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through the **Biofuels Center of North Carolina**

Feasibility Study
Evaluating the profitability of a trap effluent dewatering facility in the Raleigh area

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I. Overview and Introduction

Definitions:
Trap effluent – the material which collects in grease traps, often called trap grease. This consists of mostly water (~90%), some particulates (~5%) and some grease (~5%).
Brown grease – this is the recoverable, purified grease from the trap effluent. It is usually solid at room temperature and contains 50% free fatty acids or greater. It is also high in metals (2000 – 4000ppm), has high peroxide value (30+ meq/kg), and contains various other impurities.
Peroxide Value – Peroxide value is a measure of the amount of peroxides in oil. High peroxides implies that the oil is rancid.
Free Fatty Acid (FFA) – These also represent the level of degradation of a fat or oil. As fats and oils break down, they form free fatty acids. High FFA oils can be difficult for many biodiesel producers to process due to added esterification pretreatment steps, and will make the oil more difficult to run in a boiler application without modification.

The purpose of this study is to evaluate the profitability of building a trap effluent dewatering facility in Raleigh, NC. The plant would produce a usable brown grease product, which would be used on-site or sold. The waste water would then be discharged into the city sewer system.

The impetus for writing this study comes from several factors which have arisen within the last 10 years. First, waste water treatment plants (WWTPs) are tightening regulations on grease trap cleanings, resulting in an increased supply of trap effluent. Furthermore, increased regulation on land application of trap effluent is causing some haulers to have nowhere to discharge. The price of fats and oils has skyrocketed, including waste fats and oils, and technology has being developed in the boiler and biodiesel industry to use even the very low quality greases. While the concept of removing usable grease from trap effluent is not new, only recently have effective off-the-shelf commercialized products become available. As a result of these factors, now is an appropriate time to investigate the possibility of the removal of brown grease from trap effluent. The Raleigh area may be primed for this technology: the local WWTP does not accept trap waste, many of the disposal locations are far away, it has experienced sewer clogs due to illegal dumping, and it currently has no private sector solutions to these problems.

II. Supply and Cost.

1. Determine the quantity of trap effluent.

Estimating the quantity of trap effluent produced in and around Wake county is actually somewhat difficult. There are many different sources of information: interviews from haulers, disposal companies, and regulators; state collected data on disposal quantities from permitted compost and land application sites; and estimates based on previous country wide studies (the Urban Waste Grease Resource Assessment done in 1998). The information from each of these sources is detailed below to attempt to narrow the range on the quantity of grease around Wake County, where it goes, and what the disposal/recycling costs are for it.

- NREL study estimates (Urban Waste Grease Resource Assessment)

The Urban Waste Grease Resource Assessment performed in 1998 by NREL attempted to quantify the amount of brown grease in a variety of cities across the United States. The result of that survey showed an average of 13.7lb/person/year of usable brown grease (which they call trap grease). Only about 1/5th of this number is calculated from the quantity of trap effluent hauled and disposed from actual grease traps. The other 4/5th is calculated based on the amount of FOG (fats, oils, and greases) in the influent of the waste water treatment plants. In my estimation, this influent FOG is a non-recoverable portion of our grease resources, because it is nearly impossible to separate from the waste water influent and would require an immense amount of energy. As a result, the data from the UWGRA was reevaluated to remove the FOG portion. The method for reformulating the data are detailed in Appendix A.

Based on this reformulation, the UWGRA data shows an average of 3.79 gallons of trap effluent per person per year across the areas surveyed. However, because of the limited information and imperfect extraction of the appropriate trap effluent data from this data set, this estimate could include a significant amount of error. In addition, changes which have occurred over the last 10 years may make these results out-dated.

- City of Raleigh estimates of trap effluent hauled in the Wake County area.

Tim Beasley, Donald Smith, David Hardin, and Juan Gutierrez are the Pretreatment Coordinators for the City of Raleigh, Cary/Morrissville, Apex, and Fuquay-Varina respectively. They provided first hand estimates of the quantity of trap effluent produced in and around Wake County. They estimated 1800 trap locations in Raleigh, 780 in Cary, 125 in Apex, and 100 in Fuquay (based on registered trap effluent locations from each respective town authority). This is a total of 2805 trap locations in Raleigh and its primary suburbs. Grease traps sizes average 1000 gallons but only produce roughly 480 gallons of trap effluent per month (based on discussions with Tim Beasley, Donald Smith, and David Hardin). This yields 18.65 gallons of trap effluent per person per year and a total of 16.15 million gallons of raw trap effluent per year in Raleigh and its surrounding suburbs (see Table 1). When asked about the market-share of companies operating in the Wake County area, Tim said that the trap effluent hauling market was roughly controlled as follows: 40% Carolina byproducts, 25% East Coast Resources (land application), 25% Beasley Environmental (composting), and 10% other (composting and/or land application).

