	5.3%	5.3%	21.6%	8.8%	34.2%
2nd STAGE UF PERMEATE: BLEND	511	7,462	20,624	37,757	50,335	125,849	37,715	150,967	4,038
		#/acre	40.4	73.9	98.5	246.3	73.8	295.4	7.9
Share of TOTAL	20.8%	22.9%	6.2%	16.9%	17.6%	20.2%	18.9%	24.9%	14.5%
		Average CV	3.1%	2.6%	2.6%	2.7%	7.2%	11.8%	11.8%
	Acres	TOTAL Manure	TOTAL MANURE NUTRIENTS APPLIED (POUNDS)						
TOTAL Tons	443	7,935	230,386	19,195	25,578	63,957	20,799	49,114	6,464
Total Gallons	2,461	32,538	100,688	204,315	260,624	558,274	179,132	558,108	21,446
TOTAL POUNDS APPLIED			331,074	223,511	286,202	622,231	199,931	607,222	27,909

TABLE 5. COMPARISON OF 1st and 2nd YEAR MANURE NUTRIENT CREDITS ACROSS TIME and BY DEGREES OF SEPARATION -- AS APPLIED (Pounds/1,000 Gallons)

	AVERAGE						Coefficient of Variation (CV)						
BASE Applied Manure Composition Summary: 2006-2009, NO Separation (Agitated Pit Manure)													Number
	DM	N-1st	N 1st/2nd	P	K	S	DM	N-1st	N 1st/2nd	P	K	S	Samples
2006	3.6	6.7	8.1	4.2	13.7	1.4	40%	28%	17%	46%	25%	29%	34
2007	3.4	5.6	7.0	3.6	14.3	1.0	43%	21%	21%	58%	24%	64%	60
2008	2.8	5.7	7.1	3.6	11.3	0.8	41%	21%	21%	52%	37%	43%	53
2009	2.2	5.4	6.8	3.1	13.5	0.5	32%	21%	21%	49%	30%	30%	53
AVERAGE (BASE)	3.0	5.9	7.2	3.6	13.2	0.9	39%	23%	20%	51%	29%	42%	200
Separator Manure Composition Summary: Fall 2008-Spring 2010 (Separator Calibration)													Number
	DM	N-1st	N 1st/2nd	P	K	S	DM	N-1st	N 1st/2nd	P	K	S	Samples
Raw w/o Sand	3.8	7.8	9.9	4.1	14.3	0.8	9.7%	12.1%	16.0%	22.0%	34.2%	18.0%	41
PRESS SOLIDS	27.3	2.9	3.6	1.6	3.6	0.9	24%	10%	22%	19%	45%	20%	40
UF Concentrate	4.7	10.1	13.2	7.5	13.8	1.0	19%	16%	31%	17%	35%	21%	25
UF Permeate (Tea Water)	1.0	3.5	4.4	0.3	13.7	0.5	15%	17%	28%	31%	39%	29%	29
3rd Stage	2.0	5.2	6.7	2.6	11.1	0.5	9%	6%	15%	14%	13%	6%	7
Applied Manure Composition Summary: 2012 Crop Year (Calibrated Separator)													Number
	DM	N-1st	N 1st/2nd	P	K	S	DM	N-1st	N 1st/2nd	P	K	S	Samples
PRESS SOLIDS	29.2	2.4	3.3	2.7	6.3	0.8	4%	12%	12%	21%	9%	35%	6
UF Concentrate	3.9	7.9	9.9	7.2	16.0	0.7	13%	20%	19%	19%	15%	32%	22
UF Permeate: Target	1.3	2.9	3.9	0.6	16.9	0.5	11%	5%	5%	22%	9%	34%	7
UF Permeate: By-Pass Blend	2.8	5.1	6.8	5.1	20.1	0.5	3%	3%	3%	7%	12%	12%	6
2012 Crop Year (Calibrated Separator) CV: Change from BASE (2006-2009) CV													
	CV CHANGE						CV %CHANGE						
	DM	N-1st	N 1st/2nd	P	K	S	DM	N-1st	N 1st/2nd	P	K	S	
Solids	-35%	-11%	-8%	-30%	-20%	-6%	10.2	1.9	1.6	2.5	3.3	1.2	
UF Concentrate	-26%	-3%	-1%	-33%	-14%	-10%	3.1	1.2	1.0	2.7	1.9	1.3	
UF Permeate: Target	-29%	-18%	-15%	-30%	-20%	-7%	3.7	4.3	3.8	2.4	3.3	1.2	
UF Permeate: By-Pass Blend	-36%	-20%	-17%	-44%	-17%	-30%	12.6	8.7	7.6	7.1	2.4	3.5	

TABLE 6. COMPARISON OF 1st and 2nd YEAR MANURE NUTRIENT CREDITS BEFORE (BASE) AND AFTER SEPARATION: AS APPLIED (Pounds/1,000 Gallons)

	AVERAGE COMPOSITION: Pounds/1,000 gallons						COEFFICIENT of VARIATION (CV): % of AVERAGE						
BASE: 2006-2009, NO Separation (Agitated Pit Manure)													Number
	DM	N-1st	N: 1st and	P	K	S	DM	N-1st	N: 1st and	P	K	S	Samples
AVERAGE Prior to Separation	3.0	5.9	7.2	3.6	13.2	0.9	39.1%	22.9%	20.0%	51.4%	28.8%	41.6%	200
AFTER SEPARATION: 2012 Crop Year													Number
	DM	N-1st	N: 1st and	P	K	S	DM	N-1st	N: 1st and	P	K	S	Samples
Solids (TONS)	29.2	2.4	3.3	2.7	6.3	0.8	4%	12%	12%	21%	9%	35%	6
UF Concentrate	3.9	7.9	9.9	7.2	16.0	0.7	13%	20%	19%	19%	15%	32%	42
UF Permeate: Target	1.3	2.9	3.9	0.6	16.9	0.5	11%	5%	5%	22%	9%	34%	7
UF Permeate: By-Pass Blend	2.8	5.1	6.8	5.1	20.1	0.5	3%	3%	3%	7%	12%	12%	18
Weighted Average							5.9%	14.3%	14.2%	16.8%	12.8%	30.0%	

