Report

Community Manure Management Feasibility Study

Dane County, WI

February 2008

Report for

Dane County, Wisconsin

Community Manure Management
Feasibility Study

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SECTION 4
DESIGN BASIS AND FINANCIAL EVALUATIONS

This section presents our opinion of cost evaluations of the eight manure management alternatives described in Section 3. A description of the facilities included in each alternative is presented, and opinions of capital, operational and maintenance (O&M), and overall life cycle costs are developed in this section. Cost sensitivity analyses are presented with respect to major O&M cost variables.

4.01 DESIGN BASIS

Chapters 2 and 3 discussed the current characteristics of each cluster and the assumed characteristics of the prototype farm in general. Based on that information, the preliminary design basis for each of the management alternatives was developed (Table 4.01-1). This design basis was used to develop preliminary facility and equipment requirements, which were then used to obtain proposals from manure management equipment and system providers and vendors.

The design basis was developed using the information collected with the farm surveys, and additional references were used to complete the design basis when the survey farm data was either incomplete or varied too much to rely on. These references included *Publication A2809 Nutrient Application Guidelines for Field, Vegetable, and Fruit Crops* in Wisconsin issued by the UW Extension and the *Nutrient Management Fast Facts* brochure from the Nutrient and Pest Management Program at the UW Extension. Most significantly, the solids content of the manure was assumed to be as presented in *Publication A2809,* Table 9.2.

It is noted that these design conditions are preliminary, and additional data collection, manure characterization, and quantity estimation should be conducted before proceeding to an implementation phase. For example, the manure production rate for the Waunakee Cluster was approximately 50 percent higher than for the Middleton Cluster (9.9 dry lbs/day/A.U. vs. 6.4 dry lbs/day/A.U.). While both of these values are within the normal range of manure production for dairy cattle of 6 to 10 lbs/day/A.U., this variation was not expected and is not readily explained. The Middleton Cluster does have higher numbers of young cattle and handles more of the manure in a dry form versus liquid form. Inaccurate manure estimation quantities might explain most of the discrepancy.

To develop facility requirements (sizes and capacities) for each of the three design conditions (individual farms, Waunakee Cluster, Middleton Cluster), a 25 percent allowance in the total manure quantities was included to provide capacity for additional manure loadings and/or alternate feed stocks such as industrial wastes. However, in the following sections, the mass balances and figures presented for each manure management alternative do not include this 25 percent allowance to better reflect the anticipated manure quantities. The quantities do, however, reflect the anticipated growth of the farms represented in the alternative analyses.

The alternatives included below for both the individual farms and the farm clusters assume that sand separation has already taken place prior to the equipment and processes described in the following sections for each of the management alternatives. All of the alternatives include some

TABLE 4.01-1

PRELIMINARY DESIGN BASIS

	Prototype Farm	Waunakee Cluster	Middleton Cluster
General Characteristics			
Total Number of A.U. (2007)	500	3,145	3,813
Anticipated Percent Growth through 2012 (Percent)	7	9	4
Total Number of A.U. (2012)	535	3,434	3,966
Additional Growth Allowance (Percent)	25	25	25
Design A.U.	669	4,293	4,957
Manure Production Rate (dry lbs/day/A.U.)[a]	6.3	9.9	6.4
Liquid Manure Generation[b]			
Percentage of Total Manure Solids	46	80	50
Mass of Manure Solids (dry lbs/day)	1,938	34,000	15,862
Solids Concentration of Manure (Percent)	6.0	6.0	6.0
Volume of Liquid Manure (gallons/day)	3,873	67,946	31,699
Nutrient Loadings:			
N (lbs/day)	93	1,631	761
P_2O_5 (lbs/day)	35	612	285
K_2O (lbs/day)	77	1,359	634
S (lbs/day)	16	285	133
Solid Manure Generation[b]			
Percentage of Total Manure Solids	54	20	50
Mass of Manure Solids (dry lbs/day)	2,275	8,500	15,862
Solids Concentration of Manure (Percent)	24	24	24
Volume of Solid Manure (gallons/day)	1,137	4,247	7,925
Nutrient Loadings:			
N (lbs/day)	47	177	330
P_2O_5 (lbs/day)	24	89	165
K_2O (lbs/day)	43	159	297
S (lbs/day)	7	27	50
Total Manure Generation Summary			
Total Mass (dry lbs/day)	4,213	42,500	31,724
Total Solids Content (Percent)	10.1	7.1	9.6
Total Manure Production (wet tons/day)	21	301	165
Total Manure Volume (gal/day)	5,010	72,192	39,624
Total Nutrient Loadings			
N (lbs/day)	137	1,808	1,091
P_2O_5 (lbs/day)	59	700	450
K_2O (lbs/day)	120	1,518	931
S (lbs/day)	23	312	183

[a] Based on survey data.
[b] Liquid manure is generally flushed as a liquid or semi-liquid and stored in a tank of lagoon; solid manure is generally scraped and stored in a stack or pile on-site.

level of storage prior to the alternative technologies employed, and at a minimum, sand would tend to settle within such storage structures.

One alternative that was not included, but that has been employed on an individual farm basis, is simple solids separation (no polymer or other chemical addition) using screw presses or similar equipment. This type of equipment may be used to recover some of the fiber in the manure, and the fiber can often be reused as animal bedding even without digesting or otherwise treating the solids. However, the amount of P removed in such a system (typically 20 to 30 percent) is lower than required to meet the County's goals for phosphorus reduction. Therefore, simple solids separation without any chemical addition was not evaluated in this report. In addition, new technologies and methods for managing manure are under development, and significant research is being conducted world wide on manure management. The technologies considered herein represent viable technologies at the current time, and we understand that new technologies may be developed in the near future that could change these evaluations.

4.02 INDIVIDUAL FARM ALTERNATIVES–DETAILED DESCRIPTIONS

This chapter provides a discussion of the equipment, tanks, building, and related construction elements required for each of the individual farm alternatives. In the following analyses, quantities, performance, and similar information provided should be considered as preliminary.

A. Alternative F-1: Fine Solids Separation with Polymer Addition

Raw manure would be collected at a central manure receiving pit sized to hold two days of manure generation. Manure would be pumped to the solids separation equipment, and polymer would be injected into the pipe prior to the separation equipment to improve solids capture. The polymer system includes a polymer makeup and delivery system that uses emulsion polymers (liquid dry polymers could also be used) delivered and stored in portable 2,200-pound (about 300 gallons) tote containers. Polymer would be diluted with fresh water prior to being mixed into the manure.

Separated solids would be transferred to a covered storage space protected from the elements, where the solids could be stored for up to three months as needed. The liquid portion of the separated manure would be pumped to storage. The storage lagoon would be sized for six months of storage. Cost opinions assume there is an existing raw manure storage lagoon, which would be converted to storage for effluent liquids. The estimated volume of this existing storage lagoon is 1 million gallons based on manure production rates. In this alternative, the addition of polymer water and dewatering equipment wash water would require additional storage capacity, resulting in a total storage volume requirement of approximately 3-million gallons. Therefore, a new 2-million-gallon storage lagoon is required. The liquid is assumed to be land-applied by trucking on nearby land (reduced trucking compared to the existing operations) since the P content is significantly less than the phosphorus content of the raw sludge.

This system will be equipped with a nonpotable water (NPW) system incorporating a storage tank and booster pumps to feed wash water to the fine solids separation unit and to feed dilution water to the polymer system. The storage tank would be filled from the farm's well.

Figure 4.02-1 shows the mass balance through the solids separation process. The mass balance was generated using manufacturer's data for system performance. Based on this data, about 77 percent of the raw manure volume is conveyed to liquid storage along with the water added for polymer dilution and screen wash water, and the liquid portion contains about 55 percent of the solids, N, P, and K. Polymer dilution water and wash water are assumed to add negligible solids and nutrients.

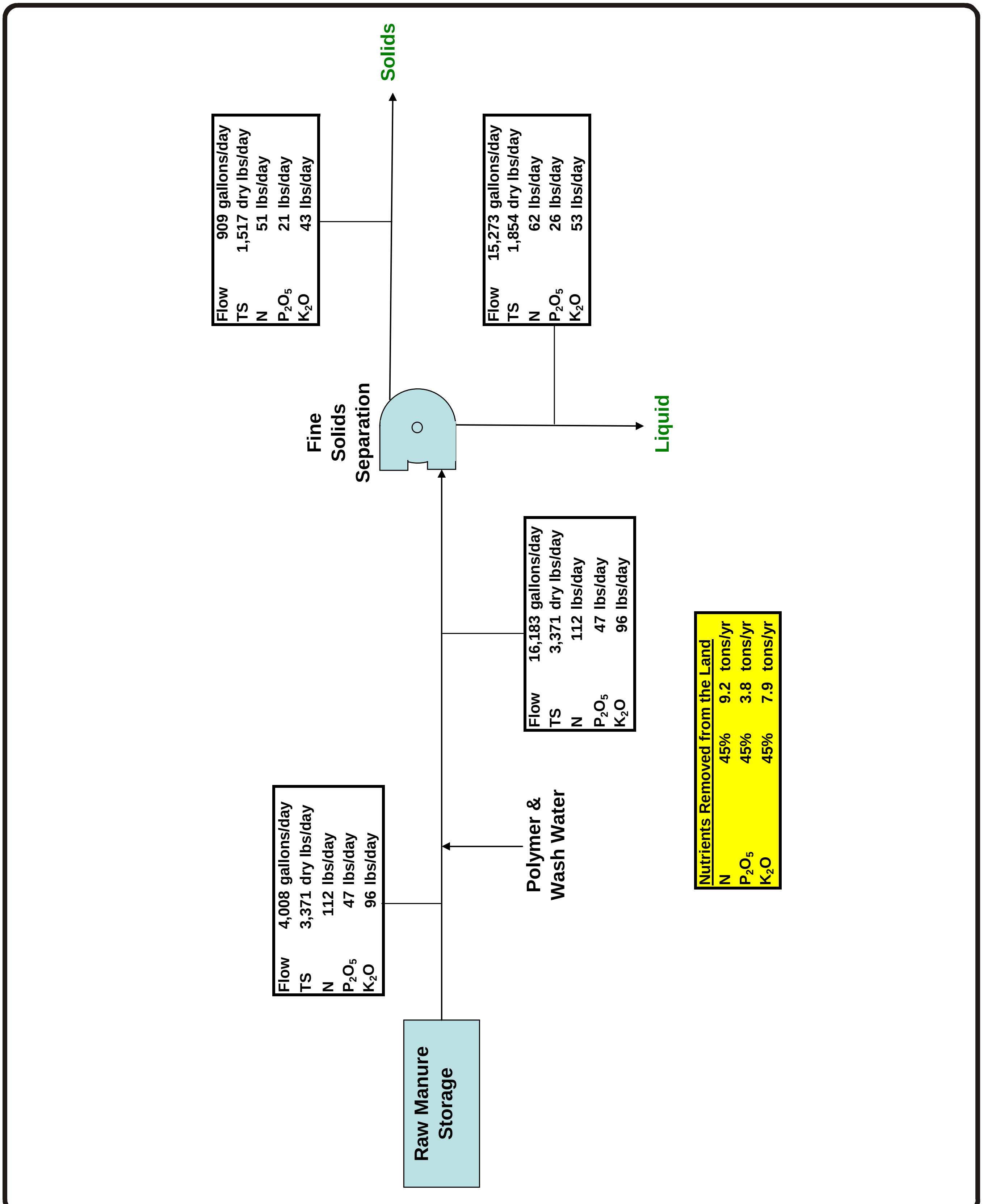
The polymer demand for this system is about 60 lbs/day. The system would also require approximately 3,800 gallons of polymer makeup water and 8,400 gallons of screen wash water per day. The system is designed to operate approximately 40 to 50 hours/week and is anticipated to require 0.5 full-time staff for operations and maintenance.

B. Alternative F-2: Fine Solids Separation with Ferric Chloride and Polymer Addition

This alternative is very similar to Alternative F-1. The basic difference is the addition of ferric chloride to the solids separation equipment feed line, which improves P and solids capture, resulting in higher P in the solids and lower solids and nutrients in the liquid portion. The ferric chloride feed system would be similar to the polymer feed system with the exception that dilution water is not required for the ferric system.

A new solids storage structure will be constructed to hold about one month of solids. This storage time is less than in Alternative F-1 and was assumed because of the higher nutrient value of the solids and the subsequent increased likelihood of transporting the solids off-site more readily than in Alternative F-1. The solids can be land-applied, sold to another end user, or composted. We have assumed the liquids would be applied to nearby fields using irrigation equipment. We have included traveling spray guns, approximately one-half mile of underground piping to nearby fields, and a 100 hp irrigation pump in our cost opinions. The storage lagoon would be sized for about three months of storage, which will be approximately 1-million gallons. Cost evaluations assume that the existing 1-million-gallons storage lagoon will be converted to storage for treated liquids. The duration for liquids storage has been reduced because liquids will have low enough nutrient content to allow spray application to growing crops.