Assuming a similar ratio of trap effluent produced to population, Table 2 shows the amount of expected trap effluent in the surrounding counties.

County	Population	Average gal/mo trap effluent per trap location	Trap Locations	Trap effluent/mo	Trap effluent/yr	Trap effluent gal/person/yr
	A	*B*	*C*	*B x C*	*B x C x 12*	*(B x C x12)/A*
Wake County	866,410.00	480	2805	1346400	16156800	**18.65**
* Population data was taken from Wikipedia, Wake County, current to 2007. Trap grease collected per location and number of locations data came from Tim Beasley						

Table 1: Wake County trap effluent Estimation

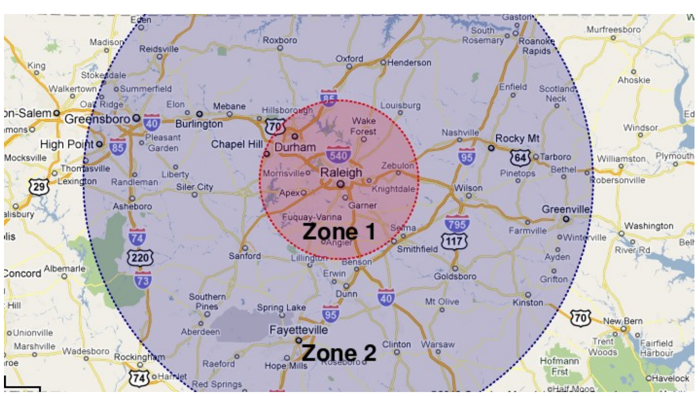


Illustration 1: Map of Wake County area

Overview of trap effluent in Wake and surrounding counties				
Average trap / person / year (gal)*	18.65			
% usable brown grease in trap effluent	2.00%			
County	Population**	Expected trap effluent gpy	Expected brown grease gpy***	% total
Zone 1 (~25mi)				
Wake	866,410	16,158,547	323,171	46.05%
Chatham	63,077	1,176,386	23,528	3.35%
Durham	262,715	4,899,635	97,993	13.96%
Orange	126,532	2,359,822	47,196	6.73%
Granville	57,044	1,063,871	21,277	3.03%
Franklin	58,927	1,098,989	21,980	3.13%
Nash	93,674	1,747,020	34,940	4.98%
Wilson	77,527	1,445,879	28,918	4.12%
Johnston	163,428	3,047,932	60,959	8.69%
Harnett	112,030	2,089,360	41,787	5.95%
Subtotal, Zone 1	**1,881,364**	**35,087,439**	**701,749**	**50.40%**
Zone 2 (~75mi)				
Lee	59,091	1,102,047	22,041	3.19%
Moore	85,608	1,596,589	31,932	4.62%
Randolph	141,186	2,633,119	52,662	7.63%
Guilford	472,216	8,806,828	176,137	25.50%
Caswell	23,248	433,575	8,672	1.26%
Person	37,438	698,219	13,964	2.02%
Vance	42,891	799,917	15,998	2.32%
Warren	19,388	361,586	7,232	1.05%
Halifax	54,983	1,025,433	20,509	2.97%
Edgecombe	52,682	982,519	19,650	2.85%
Pitt	156,081	2,910,911	58,218	8.43%
Greene	20,677	385,626	7,713	1.12%
Lenoir	56,826	1,059,805	21,196	3.07%
Wayne	113,671	2,119,964	42,399	6.14%
Duplin	53,362	995,201	19,904	2.88%
Sampson	63,927	1,192,239	23,845	3.45%
Cumberland	312,696	5,831,780	116,636	16.89%
Moore	85,608	1,596,589	31,932	4.62%
Subtotal, Zone 2	**1,851,579**	**34,531,948**	**690,639**	**49.60%**
TOTAL	**3,732,943**	**69,619,387**	**1,392,388**	

Table 2: Overview of trap effluent in Wake and Surrounding Counties

* based calculations of trap grease in Wake County
** population data from US Census Bureau website
*** Usable grease calculation is based information from trap grease dewatering companies – Discussed in later sections.

