FINAL REPORT

KNOX COUNTY
CO-COMPOSTING PILOT STUDY

December 2001

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SECTION 1 – INTRODUCTION

This report presents the activities of Contract No. 01-204 between Knox County, Tennessee and Compost And Technology Solutions, Inc. (CATS) dated June 24, 2001. Task 1 of this contract called for a site visit by a CATS representative. This site visit was accomplished on July 18 and 19, 2001.

Task 2 of the contract called for preparation of a pilot study protocol. This protocol was completed on July 27, 2001 and submitted to the Knox County Solid Waste Division for their review and comments. Copies of this document were forwarded to the Knoxville Utility Board (KUB) for their review as well.

Task 3 of the contract called for pilot study assistance. This task contained three subtasks. Subtask 1 was to prepare for and present a training seminar for Knox County, KUB, and other interested parties. This subtask was completed on August 28, 2001 when a presentation was made to 29 participants at the Knox County Department of Engineering. Complete handouts of a presentation summary and all slides presented were given to each participant. Subtask 2 called for supervision of building of six compost piles, and this was accomplished on August 29, 2001. Subtask 3 included ongoing telephone consultation during the compost and curing periods.

Task 4 called for preparation of a final report describing the pilot study (Section 2 of this report) and preparation of an economic analysis of composting based on the findings of the pilot study (Section 3 of this report). Also included in this report are Implementation Recommendations (Section 4 of this report).

SECTION 2 – THE PILOT STUDY

2.1 – INTRODUCTION

The pilot study piles were built on August 29, 2001. Joel E. Alpert, Ph.D., was responsible for site supervision; Erik Spaven, Rodney Rockett, and John Evans from Knox County Solid Waste Division were responsible for data gathering and measurements; Monica Sowders and Jeff Hooyman from KUB were responsible for site preparation and grease additions to the mix; representatives from the Southeastern Mulch Company were responsible for materials movement and operation of the front-end loaders; and Synagro provided a mix box and operators. In addition to the personnel involved in one way or another, representatives from the State of Tennessee regulatory authorities and personnel from other wastewater utilities were onsite to observe the activities.

The rest of this section will describe the various piles that were built (Section 2.2) and interpret the findings (Section 2.3). The pile temperatures and analytical results are contained in Appendices A and B, respectively.

2.2 – PILE DESCRIPTIONS

There were a total of nine piles built on August 29, 2001. The piles were as follows:

- Pile 1 was comprised of KUB lime-stabilized biosolids (LSB) and fresh ground yard wastes (GWG) composted by the windrow turning method.
- Pile 2 was a mixture of LSB, KUB grease trap wastes (KUBG), and GWG. Pile 2 was composted by the windrow turning method.
- Pile 3 was comprised of the same materials as Pile 2 but was composted by the static pile method.
- Pile 4 was made up of KUBG and GWG and was composted by the windrow turning method.
- Pile 5 was a windrow of First Utility District biosolids (FUDB) and ground pallet wastes (PWG).
- Pile 6 was the same mix as Pile 5, but composting was performed by the static pile method.
- Piles 7 and 8 were a mixture of roughly one-third FUDB and two-thirds LSB with GWG as the bulking agent. These piles were composted by the windrow turning method.
- Pile 9 was a mixture of KUBG and PWG. This pile was composted by the windrow turning method.

Tables 2-1 through 2-8 show initial materials balances of the first eight piles. A materials balance for Pile 9 could not be developed since water ran out from the mix and key parameters of the grease were not measured.

Table 2-1 – Materials Balance of Pile 1 (LSB and GWG)

Material	*Solids Content (%)*	*Wet Weight (lbs)*	*Dry Weight (lbs)*	*Bulk Density (lbs/yd^3)*	*Volume (yd^3)*	*Volatile Solids (%)*
LSB	35	6,040	2,114	1,680	3.6	34
GWG	[a]19	6,470	1,229	640	10.1	61
Calculated Mix	27	12,510	3,343	913	13.7	44
Measured Mix	49					47

[a]Seems low; probably erroneous measurement.

Table 2-2 – Materials Balance of Pile 2 (LSB, KUBG, and GWG)

Material	*Solids Content (%)*	*Wet Weight (lbs)*	*Dry Weight (lbs)*	*Bulk Density (lbs/yd^3)*	*Volume (yd^3)*	*Volatile Solids (%)*
LSB	35	4,710	1,648	1,680	2.8	34
KUBG	5	3,610	180	[a]1,680	2.1	[b]
GWG	[c]19	7,490	1,423	640	11.7	61
Calculated Mix	20.5	15,810	3,251	1,188	[d]13.3	44
Measured Mix	38					48

[a]Estimate.
[b]Not measured.
[c]Reading seems low.
[d]Assume 20 percent compaction as water fills void.

Table 2-3 – Materials Balance of Pile 3 (LSB, KUBG, and GWG)

Material	*Solids Content (%)*	*Wet Weight (lbs)*	*Dry Weight (lbs)*	*Bulk Density (lbs/yd^3)*	*Volume (yd^3)*	*Volatile Solids (%)*
LSB	35	7,440	2,604	1,680	4.4	34
KUBG	5	6,140	307	[a]1,680	3.6	[b]
GWG	[c]19	9,690	1,841	640	15.1	61
Calculated Mix	20.4	23,270	4,752	1,436	[d]16.2	42
Measured Mix	36					51

[a]Estimate.
[b]Not measured.
[c]Reading seems low.
[d]Assume 30 percent compaction as water fills void.

Table 2-4 – Materials Balance of Pile 4 (KUBG and GWG)

Material	*Solids Content (%)*	*Wet Weight (lbs)*	*Dry Weight (lbs)*	*Bulk Density (lbs/yd^3)*	*Volume (yd^3)*	*Volatile Solids (%)*
KUBG	[a]5	7,570	378	*1,680	4.5	[b]
GWG	[c]19	10,770	2,046	640	16.8	61
Calculated Mix	13.2	18,340	2,424	1,230	[d]14.9	52
Measured Mix	37					57

[a]Estimate.
[b]Not measured.
[c]Reading seems low.
[d]Assume 30 percent compaction as water fills void.

Table 2-5 – Materials Balance of Pile 5 (FUDB and PWG)

Material	*Solids Content (%)*	*Wet Weight (lbs)*	*Dry Weight (lbs)*	*Bulk Density (lbs/yd^3)*	*Volume (yd^3)*	*Volatile Solids (%)*
FUDB	18	8,590	1,546	1,560	5.5	77
PWG	63	4,840	3,049	400	12.1	60
Calculated Mix	34.2	13,430	4,595	763	17.6	66
Measured Mix	41					72

Table 2-6 – Materials Balance of Pile 6 (FUDB and PWG)

Material	*Solids Content (%)*	*Wet Weight (lbs)*	*Dry Weight (lbs)*	*Bulk Density (lbs/yd³)*	*Volume (yd³)*	*Volatile Solids (%)*
FUDB	18	6,370	1,147	1,560	4.1	77
PWG	63	4,190	2,640	400	10.5	60
Calculated Mix	35.9	10,560	3,787	677	15.6	65
Measured Mix	42					70

Table 2-7 – Materials Balance of Pile 7 (FUDB/LSB[a] and GWG)

Material	*Solids Content (%)*	*Wet Weight (lbs)*	*Dry Weight (lbs)*	*Bulk Density (lbs/yd³)*	*Volume (yd³)*	*Volatile Solids (%)*
FUDB/LSB	29	10,404	3,017	1,640	6.3	48
GWG	[b]19	8,536	1,622	640	13.3	61
Calculated Mix	24.5	18,940	4,639	966	19.6	

[a]All calculations assume one-third FUDB/two-thirds LSB mix of biosolids.
[b]Reading seems low.

Table 2-8 – Materials Balance of Pile 8 (FUDB/LSB[a] and GWG)

Material	*Solids Content (%)*	*Wet Weight (lbs)*	*Dry Weight (lbs)*	*Bulk Density (lbs/yd³)*	*Volume (yd³)*	*Volatile Solids (%)*
FUDB/LSB	29	6,467	1,875	1,640	3.9	48
GWG	[b]19	4,653	884	640	7.3	61
Calculated Mix	24.8	11,120	2,759	992	11.2	

[a]All calculations assume one-third FUDB/two-thirds LSB mix of biosolids.
[b]Reading seems low.