The wash water needs of the separation equipment would probably be partially met by recycling water from the separation equipment. The effluent water has fairly low solids and nutrients, and in similar applications, the equipment vendor has indicated a significant savings by recycling water to clean the equipment screens.



ALTERNATIVE F-1
FINE SOLIDS SEPARATION WITH POLYMER ADDITION
COMMUNITY MANURE MANAGEMENT FEASIBILITY STUDY
DANE COUNTY, WISCONSIN

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FIGURE 4.02-1
1-124.005

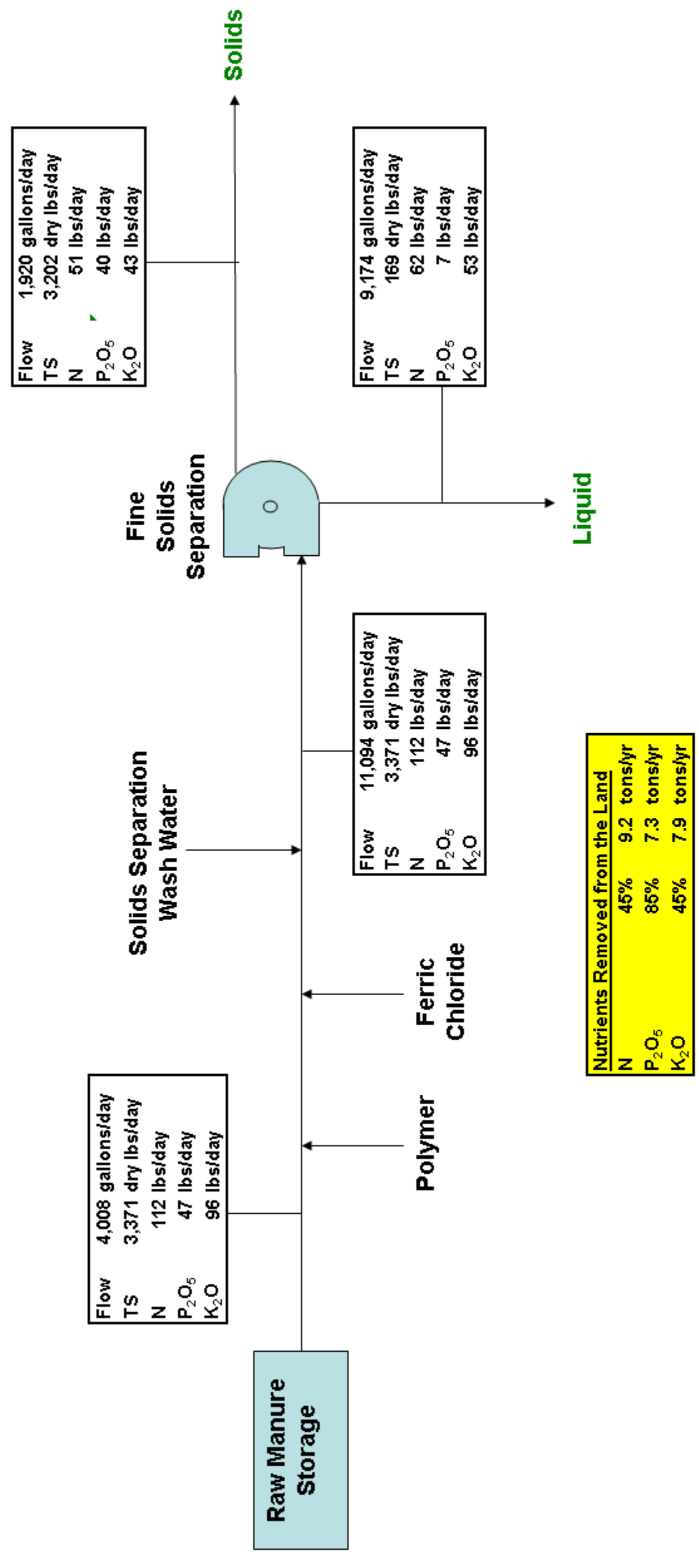
Figure 4.02-2 shows the mass balance through the solids separation process. These numbers were generated using manufacturer's data. Based on the manufacturer's estimates, the liquid portion would contain approximately 5 percent of the solids, 55 percent of the N, 15 percent of the P, and 55 percent of the K. The solids portion is 23 percent of the volume and contains approximately 95 percent of the solids and 85 percent of the P. Polymer dilution water and wash water are assumed to add negligible solids and nutrients.

The ferric chloride and polymer usage for this alternative is anticipated to be about 250 lbs/day and 30 lbs/day, respectively. The system would require approximately 1,900 gallons of polymer makeup water and 5,200 gallons of screen wash water per day. The system is designed to operate approximately 40 to 50 hours/week and is anticipated to require 0.5 full-time staff for operations and maintenance.

C. <u>Alternative F-3: Anaerobic Digestion Followed by Fine Solids Separation with Ferric Chloride and Polymer Addition</u>

Raw manure would be collected at a central location on-site and pumped to an anaerobic digester on a continuous basis. The digester would be sized for a 28-day detention time to provide adequate destruction of disease organisms and is assumed to operate at mesophilic temperatures in the range of 90° to 100°F. The digester would be an aboveground covered tank equipped with mixing and heating equipment. The anaerobic digester cover will be designed to collect biogas and would be equipped with the proper gas safety equipment and devices necessary for systems generating methane gas. Biogas would be delivered to engine-generation equipment designed to burn biogas and generate electricity. The electricity would be used on the farm to supplement demand. Heat would be recovered from the engine and used to maintain the digester temperature and provide building heat.

Anaerobically digested manure would then be pumped to a solids separation system identical to that described for Alternative F-2. Figure 4.02-3 shows the mass balance through the anaerobic digestion and solids separation processes. These numbers were generated using anticipated removal rates for anaerobic digestion and manufacturer's data for the solids separation process. It was assumed that the raw manure is about 90 percent volatile and that the anaerobic digester will destroy 35 percent of the volatile solids in the raw manure. The anticipated effluent total solids concentration from the digester is approximately 2,300 dry lbs/day. The nutrient content of the manure is expected to be conserved through the digester, although there will be some changes in the form of the nutrients, especially N and P. After solids separation, about 84 percent of the raw manure volume is conveyed to liquid storage along with the water added for polymer dilution and screen wash water. The liquid portion contains 5 percent of the solids, 55 percent of the N, 15 percent of the P, and 55 percent of the K. The solids portion contains 16 percent of the initial volume, 95 percent of the solids, and 85 percent of the P. Polymer dilution water and wash water are assumed to add negligible solids and nutrients.



ALTERNATIVE F-2
FINE SOLIDS SEPARATION WITH FERRIC CHLORIDE AND POLYMER ADDITION
COMMUNITY MANURE MANAGEMENT FEASIBILITY STUDY
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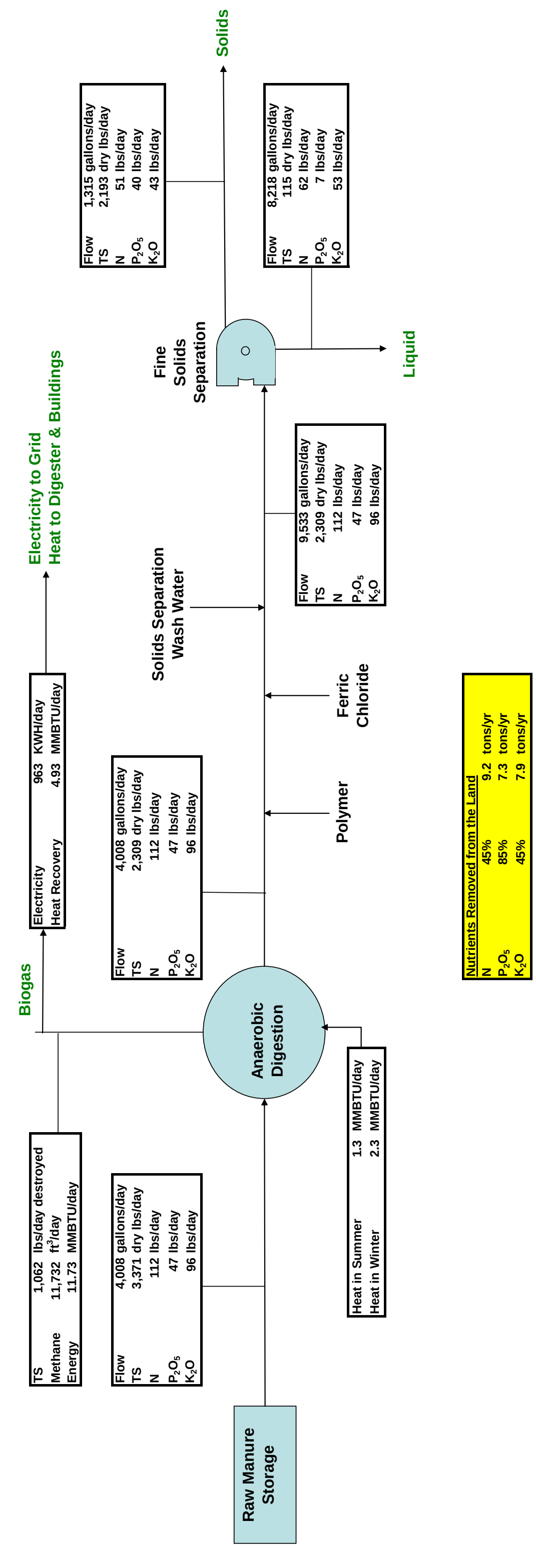
FIGURE 4.02-2
1-124.005



ALTERNATIVE F-3
ANAEROBIC DIGESTION FOLLOWED BY FINE SOLIDS SEPARATION WITH FERRIC CHLORIDE AND POLYMER ADDITION
COMMUNITY MANURE MANAGEMENT FEASIBILITY STUDY
DANE COUNTY, WISCONSIN

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FIGURE 4.02-3
1-124.005

The ferric chloride and polymer demands for the system are about 170 lbs/day and 22 lbs/day, respectively. The system would require approximately 1,300 gallons of polymer makeup water and 4,200 gallons of screen wash water per day. The system is designed to operate approximately 40 to 50 hours/week and is anticipated to require 1.0 full-time staff for operations and maintenance.

4.03 CLUSTER ALTERNATIVES–DETAILED DESCRIPTIONS

This section provides a detailed discussion of the equipment, tanks, building, and related construction elements required for each of the cluster alternatives.

A. Common Facilities–All Alternatives

For each of the cluster alternatives, raw manure must be collected at each of the cluster farms and transported to a central facility for processing by one of the five alternatives (C-1 through C-5). The facilities required at each farm are independent of the technology employed at the central facility and are required for all alternatives. These facilities are described below for the Waunakee and Middleton clusters.

1. Waunakee Cluster

The Waunakee Cluster would use pumping stations to convey raw manure at each farm to the central processing facility, as the three farms (Farms 4, 32, and 150) included in this cluster are relatively close to each other. The central facility was assumed to be located at Farm 32 because this farm has more of the desired infrastructure already in place. Farms 4 and 150 would pump their manure on a regular basis to a raw manure storage tank at Farm 32. Conveyance systems would be designed to drain as much as possible after pumping ceases to reduce the potential of lines plugging with manure that has settled in the lines.

Manure would be processed through the community facility, and the remaining liquids would be distributed among the three farms for land application. Conveyance of water to the farms would be through the same pipeline that is used for raw manure delivery. Valves at the community facility and the farms would be used to control the flow path of the manure.

The following additional infrastructure would be necessary at each farm:

a. Farm 32: Additional force main (on-site) and a pumping station.

b. Farm 150: Force main between Farm 150 and Farm 32 of approximately 1,750 feet, short-term storage for raw manure, and a raw manure pumping station. The existing 12 months of storage will be converted to finished liquid storage.

c. Farm 4: Force main between Farm 4 and Farm 32 of approximately 3,500 feet, six months of storage for finished liquid storage, and a manure pumping station. Six months of storage for this farm is estimated to be a 7.5-million-gallon lagoon.

This infrastructure will be necessary for each of the alternatives except for Alternative C-5 (Combustion). Since there will be no liquid effluent stream from Alternative C-5 (Combustion), six months storage will not be necessary for Farm 4 and short-term storage will not be necessary for Farm 150; however, the other infrastructure will still be necessary.

For Alternatives C-2 (Fine Solids Separation/Ferric), C-3 (Anaerobic Digestion), and C-4 (Drying), irrigation equipment will be necessary at each farm if the farm does not already have a means of applying liquids to fields. This document assumes that irrigation equipment is necessary at each farm.