	2012 SEPARATION: Share of TOTAL Nutrients						CV RATIO: BASE/2012 SEPARATION					
	DM	N-1st	N: 1st and	P	K	S	DM	N-1st	N: 1st and	P	K	S
Solids (TONS)	70%	8%	9%	10%	8%	23%	10.2	1.9	1.6	2.5	3.3	1.2
UF Concentrate	22%	63%	64%	69%	50%	51%	3.1	1.2	1.0	2.7	1.9	1.3
UF Permeate: Target	2%	8%	8%	2%	17%	12%	3.7	4.3	3.8	2.4	3.3	1.2
UF Permeate: By-Pass Blend	6%	16%	17%	19%	25%	14%	12.6	8.7	7.6	7.1	2.4	3.5
Weighted Average CV	100%	95%	98%	100%	100%	100%	6.6	1.6	1.4	3.1	2.3	1.4

2nd Stage UF Concentrate accounted for over half of total applied NPKS manure nutrients, while 1st stage Solids accounted for 70% of DM applications.

69% of total applied manure P was applied as 2nd Stage Concentrate with 2.7X less variability (more accuracy) than BASE (Without Separation)!!!

Use of Center Pivots with Optimal Irrigation software to apply 2nd stage UF Permeate ('Target') involved only 2% of Total Applied Manure N and P with 3.7X and 2.4X less variability (more accuracy), resepctively, compared to BASE (Without Separation).

19% of Total Manure P was applied as 2nd Stage UF Premeate BLEND with ~7X less variability (more accuracy) than BASE (Without Separation)!!!

On average, ISS Separation reduced manure nutrient variability by 1.X (1st year N), 3.1X (P), 2.3X (K), and 1.4X (S) compared to BASE (2006-2009, agitated pit manure), Prior to Separation.

NOTE: Weigted average variability (CV) of Total Applied Manure P under 2012 Crop Year Separation was 3X less variabile than BASE (2006-2009 average CV, agitated pit manure) Prior to Separation!!!

While weighted average variability (CV) of Total Applied Manure N under 2012 Crop Year Separation (~14%) was roughly comparable to BASE Without Separation (~20%), both UF Permeates (TARGET and BLEND) provided substantive reductions (~4X and ~8X, respectively) in applied N variability.

NOTE: CV's of 3% to 5% (UF Permeate BLEND and TARGET) versus ~20% (BASE Without Separation, agitated pit manures) provide much tighter (more precise) statistical bounds (Confidence Intervals) for applied manure NMP, improved agronomic profitability and enhanced environemtnal performance.

2. **Measure the economic costs (fixed (capital) and variable (labor, machinery and management time) associated with each stage of separation and each separated manure product compared to raw manure handling/storage/application.**

Activities and Results:
To measure the economic costs of each system we evaluated the cost of storing raw sand separated manure and hose drag/injection on to the fields versus separating the manure and applying it with various application systems including the use of center pivots to move about half of the manure volume.

Our table shows the cost per gallon of applying each separated product based on the distance away from the manure storage area. This cost is then multiplied by the gallons applied to come up with a total cost per field and total cost per manure type. We then compared this to using an irrigation system to apply about 4 million gallons (12.5% of total volume) of the manure through a center pivot which is currently available on the farm. At the present time, the WDNR will not allow the use of UF permeate without extensive water testing. The water testing would cost somewhere between $150 and $200 per acre, thus making the irrigation option too expensive to implement.

In the future we could apply about 50% of the total manure volume on about 600 acres of cropland if we were to get approval for the systems. This would reduce the volume of manure to be pumped in a hose system dramatically and could reduce hauling costs substantially. The amount of nitrogen applied through the pivot could also be reduced by about 30%, thus reducing nitrogen rates by about 60 pounds per acre on 600 acres. This along with reduction in application costs would save the farm about $ 105,000 dollars per year.

Center Pivot IRRIGATION COSTS			
	COST	SAVINGS	
IRRIGATION	$20,671.66	$42,224	CURRENT
Acres	N Cost/Acre	$84,448	PROJECTED
600	$35.00	$21,000	N: PROJECTED
TOTAL IRRIGATION SAVINGS		$105,448	TOTAL

The separation system costs the farm about $0.01/gallon per year. With approximately 32 million gallons processed per year, it costs the farm about $381,000 (~$130/acre) to separate and to field apply the separated manure. In our discussion above we saved about $105,000 (~$34/acre) per year in nitrogen and hauling costs via the use of center pivot irrigation, This indicates that it takes ~$243,000 per year (~$100/acre) to cover the cost of the separation system.

AVERAGE			
Total Applied Manure (gallons)	Distance (miles)	Acres	Rate/ Acre
32,538,174	2.5	2,461	12,936
Separated Manure Fraction	Cost/Gallon	Total Cost	Cost/ Acre
TOTAL UF: COSTS WITHOUT IRRIGATION	$0.0101	$327,178	$132.96
PROJECTED IRRIGATION COSTS SAVINGS	$0.0026	$84,448	$34.32
TOTAL UF: COSTS WITH IRRIGATION	$0.0075	$242,730	$98.65

With the separation system, the farm is able to apply manure throughout the growing season. This has allowed the farm to double herd size with its original manure lagoons. Manure lagoon expansion was not an option due to space limitations and regulatory constraints. Hence, manure separation costs replaced manure lagoon costs while providing substantive manure consistency (reduced variability) and management flexibility gains, reducing odor issues, and improving manure logistics (less cost for: manure agitation, haling of ***1st Stage Solids***, dragline applying ***UF concentrate***, center pivot ***UF Permeate***). Improved manure nutrient consistency, more timely Precision Ag application, and improved manure logistics will all save fertilizer dollars and reduced environmental losses. If a field by field analysis was conducted into the future and then verified by future soil testing one could also calculate the improved nutrient efficiency of separated manure products.

What We Learned:

1. We learned that with separation systems we could add cows without adding lagoon space which dramatically reduced the cost of storage and somewhat reduced environmental risk due to reduced storage.
2. The separated manure products allows us a much larger window of application as we are able to apply the UF permeate throughout the growing season through center pivot irrigation systems, rather than applying all manure either before planning or after harvest.
3. This also reduced environmental risk and improved economic efficiency as nutrients could be applied in a manner which allowed them to be used more efficiently when the crop actually needed the nutrients. Thus nutrients were less likely to be lost to the environment and were used by the crop in season rather than staying in the soil waiting to be used and/or lost through leaching or runoff.