All of the materials necessary to build the compost piles were transported to the site several days in advance and placed in discrete piles. A berm composed of ground yard waste was placed at the periphery of the property to contain any potential runoff. The grease trap wastes were delivered to the site in 250-gallon sealed containers that formerly contained dewatering polymers. The grease trap wastes were from a school and were pumped directly from the collection vehicle into the storage containers.

With the two static piles (Piles 3 and 6), a ground yard waste base about eight inches deep covered the aeration pipe. The mix of biosolids and bulking agent was covered with a one-foot-deep insulation layer comprised of ground yard waste. The aeration pipe from both piles was connected to a single plenum and blower. The pipe was connected to the negative side of the blower so that air was drawn through the composting mass, passed through the blower, and exhausted through a plenum into a pile of ground yard waste that served as a biofilter. An existing, on-site blower was utilized for this study. Unfortunately, the aeration rate from the blower was unknown, so until the piping system was modified to allow for some control of the airflow to each pile, it was impossible to maintain desired conditions in either pile.

An 18-cubic-yard Knight mix box was utilized to mix the biosolids, bulking agent, and grease trap wastes. The mix box has an internal weigh scale. The procedure for mixing was to utilize a front-end loader to add first the bulking agent, then the biosolids, then the grease trap wastes, and then more bulking agent. After each addition, the weight was recorded. The internal augers of the mix box did a good job of providing a uniform mix in 10 to 15 minutes. The mixed material was offloaded into the front-end loader bucket and placed on a pile for composting. During the mix period, samples were collected for solids, pH, and volatile solids analysis.

The major odor source during pile building was caused by the grease trap wastes, which had turned anaerobic during storage. These odors were quite strong until the liquid was mixed with the bulking agent and biosolids. There also was a slight odor from the First Utility District biosolids.

2.3 – DISCUSSION OF RESULTS

2.3.1 – Introduction

This section of the report will discuss each pile. The temperature logs, oxygen content, and graphs are contained in Appendix A, and analytical findings are contained in Appendix B.

2.3.2 – Pile 1 – LSB and GWG – Windrow

There was some concern that this pile would be slow to start composting due to the reportedly high pH of the biosolids and low volatile solids content. Fresh ground yard waste was chosen as the bulking agent since this material has some readily degradable organic material that could "kick start" the biological activity. Obviously, the solids content reported in Table 2-1 for the GWG (19 percent) is in error, and the measured value of 49 percent solids in the mix is probably more accurate than the calculated value of 27 percent. The calculated bulk density of the pile (913 lbs/yd^3) shows that there should be plenty of porosity at the mix ratio demonstrated. The pH measured for the mix on Day 1 (8.24) was significantly lower than expected, as was the measured pH of the LSB (9.45). At the measured pH, bulk density, and solids content, it was expected that no problems would occur with the biological activity of this pile, and the measured temperatures indicated that this was the case. One point in the pile reached the Class A criteria of 55^{o}C on Day 3 of composting, and all points reached the 55^{o}C criteria by Day 6. Due to the small pile size, pile temperatures showed more variability than would be expected from a full-size pile. The Class A pathogen criteria of 15 days at 55^{o}C with a minimum of five turns and the vector attraction reduction criteria of 14 days being aerobic with an average temperature of 45^{o}C were easily met for this pile. There were no malodors with this pile. Not unexpectedly given the relatively high solids content of the initial mix, relatively frequent water additions were required for this mix. The relatively low ammonia levels measured on September 7, 2001 show that most nitrogen released during composting was incorporated into the microbial mass rather than lost as ammonia.

2.3.3 – Pile 2 – LSB, KUBG, and GWG – Windrow

In Pile 2, grease trap wastes were added to provide additional energy to the lime-stabilized sludge. According to the laboratory data, this pile had a lower initial solids content, lower pH, and slightly higher volatile solids content. Probably because of the higher moisture content and the higher bulk density of this pile, it took nine days until the Class A pathogen temperature of 55°C was met. The higher bulk density apparently impeded oxygen transfer for the first seven days of composting. The pile met the 15 days at 55°C with five turnings criteria as well as vector attraction reduction requirements. The grease trap wastes created a slight malodor in this pile for about the first 10 or so days, but otherwise this mix composted well. Ammonia release was similar to Pile 1 and would not create a problem in a full-scale operation.

2.3.4 – Pile 3 – LSB, KUBG, and GWG – Aerated Static Pile

Pile 3 was similar to Pile 2 except a little wetter and much more dense, as shown in Table 2-3. The advantages of forced aeration are apparent in this pile as initial oxygen content and temperatures met Class A criteria in three days instead of nine days. There were no odors associated with this pile, and none occurred at the biofilter. The high initial bulk density of over 1,400 lbs/yd^3 made it difficult to insert the temperature and oxygen probes into the pile as the study progressed. This pile easily exceeded the three days at 55°C static pile compost criteria for Class A pathogen kill as well as vector attraction reduction requirements.

2.3.5 – Pile 4 – KUBG and GWG – Windrow

This pile was designed to determine if the grease trap wastes could be composted. This pile did not reach temperatures required to meet Class A criteria for 15 days; however, the 55°C criteria was met for about 10 days in at least one location in the pile. These results indicate that not enough solids were present in the pile to allow for enough heat generation. The pile temperatures dropped after 14 days. When the pile was examined at that time, no odor or sign of grease could be detected, indicating probable breakdown of the volatile solids present in the grease. The results of this pile are encouraging in that they show it is possible to compost grease trap wastes without dewatering. It may be possible to reach temperatures by using the same bulking agent multiple times to build up a large enough mass of degradable materials.

2.3.6 – Pile 5 – FUDB and PWG – Windrow

This pile was designed to demonstrate composting of a non-lime-stabilized biosolids. The volatile solids of this type of biosolids is higher and the pH is lower, so it was felt that a bulking agent with lower volatile solids (and a lower market demand in the Knoxville area) would still produce acceptable results. As expected, the mix had good characteristics for composting with a low bulk density, acceptable solids content, and volatile solids. This pile attained the 55°C criteria on Day 1 and easily met Class A pathogen and vector attraction reduction regulatory requirements. The ammonia release with this pile was substantially higher than Piles 1, 2, and 3, indicating that degradation of the organic matter in the biosolids released nitrogen faster than it could be taken up by the microbial mass. There was a mild odor noted on Day 16, but otherwise no problems were noted.

2.3.7 – Pile 6 – FUDB and PWG – Aerated Static Pile

This pile was similar to Pile 5, except the aerated static pile method of composting was utilized rather than the windrow method used with Pile 5. The solids contents of the two piles were similar. This pile had trouble meeting Class A temperature criteria until Day 24. The reason for this was undoubtedly due to over-aeration of this pile. As was mentioned in Section 2.2, both aerated static piles were initially connected to one manifold, and the characteristics of the blower were unknown. Since the bulk density of Pile 3 was almost twice as great as that of Pile 6, most of the air was probably forced through this pile. When separate throttles for each pile were put into place on Day 23, this problem was overcome, the airflow to Pile 6 was reduced, and this pile met Class A pathogen and vector attraction reduction requirements for static pile composting.

2.3.8 – Piles 7A and 7B – LSB, FUDB, and GWG – Windrow

These two piles were built with all of the biosolids left after building the initial six planned piles. These piles had the advantage of some additional volatile solids provided by the FUDB as compared to Pile 1. These two piles achieved 55^{o}C temperatures by Day 2, as compared to Pile 1, which did not achieve the 55^{o}C temperature criteria for Class A pathogen status until Day 6. This pile met Class A status as well as vector attraction reduction criteria. No odors were noted with these piles.

2.3.9 – Pile 9 – KUBG and PWG

This pile utilized the remainder of the grease trap wastes with ground pallets. After it was mixed, the pile released a significant amount of water, so it was impossible to determine a materials balance. The pallet wastes appeared to absorb the grease trap wastes on the surface of the chips and released only clear water. The grease trap wastes had a significant odor until mixed with the bulking agent. As expected, the mix did not meet the 55^{o}C criteria. Comparing this pile with Pile 4, it is apparent that the ground yard wastes provided substantial energy to the compost process since temperatures were consistently 10^{o}C to 15^{o}C higher in Pile 4. Both piles showed that the volatile solids supplied by the grease trap wastes are burned off by about Day 14, when temperatures of the piles tend to decrease. As with Pile 4, no sign of the grease could be discerned after about Day 14.