2. Middleton Cluster

The Middleton Cluster (Farms 89, 112, 142, 145, 156, 176, and 195) would use trucks to haul the manure to the community facility. Ideally, the community facility would be located along the Highway 12 corridor near County Highway K. Manure would be trucked to the community facility from each of the farms, and liquid residuals would be trucked back to each of the farms for storage and land application. The existing raw manure storage at each of the farms would be converted to liquid residual storage, and one of the other existing storage structures or a new storage structure would be used for raw manure storage prior to hauling to the community facility. The raw manure storage on each farm should provide approximately one week of storage or more.

The following additional infrastructure would be necessary at the farms as noted:

a. Farm 89: One week of storage for raw manure prior to hauling to community facility.

b. Farm 112: None.

c. Farm 142: One week of storage for raw manure prior to hauling to community facility.

d. Farm 145: None.

e. Farm 156: Six months of storage for liquid residuals. Storage will be sized to hold 10 percent of the liquid residual from the treatment system. This percentage was selected because this farm has 10 percent of the A.U. in this cluster. This lagoon is roughly 2-million gallons, but it varies depending on the alternative.

f. Farm 176: One week of storage for raw manure prior to hauling to community facility.

g. Farm 195: One week of storage for raw manure prior to hauling to community facility.

This infrastructure would be necessary for each of the alternatives except for Alternative C-5. Since there will be no liquid effluent stream from Alternative C-5, raw manure storage would not be necessary for Farm 89, Farm 142, Farm 176, and Farm 195, and six months of storage for liquid residuals would not be necessary for Farm 156.

For Alternatives C-2, C-3, and C-4, irrigation equipment will be necessary at each farm to spray irrigate returned water on nearby fields.

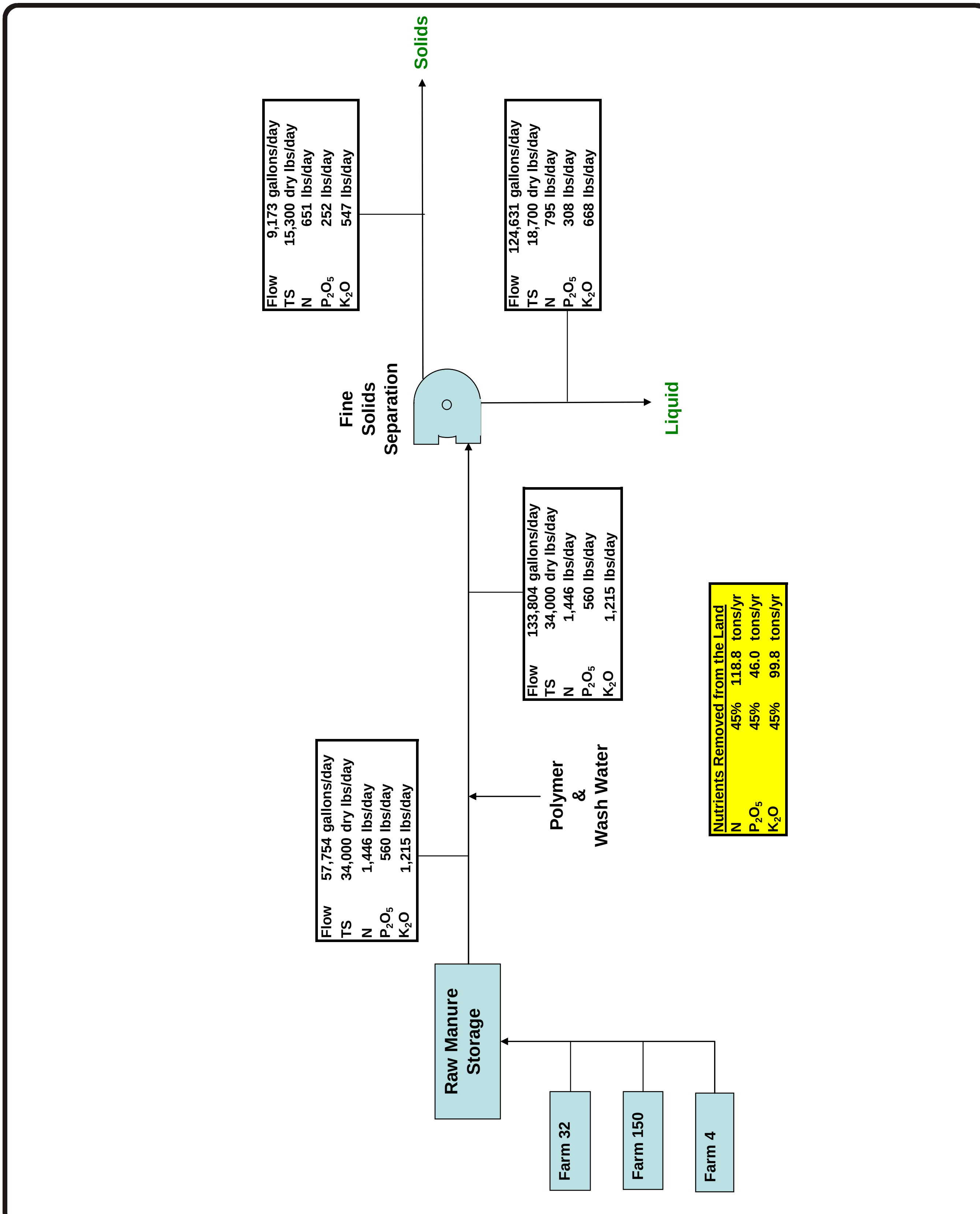
B. Alternative C-1: Fine Solids Separation with Polymer Addition

Raw manure will be delivered to a central manure receiving pit at the community facility sized to provide approximately one week of raw manure storage. The polymer dosing and solids separation equipment is similar to that described for Alternative F-1, with the exception that the equipment would be sized to handle the higher loadings, and a dry polymer system would likely be included in lieu of the emulsion polymer system for Alternative F-1. For economy reasons, dry polymer systems are normally used for larger applications with significant polymer usage.

Approximately one month of liquids residual storage will be constructed at the cluster site, which amounts to 4.5-million gallons of liquid storage in the Waunakee Cluster and 3.1-million gallons of storage in the Middleton Cluster. A new structure will be constructed to hold three months of solids at the processing facility site. The solids can be land-applied or composted. Liquids will be land-applied by the cluster farms.

Figures 4.03-1 and 4.03-2 show the mass balance through the solids separation process for the Waunakee and Middleton Clusters, respectively. Based on this information, approximately 77 percent of the initial volume and 55 percent of the solids, N, P, and K will end up in the liquid portion of the separated manure.

The estimated polymer demand for the Waunakee cluster is 600 to 650 lbs/day. The system would also require approximately 38,000 gpd of polymer makeup water and 38,000 gpd of screen wash water. The polymer demand for the Middleton cluster is estimated at 450 to 500 lbs/day. The system would require approximately 29,000 gpd of polymer makeup water and 42,000 gpd of screen wash water. Both systems were sized to operate 40 to 50 hours/week, and both systems are anticipated to require two full-time staff for operation and maintenance.



ALTERNATIVE C-1W (WAUNAKEE)
FINE SOLIDS SEPARATION WITH POLYMER ADDITION
COMMUNITY MANURE MANAGEMENT FEASIBILITY STUDY
DANE COUNTY, WISCONSIN

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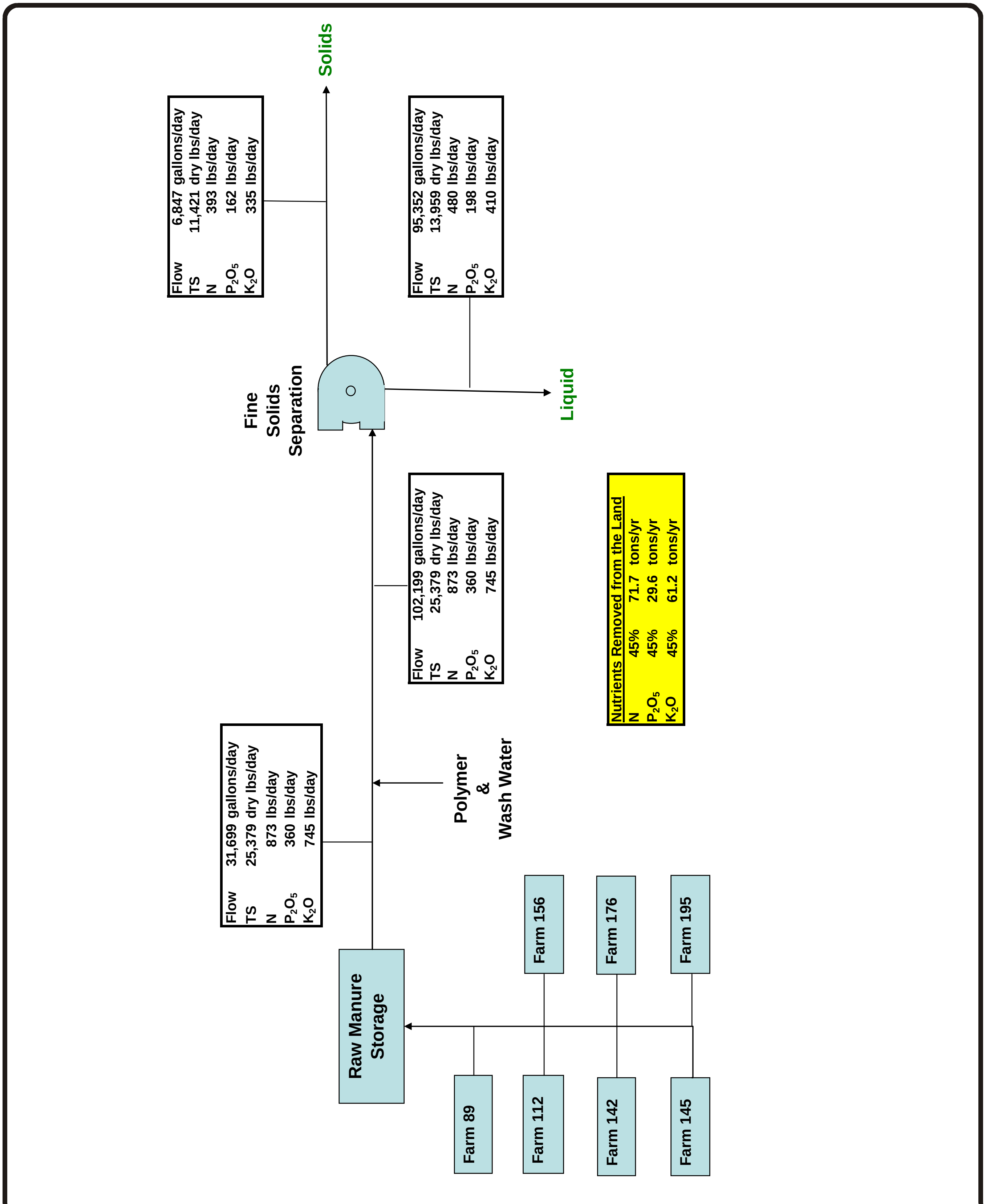
FIGURE 4.03-1
1-124.005



ALTERNATIVE C-1M (MIDDLETON)
FINE SOLIDS SEPARATION WITH POLYMER ADDITION
COMMUNITY MANURE MANAGEMENT FEASIBILITY STUDY
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FIGURE 4.03-2
1-124.005

C. Alternative C-2: Fine Solids Separation with Ferric Chloride and Polymer Addition

Raw manure will be delivered to a central manure receiving pit at the community facility sized to provide approximately one week of raw manure storage. The polymer dosing and solids separation equipment is similar to that described for Alternative F-2, with the exception that the equipment would be sized to handle the higher loadings, a dry polymer system would likely be included in lieu of the emulsion polymer system for Alternative F-2, and a bulk ferric chloride storage facility would be included in lieu of chemical storage in totes or drums.

Approximately 3.1-million gallons of storage will be necessary for liquids storage in the Waunakee Cluster, and 2.3-million gallons of storage will be necessary for liquids storage in the Middleton Cluster. A new structure will be constructed to hold one month of solids. The solids can be land applied, sold to another end user, or composted. The amount of solids storage has been reduced for this alternative and others that produce similar solids because of the increased flexibility in solids disposal. Liquids will be spray irrigated by the cluster farms.