• Estimates based on the quantity of trap grease discharged at disposal sites located in and around Wake County (land application, compost, dewatering).

The methods of trap effluent recycling and disposal in North Carolina are direct land application, composting, and a combination of dewatering and composting/landfilling the solids. In the Wake county area, direct land application using sub-surface injection is fairly common, along with composting at the two major composting operations, McGill Environmental and Brooks Composting. In addition, Carolina Byproducts services a large portion of the market and has facilities located in Greensboro and Fayetteville. It remains unclear where exactly Carolina Byproducts discharges their trap effluent water, as they do not discharge significant quantities of water to the Greensboro or Fayetteville waste water treatment plants.

Liz Patterson of the Composting and Land Application Branch of the NC Department of National Resources (NCDENR) provided state collected lists of haulers, land application sites, and composting operations. From this list, we can get an estimate of the amount of trap effluent pumped to Land Application sites and Composting operations (see Table 3). The data provided was in gallons per year for the Land Application sites and tons per year for the composting sites.

Disposal / Recycling type	Firm Name	County	Acres	Trap Effluent Pumped 2008	% of Total
Land Application	East Coast Resources	Chatham	91	2,100,000	10.74%
Land Application	Boswell & Son Septic Tank Service	Edgecombe	7	25,600	0.13%
Land Application	B & D Septic Tank	Franklin	16.1	50,000	0.26%
Land Application	David Brantley & Sons	Franklin	5.57	3,050	0.02%
Land Application	David Brantley & Sons	Franklin	7.1	3,050	0.02%
Land Application	Gerald Temple Septic Tank Service	Harnett	6.7	27,000	0.14%
Land Application	Marlin's Waste Management	Moore	17	47,600	0.24%
Land Application	Cheek Plumbing and Backhoe	Randolph	6.91	5,000	0.03%
Land Application	Eastside Septic Cleaning Service	Wake	33.95	175,000	0.89%
Land Application	Eastside Septic Cleaning Service	Wake	6.84	175,000	0.89%
Land Application	Stallings Septic Service	Wake	5	46,830	0.24%
Land Application	Mitchells Septic Tank Cleaning Service	Wilson	14	225,000	1.15%
Land Application	Creech's Septic Tank Cleaning Serv.	Wilson	28.5	128,000	0.65%
Subtotal, Land Application				***3,011,130***	***18.93%***
			Tons of trap/yr	Gal of trap/yr	
Compost	Dean Brooks	Chatham	14456.48	3,975,532	20.33%
Compost	McGill	Wake	9295.36	2,556,224	13.07%
Subtotal, Compost				***6,531,756***	***41.07%***
Carolina Byproducts disposal (assume 40% of total market)				***6,361,924***	***40.00%***
Total, all trap grease disposal				**15,904,810**	

Table 3: trap effluent disposal/recycling, Wake County Area

Because the numbers provided by the NC State DENR did not include the trap effluent hauled by Carolina Byproducts, they were not an adequate estimate the total amount of trap effluent hauled in the Wake County area. However, assuming Tim Beasley's estimate that 40% of the Wake County market is controlled by Carolina Byproducts (this number was considered a reasonable estimate by other haulers as well), we can estimate that the total trap effluent disposed in the Wake County area is 15,904,810 gallons. It is known that some haulers have dewatering boxes and dispose of the concentrated grease portion alone at a composting operation. In addition, some haulers go as far as Winston-Salem and elsewhere to discharge, which is not included in the above tally. This would suggest that the actual amount of trap effluent is higher than the 15,904,810 estimate above.

• In conclusion

Based on the various sources of data on trap effluent in the Wake County area, there is between 15,000,000 – 35,000,000 gallons of trap effluent hauled in Zone 1. In Wake County specifically there are about 15,000,000 gallons hauled. We will use the low-end estimate for Zone 1 of 15,904,810 for the remainder of the study. Zone 2 has roughly the same population, however, there is not a detailed analysis of the disposal and recycling locations in those areas. As a result, we will assume that there are another 15,000,000 gallons in Zone 2 for the remainder of the study, as it has roughly the same population as Zone 1. In total there are an estimated 30,000,000 million gallons in both Zones 1 and 2.