2.4 – SCREENING

On October 16, 2001, five-gallon samples from each pile were hand-screened through a one-half-inch screen. Percent solids of screen unders and overs were determined for each pile, as well as bulk density of each pile. The results of these analyses are shown in Table 2-9.

Table 2-9 – Analysis of Screened Samples

Pile #	***Bulk Density***	***Percent >½”***	***Percent <½”***
1	1,420	40	60
2	880	40	60
3	920	40	60
4	760	16	84
5	660	60	40
6	520	33	67
7	940	70	30
8	920	65	35
9	680	33	67

The less than one-half-inch fraction still had significant woody inclusions and would not make a good compost unless a finer screen was used. The products produced had no malodors.

2.5 – COMPOST ANALYTICAL FINDINGS

Table 2-10 shows the analytical results for the compost by pile. The results indicate that all piles would meet the USEPA regulatory standards for unlimited distribution.

Table 2-10 – Analytical Findings of Compost Samples

Element	*Pile Number*									*Units*	*503 Limit*
	1	***2***	***3***	***4***	***5***	***6***	***7***	***8***	***9***		
Fecal Coliform	<1	<1	<1	<1	<1					CFU/100 ml	<1,000 MPN/g
pH	7.84	7.91	7.73	8.28	7.58	7.57	7.71	7.68	8.01	S.U.	
% Volatile Solids	40	46	48	53	65	67	47	45	74	%	
Ammonia	<56	<56	196.8	<56	1,837.6	<56	119.7	<56	<56	mg/l	
% Solids	42	41	40	40	39	40	42	43	39	%	
Silver (Ag)	12.3	10.5	10.4	0.2	6.0	3.6	13.3	8.0	<MDL	ppm	
Cadmium (Cd)	0.5	0.5	0.5	0.2	1.6	0.3	0.6	0.5	<MDL	ppm	39
Chromium (Cr)	20.1	24.5	18.8	6.1	20.4	6.5	18.0	11.5	1.4	ppm	
Copper (Cu)	83.8	73.7	66.7	12.5	90.4	56.1	86.4	53.7	16.0	ppm	1,500
Nickel (Ni)	15.9	15.4	11.6	4.2	15.2	4.5	14.1	10.0	0.7	ppm	420
Lead (Pb)	25.0	41.1	21.0	13.3	20.9	7.4	17.7	12.1	4.8	ppm	300
Zinc (Zn)	255.3	301.2	246.0	113.2	1,034.8	125.3	301.8	183.8	169.7	ppm	2,800
Aluminum (Al)	9,262.9	8,718.4	7,731.1	3,002.0	7,632.0	5,017.6	8,279.3	6,425.4	749.7	ppm	
Calcium (Ca)	73,257.6	63,184.2	60,021.0	11,818.0	25,340.3	16,186.6	62,302.5	57,341.5	7,361.2	ppm	
Iron (Fe)	13,788.6	14,155.2	12,783.0	5,567.0	3,041.9	2,211.9	10,743.7	9,017.5	1,164.2	ppm	
Potassium (K)	2,254.1	2,422.1	2,239.1	1,525.7	3,395.0	2,173.3	2,132.1	1,995.2	756.5	ppm	
Magnesium (Mg)	2,359.7	2,302.1	1,850.0	1,187.5	1,958.2	2,134.7	2,685.9	2,497.9	729.3	ppm	
Manganese (Mn)	776.6	693.1	602.7	465.5	309.6	229.8	404.3	389.6	105.8	ppm	
Sodium (Na)	466.7	678.4	629.8	385.7	7,713.4	953.0	683.9	373.9	335.2	ppm	
Molybdenum (Mo)	5.5	5.1	2.2	0.8	3.3	4.5	2.5	2.0	<MDL	ppb	18 ppm
Arsenic (As)	3.2	<MDL	3.2	5.1	1.9	2.1	0.3	0.2	2.7	ppm	
Selenium (Se)	10.4	2.4	<MDL	<MDL	6.8	<MDL	0.3	4.4	1.81	ppb	100 ppm
Mercury (Hg)	0.2	0.3	0.1	0.2	26.5	0.3	0.7	3.6	<MDL	ppb	17
Kjeldahl Nitrogen	7,315.3	6,672.3	7,000.0	4,163.6	18,490.6	19,764.7	9,140.9	8,947.4	4,704.0	mg/l	

SECTION 3 – ECONOMIC ANALYSIS

3.1 – INTRODUCTION

This section of the report looks at the costs of implementing the following four compost scenarios:

- Section 3.2 looks at Scenario 1, whereby all of KUB's biosolids and an additional 200 wet tons per week of other biosolids are composted by the static pile compost method. The composting only takes place during the four winter months when all biosolids produced would be composted.

- Section 3.3 looks at Scenario 2, whereby the same scenario as the first scenario is presented, except that the windrow composting technique is utilized instead of the static pile method.

- Section 3.4 looks at Scenario 3, which evaluates year-round composting of liquid grease and yard waste by the windrow method.

- Section 3.5 looks at Scenario 4, which evaluates year-round composting of grease that has been concentrated by filtering the liquid grease through a biofilter. With this method, the grease is concentration by adsorption to the biofilter media, and the resultant material (biofilter media plus grease) is composted by the windrow compost method.

The economic analysis assumed that no additional site development costs would be incurred except for a pushwall, blowers, aeration equipment, and electricity for Scenario 1. The static pile scenario's local labor, fuel, and bulking agent costs provided by the Knox County Solid Waste Division were utilized in this analysis.

3.2 – SCENARIO 1 – AERATED STATIC PILE COMPOSTING OF KUB BIOSOLIDS DURING FOUR WINTER MONTHS

The KUB produces approximately 1,000 wet tons per week of biosolids. The biosolids are currently land applied, and near-term future plans call for a continuation of this practice. In the winter months (approximately mid-November to mid-March), these biosolids need to be stored in farmers' fields since they cannot be spread due to regulatory restrictions. In order to store the biosolids, it is necessary to lay a road of gravel into the field and place a gravel bed under the stored biosolids. This practice is expensive since not only must the gravel be laid down for the biosolids trucks, but it must also be removed after the biosolids are spread in the spring. The KUB is interested in evaluating biosolids composting as a way to reduce the costs of winter storage and subsequent land application. This first scenario is designed to evaluate winter composting of all of the weekly output of 1,000 wet tons of KUB biosolids plus an additional 200 wet tons of biosolids from other regional wastewater utilities that face similar winter time constraints.

The static pile method of composting relies on mechanical aeration to maintain aerobic conditions in the composting mass. This method of composting was demonstrated in the pilot study and offers the advantage of being able to contain and scrub odorous compost emissions and requires less space than does windrow composting. Table 3-1 shows the basis for this option.

Table 3-1 – Basis of Design for Knox County Aerated Static Pile Compost Cost Estimate

Item	*Units*	*Recommended Value*
Biosolids Solids Content	%	30
Biosolids Volatile Solids	%	60
Biosolids Bulk Density	lb/yd^3	1,600
Bulking Agent Solids Content	%	60
Bulking Agent Volatile Solids	%	60
Bulking Agent Bulk Density	lb/yd^3	520
Mix Solids Content	%	30-40
Mix Bulk Density	lb/yd^3	<1,100
Unscreened Compost Solids Content	%	60
Unscreened Compost Volatile Solids Loss	%	15
Unscreened Compost Bulk Density	lb/yd^3	<1,000
Curing Compost Solids Content	%	45-50
Curing Compost Bulk Density	lb/yd^3	<1,200
Finished Compost Solids Content	%	60-65
Finished Compost Bulk Density	lb/yd^3	900-1,000
Biosolids Storage	hours	16
Bulking Agent Storage	days	30
Number of Active Compost Piles	#/day	18/21
Curing (static pile) Period	days	30
Compost Storage	days	60
Bulking Agent Storage Height	feet	12
Biosolids Storage Height	feet	3
Compost Mix Height	feet	10
Compost Storage Height	feet	10
Curing Pile Height	feet	10
Compost Plenum Depth	feet	1
Compost Insulation Cover Depth	feet	1
Months of Composting	months	4
Method of Mixing	method	Mix Box
Type of Aeration	type	Negative and Negative/Positive
Aeration Rate	cfh/dry ton biosolids	3,000
Odor Control Mechanism	mechanism	Biofilter
Biofilter Flow Rate	cfm/ft^2	5
Days of Operation	days/week	6
Hours of Operation	hours/day	10
Amount of Biosolids Processed	dry tons/wet tons per week	360/1,200

Winter biosolids composting could be compatible with the existing mulch operation at either the Solway site or the Forks of the River site since delivery of leaves and yard trimmings generally stops around mid-November and does not begin again until mid-March. For this reason, no additional pads may be required.