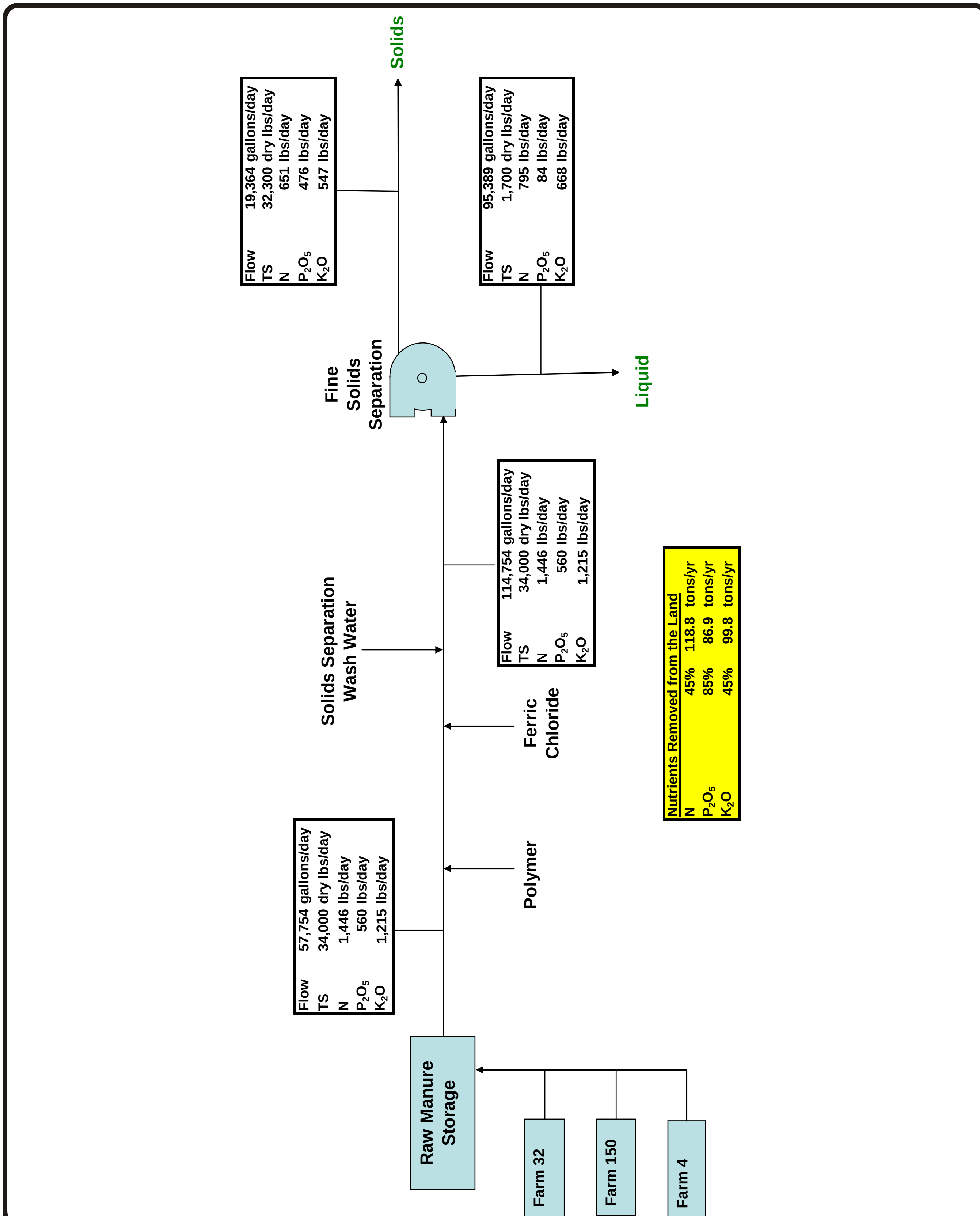
Figures 4.03-3 and 4.03-4 show the mass balance through the solids separation process for the two clusters. These balances were generated using manufacturer's data for system performance. Based on this information, 75 to 85 percent of the raw manure volume is conveyed to liquid storage along with the water added for polymer dilution and screen wash water. The liquid portion contains less than 5 percent of the solids, approximately 15 percent of the P, and 55 percent of the N and K for both clusters.

The anticipated average polymer and ferric chloride demands for the Waunakee cluster are 320 lbs/day and 2,600 lbs/day, respectively. The system would also require approximately 19,000 gallons of polymer makeup water and 38,000 gallons of screen wash water per day. A portion of the wash water flows are assumed to be recycled water from the separator.

The anticipated average polymer and ferric chloride demands for the Middleton cluster are 240 lbs/day and 1,900 lbs/day, respectively. The system would also require approximately 15,000 gpd of polymer makeup water and 42,000 gpd of screen wash water. Both systems are designed to operate 40 to 50 hours/week, and both systems are anticipated to require two full-time staff for operations and maintenance.

D. Alternative C-3: Anaerobic Digestion Followed by Solids Separation with Ferric Chloride and Polymer Addition

Raw manure will be delivered to a central manure receiving pit at the community facility sized to provide approximately one week of raw manure storage. The digestion, biogas utilization, chemical addition, and solids separation and equipment would be similar to that described for Alternative F-3. In addition to providing electricity for use on the farm, however, excess electricity is assumed to be sold to the local utility.



ALTERNATIVE C-2W (WAUNAKEE)
FINE SOLIDS SEPARATION WITH FERRIC CHLORIDE AND POLYMER ADDITION
COMMUNITY MANURE MANAGEMENT FEASIBILITY STUDY
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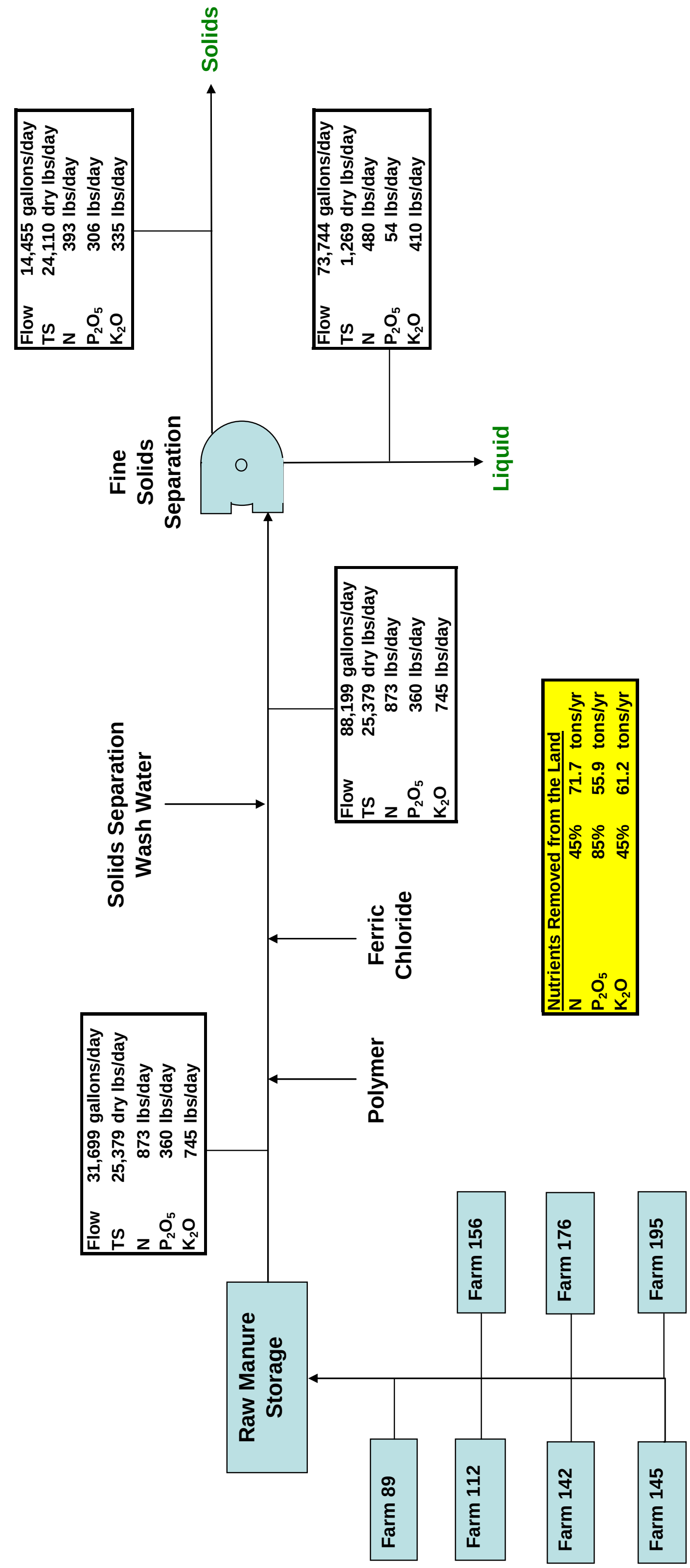
FIGURE 4.03-3
1-124.005



ALTERNATIVE C-2M (MIDDLETON)
FINE SOLIDS SEPARATION WITH FERRIC CHLORIDE AND POLYMER ADDITION
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FIGURE 4.03-4
1-124.005

The on-site liquid storage lagoon should be sized for one month of storage. Approximately 2.8-million gallons of storage would be necessary for on-site liquid storage at the Waunakee cluster, and about 1.9-million gallons of storage would be necessary for liquids storage in the Middleton cluster. A new structure will be constructed to provide approximately one month of solids storage. The solids can be land-applied, sold to another end user, or composted. Liquids would be spray irrigated by the cluster farms.

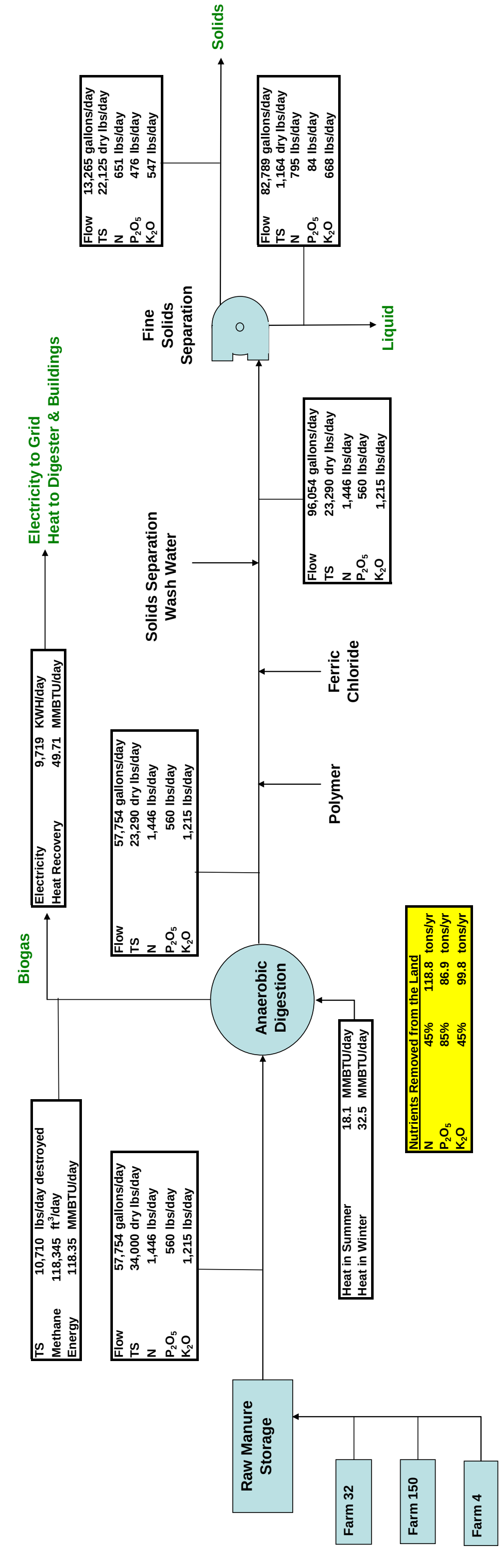
Figures 4.03-5 and 4.03-6 present the mass balance through the anaerobic digestion and solids separation process for each cluster. The digestion performance was assumed to be similar to that described for Alternative F-3. The effluent total solids from the digester are projected to be approximately 29,000 dry lbs/day for the Waunakee cluster and 22,000 lbs/day for the Middleton cluster. The total mass of nutrients is expected to be conserved through the digester. Digestion and solids separation performances were developed based on manufacturers' data for system performance. Manufacturers used existing installations to estimate performance for each cluster. Based on these analyses, 85 to 90 percent of the raw manure volume would be conveyed to liquid storage along with the water added for polymer dilution and screen wash water. The liquid portion contains less than 5 percent of the solids, 15 percent of the P, and 55 percent of the N and K for both clusters.

The chemical demands for the Waunakee cluster are about 220 lbs/day of polymer and 1,800 lbs/day of ferric chloride. The system would require approximately 13,000 gallons of polymer makeup water and 25,000 gallons of screen wash water per day. The chemical demands for the Middleton cluster are about 160 lbs/day of polymer and 1,300 lbs/day of ferric chloride. Polymer dilution water and screen wash water are estimated to require approximately 10,000 gpd and 25,000 gpd, respectively. Both systems are designed to operate approximately 40 to 50 hours/week and are estimated to require two full-time staff for operation and maintenance.