2. Determine the quantity of usable brown grease in trap effluent.

• Interviews with experienced plant operators and experts: Bob Armantrout of Pacific Biodiesel, Frank Burt of BWI, William Windsor of ABF, and Dr. K. Shaine Tyson formerly of NREL.

The 1998 UWGRA used 10% as their estimate for the amount of usable brown grease in trap effluent. In discussions with Dr. K. Shaine Tyson, who oversaw this and other studies on the use of trap effluent for biodiesel, she suggested the percent usable brown grease in trap effluent ranged from <1% to 7%. She referenced three currently operation dewaterers which see 2 – 3%, 2.2%, and 2% respectively. Her experience is that cold weather reduces the percent brown grease in trap effluent, as do recessions.

Bob Armantrout worked for Pacific Biodiesel in Maui, Hawaii in 2002 – 2003 and worked directly with the trap effluent dewatering part of their business. They calculated yield based on a mass flow meter for the incoming trap effluent, and volumetric sales numbers for the resulting brown grease. In Bob's experience over several years, the trap effluent was roughly 5 – 8% usable brown grease.

Frank Burt of Burt's Waste Incorporated (BWI) operates a 60,000 gallon per day trap effluent dewatering facility in Louisiana, and sells his proprietary grease dewatering system. He has sold 11 units in total. Frank claims that trap effluent yields 2% brown grease from traps which have been fully pumped, a number which he has seen at his own plant and at plants he has sold. Traps which are only "skimmed", or partially pumped, yield 6 – 8% grease. Because regulations have become more stringent in most areas for complete pumping of trap effluent, Frank claims 2% is the only realistic number for future dewatering facilities. Customers which use his system provided similar data.

It is possible that increased regulation, enforcement, and other factors have caused the amount of usable brown grease in trap effluent to decrease significantly over the last 10 years. Based on the information provided, 2% brown grease in trap effluent will be used for the remainder of this study.

1. Evaluate the cost of disposal.

• Understanding the disposal market: compost, land application, dewatering.

The trap effluent disposal and recycling market is widely varied across the country. Many locales have a single drop-off point which is defined by the State or County which all trap haulers must use. This may be a land application site (using direct injection into the soil), a dewatering site, a city sewer which is close to the WWTP, or the WWTP itself may put the grease through an anaerobic digester. North Carolina has many locations for trap effluent disposal and recycling. Table 3 outlines those available in and around Wake County.

The single largest disposal source is in Carolina Byproducts (CBP). CBP was unable to be contacted, but other sources suggested that CBP mixes the product in with their restaurant grease to create a typical 15% FFA yellow grease product for sale or dewaters and composts their trap waste, however, these sources were unable to be verified. The WWTPs in Greensboro and Fayetteville said that CBP is not a significant industrial user meaning it discharges less than 5% of the WWTPs influent COD/BOD and discharges less than 25,000 gallons per day. A direct discharge permit (NPDES) was unable to be found at either location for industrial waste water, though they do have one for stormwater runoff. In the end, CBP's method of trap grease disposal was unable to be determined during the course of this study.

The second largest disposal source in the Wake County area is compost sites. McGill and Brooks both take significant quantities of trap effluent, which is mixed with other solid compostable waste (like wood chips) and creates a saleable compost product which is sold primarily into landscaping.

Land application makes up the final method of disposal. Land application sites are permitted by the the state of North Carolina. The permit itself costs $200 - $500 per year, however, there are significant costs involved in the permitting process, including process design and engineering documents, crop rotation and land maintenance plans, etc. Land application is probably the lowest cost method of disposal once the fixed costs associated with the initial permits are overcome. However, there are a very limited number of sites, as permits are limited and becoming more strict on the type and quantity of material which can be injected into soils. In addition, trap effluent must be mixed in with septic waste before being injected, therefore application is further limited. Finally, those with permits generally do not open up their operations to others, even for a fee, because of the liabilities associated with potential mistakes – for example, if someone accidentally dumped something other than trap effluent, it is ultimately the permit holder who is liable.

- Estimate hauling costs, tipping fees, and other costs.