4. The center pivot was a more cost effective way of applying the nutrients and required much less labor and management than is required in a hose drag application system.
5. The reduced need for pit manure agitation also lowered cost of applying separated manure nutrients.
6. More uniform (via reduced variability) manure nutrients helps to reduce the over and under application of nutrients.

SUMMARY TABLES

TABLE 7. 2012 COST OF SEPARATED MANURE APPLICATION

Separated Manure Fraction	Distance	Acres	Distance Index (Acre Miles)	Rate/ Acre	Total Applied Manure	Cost/ Unit	Total Cost	Cost/ Acre
1st STAGE SOLIDS (tons)	3.8	442.8	344.9	18.0	7,935	$6.66	$53,607	$121.08
2nd STAGE: UF CONCENTRATE (Fall, 2011)	2.9	960.6	203.1	12,946	12,391,605	$0.0122	$134,453	$139.96
2nd STAGE: UF CONCENTRATE (Spring 2012)	2.6	649.0	189.0	9,755	6,420,546	$0.0111	$65,480	$100.89
2nd STAGE: UF CONCENTRATE (TOTAL)	2.8	1,610	197.7	11,731	18,812,151	$0.0118	$199,933	$124.21
2nd STAGE UF PERMEATE: TARGET	2.3	340.0	293.3	16,911	6,264,140	$0.0096	$62,895	$184.99
2nd STAGE UF PERMEATE: BLEND	1.8	511	109.4	14,611	7,461,883	$0.0087	$64,349	$125.93
2nd STAGE UF PERMEATE: TOTAL	1.9	851	159.6	15,238	13,726,023	$0.0089	$127,244	$149.52
TOTAL UF: COSTS WITHOUT IRRIGATION	2.5	2,461	184.6	12,936	32,538,174	$0.0108	$327,178	$132.96
TOTAL ALL SEPARATED MANURES	2.7	2,903	206.3				$380,785	$131.15

3. **Develop a model to work with SNAPPlus (Soil Nutrient Application Planner) to help determine optimal economic and environmental manure management strategies. Model will interface nutrient, soil, rotation, and tillage management using separated versus raw manure nutrients. This more efficient utilization of manure nutrients via separation may improve yields, economic returns per acre and reduce nutrient losses due to improve environmental performance.**

Activities and Results:
Working with Landmark Cooperative, we developed a model for using use SNAP-Plus with each separated manure product. Separated manure products were extensively samples (see objective 1 above) prior to field application, and were then "backfilled" with commercial fertilizer to meet crop needs.

Resistance by our regulator agency did not allow us to completely optimize the use of the products as they were unwilling allow us to use our separated manure nutrient management plans on all fields and using all separated manure fractions, especially applying the UF permeate via center pivot irrigation with optimal irrigating software. In order to use UF permeate on a field we had to have and extensive water well testing program which made the technology unaffordable.

Our CIG demonstration suggests that we should use BMPs to apply manure nutrients and manage the application rates of these nutrients through Precision Ag technologies, better sampling and understanding of the separated manure products nutrient qualities rather than using water testing on the fields.

With reliable, statistically based manure composition estimates, it is relatively straight forward to optimally blend **2nd Stage UF** components (***Concentrat***e and ***Permeate: TARGET***) to meet site specific, crop/field level N needs while holding P at a fixed rate. **TABLE 8** provides an example where a ~50/50 UF Permeate/Concentrate blend provides 100 pounds of N (and 260 pounds of K) while holding P to 60 pounds (crop removal). Higher soil test P situations further restricting P applications would suggest larger proportions of ***UF Permeate: TARGET*** "blends" (average P 0.6 pounds/acre versus 3.6 pounds/acre for agitated pit manure). Higher N:P ratios in ***UF Permeate: TARGET*** type separated manure products yield manure NMPs with manure applications to better meet crop/field N needs without hitting NRCS 590 P constraints.

These types of "optimal" manure NMP strategies (BMP) using separation, reliable manure sampling, and Precision Ag provide considerable nutrient management flexibility as well as opportunities to improve both economic (reduced application cost and better nutrient use efficiency) and environmental performance (reduced soil and PI loss). This model could be further developed after we get more buy in from our regulatory agency, especially as concerns use of center pivots with optimal manure based "fertigation" software and **UF Permeate** type manure products.

TABLE 9 provides a whole farm (acreage weighted average) summary of field level ANNUAL environmental performance (soil loss and PI) over time using SNAP-Plus management reports. **<u>NOTE</u>:** These are ANNUAL field level environmental performance data. These ANNUAL field level measures are then averaged over the rotation to compute the Soil Loss and PI measures used in NRCS 590 planning.

- Across the whole "farm" (acreage weighted average), from 2008-2014, Average ANNUAL Soil Loss is less than ~1/2 'T' and ~1/3 of PI = '6'. This is relatively strong environmental performance showing that SNAP-Plus based manure NMP is improving performance over time, especially after the doubling of herd size and additional of ~1,000 new acres in 2011.
- Average ROTATIONAL (2008-2014) Soil Loss across the whole farm (1.7 t/acre) remains less than half of 'T' (3.7).
- Average ROTATIONAL PI (2008-2014) across the whole farm (2.2) remains less than 1/3 of PI = '6' and, there are no individual fields with Rotational Average PI > '6'.
- On average from 2008-2014, ~600 acres (16% of total) have Average ANNUAL Soil Loss > 'T'. This % has generally declined from a BASE (2008) of 19%. Most of these acres are in the corn silage portion of the 8 year rotation and these ANNUAL losses are then included in field level ROTATIONAL averages. Only 4 fields (304 acres, 7% of total) have ROTATIONAL Average Soil Loss > 'T'. Increased use of No-Till, Precision Ag, and/or cover crops following corn silage acres will be needed to further reduce these soil losses.
- On average from 2008-2014, ~127 acres (3% of total) had ANNUAL PI's > '6'. This % has generally declined from a BASE (2008) of 7% to 0% by 2014. There are no individual fields with Rotational Average PI > '6'. This is very strong environmental performance with sequential improvement.