E. <u>Alternative C-4: Fine Solids Separation with Ferric Chloride and Polymer Addition Followed by a Dryer/Pelletizer</u>

This alternative includes the entire Alternative C-2 followed by a dryer system to produce a final solids product with a moisture content of about 10 to 15 percent or less. The solids from the solids separation equipment will be transferred to a storage bin that will act as the feed hopper for the dryer. From there, an auger will be used to feed solids into the dryer. The drying process uses three different stages to dehydrate the solids. The different stages are controlled by individual burners and are designed to maximize drying while limiting burning or overheating of the material. The dryer also has a thermal oil heating system and a condenser and off-gassing system. Once the manure has been dried, it will be transferred to final product storage through a discharge/cooling conveyor. Final storage is sized to hold one month of dried material.

The dryer will be operated in a batch mode where separated solids will be collected and stored until the feed hopper is nearly full. Then the dryer will be started and operated until the feed solids supply is depleted. Because of manufacturer's sizing limitations, the dryer at each cluster has



ALTERNATIVE C-3W (WAUNAKEE)
ANAEROBIC DIGESTION FOLLOWED BY SOLIDS SEPARATION WITH FERRIC CHLORIDE AND POLYMER ADDITION
COMMUNITY MANURE MANAGEMENT FEASIBILITY STUDY
DANE COUNTY, WISCONSIN

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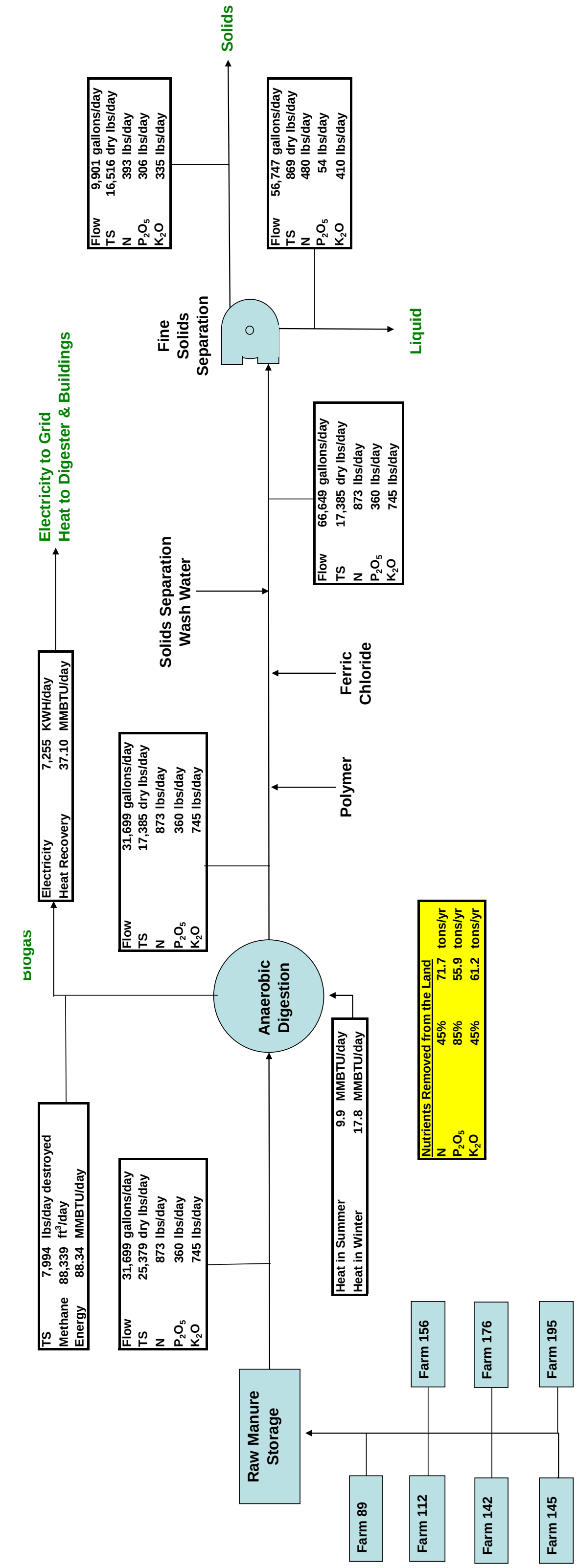
FIGURE 4.03-5
1-124.005



ALTERNATIVE C-3M (MIDDLETON)
ANAEROBIC DIGESTION FOLLOWED BY SOLIDS SEPARATION WITH FERRIC CHLORIDE AND POLYMER ADDITION
COMMUNITY MANURE MANAGEMENT FEASIBILITY STUDY
DANE COUNTY, WISCONSIN

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FIGURE 4.03-6
1-124.005

excess capacity. The dryer would be sized to operate at 80 percent of its capacity for the Waunakee cluster and about 60 percent of its capacity in the Middleton cluster. The efficiency of the system will be maximized when operated at the design solids throughput capacity. Therefore, if this alternative is further evaluated, additional manufacturers should be contacted to determine if the capacity of the dryer can more closely match the design solids throughput.

Figures 4.03-7 and 4.03-8 show the mass balance through the solids separation and drying processes for the two clusters. These balances were generated using manufacturers' estimates for system performance. Approximately 75 to 85 percent of the raw manure volume would be conveyed to liquid storage following the dewatering step along with the water added for polymer dilution and screen wash water. This liquid portion contains less than 5 percent of the solids, 10 percent of the P, and 55 percent of the N and K for both clusters. The solids are dried to approximately 85 to 90 percent dryness. Polymer dilution water and wash water are assumed to add negligible amounts of solids and nutrients.

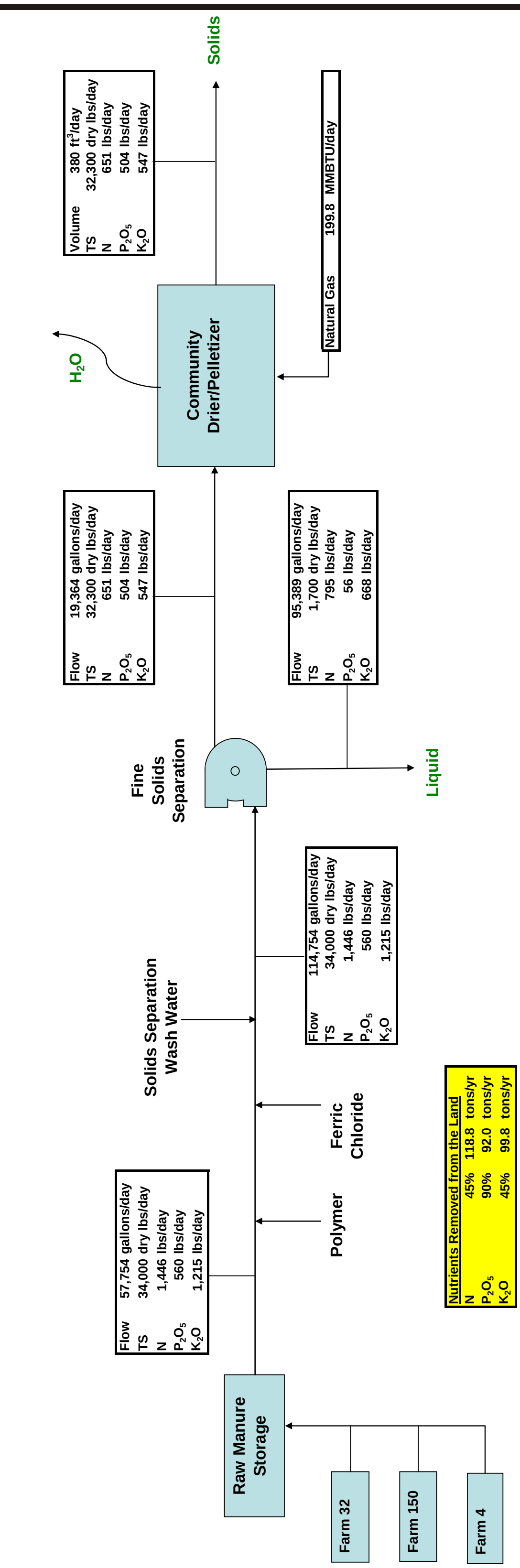
The chemical demands for the Waunakee cluster are 320 lbs/day of polymer and 2,600 lbs/day of ferric chloride. The system also requires approximately 19,000 gpd of polymer makeup water and 38,000 gpd of screen wash water. The chemical demands for the Middleton cluster are 240 lbs/day of polymer and 1,900 lbs/day of ferric chloride. Estimated water requirements are 15,000 gpd of polymer makeup water and 42,000 gpd of screen wash water. The solids separation systems are designed to operate 40 to 50 hours per week. The dryer will operate approximately 5.6 days per week for the Waunakee cluster and 4.2 days per week for the Middleton cluster. Both systems are anticipated to require two full-time staff for operation and maintenance.

F. <u>Alternative C-5: Manure Combustion</u>

In this alternative, raw manure would be delivered to a raw manure storage tank sized to provide about one week of storage. From there the raw manure would be pumped into a drying vessel that uses recovered heat and mixing to evaporate moisture and achieve relatively dry solids (moisture content is approximately 40 percent). After drying, the manure can be used for bedding or it can continue to the combustion system (boiler). In the boiler, the dried manure is combusted to create steam. The steam is piped to a turbine/generator set and used to generate electricity. Waste steam heat is recovered and used in the upstream drying process.

Figures 4.03-9 and 4.03-10 show the mass balance through the drying and incineration processes for each cluster. These numbers were generated using manufacturers' data for system performance. Manufacturers' used existing installations to estimate future performance.

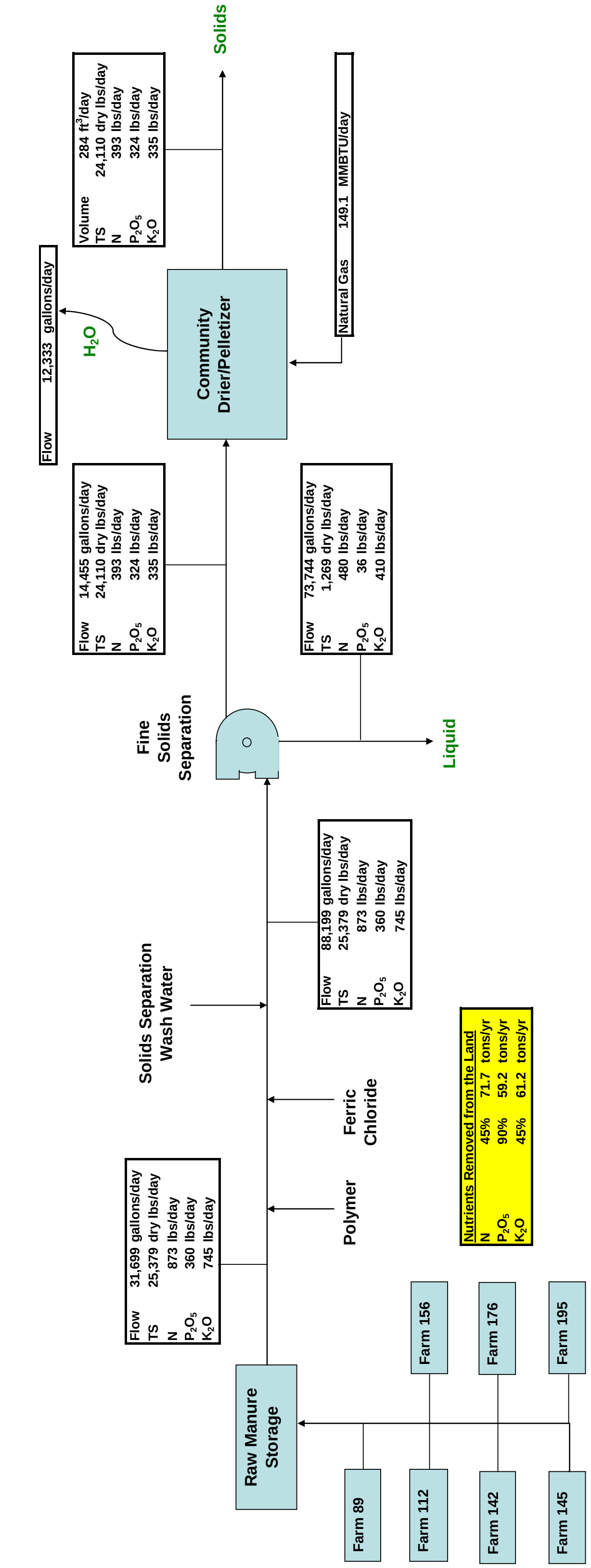
This system will operate 168 hours per week and will require two full-time staff for operations and maintenance.