Table 3-2 shows a materials balance for the 200 wet tons per day, six days per week operation.

Table 3-2 – Materials Balance for 60 Dry Tons per Day[a] Static Pile Compost Facility

Feedstock	*Total Solids (%)*	*Volatile Solids (%)*	*Wet Tons*	*Dry Tons*	*Bulk Density (lb/yd³)*	*Volume (yd³)*
Biosolids	30.0	60.0	200.0	60.0	1,600	250.0
Bulking Agent	60.0	60.0	100.0	60.0	520	384.6
Input Mix[b]	40.0	70.0	300.0	120.0	1,050	571.1
Base[c]	60.0	60.0	17.1	10.3	600	57.1
Cover[d]	60.0	60.0	35.2	21.1	1,000	70.5
Compost Loss[e]	60.0		112.3	7.4		
Uncured Compost[f]	60.0	59.1	240.0	144.0	783	613.0
Recycle[g]	60.0	60.0	60.1	36.0	520	231.0
Compost	60.0	58.8	179.9	108.0	1,000	360.0

[a]Assumes no grease input.
[b]Assumes a 10-percent consolidation on mixing.
[c]Assumes a 10-foot mix height and a 1-foot base.
[d]Assumes covering the two ends and the top every day with a one-foot layer of compost.
[e]Assumes a 10-percent volatile solids loss for the mix and none for the base and cover.
[f]Assumes a 15-percent consolidation.
[g]Assumes recovery of 60 percent of the bulking agent volume and ignores the cover and base.

In order to minimize equipment needs, it was assumed that the site would be operated 10 hours per day, similar to the existing mulch operation.

Table 3-3 summarizes the bulking agent needs for the operation.

Table 3-3 – Bulking Agent Requirements

Month 1	24 days x (Bulking Agent + Base + Cover)	12,293 yd^3
Month 2	24 days x (Bulking Agent + Base – Recycle)	5,057 yd^3
Month 3	24 days x (Bulking Agent + Base – Recycle)	5,057 yd^3
Month 4	24 days x (Bulking Agent + Base – Recycle)	5,057 yd^3
Month 5	24 days x (– Recycle)	- 5,544 yd^3
Total		22,020 yd^3

Since this is not a year-round, steady-state compost facility, more bulking agent will be required in the first month before initial product screening and bulking agent recovery occurs. A total of 22,000 cubic yards of bulking agent will be required for this option. In the first month, bulking agent will be required for pile base and pile cover, while in Months 2 through 4, curing compost will be utilized as pile cover. After the fifth month of composting, 5,500 cubic yards of cured bulking agent will be available for sale as a mulch product.

Table 3-4 shows the site sizing calculations by activity.

These sizings assume that all activities occur each month. In reality, because there is no curing or compost storage in Month 1, no storage in Month 2, no composting after Month 4, and no composting or curing after Month 5, the site requirements will be constantly changing. Table 3-4 does not assume internal roadways. Figure 3-1 determines an allowance for these turn areas.

Table 3-4 – Site Sizing Calculations

Activity	*Cubic Yards/Day*	*Number Days*	*Cubic Yards*	*Area Required (ft^2)*
Biosolids Storage[a]	250.0	2	500	4,500
Bulking Agent Storage[b]	512.2	24	12,293	31,684
Mix Area[c]				600
Compost Area[d]	571.1	22	12,564	38,000
Screen Area[e]				2,500
Cure Area[f]	360.0	30	10,800	29,160
Compost Storage[g]	360.0	60	21,600	63,000
Total[h]				169,444

[a]Assumes a 3-foot pile height and a three-sided open enclosure.
[b]Assumes a 12-foot pile height = 27,659 ft^2, or 166 x 166; therefore, accounting for slope need, 178 x 178 = 31,684.
[c]Assumes a 20-foot x 30-foot area.
[d]Assumes 22 piles areas: 15 active and 4 extra. Assumes a 10-foot mix height. If piles are 85 feet long, then 85 x 400 = a 34,000-ft^2 pushwall on one side and on the ends (95 x 400); accounts for slope.
[e]Assumes a 100-foot x 25-foot area.
[f]Assumes screening before curing. Assumes a 10-foot height with no aeration = 29,160 ft^2, or 171 x 17, to account for slopes.
[g]Assumes a 10-foot height in the open on an impervious surface = 58,320 ft^2, or 241 x 241, or 251 x 251 = 63,000 to account for slopes.
[h]During peak Months 2 through 4.

Figure 3-1 – Sizing Calculations for Impervious Pad and Biofilter

Impervious Pad Sizing

Assume a 25-foot aisle space around the perimeter to allow for internal front-end loader movement:

Square root of 169,444 = 412 x 412 + 25-foot perimeter on all four sides
437 x 437 = 190,969 ft^2 paved required

Biofilter Sizing

1. Assume process air of 3,000 cfh/dry ton x 60 dry tons/day x 22 days = 3,960,000 cfh
2. Assume need equal amount of ambient air to cool process air = 3,960,000 cfh
3. Total input air = process air + cooling air = 7,920,000 cfh = 132,000 cfm
4. At a filtration rate of 5 cfm/ft^2, require 132,000/5 = 26,400 ft^2
5. With a 3-foot-high biofilter, need 26,400/400, need 400-foot x 66-foot biofilter

From this figure, it can be seen that almost 191,000 square feet are required at the peak month. Figure 3-1 also shows calculations for a biofilter to scrub odorous offgases. This 26,400-square-foot area would be required during Months 1 through 4, and the biofilter media could be sold after the compost season or left in place for the next year's compost period.

Table 3-5 shows equipment usage for this scenario.

Again, all calculations are based on peak activity at the site. In Month 1, since no curing or storage occurs, it would be possible to operate with only two loaders.

Table 3-5 – Equipment Usage – Static Pile

Mix Box Calculations				
Volume of Mix (yd^3)	***Volume of Mix Box (yd^3)***	***# of Mixes***	***Mix Time/Cycle (min)***	***Time (min)***
634.6	16	40	15	595[a]

Screen Sizing Calculations		
Volume to be Screened (yd^3)	***Hours of Screening***	***Volume/Hour Screen Size (yd^3/hour)***
613.0[b]	10	62

Front-end Loader[c] Utilization Calculations					
Function	***Cubic Yards***	***Min/Cycle***	***Volume/Cycle***	***Cycles Required***	***Min Required***
Bulking Agent to Mix	384.6	3	8	48	144
Biosolids to Mix	250.0	2	8	31	62
Mix to Pile	634.6	2	8	80	160
Lay Base	57.1	3	8	7	21
Lay Cover	70.5	5	8	9	45
Mix to Screen	613.0	4	8	77	308
Recycle to Store	231.0	3	8	29	87
Compost to Cure	360.0	3	8	45	135
Cure to Store	360.0	3	8	45	135
Store to Market	360.0	4	8	45	135
Subtotal	3,320.8			416	1,232
10% Contingency	332.1			42	123
Total	3,652.9			458	[d]1,355 (22.5 hours)

[a]One 18-yd^3 mix box can handle mixing in a 10-hour day.
[b]Includes base, cover, and uncured compost.
[c]Assumes an 8-yd^3 bucket.
[d]Need two 8-yd^3 bucket loaders (one 4-yd^3 loader) for a 10-hour workday.