SUMMARY TABLES

TABLE 8. Optimal UF Permeate/Concentrate Blending

Nutrient	Nutrient Values		50.9% Perm				
	Perm	Conc	Perm	Conc	Avg		
N	3.76	9.37	1.91	4.60	6.51		
P	0.58	7.36	0.30	3.61	3.91		
K	16.76	17.06	8.53	8.38	16.91		
			50.9%	49.1%	Required % Mixture		
Gallons/Acre to = 60# P	103,448	8,152		Gallons of Blend to Apply	15,351	Targets	Change Targets to desired level of N or Pand click Solve button.....
N	388.97	76.39		NPK of resulting Blend	100.00	100	
P	60.00	60.00			60.00	60	
K	1,733.79	139.08			259.55		

Solve for Target N

Maximize N (= target N) subject to P ≤ Target P by Changing % Perm

Data, Solver, Solve, OK

	Summary		
	Apply	15,351	Gallons/acre
	Blend	50.9%	Perm
	Blend	49.1%	Conc
This blend provides	Pounds	100	N/acre
	Pounds	60	P/acre
	Pounds	260	K/acre

TABLE 9. WHOLE FARM (Acreage Weighted Average) ENVIRONMENTAL ANNUAL PERFORMANCE SUMMARY (VIA SNAP-PLUS)***

Year	Acres	Field 'T' t/ac	Sediment Delivery Total (soil loss)	RATIO: Soil Loss/ Field T (%)	PI	RATIO: PI / "6" (Threshold)
2008	3,111	3.5	1.9	55%	2.0	34%
2009	3,200	3.5	1.8	50%	2.0	34%
2010	3,376	3.5	1.4	40%	1.7	28%
2011	4,159	3.7	1.7	48%	2.5	41%
2012	4,229	3.7	1.6	44%	2.6	43%
2013	4,229	3.7	1.5	40%	2.0	33%
2014	4,157	3.7	1.7	47%	2.1	34%
AVERAGE ANNUAL	3,780	3.6	1.7	46%	2.1	35%
ROTATIONAL AVERAGE (2008-2014)	4,229	3.7	1.7	47%	2.2	36%

*** NOTE: These are ANNUAL field level environmental performance data. These ANNUAL field level measures are then averaged over the rotation to compute the Soil Loss and PI measures used in NRCS 590 planning.

Across the whole "farm" (acreage weighted average), from 2008-2014, Average ANNUAL Soil Loss is less than ~1/2 'T' and ~1/3 of PI = '6'. ROTATIONAL Average Soil Loss is nearly identical.

Year	Number Fields > 'T'	Acres > 'T'	% Acres > 'T'	Number Fields PI > '6'	Acres PI > '6'	% Acres PI > '6'
2008	6	584	19%	2	228	7%
2009	10	793	25%	0	0	0%
2010	7	634	19%	1	147	4%
2011	10	500	12%	3	93	2%
2012	6	334	8%	6	267	6%
2013	9	638	15%	3	156	4%
2014	8	685	16%	0	0	0%
AVERAGE ANNUAL	8	595	16%	2	127	3%
ROTATIONAL AVERAGE (2008-2014)	4	304	7%	0%	0	0%

*** NOTE: These are ANNUAL field level environmental performance data. These ANNUAL field level measures are then averaged over the rotation to compute the Soil Loss and PI measures used in NRCS 590 planning.

Fields with ANNUAL Soil Loss > 'T' and PI > '6' are likley in the more environemntally "risky" potion of the rotation (corn silage).

On average from 2008-2014, ~600 acres (16% of total) have ANNUAL Soil Loss > 'T'. This % has generally declined from a BASE (2008) of 19%. Only 4 fields (304 acres, 7% of total) have ROTATIONAL Average Soil Loss > 'T';

On average from 2008-2014, ~127 acres (3% of total) had ANNUAL PI's > '6'. This % has generally declined from a BASE (2008) of 7% to 0% by 2014. No fields have have ROTATIONAL Average PI > '6'.

4. **Educate producers, consultants, crop advisors and agricultural equipment representatives on the use of manure separation technologies and the combination of these technologies with precision farming systems to manage manure nutrients more efficiently to improve farm profitability while reducing environmental risks.**

Activities and Results:
Annually we have attended and presented programs on our research at the Wisconsin Custom Applicators and Professional Nutrient Applicators of Wisconsin Annual meetings. Several hundred producers, custom applicators, crop advisors and consultants have been in attendance and learned about these new technologies. We have also spent numerous hours educating Department of Natural Resources professionals on this information.

Our extension service and custom applicators organizations hosted the North American Manure Management Expo in Wisconsin this year and we presented our data at this event. We also look to presenting the information at our future Crop Management Conferences and at events like the National No-till Conference in the future.

3) Lessons Learned

What We Demonstrated:
Manure separation can radically reduce important manure nutrient variability (most importantly P), increase controlled application of manure nutrients, as well as reduce costs (next section) and improve environmental performance.

From our sampling protocols we demonstrated that raw manure stored in a lagoon has a great amount of variability when applied to the field even though it has been stored and agitated before application. Separating the manure into components allowed us to reduce the variability of manure nutrient quality, thus allowing us to apply more uniform manure nutrients to the field. This indicates that separated manure products are much more like commercial fertilizer products when applied rather than having highly variable nutrient contents that are in normally stored slurry manure.

The ***UF permeate*** fraction of the separation was nearly 2/3rds of the total volume of the manure and could be most efficiently applied through use of center pivot and optimal irrigation software. Because this fraction contains mostly soluble nitrogen (N) and potassium (K) and very little phosphorous (P: ~0.5 pounds/1,000 gallons), it is economically and environmentally efficient to apply this product in season, during high moisture demand and low soil moisture levels. This allows the growing crop to utilize the soluble (and potentially leachable) N which can be “spoon fed” (e.g., 20 pounds of N via a ¼” center pivot application) to the crop multiple times throughout the growing season to maximize nitrogen use efficiency (and minimize leaching losses).