ALTERNATIVE C-4W (WAUNAKEE)
FINE SOLIDS SEPARATION WITH FERRIC CHLORIDE AND POLYMER ADDITIONS FOLLOWED BY A DRYER/PELLETIZER
COMMUNITY MANURE MANAGEMENT FEASIBILITY STUDY
DANE COUNTY, WISCONSIN

STRAND ASSOCIATES, INC.® ENGINEERS

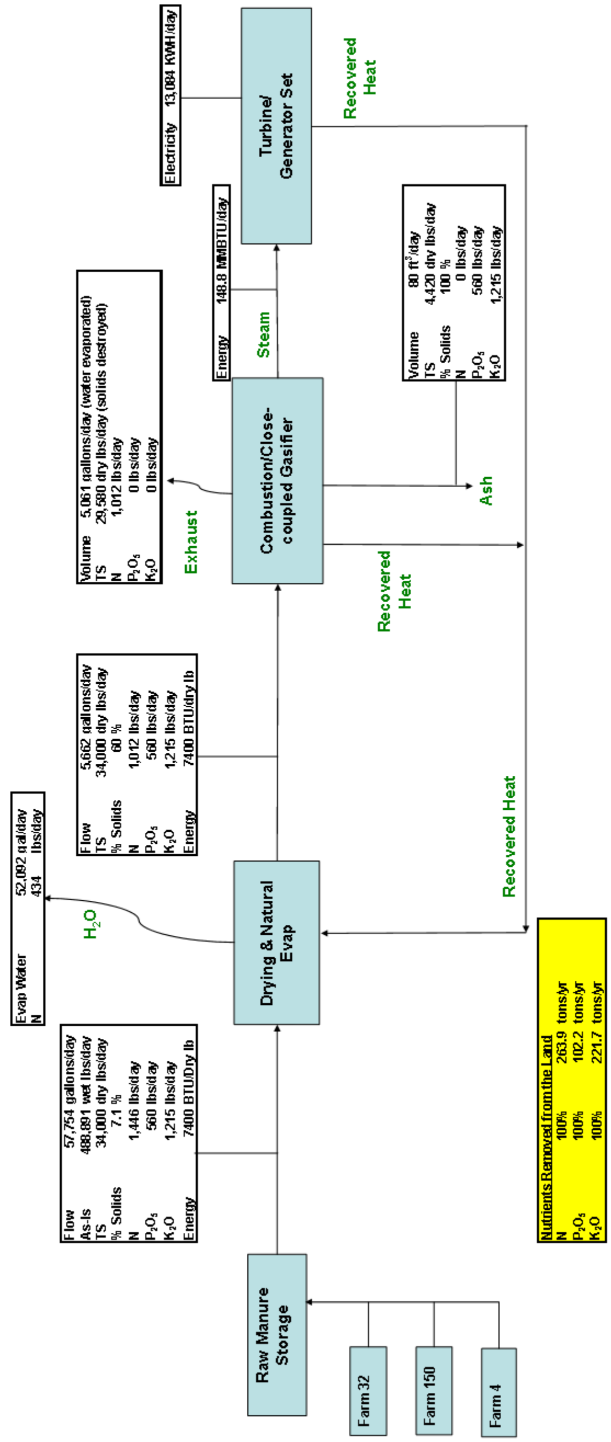
FIGURE 4.03-7
1-124.005



ALTERNATIVE C-4M (MIDDLETON)
FINE SOLIDS SEPARATION WITH FERRIC CHLORIDE AND POLYMER ADDITION FOLLOWED BY A DRYER/PELLETIZER
COMMUNITY MANURE MANAGEMENT FEASIBILITY STUDY
DANE COUNTY, WISCONSIN

STRAND ASSOCIATES, INC.® ENGINEERS

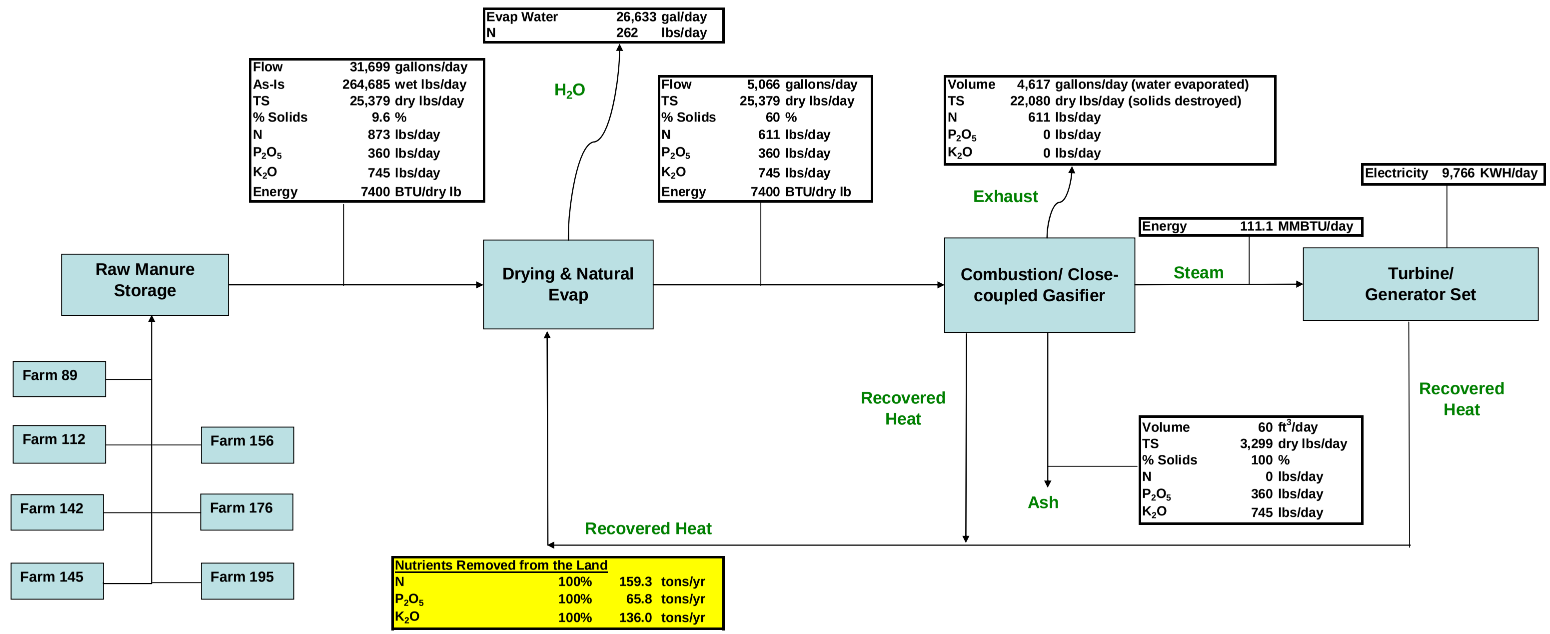
FIGURE 4.03-8
1-124.005



ALTERNATIVE C-5W (WAUNAKEE)
MANURE COMBUSTION
COMMUNITY MANURE MANAGEMENT FEASIBILITY STUDY
DANE COUNTY, WISCONSIN

STRAND ASSOCIATES, INC.® ENGINEERS

FIGURE 4.03-9
1-124.005



ALTERNATIVE C-5M (MIDDLETON)
MANURE COMBUSTION
COMMUNITY MANURE MANAGEMENT FEASIBILITY STUDY
DANE COUNTY, WISCONSIN

STRAND ASSOCIATES, INC.® ENGINEERS

FIGURE 4.03-10
1-124.005

4.04 OPINION OF CAPITAL COSTS

At this early stage of planning, detailed opinions of capital cost cannot be developed precisely, since the project elements and details have not been considered thoroughly. Based on our experience with similar projects, we used the following procedure to develop opinions of capital cost for the eight management alternatives:

1. Proposals for major equipment were solicited from manure processing equipment manufacturers and vendors. We typically add a 35 percent factor to account for labor, miscellaneous materials, and other unforeseen items required to install the equipment.

2. For some equipment and structures, our past experience with similar projects was relied on to develop costs.

3. Equipment and control building sizes were estimated and assigned a unit cost of $\$100/ft^2$.

4. Solids storage facilities were assigned a unit cost of $\$25/ft^2$ plus an additional $350/cy for the concrete slab. Slabs were estimated to be 1 foot thick.

5. Underground piping (force mains) was assigned a unit cost of $60/LF.

6. Percentages of equipment costs and buildings cost subtotals were used to estimate subcontractor installation costs for piping and mechanical (10 percent), electrical (10 percent), heating and ventilation (5 percent), and site work (5 percent).

7. These percentages are based on past projects and the current construction market.

8. General conditions for the contractor have been estimated at 8 percent of the cost of the equipment, buildings, mechanical, electrical, heating and ventilating, and site work costs. Contingencies at 25 percent and engineering/legal services at 15 percent of the total construction cost were included in the overall capital cost opinion for the eight alternatives.

These assumptions are summarized in Table 4.04-1.

A summary of the opinions of capital cost are included in Table 4.04-2 for all the alternatives. The detailed cost evaluations are included in Appendix C. In general, the capital costs for the Waunakee cluster are greater than those for the Middleton cluster because of the infrastructure required to pump manure to the cluster site. In addition, the volumes of manure are greater in the Waunakee cluster based on the data contained in the farm surveys responses.

On a per animal unit basis, the costs for the larger cluster facilities are considerably lower than the costs at an individual farm. In particular, the capital cost per animal unit for the Middleton Cluster is approximately one-half the capital cost per A.U. for the individual farm for similar technologies (i.e., comparing Alternative F3 with Alternative C-3M). This is the result of significant economies of scale that would be realized by constructing a cluster facility to serve more than one farm.

Alternative	P Removed (%)	Capital Costs		
		Total	Per Current A.U.	Per Design A.U.
Individual Farm[a]				
F-1	45%	$1,426,000	$2,850	$2,130
F-2	85%	$1,685,000	$3,370	$2,510
F-3	85%	$2,840,000	$5,680	$4,240
Waunakee Cluster[b]				
C-1W	45%	$6,423,000	$2,040	$1,500
C-2W	85%	$8,415,000	$2,680	$1,960
C-3W	85%	$11,495,000	$3,660	$2,680
C-4W	90%	$13,507,000	$4,300	$3,150
C-5W	100%	$11,333,000	$3,600	$2,640
Middleton Cluster[c]				
C-1M	45%	$5,127,000	$1,340	$1,030
C-2M	85%	$8,215,000	$2,150	$1,660
C-3M	85%	$10,934,000	$2,870	$2,210
C-4M	90%	$13,247,000	$3,470	$2,670
C-5M	100%	$10,319,000	$2,710	$2,080

[a] Current A.U. = 500; design A.U. = 669.
[b] Current A.U. = 3,145; design A.U. = 4,293.
[c] Current A.U. = 3,813; design A.U. = 4,957.
[d] the opinion of costs are considered +/- 25 percent at this time.

Table 4.04-2 Opinion of Capital Cost Summary[d]

4.05 OPINION OF OPERATION AND MAINTENANCE (O&M) COSTS

O&M costs include the costs or revenues anticipated to occur on a regular, on-going basis. Opinions of annual O&M costs were developed for three scenarios: (1) Year 2007 condition with the existing herd sizes, (2) Year 2012 conditions including the anticipated growth of the herds, and (3) Year 2012 conditions including the anticipated growth and the 25 percent allowance for additional manure or industrial waste loadings to the facility. The design basis for the individual farm, Waunakee Cluster, and Middleton Cluster included 535 A.U., 3,434 A.U., and 3,966 A.U., respectively.

Category	Unit O&M Cost	
	(2007)	(2012)[1]
Labor (per hour)	$ 40	$45
Electricity (per KWH)	$0.10	$0.11
Electricity Buy-Back Rate (per KWH)[2]	$0.065	$0.070
Natural Gas (per therm)	$1.00	$1.13
Solids Value (per wet ton)		
Alt. F-1, C-1	$5	$6
Alt. F-2, C-2	$10	$11
Alt. F-3, C-3	$20	$23
Alt. C-4, C-5	$50	$57
Renewable Energy Certificates (per KWH)[2]	Included above[2]	
GHG Emission Reductions Credit (per $MtCO_2e$)[3]	$6	$12
Polymer (per pound)	$1.50	$1.70
Ferric Chloride (per gallon)	$1.00	$1.13
Maintenance and Supplies[4] (% of equipment costs)	2.0	2.3
Land Rental (per acre/year)	$140	$158

1 Year 2012 costs assumed to increase at the rate of inflation (2.5 percent/year) except for GHG emission reductions and RECs.
2 The electrical buy-back rate includes RECs associated with the electrical generation from biogas.
3 $MtCO_2e$ = metric ton of CO_2 equivalent; 1 metric ton ~ 2,200 lbs.
4 Maintenance costs estimated by manufacturers were used in lieu of percentages when provided.