The structural costs for this option include a pushwall to be placed between the end of the compost pile and the aeration blowers. This wall is not absolutely necessary, as it is possible to use roadway barriers for this task. If roadway barriers are used, the capital costs would be lower, but care would be required to keep the blower area clean. If the concrete pushwalls were not utilized, the site would have to be marginally larger to account for side slopes. Table 3-6 shows the costs of a 12-foot-high pushwall.

Table 3-6 – Capital Costs – Structural

Item	***Unit Cost***	***Units***	***Quantity***	***Estimated Cost***
Concrete Pushwalls[a]	450.00	yd^3	182	82,000
Subtotal				82,000
Electricity[b]				8,200
Overhead and Profit[c]				10,824
Total Structures				$101,024

[a]Assumes 12 feet high, 1 foot thick, ±410 linear feet to protect blowers = 4,920 ft^3 = 182 yd^3.
[b]Assumes 10 percent of Subtotal.
[c]Assumes 10 percent of Subtotal plus Electricity.

The capital costs for the compost aeration system and biofilter are shown in Table 3-7.

Table 3-7 – Capital Costs – Aeration System/Biofilter

Item	*Unit Cost*	*Units*	*Quantity*	*Estimated Cost*
Aeration Blowers	2,500.00	ea	22	55,000
Aeration Ductwork[a]	2,580.00	ea	22	56,760
Aeration Blower Installation	400.00	ea	22	8,800
¾-inch Round Washed Stone	59.45	yd^3	625	37,156
Installation[b]	7.07	yd^3	625	4,418
Media Blended and Delivered	20.00	yd^3	1,900	38,000
Wood Chips	10.00	yd^3	470	4,700
Installation[c]	16.15	yd^3	2,370	38,275
Surface Irrigation	0.60	ft^2	21,000	15,600
36-inch Collection Ducts[d]		allowance	155,000	155,000
Biofilter Booster Fans	15,000.00	ea	2	30,000
Biofilter Header and Piping[e]		allowance		60,000
Subtotal				503,709
Overhead and Profit[f]				60,445
Total Aeration System/Blower				$564,154

[a]Includes 6-inch duct, elbows, a butterfly damper, 12-inch duct, tees, elbows, and flanges.
[b]Includes a front-end loader, a bulldozer, and labor for the stone.
[c]Includes a front-end loader, an excavator, and labor for the wood chips and the media.
[d]Includes 34-inch tees, flanges, elbows, 300-foot 34-inch duct, 400-foot 24-inch duct, and transitions.
[e]Includes 300-foot 24-inch duct, elbows, an inserta tee, 8-inch drilled pipe, elbows, and an end cap.
[f]12 percent of Subtotal.

These costs include reusable piping and connectors for both the compost system and the biofilter. Five horsepower blowers would be used to aerate the piles, with a single blower per pile. There will be 18 active piles with four spaces left to tear down and build piles. Since the facility only operates on a six-day basis, the 18 active piles will allow for 21 days of composting. This is more than sufficient to meet USEPA Class A pathogen and vector attraction reduction requirements. Table 3-8 shows the capital costs for Knox County's purchase of moving equipment, including front-end loaders, a mix box, and a screen.

Table 3-8 – Capital Costs – Moving Equipment

Item	*Unit Cost*	*Units*	*Quantity*	*Estimated Cost*
Front-end Loaders	250,000.00	8 yd^3	2	500,000
Front-end Loader	150,000.00	4 yd^3	1	150,000
Mix Box	115,000.00	18 yd^3	1	115,000
Screen	120,000.00	600 yd^3/hour	1	120,000
Total Moving Equipment[a]				$885,000

[a]Assumes direct County purchase, so no overhead and profit.

No County discounts are assumed in these costs. Since the compost facility is only operational for five months, it may be cost effective to lease or rent some of this equipment.

Table 3-9 summarizes the capital costs.

Table 3-9 – Summary of Capital Costs

Item	*Capital Cost*
Structural	101,024
Aeration System/Biofilter	564,154
Moving Equipment	885,000
Subtotal	1,459,258
Engineering[a]	175,111
Contingency[b]	326,873
Total	$1,961,243

Amortized Capital Costs[c]	*Capital Cost*	*Annual Cost*
20-Year	135,776	10,836
10-Year	758,223	98,019
7-Year	1,189,440	205,359
Total		$314,214
Total Cost/Ton[d]		$15.40

[a]12 percent of Subtotal.
[b]20 percent of Subtotal plus Engineering.
[c]Structural based on 5 percent, 20 years; aeration system biofilter based on 5 percent, 10 years; and moving equipment based on 5 percent, 7 years amortization.
[d]Based on 1,200 wet tons per week x 17 weeks.

The $1,950,000 figure includes the costs of pushwalls, reusable pipe, and County purchase of all equipment new as well as a 12-percent engineering and a 20-percent contingency factor. The annualized capital costs amount to $314,214 per year, based on a 5-percent interest rate and amortizing the pushwall over 20 years, the compost aeration system over 10 years, and the moving equipment over 7 years. These are very conservative numbers given the seasonal usage. Using these factors, the annual cost is $314,214, or $15.40 per wet ton.

The operation and maintenance (O&M) costs are shown in Table 3-10.

Table 3-10 – O&M Costs

Item	*Unit Cost*	*Units*	*Daily Quantity*	*Annual Quantity*	*Annual Estimated Cost*
Labor	14.00	$/hour	50	6,000	84,000
Laboratory	3,000.00	$/year			3,000
Front-end Loader O&M	29.59	$/hour	30	3,600	106,524
Screen O&M	17.61	$/hour	10	720	12,679
Batch Mixer O&M	15.00	$/hour	10	720	10,800
Bulking Agent[a]	6.20	$\$/yd^3$		22,020	136,524
Electricity[b]	0.06	$/kwh	2,880	345,600	20,736
Administrative		lump			20,000
O&M Costs					394,263
O&M Costs/dry ton[c]					63.80
O&M Costs/wet ton					19.14
Potential revenue is $37,080 for each $\$1/yd^3$ received in sales. Normally sells for $\$5/yd^3$ to $\$10/yd^3$ elsewhere.					

[a]Assumes ground brush is obtained at retail market price average for area. Assumes screened bulking agent resold at same price after compost season.
[b]For aeration and biofilter blowers only.
[c]Based on an average of 60 dry tons per day x 103 days.

These costs are based on five people: three operators, one and a half laborers, and a half-time supervisor/mechanic. Laboratory costs include all USEPA-mandated Part 503 analyses for the four-month period. Unit O&M costs were provided by the manufacturer and include oil, parts, and labor for all routine warranty maintenance. Bulking agent was assumed at the average retail price in the Knoxville area of $6.20 per cubic yard. Any bulking agent remaining after the compost season is assumed to be sold for the same amount. Electricity is for the operation of the blowers for aeration and biofilter booster fans. Administrative costs include time for secretarial services, billing, and minimal insurance. The O&M costs are $19.14 per wet ton. No revenue for compost sales is assumed. If the compost were sold, then O&M costs could be reduced by $1.80 for each dollar per cubic yard received. The total annualized plus capital costs are estimated to be $34.50 per wet ton processed.

3.3 – SCENARIO 2 – WINDROW COMPOSTING OF KWB DURING FOUR WINTER MONTHS

This scenario is identical to Scenario 1, except that the windrow compost method is utilized instead of the static pile method. Table 3-11 shows the basis of design for this scenario.

Note that this method does not allow for any auxiliary odor control. Again, the facility is designed to operate 6 days per week, 10 hours per day. The materials balance for this facility is shown in Table 3-12, and the bulking agent per year is shown in Table 3-13.

The site size per activity is shown in Table 3-14.

The area for composting is based on a Scarab 16 as shown in Table 3-15.