The ***UF concentrate*** (retentate) produces a liquid slurry) containing most of the manure P, twice the concentration of **BASE** ***agitated pit manure*** (7.2 versus 3.6 pounds/1,000 gallons) **but** with more than 2X less variability (19% CV versus 51%). ***UF Concentrate*** has slightly higher N concentration than **BASE *agitated pit manure*** (9.7 versus 7.2 pounds/1,000 gallons) and roughly the same variability (CV ~ 20%), but has much less soluble nitrogen (removed in the ***UF Permeate*** "tea water") than **BASE *agitated pit manure***. Additionally, both these P and N nutrients are likely bound up with the higher levels of DM in the ***UF Concentrate*** (3.9 versus 3.0 pounds/1,000 gallons). This then allowed us to apply (hose drag/inject) about 1/3 the manure volume containing 2/3 of the N and P manure nutrients compared to the **BASE *agitated pit manure.*** In addition, this product had less soluble N, so it was more stable and less likely to leach compared to raw manure.

What We Learned: Our largest lesson learned is that we need to work closely with the regulatory agencies to help them better understand the potential environmental benefits of using this technology.

1) We pretty much predicted that manure uniformity would improve when we removed most of the water from the concentrate when we separated the manure into various fractions.
2) We had strong resistance from agencies in understanding how we might better manage manure nutrients through separation and irrigation technologies.
3) We also had more equipment failures than expected. It took nearly 2 years for the separation company to work the bugs out of their system so the system would produce separated manure products reliably.
4) We found but have not totally proven that we may be able to use less nutrient per acre with the separated products, because the products are more uniform in quality and therefore we can apply them more precisely rather than over and under estimating their nutrient levels.
5) We were also able to use irrigation systems to apply many of the nutrients, particularly nitrogen, throughout the growing season. This allowed us to put the nutrients on at a lower rate which improves our overall farm nutrient use efficiency and farm profitability
6) Two thirds of the manure liquids did not require near as much agitation and could be applied through a center pivot rather than having to be applied with a hose drag system if application regulations were adjusted to the new technologies.
7) The bulk of UF permeate can be used in season through irrigation, and then the remainder of this product can be optimally blended with concentrate to balance nutrient needs of fields and crops.
8) Manure storage requirements for farms can be reduced or maintained even with expanding cow numbers, because manure nutrients can be concentrated (***1st Stage Solids*** and ***2nd Stage UF Concentrate***: reduced volume and variability) as well as applied during the cropping season through irrigation (***2nd Stage UF Permeate***).

4) Dissemination

Dissemination was explicitly covered in our **4th Objective**, summarized in **Section 2) Project Activities & Results**, above.

5) Project Documents

1) NFWF UW Madison Manure Separation CIG ANNUAL Report -- 2010.pdf (attached)
2) NFWF UW Madison Manure Separation CIG ANNUAL Report -- 2009.pdf (attached)

National Fish and Wildlife Foundation
ANNUAL Report: 2009

Project Name: Optimizing Manure Nutrient Utilization
Recipient Organization/Agency: UW-Madison
Date Submitted: October 30, 2009

We are making excellent progress towards our four objectives. In our original planning we planned to concentrate on phase I in the first year of the study and then work on phases 2 and 3 in years 2 and 3. However, mechanical problems with the ISS manure separation equipment, a key component of our CIG proposal, have caused delays in our ability to test and refine our phase 1 sampling protocols. Portions of the manure separation equipment were removed and redesigned to increase the capacity of the equipment and the equipment has just been recently reinstalled and is working well at this time.

We have a good start on the sampling protocols in phase 1 and will continue to refine these protocols now that the equipment is working more reliably. We have also spent considerable efforts on phases 2 and 3 which are dependent on the data from phase 1. We would like to have at least 3 years of separated manure data from the study to compare with the three previous years of manure management and sampling data we have from this farm. The data from last year's separated manure was not reliable as the new manure separation system was not functioning properly at all times. Thus the analysis of the separated manure products needs to be continued at least 3 years to have good sound information to meet our project objectives. Thus, we will need a no-cost one year extension to this project – if possible -- so we will have at least three years of complete manure analysis from the new manure separation system.

In phase 1 we are working to accomplish Objective 1 which is "Develop a practical manure sampling protocol to evaluate the nutrient content and uniformity of nutrients in raw manure and separated manure products at various stages in the manure enterprise (e.g., at separation, storage, and application)." We have made strong progress on this objective. We have a basic sampling protocol in which we sample each of the separated products weekly and enter this information into a data base. Dr Laboski is working with us to evaluate the results of these samples. We are trying to determine if the current system of manure analysis for more traditional manures will work well to estimate the nutrient analysis and credits of these various separated products or if we may have to modify the analysis protocols and equations to more accurately represent the separated manure products. In particular, there is a permitting related, nutrient management issue as to the first year availability of the N in the liquid separated manure fraction (T water). DNR regulators argue that this availability is likely higher than more traditional manures, hence requiring less T water application to be NRCD 590 compliant.

Dr. Laboski is evaluating our sampling test results and comparing them with sampling data from other research she is doing on various types of manure. After we make these evaluations we will be able to fine tune our sampling procedures/protocols and fine tune our nutrient estimations for these separated manure products, especially the more volatile (water soluble) N fractions.

We have also made progress relative to objective 2 which is "Measure the economic costs (fixed (capital) and variable (labor, machinery and management time)) associated with each stage of separation and each separated manure product compared to raw manure handling, storage, and application." We are collecting economic evaluation information as we manage the various types of manure and evaluating the cost of manure management from years prior to installing the separation system.

In objectives 3, "Develop a model to work with SNAP-Plus (Soil Nutrient Application Planner) to help determine optimal economic and environmental manure management strategies…" and objective 4, "Educate producers, consultants, crop advisors and agricultural equipment representatives on the use of manure separation technologies and the combination of these technologies with precision farming systems to manage manure nutrients more efficiently to improve farm profitability while reducing environmental risks", we are working to have more efficient utilization of manure nutrients. As part of the permitting process, a full SNAP-Plus analysis (nutrient management plans) has been run for the partner dairy under both the current herd size with more traditional(lagoon and bedded pack) manures, as well as with a doubling of herd size with use of the new manure separation system. This SNAP+ analysis of a doubled herd size with the new separation system uses our best estimates as to the nutrient content of the separated manure products. We plan to update these preliminary nutrient management plans with the analysis of 3 years of observations on the nutrient compositions of these separated manure products as we have more complete research information.