Table 4.05-1 O&M Unit Costs (2007)

Table 4.05-1 presents a summary of the unit costs we have included in these evaluations. Most of the O&M cost categories were inflated by 2.5 percent annually to derive the year 2012 O&M costs. The exception to this is the GHG reduction credit and associated revenue stream, which are expected to increase at a rate faster than inflation. Projections from the Carbon Solution Group™ were applied to the potential GHG emission reduction credits in 2007 and 2012. Detailed O&M costs for all alternatives are presented in Appendix C.

The following discussion presents some of the assumptions and background information for each of the O&M cost categories.

Labor was estimated on a full-time equivalent (FTE) basis at a rate of $40/hour, which includes fringe benefits. Operators are expected to be knowledgeable about mechanical systems and treatment process environments. It is expected that they will be familiar with chemical feed systems and working in hazardous environments.

Electricity and natural gas usage was estimated based on manufacturers' information and horsepower operating hours. Unit costs for electricity and natural gas are an approximate average rate in Dane County at this time. An energy credit was applied where alternatives would generate excess energy. The credit assumes the excess energy would be used to generate electricity (Alternatives F-3, C-3, and C-5), and any electricity generated beyond that needed on-site would be purchased by the local power utility at an average buy-back price of $0.065/kWh based on current rates. This buy-back rate is based on one utility company's existing program in Wisconsin, in which the utility purchases electricity and associated renewable energy credits generated by anaerobic digesters owned by its Wisconsin customers. Under a 10-year contract, customers receive $0.08/ kWh for electricity generated on-peak (9 A.M. to 9 A.M.) and $0.049/ kWh for electricity generated off-peak (9 P.M. to 9 A.M.). Assuming relatively uniform biogas generation throughout a typical day, the average buy-back rate is approximately $0.065/ kWh.

In lieu of electrical generation, the excess energy could be in the form of excess biogas produced at a manure digestion facility (Alternatives F-3 and C-3). The excess biogas could be cleaned to near natural gas quality and injected directly into a natural gas pipeline, or the biogas could be used by a nearby industry to supplement natural gas usage (e.g., used in a boiler). This latter potential may especially be feasible for the Middleton Cluster because of its location. However, this use was not considered in these analyses.

There are at least a few examples of cleaning manure-based biogas to natural-gas grade quality. The Scenic View Dairy in Fennville, Michigan, was started up in 2007 and digests manure from approximately 2,000 dairy cattle (2,800 A.U.). The excess methane generated may be used on-site or injected into a natural gas pipeline. A similar, but larger facility in Texas was installed to produce pipeline-grade natural gas from biogas generated from anaerobic digestion of manure from up to 10,000 cows.

Solids management is one of the most significant O&M cost variables in these analyses since the value of the final solids products will likely vary considerably as a function of the management alternative, the location, and the market for the solids at any given time. Potential disposal markets include composting operations, supplement for wood processing/fiberboard, use as a soil amendment and/or fertilizer, and potting soil replacement among others. None of these markets are well developed at this time. However, based on our discussions with researchers (Forest Products Laboratory, UW-Platteville) and entities engaged in these markets, we understand that the high-end value of the solids produced from anaerobic digestion (Alternatives F-3 and C-3) is about $30/ton at this time. Alternatives F-1 and C-1, as well as F-2 and C-2, would have lower market value on average because of the potential for disease organisms, the poorer consistency in fiber characteristics, and the potential odors from such material. In addition, based on a manure management operation in southeast Wisconsin, we believe the market for dried manure may be as high as $80 or $90 per ton. The values used in these analyses are lower than the values cited herein to provide a measure of conservatism. However, we have also included a sensitivity analysis as a function of the value of the solids generated in manure management alternatives later in this chapter.

GHG emission reduction credits are based on the estimated mass of GHG emissions eliminated with each alternative compared to the existing method of lagoon storage and land application. The inherent assumption in this determination is that, within the storage lagoons, anaerobic conditions generate methane gas, which is released to the atmosphere. The amount of methane production expected from lagoon storage is based on the site location–in northern climates, the average temperature is lower and the amount of biological activity in the lagoon decreases, resulting in lower methane production. Therefore, the GHG credits are typically lower in northern climates as compared to a similar facility located in the south. By implementing alternate manure management systems, some or all of the organic material will not be stored for long periods of time, and, therefore, methane emissions will be reduced.

For Alternatives F-3, C-3, and C-5, in which either biogas or manure is combusted to produce energy, CO_2 and other GHGs may be given off in excess of the levels that would have been emitted from storage lagoons. However, the GHG emissions from a lagoon are considered biogenic (produced by natural life processes, including the natural processes inherent to plants and animals) as opposed to anthropogenic (derived from human activities). Therefore, the emissions associated with the combustion of the biogas captured (or from the manure itself) do not count as increased GHG emissions. This is because the feedstocks in the manure are natural carbon sequesters, and in a natural aerobic environment where the material is allowed to decay, these emissions would have occurred naturally (biogenically). Therefore, combusting the biogas does not result in anthropogenic emissions such as would occur with the combustion of fossil fuels.

GHG emission reduction credits included in these analyses are based on preliminary estimates from the Carbon Solution Group™. The estimated GHG emission reduction from a 5,000-A.U. anaerobic digestion system was estimated at approximately 18,500 $MtCO_2e$/year. For the purposes of this evaluation, we have developed approximate GHG emission reductions for the alternatives based on solids eliminated from long-term lagoon storage (Table 4.05-2).

Renewable energy certificates (RECs) are included in the electrical buy-back cost noted above and in Table 4.05-1. The value of RECs is expected to vary significantly and generally increase over time. Based on recent information, the current value of RECs is in the range of \$0.004 to \$0.005/ kWh, or approximately 5 to 10 percent of the buy-back value of electricity.

Chemical cost opinions were developed based on manufacturers' estimates and our experience with polymer and ferric chloride in wastewater treatment applications. Maintenance and supply costs were estimated at 2 percent of the equipment costs or as specified by the manufacturer.

Raw manure hauling and liquid disposal costs were estimated for the Middleton Cluster using the *Professional Nutrient Applicators of Wisconsin Truck Haul Job Estimator* spreadsheet. Trips were assumed to be two-way hauling trips with raw manure being hauled to the cluster and finished liquids being hauled back to the farm for as many trips as possible. In all cases the volume of finished liquids exceeds raw manure, which required additional one-way trips to haul finished liquids to the farms. Raw manure and finished liquids will be pumped in the Waunakee Cluster. The costs for pumping are accounted for in the equipment costs and the power costs. It was assumed that farmers will own enough land for spray irrigation of liquid residuals.

Alternative	Solids Removed (% of Existing)	GHG Emission Reduction[a] ($MtCO_2e$/year)
Individual Farms (535 A.U., 1.7 dry tons/day)		
F-1	45	890
F-2	95	1,880
F-3[b]	100	1,980
Waunakee Cluster (3,434 A.U., 17 dry tons/day)		
C-1W	45	8,900
C-2W	95	18,800
C-3W[b]	100	19,800
C-4W[c]	100	15,000
C-5W	100	19,800
Middleton Cluster (4,000 A.U., 12.7 dry tons/day)		
C-1M	45	6,650
C-2M	95	14,000
C-3M[b]	100	14,800
C-4M[c]	100	11,900
C-5M	100	14,800

[a] Based on 18,500 $MtCo_2e$/year reduction from a 5,000-A.U. anaerobic digestion facility designed to handle 15.9 dry tons/day of solids (Carbon Solutions Group[TM]). GHG generation from vehicular fuel and operating power are not included as these values are minor compared to the GHG reductions. Results are preliminary and subject to a more detailed investigation.
[b] Assumed solids in liquid are nonbiodegradable.
[c] Natural gas used in the drying process estimated at 199.8 MMBTU/day for the Waunakee Cluster and 149.1 MMBTU/day for the Middleton Cluster. GHG equivalent of natural gas ~ 117 lbs CO_2/MMBTU.

Table 4.05-2 GHG Emission Reductions

The current O&M costs for the individual farms and the cluster farms were developed for comparison by using data reported in the survey for each of the cluster farms extrapolated to the design A.U. size. The cluster data was used to estimate the individual farm costs using average costs per A.U. The current operating costs generally consist of three elements, labor, hauling, and land rental, as discussed here:

1. Labor costs were estimated using the reported time from each farm for hauling manure, applying manure, and maintaining manure-related equipment and labor cost of $40 per hour.

2. Hauling costs were estimated using the *Truck Haul Job Estimator* spreadsheet. Half of the average maximum hauling distance for the cluster was used as the hauling distance.

3. Land rental costs were estimated using reported acres rented that manure is spread on at an annual cost of $140/acre.

Table 4.05-3 presents our opinion of annual O&M costs for the existing individual farms, existing farm clusters, and each of the manure management alternatives. The O&M costs are presented in the current year (2007) as well as in the year 2012. Appendix C presents more detailed opinions of O&M costs for all of the alternatives evaluated.

Alternative	P Removed (%)	Opinion of Net Annual O&M Expense (Revenue)			
		Year 2007	Year 2012	Year 2012 + 25% (design A.U.)	Per A.U. (2007)
Individual Farm[a]					
Existing	0%	$82,000	$93,000	$107,000	$164
F-1	45%	$152,000	$165,000	$193,000	$304
F-2	85%	$53,000	$47,000	$48,000	$106
F-3	85%	$82,000	$78,000	$80,000	$174
Waunakee Cluster[b]					
Existing	0%	$936,000	$1,059,000	$1,218,000	$298
C-1W	45%	$1,007,000	$1,086,000	$1,291,000	$320
C-2W	85%	$98,000	$20,000	($13,000)	$30
C-3W	85%	($220,000)	($350,000)	($480,000)	($68)
C-4W	90%	$884,000	$890,000	$1,072,000	$281
C-5W	100%	($183,000)	($296,000)	($409,000)	($73)
Middleton Cluster[c]					
Existing	0%	$682,000	$772,000	$926,000	$179
C-1M	45%	$946,000	$1,031,000	$1,222,000	$248
C-2M	85%	$600,000	$612,000	$701,000	$156
C-3M	85%	$304,000	$268,000	$271,000	$82
C-4M	90%	$1,144,000	$1,210,000	$1,451,000	$300
C-5M	100%	$235,000	$199,000	$193,000	$51

[a] Year 2007 A.U. = 500; Year 2012 A.U. = 535; design A.U. = 669.
[b] Year 2007 A.U. = 3,145; Year 2012 A.U. = 3,434; design A.U. = 4,293.
[c] Year 2007 A.U. = 3,813; Year 2012 A.U. = 3,966; design A.U. = 4,957.
[d] O&M costs do not include the cost for any commercial fertilizer required to replace manure-based fertilizer not applied to the soil in any of the alternatives.

Table 4.05-3 Opinion of Annual O&M Costs[d]

The annual O&M cost opinions developed in Table 4.05-3 should not be considered to be precise costs, as they are derived from a number of assumptions, simplifications, and data provided by vendors, farmer surveys, and our past experience. However, on a comparative basis several significant observations are noted:

1. For the individual farm alternatives, only Alternative F-2–Fine solids removal with polymer and ferric addition appears to lower annual O&M costs significantly compared to the existing O&M cost opinions.

2. For the cluster alternatives, the Waunakee Cluster appears to have significantly lower annual O&M costs than the Middleton Cluster. This is mainly because in the Waunakee Cluster, manure and returned liquids are pumped to and from the cluster site, whereas in the Middleton Cluster the manure and returned liquids are transported by truck.

3. For the Waunakee Cluster, all of the alternatives except C-1W (solids separation) and C-4W (drying) are anticipated to lower annual O&M costs significantly compared to the existing farms' O&M costs. The reason that Alternative C-1W is not anticipated to lower annual O&M costs for the farms in that cluster is that, because of the relatively lower solids and phosphorus removal achieved by this technology, the nutrient level of the liquids returned to the farms will still require trucking to the land, which has a higher O&M cost than pumping to land application fields. Alternative C-4W has a high annual cost for natural gas.

4. For the Waunakee Cluster, the options that include energy recovery (Alternatives C-3W and C-5W) appear to generate net revenue. That is, the preliminary estimate of revenue streams (sale of solids, electricity buy-back, and GHG emission reduction credits) exceed the annual costs to operate the facilities. In addition, as the amount of manure handled increases, the net revenue appears to increase.

5. For the Middleton Cluster, only the alternatives with energy recovery (Alternatives C-3M and C-5M) appear to lower annual O&M costs to a significant degree compared to the existing farms' collective O&M costs.