Table 3-11 – Basis of Design for Knox County Windrow Compost Cost Estimate

Item	*Units*	*Recommended Value*
Biosolids Solids Content	%	30
Biosolids Volatile Solids	%	60
Biosolids Bulk Density	lb/yd^3	1,600
Bulking Agent Solids Content	%	60
Bulking Agent Volatile Solids	%	60
Bulking Agent Bulk Density	lb/yd^3	520
Mix Solids Content	%	38-40
Mix Bulk Density	lb/yd^3	<1,100
Unscreened Compost Solids Content	%	60
Unscreened Compost Volatile Solids Loss	%	15
Unscreened Compost Bulk Density	lb/yd^3	<1,000
Curing Compost Solids Content	%	45-50
Curing Compost Bulk Density	lb/yd^3	<1,200
Finished Compost Solids Content	%	60-65
Finished Compost Bulk Density	lb/yd^3	900-1,000
Biosolids Storage	hours	16
Bulking Agent Storage	days	30
Number of Active Compost Piles	#/day	18/21
Curing (static pile) Period	days	30
Compost Storage	days	60
Bulking Agent Storage Height	feet	12
Biosolids Storage Height	feet	3
Compost Mix Height	feet	8
Compost Storage Height	feet	10
Curing Pile Height	feet	8
Compost Plenum Depth	feet	
Compost Insulation Cover Depth	feet	
Months of Composting	months	4
Method of Mixing	method	Mix Box
Type of Aeration	type	Windrow Turning
Aeration Rate	not applicable	not applicable
Odor Control Mechanism	mechanism	None
Days of Operation	days/week	6
Hours of Operation	hours/day	10
Amount of Biosolids Processed	dry tons/wet tons per week	360/1,200

Table 3-12 – Materials Balance for 60 Dry Tons per Day[a] Windrow Compost Facility

Feedstock	*Total Solids (%)*	*Volatile Solids (%)*	*Wet Tons*	*Dry Tons*	*Bulk Density (lb/yd^3)*	*Volume (yd^3)*
Biosolids	30.0	60.0	200.0	60.0	1,600	250.0
Bulking Agent	60.0	60.0	100.0	60.0	520	384.6
Input Mix[b]	40.0	70.0	300.0	120.0	1,050	571.1
Compost Loss[c]	60.0		112.3	7.4		
Uncured Compost[d]	60.0	59.1	187.7	112.6	773	485.4
Recycle[e]	60.0	60.0	60.1	36.0	520	231.0
Compost	60.0	58.8	127.6	76.6	1,000	255.2

[a]Assumes no grease input.
[b]Assumes a 10-percent consolidation on mixing.
[c]Assumes a 10-percent volatile solids loss.
[d]Assumes a 15-percent consolidation.
[e]Assumes recovery of 60 percent of the bulking agent volume.

Table 3-13 – Bulking Agent Requirements

Month 1	24 days x Bulking Agent	9,230 yd^3
Month 2	24 days x (Bulking Agent – Recycle)	3,686 yd^3
Month 3	24 days x (Bulking Agent – Recycle)	3,686 yd^3
Month 4	24 days x (Bulking Agent – Recycle)	3,686 yd^3
Month 5	24 days x (– Recycle)	- 5,544 yd^3
Total		14,745 yd^3

Table 3-14 – Site Sizing Calculations

Activity	***yd^3/day***	***# Days***	***yd^3***	***Area Required (ft^2)***
Biosolids Storage[a]	250.0	2	500	4,500
Bulking Agent Storage[b]	384.6	30	11,538	29,929
Mix Area[c]				600
Compost Area[d]	571.1	20	11,422	131,566
Screen Area[e]				2,500
Cure Area[f]	255.2	30	7,656	20,736
Compost Storage[g]	255.2	60	15,312	45,369
Total[h]				235,200

[a]Assumes a three-foot pile height.
[b]Assumes a 12-foot pile height = 23,960 ft^2, or 16 x 16; therefore, accounting for slope need, 173 x 173 = 29,929.
[c]Assumes a 20-foot x 30-foot area.
[d]Assumes 20 pile areas: 18 active and 2 extra. See Table 3-15, assumed Scarab 16.
[e]Assumes a 100-foot x 25-foot area.
[f]Assumes screening before curing. Assumes 10-foot height with no aeration = 20,671 ft^2, or 144 x 144 = 20,736 to account for slopes.
[g]Assumes 10-foot height in an open area on an impervious surface = 41,342 ft^2, or 203 x 203, or 45,369 ft^2 to account for slopes.
[h]During peak Months 2 through 4.

Table 3-15 – Compost Windrow Requirements (Screening Before Curing)

Turning Machine	*Windrow Capacity (yd^3/ft)*	*# of Windrows*	*Length of Each Windrow (ft)*	*Spacing Between Windrows (ft)*	*Turning Distance (ft)*	*Windrow Width (ft)*	*Required Pad Area (ft^2)*	*Machine Cost ($)*	*Processing Speed (ft/min)*	*Processing Time (hr/turning)*	*Processing Unit Cost ($/hr)*	*Cost per Turning ($)*
Scarab 10	1.01	20	560	2.5	21	10	153,510	175,000	25.0	7.5	44.42	331.67
Scarab 12	1.3	20	439	2.5	23	12	143,075	180,000	25.0	5.9	50.02	292.78
Scarab 14	1.78	20	321	3.5	30	14	136,017	193,000	25.0	4.3	52.82	226.07
Scarab 16	2.29	20	250	4.5	32	16	131,566	208,000	25.0	3.3	59.82	199.40
Scarab 18	2.85	20	200	3.5	33	18	116,242	227,000	25.0	2.7	63.50	169.33
Scarab 20	3.37	20	169	3.5	35	20	114,003	241,000	25.0	2.25	73.87	166.45
Scat 4832	2.96	20	192	3.5	35	20	124,974	255,000	20.0	3.2	44.42	142.14
Scat 4932	3.7	20	154	0	35	10	44,800	290,000	20.0	2.6	44.42	114.01

The Scarab 16 was chosen based on its versatility and capital costs. This piece of equipment can be transported to other sites and is not oversized for the job. Other equipment could be chosen, as shown in Table 3-15. The objective is to reduce site size requirements or operating costs. Figure 3-2 shows that at maximum capacity (Months 2 through 4), the site would require approximately 256,000 cubic feet to contain all activities and allow room for internal front-end loader movement.

Figure 3-2 – Sizing Calculations for Impervious Pad

Impervious Pad Sizing

Assume a 25-foot aisle space around the perimeter to allow for internal front-end loader movement:

Square root of 235,200 = 485 x 485 + 25-foot perimeter on all four sides

535 x 535 = 286,225 ft^2 paved required

This size is based on screening before curing and not aerating the cure pile. More room would be required if windrow curing were desired.

Table 3-16 shows the projected equipment requirements at the peak months.

Table 3-16 – Equipment Usage – Windrow

Mix Box Use Calculations				
Volume of Mix (yd^3)	***Volume of Mix Box (yd^3)***	***# of Mixes***	***Mix Time/Cycle (min)***	***Time (min)***
634.6	16	40	15	595[a]

Screen Sizing Calculations		
Volume to be Screened (yd^3)	***Hours of Screening/Peak Day***	***Volume/Hour Screen Size (yd^3/hour)***
485.4	10	50

Front-end Loader[b] Utilization Calculations					
Function	***Cubic Yards***	***Min/Cycle***	***Volume/Cycle***	***Cycles Required***	***Min Required***
Bulking Agent to Mix	384.6	3	8	48	144
Biosolids to Mix	250.0	2	8	31	62
Mix to Pile	634.6	2	8	80	160
Mix to Screen	485.4	4	8	6.1	243
Recycle to Store	231.0	3	8	29	87
Compost to Cure	255.2	3	8	32	96
Cure to Store	255.2	3	8	32	96
Store to Market	255.2	4	8	32	128
Subtotal	2,751.2			345	1,026
10% Contingency	275.1			34	102
Total	3,026.3			379	[c]1,128 (18.8 hours)

[a]One 18-yd^3 mix box can handle mixing in a 10-hour day.
[b]Assumes an 8-yd^3 bucket.
[c]Need two 8-yd^3 bucket loaders for a 10-hour workday.

Because less material is being moved (no base and cover) than with the static pile method, it is possible to operate with only two 8-cubic-yard bucket front-end loaders, even during the peak month. The windrow turner usage was shown in Table 3-15.

The only capital costs required for the windrow composting are shown in Table 3-17.