Separation may improve yields and economic returns per acre and as well as reduce nutrient losses, thus improving economic and environmental performance. By having manure products which more closely match the land/crop nutrient needs, we are likely to reduce the risk of nutrient losses to the environment. We are also working to integrate the use of SNAP+ and improve environmental performance of farms when managing and applying manure. To address these objectives we have been working with SNAP+ developers and DNR to integrate our research results and make significant progress on these objectives.

We have been working with DNR/NRCS in the permitting process for this farm as it relates to using these separated manure products. These new manure products create some new application challenges relative to permitting (in particular, first year nitrogen (N) availability in the liquid fraction ("tea water") of the separated manure products. We are working with DNR to develop application and monitoring protocols for the application of the separated manure products which are acceptable for the CAFO permitting process.

The preliminary lab tests show the t-water which will be applied through a center pivot irrigation system may have very soluble sources of nitrogen (N) and potassium (K). Thus we need to be careful that the N and K don't leach into ground water and/or to tiles which could move into surface water. We have come up with a plan to monitor the application of T-water with optimal irrigation modeling software so we can manage how much water (and N) we put on relative to crop moisture needs. We are also estimating the crops weekly need for N and applying the T water in small amounts to provide about 30 pounds of nitrogen at a time. In contrast, standard manure based nutrient management plans would apply total crop needs in the fall and/or spring, hence exposing the leachable fractions of N to environmental losses.

Our goal is apply on enough T water to keep the nutrients in the root zone and keep the field moisture level at about 50% of its water holding capacity so that if a large rain comes it will not drive the nitrogen out of the root zone. This will significantly reduce the risk of losing the nitrogen to either groundwater (via leaching) or surface water (via tiles).

To ensure that the irrigation modeling software is working properly to estimate how much T-water can be applied we are using soil probes which wirelessly communicate with a receiver in the farm office so we can monitor soil moisture levels at 12 and 24" of depth in the soil. This information is then compared with the estimates the irrigation monitoring to verify and calibrate the irrigation modeling software. We purchased several remote moisture sensors to generate these validation data and have applied them in a sampling grid. This sampling grid has been developed based on the expert advice of our collaborating biological systems engineer. Two crops (corn silage corn and hay) and two general soil types with different leaching capacities on tiled and non-tiled areas of the field are being used to evaluate different field cropping, soil type and drainage scenarios. The sensors are located in several different soil types in the field and in different crops so we can learn if the moisture estimates in different crops and soil types are estimated correctly by the irrigation modeling software.

National Fish and Wildlife Foundation
ANNUAL Report: 2010

Project Name: Optimizing Manure Nutrient Utilization
Recipient Organization/Agency: UW-Madison

We continue to make excellent progress towards our four objectives. As we discussed in our report last year, mechanical problems with the ISS manure separation equipment, a key component of our CIG proposal, caused delays in our ability to test and refine our phase 1 sampling protocols. Fortunately ISS has removed and redesigned the equipment to increase the capacity of the equipment so it is working more reliably and efficiently. We now have much more robust separated manure products data which we can share and we hope to continue to capture this data for another year to increase the reliability of our sampling protocol.

We have also spent considerable efforts on **phases 2 and 3** which are dependent on the data from phase 1. In order to address phase 2 we need DNR to let us apply one of the separated manure products called "tea water" (the UF (ultra-filtration) permeate) through a center pivot irrigation system. Thus, Our CIG project has played a very active role in our partner dairy's DNR permitting process as DNR has needed education and assistance in understanding use of these new technologies

It has been a real challenge for us to get clearance from them to research the application of this manure product. They would like the farm to install monitoring wells and possibly take tile line samples. To reduce the risk of T-water leaching through the soil into tile lines, we have recommended that T-water be put on in .25 inch/acre increments 4 to 6 times throughout the growing season so the crop can use both the moisture and nitrogen in the T-water before it has a chance to leach out of the root zone. We have also installed sensors which estimate soil moisture at 12 and 24 inches of depth at strategic locations throughout the irrigated field to estimate soil moisture levels. Combining this information with optimal irrigation modeling software to manage the 2 foot root-zone soil moisture levels is a BMP which should allow to irrigate the tea water only when the soil is at a low enough moisture content that the soil should be able to hold the moisture and nitrogen so that it can be used up by the growing crop before they can be leached from the root zone. This should make this system of manure product application efficient economically and environmentally.

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The attached tables summarize an outlier analysis (using box-plots) that was used to "clean up" the 40+ manure and separated manure component analyses we have sampled and tested to date. After omitting all manure sampling results with identified outliers, we then computed average 1st and 2nd year nutrient availability based on the lab analyses. These tables summarize manure nutrient composition as it moves through the manure/nutrient management system at the dairy. Raw manure with the bedding sand is first separated from the sand. We compare the change and % change in dry matter (DM), nitrogen (**N**), phosphorous (**P**), potassium (**K**) and sulfur (**S**) ***composition*** as well as ***variability*** (using the coefficient of variation, the standard deviation divided by the mean = % variability around the mean at one standard deviation).

1. The first comparison measures the impact of the sand separation comparing raw manure without sand versus raw manure with sand as the BASE.
2. After sand separation, manure without sand is the standard manure as applied, prior to the use of additional manure separation. This manure product is further separated into Pressed Solids and a liquid fraction that is then processed with UF technology. We analyze both manure fractions at this point.
    a. Separated sand
    b. Press soilds.
3. The liquid fraction processed via the UF stage of separation generated two additional fractions that we then analyze in comparison to the BASE (raw manure without sand).
    a. UF Permeate (tea water).
    b. UF Concentrate.

These preliminary analyses of changes in manure fraction nutrient composition and variability across the stages of separation indicate that we will perhaps need to both fine tune the sampling protocols (agitate the sand separated raw manures and liquid fractions better before additional separation and sampling) as well as using the substantively improved separation technology.

Dr. Laboski is evaluating our sampling test results and comparing them with sampling data from other research she is doing on various types of manure. After we make these evaluations we will be able to fine tune our sampling procedures/protocols and fine tune our nutrient estimations for these separated manure products, especially the more volatile (water soluble) N fractions.