6. For the anaerobic digestion (C-3W) and combustion (C-5W) alternatives for the Waunakee Cluster, the amount of electrical generation potential is approximately 9,700 kWh/day and 13,100 kWh/day, respectively. This is equivalent to the amount of power used by approximately 415 and 560 homes, respectively, with an average energy use of 700 kWh/month.

7. Similarly, for the Middleton Cluster Alternatives C-3M and C-5M, the amount of electrical generation potential is approximately 7,300 kWh/day and 9,800 kWh/day,

respectively, which is equivalent to the amount of power used by approximately 313 and 420 homes, respectively.

8. On a preliminary basis, the potential GHG emissions reduction from eliminating long-term lagoon storage of the manure is estimated at approximately 19,800 metric tons/year of equivalent CO_2 for Alternatives C-3W and C-5W (Table 4.05-2). This is approximately equivalent to:

   - The CO_2 emissions from the annual electrical generation to supply 3,800 homes using 700 kWh/month of electricity (1 kWh of electricity ~ 1.37 lbs CO_2).

   - The CO_2 emissions from the annual natural gas use of 3,900 homes using 80 therms of natural gas/month (1 MMBTU of natural gas ~ 117 lbs CO_2).

   - The CO_2 emissions from driving approximately 50-million miles/year at an average fuel economy of 25 miles/gallon (1 gallon of gasoline ~ 21.7 lbs CO_2).

9. For each of the alternatives, the cost of supplying commercial or other fertilizer to replace the manure-based fertilizer was not included as these costs will vary significantly based on the soil needs, crops planted, available land at each farm and amount of land required to be rented, and similar factors. Such an analysis is beyond the scope of this report. However, it is noted that the cost of commercial fertilizer has increased by 40 to 75 percent from a year ago, which is in large part due to significant increases in natural gas prices and transportation costs. Recent commercial fertilizer values are reported as $0.50/lb of N, $0.40/lb of P, and $0.33/lb of K. At these costs, the added cost to purchase commercial fertilizer could increase the overall O&M costs of the manure management alternatives, and in some cases, the cost increase could be significant.

4.06 ANNUAL O&M SENSITIVITY ANALYSES

Several factors have a major impact on the annual cost to operate manure management facilities. However, a few of the O&M categories could have a major impact on the viability of the manure management alternatives evaluated herein because of the uncertainty of such costs over time. For example, while labor costs are a significant component of the annual O&M cost for a facility, labor costs are relatively simple to project over time. However, the value of the residual solids from a manure management facility could and would vary significantly as markets are developed for such materials. The following paragraphs present sensitivity analyses for the following O&M categories, which were selected specifically because the projection of such costs into the future is relatively uncertain: manure/returned liquids hauling costs, solids disposal revenue, and GHG emission reduction credits. The base conditions for the sensitivity analyses were 2007 conditions and unit costs. Tables 4.06-1, 4.06-2, and 4.06-3 present summaries of these analyses for the individual farm alternatives, Waunakee Cluster alternatives, and the Middleton Cluster alternatives.

A. Liquid Disposal/Manure Trucking

Manure hauling and returned liquid hauling costs are the most significant annual cost item for several of the alternatives, especially for the Middleton Cluster alternatives. These costs are dependent on labor and fuel costs, as well as the cost for land rental, truck maintenance, and related expenses. For this sensitivity analysis, we have calculated the total unit cost for trucking manure and returned liquids as a function of raw manure quantities only for each alternative. This results in a cost per volume of raw manure trucked and is in the range of $0.026 to $0.048 per gallon of raw manure for the various alternatives.

Since each alternative has varying unit costs for hauling manure (and return liquids), the sensitivity analyses varied this unit cost from 50 percent to 150 percent of the calculated unit cost (100 percent = value calculated for Table 4.05-3).

As noted previously, the management systems would be designed with a capacity of approximately 25 percent larger than required for the anticipated growth of the farm(s) being served by the system. This provides the potential of hauling additional manure from other farms to the manure management facility. The cost of hauling this additional manure cannot be determined or even estimated within reason since it is dependent on the location of the farm, quantity of manure hauled, regularity of manure hauling, and other factors. For that purpose, unit costs for such additional hauling was not included herein.

B. Solids Disposal Revenue

The value of the final solids products could vary considerably as markets develop for these materials. As noted previously, we have assumed the value of the solids is dependent on the alternative management system. We assigned a base value of $5/wet ton for alternatives F1 and C-1; $10/wet ton for Alternatives F-2 and C-2 (higher nutrient content), $20/wet ton for Alternatives F-3 and C-3 (fewer concerns with disease organisms), and $50/wet ton for Alternatives C-4 and C-5 (concentration nutrients and improved transportability). For the sensitivity analyses, we allowed the value for each alternative to range from a net cost of $5/wet ton to dispose of the material (no net value) to a high end value of triple the base value used in Table 4.05-3.

C. GHG Emission Reduction Credits

The value of GHG emission reduction credits will likely increase over time and has the potential of significantly increasing. However, there will potentially be restrictions on the level of credits available as the result of carbon market policies. For example, in some countries, limits may be placed on entities so that only a certain percentage of GHG reduction goals for a given entity may be allowable through purchase on the carbon market, with the remaining GHG reduction required

TABLE 4.06-1

INDIVIDUAL FARMS–O&M COST SENSITIVITY ANALYSES

	Annual O&M Cost (Revenue)		
	Alt. F-1	Alt. F-2	Alt. F-3
Base Annual O&M Cost (Revenue)	$152,000	$53,000	$ 82,000
Manure and Liquid Hauling Sensitivity Analyses			
Base Condition (unit cost/gallon)	$ 0.046	NA	NA
50% of current cost	$119,000	$53,000	$ 82,000
75% of current cost	$135,000	$53,000	$ 82,000
100% of current cost (base condition)	$152,000	$53,000	$ 82,000
125% of current cost	$169,000	$53,000	$ 82,000
150% of current cost	$186,000	$53,000	$ 82,000
Solids Disposal Revenue Sensitivity Analyses			
Base Condition (unit value /wet ton)	$ 5.00	$ 10.00	$ 20.00
$5/ton cost of disposal	$166,000	$95,000	$130,000
$0/ton	$159,000	$81,000	$120,000
base value condition (see above)	$152,000	$53,000	$ 82,000
twice base value	$145,000	$25,000	$ 44,000
triple base value	$138,000	($3,000)	$ 6,000
GHG Emission Reduction Credit Sensitivity Analyses			
Base Condition (unit value/MtCO2e)	$ 6.00	$ 6.00	$ 6.00
$3/MtCO2e	$155,000	$59,000	$ 88,000
$6/MtCO2e (base condition)	$152,000	$53,000	$ 82,000
$10/MtCO2e	$149,000	$46,000	$ 74,000
$15/MtCO2e	$145,000	$37,000	$ 64,000
$20/MtCO2e	$140,000	$27,000	$ 54,000

TABLE 4.06-2

WAUNAKEE CLUSTER–O&M COST SENSITIVITY ANALYSES

	Annual O&M Cost (Revenue)				
	Alt. C-1W	Alt. C-2W	Alt. C-3W	Alt. C-4W	Alt. C-5W
Base Annual O&M Cost (Revenue)	$1,007,000	$ 98,000	($220,000)	$438,000	($183,000)
Manure and Liquid Hauling Sensitivity Analyses					
Base Condition (unit cost/gallon)	$ 0.026	NA	NA	NA	NA
50% of current cost	$ 729,000	$ 98,000	($220,000)	$438,000	($183,000)
75% of current cost	$ 868,000	$ 98,000	($220,000)	$438,000	($183,000)
100% of current cost (base condition)	$1,007,000	$ 98,000	($220,000)	$438,000	($183,000)
125% of current cost	$1,146,000	$ 98,000	($220,000)	$438,000	($183,000)
150% of current cost	$1,286,000	$ 98,000	($220,000)	$438,000	($183,000)
Solids Disposal Revenue Sensitivity Analyses					
Base Condition (unit value/wet ton)	$ 5.00	$ 10.00	$ 20.00	$ 50.00	$ 50.00
$5/ton cost of disposal	$1,141,000	$ 523,000	($ 71,000)	$569,000	($152,000)
$0/ton	$1,074,000	$ 381,000	($101,000)	$557,000	($155,000)
base value condition (see above)	$1,007,000	$ 98,000	($220,000)	$438,000	($183,000)
twice base value	$ 940,000	($185,000)	($339,000)	$319,000	($211,000)
triple base value	$ 873,000	($468,000)	($458,000)	$200,000	($239,000)
GHG Emission Reduction Credit Sensitivity Analyses					
Base Condition (unit value/MtCO2e)	$ 6.00	$ 6.00	$ 6.00	$ 6.00	$ 6.00
$3/MtCO2e	$1,034,000	$ 155,000	($161,000)	$498,000	($124,000)
$6/MtCO2e (base condition)	$1,007,000	$ 98,000	($220,000)	$438,000	($183,000)
$10/MtCO2e	$ 972,000	$ 23,000	($299,000)	$359,000	($262,000)
$15/MtCO2e	$ 928,000	($ 72,000)	($399,000)	$260,000	($362,000)
$20/MtCO2e	$ 883,000	($166,000)	($498,000)	$160,000	($461,000)

TABLE 4.06-3

MIDDLETON CLUSTER–O&M COST SENSITIVITY ANALYSES

	Annual O&M Cost (Revenue)				
	Alt. C-1M	Alt. C-2M	Alt. C-3M	Alt. C-4M	Alt. C-5M
Base Annual O&M Cost (Revenue)	$946,000	$600,000	$304,000	$812,000	$235,000
Manure and Liquid Hauling Sensitivity Analyses					
Base Condition (unit cost/gallon)	$ 0.048	$ 0.040	$ 0.034	$ 0.040	$ 0.026
50% of current cost	$ 667,000	$371,000	$106,000	$ 583,000	$ 82,000
75% of current cost	$ 807,000	$485,000	$205,000	$ 697,000	$159,000
100% of current cost (base condition)	$ 946,000	$600,000	$304,000	$ 812,000	$235,000
125% of current cost	$1,086,000	$715,000	$403,000	$ 927,000	$312,000
150% of current cost	$1,225,000	$830,000	$502,000	$1,042,000	$388,000
Solids Disposal Revenue Sensitivity Analyses					
Base Condition (unit value/wet ton)	$ 5.00	$ 10.00	$ 20.00	$ 50.00	$ 50.00
$5/ton cost of disposal	$1,046,000	$918,000	$415,000	$910,000	$258,000
$0/ton	$ 996,000	$812,000	$393,000	$901,000	$256,000
base value condition (see above)	$ 946,000	$600,000	$304,000	$812,000	$235,000
twice base value	$ 896,000	$388,000	$215,000	$723,000	$214,000
triple base value	$ 846,000	$176,000	$126,000	$634,000	$193,000
GHG Emission Reduction Credit Sensitivity Analyses					
Base Condition (unit value/MtCO2e)	$ 6.00	$ 6.00	$ 6.00	$ 6.00	$ 6.00
$3/MtCO2e	$966,000	$642,000	$349,000	$857,000	$280,000
$6/MtCO2e (base condition)	$946,000	$600,000	$304,000	$812,000	$235,000
$10/MtCO2e	$919,000	$544,000	$245,000	$753,000	$176,000
$15/MtCO2e	$886,000	$474,000	$171,000	$679,000	$102,000
$20/MtCO2e	$853,000	$404,000	$ 96,000	$604,000	$ 27,000

to be achieved through the entities direct initiatives to reduce GHGs. This could limit market demand in the future for carbon credits. Our sensitivity analyses for GHG reduction credits place a value per metric ton of carbon equivalents in the range of $3 to $20. In the O&M cost evaluations (Table 4.05-3), we assumed a value of $6/MtCO$_2$e.

4.07 SUMMARY OF FINANCIAL EVALUATIONS

Based on these evaluations, including the opinions of capital cost and O&M cost, as well as the sensitivity analyses, the following conclusions apply:

- Per animal unit, the cluster alternatives are generally lower in both capital and O&M costs than the individual farm alternatives.

- The Waunakee Cluster has higher capital costs than the Middleton Cluster, which is the result of the costs to construct pumping stations and force mains to convey manure to the cluster site and return liquid to the farms.

- The Middleton Cluster has higher annual O&M costs, which mainly result from the high cost of trucking manure to the cluster site and trucking liquid back to the farms.

- The cluster anaerobic digestion alternatives (C-3W and C-3M) and combustion alternatives (C-5W and C-5M) have the lowest annual O&M cost and are expected to save significant annual O&M costs compared to the existing operations. The preliminary cost opinions for the Waunakee Cluster indicate that these alternatives may provide a net operating surplus (revenue exceeds costs).

- The alternatives are very dependent on the actual unit O&M costs noted in Section 4.06. In particular, the cost of trucking, the value of separated solids, and the value of GHG emission reduction credits will be important in determining financial viability of various alternatives.