Table 3-17 – Capital Costs – Moving Equipment

Item	*Unit Cost*	*Units*	*Quantity*	*Estimated Cost*
Front-end Loaders	250,000.00	8 yd^3	2	500,000
Mix Box	115,000.00	18 yd^3	1	115,000
Screen	120,000.00	600 yd^3/hour	1	120,000
Scarab 16	208,000.00	ea	1	208,000
Total Moving Equipment[a]				943,000
Engineering[b]				47,150
Total				$990,150
Annual Amortized Costs[c]				$170,951
Total Costs/Wet Ton[d]				$8.38

[a]Assumes direct County purchase; no overhead and profit.
[b]5 percent of Total Moving Equipment.
[c]5 percent interest over seven years.
[d]Based on 1,200 wet tons per week x 17 weeks.

These include costs for two 8-cubic-yard bucket front-end loaders, a mix box, a screen, and a Scarab 16. It is assumed that the County would buy these directly, so no markup is assumed except for engineering at five percent. This equipment is amortized over seven years at five percent interest, even though the equipment will only be used four to five months per year on this project. The amortized costs amount to $8.38 per wet ton of biosolids composted.

The O&M costs are presented in Table 3-18.

Table 3-18 – O&M Costs

Item	*Unit Cost*	*Units*	*Daily Quantity*	*Annual Quantity*	*Annual Estimated Cost*
Labor	14.00	$/hour	40	4,800	67,200
Laboratory	3,000.00	$/year			3,000
Windrow Turner	59.82	$/hour	3.5	420	25,124
Front-end Loader O&M	29.59	$/hour	20	2,400	71,016
Screen O&M	17.61	$/hour	8	576	10,143
Batch Mixer O&M	15.00	$/hour	10	720	10,800
Bulking Agent[a]	6.20	$/$yd^3$		14,745	91,419
Administrative		lump			20,000
O&M Costs					298,702
O&M Costs/dry ton[b]					48.33
O&M Costs/wet ton					14.50
Potential revenue is $26,286 for each $1/$yd^3$ received in sales. Normally sells for $5/$yd^3$ to $10/$yd^3$ elsewhere.					

[a]Assumes ground brush is obtained at average area retail cost of $6.20 per cubic yard.
[b]Based on an average of 60 dry tons per day x 103 days.

These include costs for two front-end loader operators, one windrow machine operator/mechanic, and one laborer. Laboratory costs cover regulatory requirements, and equipment maintenance fees were provided by the manufacturers to cover warranty maintenance labor and parts. Administrative costs cover secretarial, billing, and some insurance costs. A cost of $6.20 per cubic yard is assumed for the bulking agent. This is the average retail price for mulch produced in the Knoxville area. It is possible that a lower cost could be negotiated or the compost produced could be bartered for the bulking agent. This would reduce the composting price by $4.44 per wet ton. Fuel is included in the hourly operating costs. No electricity is required for windrow composting. The total annual O&M costs are $48.33 per dry ton, or $19.14 per wet ton processed. The total cost per wet ton is $34.54, including annual capital costs. No revenue is assumed for compost sales. The O&M costs could be reduced by $1.30 per wet ton for each dollar per cubic yard obtained.

3.4 – SCENARIO 3 – LIQUID GREASE TRAP WASTES COMPOSTING

In this scenario, liquid grease trap wastes are brought by tanker trucks to a composting site, where they are pumped into a storage tank designed to hold two days of liquid (20,000 gallons). The liquid would then be mixed with a bulking agent, as was done with Pile 4 of the demonstration. The pile would be windrowed for 14 days, when the bulking agent would be remixed, and a new windrow would be formed. It is assumed that each windrow could be recycled a minimum of seven times. At the end of the useful life, the bulking agent, if it did not meet Class B pathogen criteria at a minimum, would be used in a biosolids compost operation.

The key assumptions used in this analysis are shown in Table 3-19.

Table 3-19 – Key Assumptions in Designing a Liquid Grease Trap Waste Compost Site

Item	*Units*	*Recommended Value*
Liquid Storage	days	2
Daily Volume of Liquid	gallons	10,000
Method of Mixing	method	Mix Box
Method of Composting	method	Windrow
Days of Composting	days	14
# of Cycles Bulking Agent Used	#	7
Solids Content of Liquid	%	3.5
Volatile Solids of Liquid	%	70
Bulking Agent Storage	days	14
Operational Days per Week	days/week	6
Hours of Operation/Day	hours/day	10
Odor Control	method	None

A materials balance is given in Table 3-20.

Table 3-20 – Materials Balance for Liquid Grease Trap Waste Compost Scenario[a]

Material	*Solids Content (%)*	*Volatile Solids (%)*	*Wet Tons*	*Dry Tons*	*Bulk Density (lbs/yd^3)*	*Cubic Yards*
Liquid Grease	3.5	70	41.7	1.5	1,674	49.8
Bulking Agent	60	60	59.3	35.6	640	185.4
Mix[b]	36.7		101.0	37.1	908	222.5
Recycle	60		59.3	35.6	640	185.4

[a]Based on Pile 4 of the demonstration study.
[b]Assumes 20 percent increase in volume over bulking agent.

Table 3-21 shows area requirements for each compost function, while Table 3-22 shows the annual bulking agent need of a little under 7,000 cubic yards.

Table 3-21 – Site Sizing Calculations

Activity	*Cubic Yards/Day*	*Number of Days*	*Cubic Yards*	*Area Required (ft^2)*
Liquid Storage[a]	50.0	2	100	314
Bulking Agent Storage[b]	185.4	14	2,600	7,921
Mix Area[c]				600
Compost Area[d]	222.5	14	3,115	48,544
Total				57,379

[a]Assumes a 20-foot diameter silo.
[b]Assumes a 12-foot pile height = 5,850 ft^2, or 77 x 77; therefore, accounting for slope need, 89 x 89 = 7,921.
[c]Assumes a 20-foot x 30-foot area.
[d]Assumes 14 piles areas: 12 active and 2 extra. Assumes a Scarab 16 = 2.29 yd^3/ft windrow capacity, 14 windrows, 100-foot windrows, 4.5 feet between windrows, 32-foot turn distance, and 16-foot-wide windrows.

Table 3-22 – Bulking Agent Requirements

# Cycles in Useful Life	*# Cycles/Year*	*Bulking Agent/Day (yd^3)*	*# Days/Cycle*	*yd^3/hour*
7	26	185.4	10	6,886

Figure 3-3 shows that a total area of slightly more than 70,000 square feet would be required based on the use of a Scarab 16 turner.

Figure 3-3 – Sizing Calculations

Impervious Pad Sizing

Assume a 25-foot aisle space around the perimeter:

Square root of 57,379 = 240 x 240 + 25-foot perimeter on all four sides

265 x 265 = 70,225 ft^2 paved required

The area could be reduced by the use of a front-end loader to turn the piles and by building the piles higher. The area could also be reduced of a SCAT turner or static pile composting were used.

As shown in Table 3-23, a single mix box could handle the daily volume in four hours. A single six-cubic-yard front-end loader would be required for seven hours per day on those days when recycle is moved offsite (every 14 weeks or so) and in five hours on a regular day. The Scarab 16 would only be required one hour per day, three days per week. The windrow turner would be available for other compost activities the vast majority of the time.

The only capital costs that would be required would be for moving equipment since it is assumed that a suitable paved area would be available. The costs for new equipment are shown in Table 3-24 and assume no County discounts.

The cost of moving equipment is estimated to be $527,000. These costs were amortized over seven years at five percent borrowing rate to give an annual amortized cost of $95,500, or a cost of $0.03 cents per gallon of grease trap wastes treated.

The O&M costs are shown in Table 3-25.

Table 3-23 – Equipment Usage

Mix Box Use Calculations				
Volume of Mix (yd^3)	***Volume of Mix Box (yd^3)***	***# of Mixes***	***Mix Time/Cycle (min)***	***Time (min)***
235.2	16	15	15	225[a]

Front-end Loader[b] Utilization Calculations					
Function	***Cubic Yards***	***Min/Cycle***	***Volume/Cycle***	***Cycles Required***	***Min Required***
Bulking Agent to Mix	185	3	6	31	93
Mix to Pile	223	2	6	38	76
Recycle to Store	185	3	6	31	93
Recycle to Market/Disposal	185	4	6	31	124
Subtotal	778			131	386
10% Contingency	78			13	39
Total	856			146	[c]425 (7.1 hours)

Windrow Turner[d] Utilization Calculations			
Length of Pile (ft)	***# of Piles***	***Process Speed (ft/min)***	***Process Time[e] (min/turn)***
100	14	25	56

[a]One 18-yd^3 mix box can handle mixing in a 10-hour day.
[b]Assumes a 6-yd^3 bucket.
[c]Need one 6-yd^3 bucket loader for a 10-hour workday.
[d]Assumes a Scarab 16.
[e]If all piles are turned every day, in reality, only need every third day or so.