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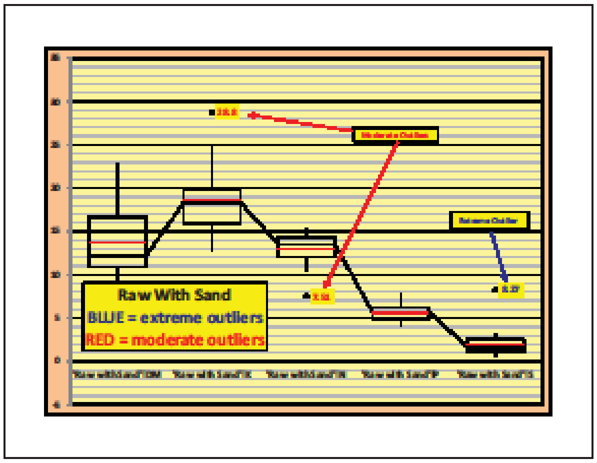
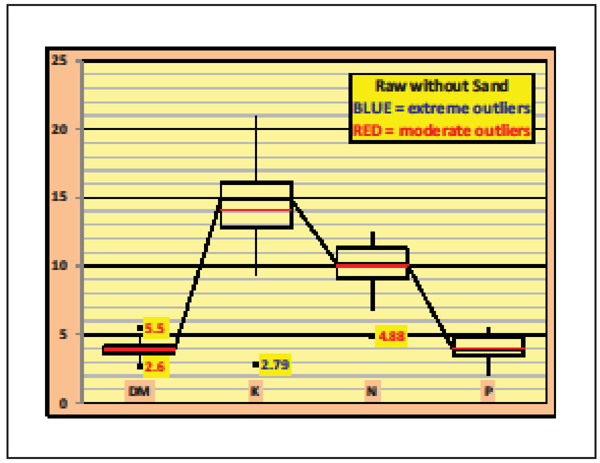
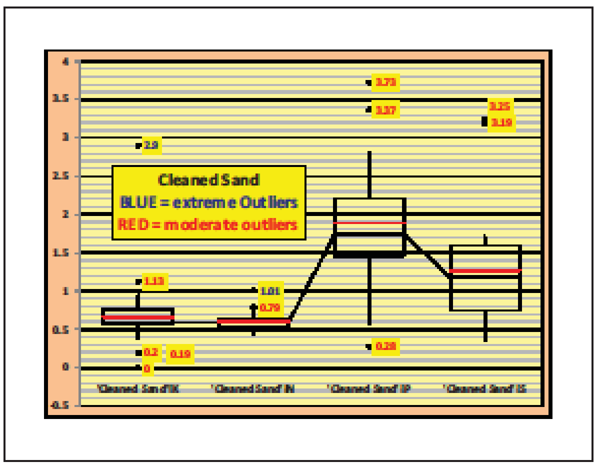
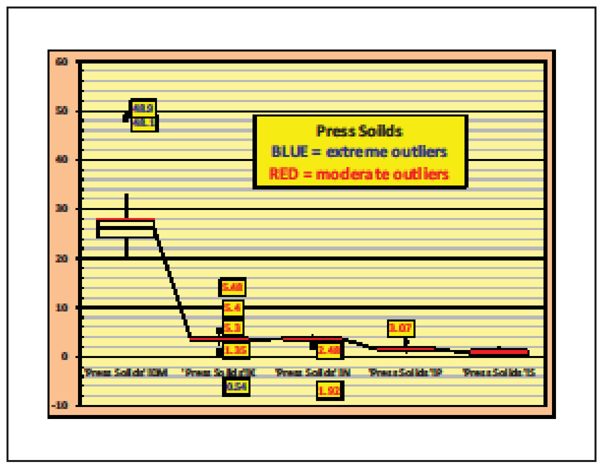
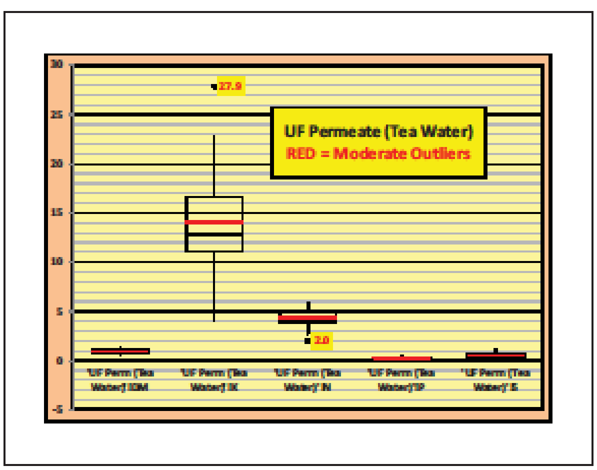
Figure 1: Outlier Analysis of Separated Manure Fractions.

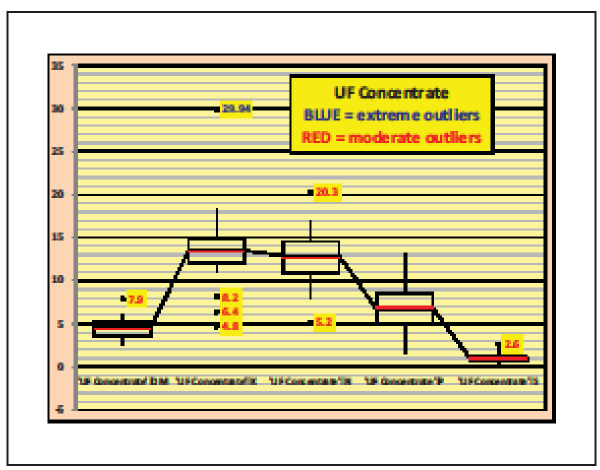












Manure Separation Precision Ag CIG: Manure Composition and Variability Summary

CIG Summary: Comparison of Nutrient Composition of Manure Fractions

Raw without sand (BASE)

	DM	N	P	K	S
Year 1					
Average	3.758	7.824	3.427	12.455	0.703
Coeff Variability (CV)	13.1%	15.2%	19.2%	26.6%	38.1%
Year 2					
Average	3.759	9.890	4.079	14.334	0.841
Coeff Variability (CV)	9.7%	12.1%	16.0%	22.0%	34.2%
Change versus Raw with Sand: Year 2					
Average	-7.899	-2.983	-1.396	-3.781	-0.993
% change	-67.8%	-23.2%	-25.5%	-20.9%	-54.1%
Coeff Variability (CV)	-24.4%	2.4%	-0.4%	6.6%	-15.0%
% change	-71.6%	24.3%	-2.6%	43.4%	-30.5%

Summary: Raw w/o versus Raw with Sand

DM: Decrease Average ~2/3 (-68%), decreases CV = -72%
N: Decrease AVG -23%, Increase CV +24%
P: Decrease AVG -26%, Decrease CV slightly (-3%)
K: Decrease AVG -21%, Increase CV +44%
S: Decrease AVG -54%, Decrease CV -31%

Sand separation reduces all manure nutrient compositions, decreases the variability on DM, P (slightly) and S, while increasing the variability of N and K.