Table 3-24 – Capital Costs – Moving Equipment

Item	***Unit Cost***	***Units***	***Quantity***	***Estimated Cost***
Front-end Loaders	185,000.00	6 yd^3	1	185,000
Mix Box	115,000.00	18 yd^3	1	115,000
Scarab 16	227,000.00	ea	1	227,000
Total Moving Equipment[a]				$527,000
Engineering (5%)				26,350
Total				$553,350
Annual Amortization[b]				$95,537
Annual Amortized Cost[c]		$/gallon		$0.0031

[a]Assumes direct City purchase; no overhead and profit.
[b]Amortized over seven years at five percent interest.
[c]Based on 10,000 gallons/day x 6 days/week x 52 weeks/year = 3,120,000 gallons/year.

Table 3-25 – O&M Costs

Item	***Unit Cost***	***Units***	***Daily Quantity***	***Annual Quantity***	***Annual Estimated Cost***
Labor	14.00	$/hour	12	31,201	436,814
Laboratory	3,000.00	$/year			3,000
Front-end Loader O&M	29.59	$/hour	8	2,496	73,857
Scarab O&M[a]	59.82	$/hour	1	156	9,332
Batch Mixer O&M	15.00	$/hour	4	1,248	18,720
Bulking Agent[b]	6.20	yd^3		6,886	42,693
Administrative		lump			15,000
O&M Costs					599,416
O&M Costs/gallon[c]					0.192

[a]Assumes three turns per week.
[b]Assumes ground brush is obtained at average retail price for the Knoxville area.
[c]Assumes 10,000 gallons/day x 312 days.

It is assumed that one person could run the site in an eight-hour day. An additional one-half time person was assigned for maintenance and assistance. No labor is assumed to oversee liquid waste offloading. Laboratory costs are assumed for periodic pathogen testing and also limited nutrient and heavy metal testing of bulking agent before sale or disposal after useful life is expended. Administrative costs cover coordination, secretarial, permitting, and some insurance. No revenue is assumed for sale of bulking agent that has lived its useful life nor is a cost for disposal assumed. The total annual O&M costs are estimated to be $599,416 per year with a cost per gallon of $0.195, inclusive of annual capital costs. No revenue for compost sales are assumed.

3.5 – SCENARIO 4 – BIOFILTER GREASE TRAP WASTE COMPOSTING

This scenario is based on the observation made during construction of Pile 9 of the pilot study. During formation of this pile, it was noted that more liquid grease trap wastes were added to the mix than could be absorbed by the bulking agent but that the liquid that was released appeared to be water only, with the grease being selectively absorbed to the bulking agent. This scenario would be accomplished as follows. When the liquid grease trap trucks arrived at the wastewater treatment plant, they would dump the wastes into specially designed watertight dumpsters that would spread the liquid uniformly over the surface of a biofilter. The liquid would pass through the biofilter, with the grease being absorbed to the media and the water passing through the base of the dumpster into a sewer line. When the absorption capacity of the biofilter becomes saturated, the dumpster would be removed, and a new biofilter/dumpster would be placed in its spot. The biofilter/dumpster would then be transported to a compost site, where the media would be placed in windrows and composted for up to 30 days. The finished compost could either be recycled as new media, or if it meets Class A pathogen criteria, it could be screened and sold. The biofilter media could be any of the following: ground pallets, ground yard waste, or finished compost. It would be expected that the absorptive capacity of the biofilter would be greatest with the compost and least with the wood chips. This scenario, if shown to be effective, would have the following advantages:

- Less traffic at the compost site
- No need for mixing
- No need for a sewer system at the compost site
- Less material to be handled and composted
- Potential to meet Class A pathogen criteria due to increased solids of grease trap wastes
- Lower odor potential since grease is absorbed to the bulking agent
- Lower demand for bulking agent
- Lower costs

This scenario has the following unknowns, which would need to be defined before a full-scale facility could be designed:

- Absorptive capacity of various biofilter media
- Ability to reach Class A pathogen kill criteria
- Strength of leachate returned to the wastewater treatment plant

- Design of dumpster/biofilters and costs thereof
- Odor potential at both the biofilter site and the compost site
- Required length of compost period

Once these unknowns are resolved, it would be possible to develop an economic analysis of this option.

SECTION 4 – IMPLEMENTATION

4.1 – INTRODUCTION

This section of the report describes the steps Knox County would need to undertake to develop a biosolids compost facility. These steps include the following:

- Develop letters of interest from area wastewater treatment facilities
- Determine a site for the compost facility
- Determine who would operate the facility and finalize costs
- Perform Scenario 4 demonstration
- Obtain permits
- Finalize agreements with utilities and operators

Each of these steps will be discussed in subsequent subsections.

4.2 – LETTERS OF INTEREST

This report gives a good first cut at what potential costs would be for construction and operation of a seasonal compost facility capable of handling 1,200 wet tons per week of dewatered biosolids. Using this information, it would be possible to go to all the area wastewater utilities and ask about their level of interest and willingness to commit a set amount of biosolids for a defined seasonal period for a not-to-exceed price for a given number of years. For example, Utility A would agree to participate in the compost facility if the cost for biosolids delivered to the compost facility gate was not more than $35 per wet ton. The utility would commit to deliver no less than 30 wet tons per day nor more than 50 wet tons per day, for an average daily load of 45 wet tons per day, Monday through Friday, from November 15 through March 15, for a period of three years.

4.3 – LOCATE SITE

Once a realistic estimate of potentially available biosolids is developed, it will be possible to determine site size requirements, and a single site can be chosen for the compost site. The two alternatives include Solway or Fork of the Rivers.

4.4 – FINALIZE CAPITAL AND OPERATIONAL ISSUES

Knox County would have to decide whether to utilize a private contractor or County forces to operate the facility. Inherent in these decisions is level of control the County wishes to exert. Unlike the mulch operation, which has relatively few regulatory constraints, composting of biosolids is highly regulated and has a high potential for neighborhood concerns if not operated correctly. Because of these constraints, the County would have to develop a tight contract that apportions risk and has appropriate County control. The County would also need to determine if it wanted to use its purchasing power to obtain moving equipment, which would be assigned to the site and utilized only on the composting or approved projects, or let the contractor, if contractor-operated, purchase and utilize its own equipment. The County would need to determine who would be responsible for composting analysis and marketing and what, if any, penalties would occur if contract provisions are not met. Once these decisions are met, it would be possible to determine actual operations costs and, thus, determine actual operations costs and, thus, determine if prices contained in the letters of intent (see Section 4.2) could be met.

4.5 – SCENARIO 4 DEMONSTRATION

A key potential issue that could impact site sizing and costs is composting of grease trap wastes and Scenario 4, as described in Section 3. A number of issues need to be resolved before the viability of this option can be determined. Knox County and KUB should modify a dumpster and test alternative biofilter media to determine amounts of liquid that could pass through the media before breakthrough occurs. The biofilter/grease trap waste mix should be analyzed for solids content, bulk density, pH, and volatile solids and composted if at all possible. Depending on amount of odor, either windrow and/or static pile composting should be utilized. Once this demonstration is completed, it will be possible to determine costs of this option and integrate it into site needs (see Section 4.3).

4.6 – PERMITS

Once the tasks in Sections 4.2 through 4.5 have been accomplished, it will be possible to go to the State of Tennessee to present findings of the pilot study and discuss site issues and permit requirements. It is anticipated that the major site issues will be site runoff and monitoring/analysis/recordkeeping. Knox County would also need to discuss permit requirements with the regional USEPA office since the State of Tennessee has decided not to take primacy under 40 CFR Part 503 regulations. The USEPA permit will have operational and reporting requirements but not site requirements.

4.7 – CONTRACTS

Once the above are accomplished, Knox County would have to finalize agreements with the utilities and the site operator.