Raw with Sand

	DM	N	P	K	S
Year 1					
Average	11.925	10.298	4.644	16.442	1.728
Coeff Variability (CV)	36.8%	11.0%	17.8%	17.6%	65.0%
Year 2					
Average	11.658	12.872	5.475	18.115	1.834
Coeff Variability (CV)	34.1%	9.7%	16.5%	15.3%	49.1%

Virtually all manure nutrients applied to fields at Larson Acres are from Manure w/o Sand. This comparison (Raw w/o versus Raw with Sand) measures the impacts of the sand separation for applied manures, the BASE manure "fraction" for the remaining nutrient composition/variability analysis.

Cleaned Sand

	DM	N	P	K	S
Year 1					
Average	87.559	0.510	1.616	0.586	1.088
Coeff Variability (CV)	2.6%	39.0%	38.7%	80.6%	53.8%
Year 2					
Average	87.582	0.572	1.843	0.699	1.165
Coeff Variability (CV)	2.9%	15.1%	27.9%	21.6%	36.6%
Change versus Raw w/o Sand: Year 2					
Average	83.824	-0.318	-2.236	-13.635	0.324
% change	2230.2%	-94.2%	-54.8%	-95.1%	38.6%
Coeff Variability (CV)	-6.8%	3.0%	11.9%	-0.4%	2.3%
% change	-69.8%	25.0%	73.9%	-1.7%	6.7%

Summary: Cleaned Sand versus Raw w/o Sand

DM: Increase ~22X, decrease CV -70%
N: decrease -94%%, Increase CV +25%
P: decrease -55%, Increase CV +74%
K: decrease -95%, ~ no change in CV -2%
S: Increase +39%, Increase in CV +7%

Cleaned sand removes massive (sand) solids and contains some N|P|K (0.5%, 1.8%, 0.8%) and substantive S (1.1%, a 39% increase over the BASE manure w/o Sand).

Press Solids

	DM	N	P	K	S
Year 1					
Average	27.966	2.875	1.406	3.132	0.779
Coeff Variability (CV)	25.4%	13.1%	26.5%	27.6%	44.7%
Year 2					
Average	27.790	3.639	1.608	3.623	0.884
Coeff Variability (CV)	25.9%	10.1%	22.5%	18.5%	45.0%
Change versus Raw w/o Sand: Year 2					
Average	24.032	-6.251	-2.471	-10.711	0.043
% change	639.4%	-63.2%	-60.6%	-74.7%	5.1%
Coeff Variability (CV)	16.2%	-2.0%	6.4%	-3.4%	10.8%
% change	167.4%	-16.5%	40.1%	-15.7%	31.6%

Summary: Press Solids versus Raw w/o Sand

DM: Increase ~6.3X, Increase CV ~1.7X
N: decrease -63%, decrease CV -17%
P: decrease -60%, Increase CV +40%
K: decrease -75%, decrease CV -16%
S: Increase +5%, Increase in CV +32%

Manure w/o sand is pressed to generate a liquid fraction for the UF process. The resulting Press Solids have substantively (>60%) reduced N|P|K levels and increased DM|S (+600-5%). While variability of N|K are reduced (~16%), P|S variability increases >30%.

UF Permeate (tea water)

	DM	N	P	K	S
Year 1					
Average	1.006	3.507	0.223	12.527	0.440
Coeff Variability (CV)	15.6%	20.6%	27.9%	34.3%	37.9%
Year 2					
Average	1.010	4.425	0.262	13.710	0.515
Coeff Variability (CV)	14.6%	16.9%	27.9%	30.9%	38.8%
Change versus Raw w/o Sand: Year 2					
Average	-2.748	-5.464	-3.817	-0.624	-0.326
% change	-73.1%	-55.3%	-93.6%	-4.4%	-38.7%
Coeff Variability (CV)	4.9%	4.8%	11.9%	8.9%	4.6%
% change	50.2%	39.7%	74.0%	40.6%	13.6%

Summary: UF Permeate (tea water) versus Raw w/o Sand

DM: decrease -73%, Increase CV +50%
N: decrease -55%, Increase CV +40%
P: decrease -94%, Increase CV +74%
K: small decrease (-4%), Increase CV +41%
S: decrease -39%, Increase in CV +14%

"Tea Water" is the liquid/permeate fraction from the UF process that is particularly interesting for its N|K with reduced P components. While P is reduced 94% from the BASE manure, its variability increases 74%, as does N|K variability (~40%).

UF Concentrate

	DM	N	P	K	S
Year 1					
Average	4.478	10.073	5.738	11.867	0.842
Coeff Variability (CV)	27.4%	24.9%	42.2%	33.6%	49.5%
Year 2					
Average	4.660	13.238	7.463	13.763	1.026
Coeff Variability (CV)	19.2%	15.6%	30.8%	17.4%	35.4%
Change versus Raw w/o Sand: Year 2					
Average	0.901	3.348	3.384	-0.571	0.185
% change	24.0%	33.9%	83.0%	-4.0%	22.0%
Coeff Variability (CV)	9.5%	3.5%	14.7%	-4.6%	1.2%
% change	97.7%	29.3%	91.8%	-20.5%	3.4%

Summary: UF Concentrate versus Raw w/o Sand

DM: Increase ~2.4X (238%), Increase CV +90%
N: decrease -30%, Increase CV 1.8X (+182%)
P: Increase 2.3X (+234%), Increase CV +75%
K: decrease -93%, Increase CV +88%
S: Increase ~10X (+970%), decrease CV -40%

UF Concentrate, the UF co-product with "tea water", has increased DM|N|P|S and decreased K nutrients as well as variability.