Hauling costs were estimated by selecting random points from the Raleigh area and calculating time and mileage to each of the aforementioned disposal locations (see table 4 and 5). See Appendix B for details on distance calculation. The estimated values for truck and labor costs are based on internal experience of running commercial trucking fleets.

The disposal costs in table 4 for land application are based on discussions with the owner of East Coast Recycling, who is the largest land applier in the area. Though he could not state an actual per gallon cost for land application, he did state that he would switch discharge locations given a $.05 tipping fee. Therefore, it is assumed that land application locations are paying slightly more than that currently.

The tipping fee for the composting operations are based on discussions with haulers, the composters themselves, and Tim Beasley. While the actual price for discharge depends on each hauler (there is not a single set price), the range is $.10 - $.15/gal. Therefore, the average of $.125/gal was used.

The disposal cost for CBP was much more difficult to obtain. CBP was unable to be contacted, and as a result discussions with others and estimates were used. According to Tim Beasley, they

		A	B	B x W	A x T	D x L					
Disposal / Recycling type	Firm Name	Miles to/from Raleigh (road)	Time (min) to/from disposal loc.	Labor per load	Truck cost. per load	Tipping/disposal cost per load	Total cost per load	Truck and labor, % of total cost	Tipping/Disposal, % of total cost	Trap Effluent Pumped 2008	% of Total
Land Application	East Coast Resources	40.0	48.6	$8.11	$13.99	$150.00	$172.09	12.84%	87.16%	2,100,000	13.20%
Land Application	Boswell & Son Septic Tank Service	120.9	147.1	$24.52	$42.30	$150.00	$216.82	30.82%	69.18%	25,600	0.16%
Land Application	B & D Septic Tank	50.2	61.1	$10.19	$17.57	$150.00	$177.76	15.61%	84.39%	50,000	0.31%
Land Application	David Brantley & Sons	56.8	69.2	$11.53	$19.89	$150.00	$181.42	17.32%	82.68%	3,050	0.02%
Land Application	David Brantley & Sons	59.2	72.1	$12.02	$20.73	$150.00	$182.75	17.92%	82.08%	3,050	0.02%
Land Application	Gerald Temple Septic Tank Service	74.9	91.2	$15.20	$26.21	$150.00	$191.41	21.63%	78.37%	27,000	0.17%
Land Application	Marlin's Waste Management	136.8	166.5	$27.75	$47.87	$150.00	$225.62	33.52%	66.48%	47,600	0.30%
Land Application	Cheek Plumbing and Backhoe	111.3	135.5	$22.59	$38.96	$150.00	$211.55	29.09%	70.91%	5,000	0.03%
Land Application	Eastside Septic Cleaning Service	25.1	30.5	$5.09	$8.78	$150.00	$163.87	8.46%	91.54%	175,000	1.10%
Land Application	Eastside Septic Cleaning Service	25.3	30.8	$5.13	$8.84	$150.00	$163.97	8.52%	91.48%	175,000	1.10%
Land Application	Stallings Septic Service	29.6	36.1	$6.02	$10.38	$150.00	$166.39	9.85%	90.15%	46,830	0.29%
Land Application	Mitchells Septic Tank Cleaning Service	113.1	137.6	$22.94	$39.57	$150.00	$212.51	29.42%	70.58%	225,000	1.41%
Land Application	Creech's Septic Tank Cleaning Serv.	83.3	101.4	$16.90	$29.15	$150.00	$196.06	23.49%	76.51%	128,000	0.80%
Subtotal, Land Application										***3,011,130***	***18.93%***
										Gal of trap/yr	
Compost	Dean Brooks	93.7	114.1	$19.01	$32.79	$312.50	$364.30	14.22%	85.78%	3,975,532	25.00%
Compost	McGill	45.2	55.0	$9.17	$15.81	$312.50	$337.48	7.40%	92.60%	2,556,224	16.07%
Subtotal, Compost										***6,531,756***	***41.07%***
Carolina Byprodu	Carolina Byproducts	118.6	144.4	$24.07	$41.52	$135.00	$200.59	32.70%	67.30%	***6361924***	***40.00%***

Grant Total, quantity of trap grease disposed in and around Wake County **15904810**

Table 4: Calculation of hauling costs by disposal location

discharge roughly 0.5 million gallons per year to McGill, but this may be concentrated grease material with the water already removed, or it may be trap effluent. After extensive searching, it remains unclear exactly how CBP deals with their trap grease. However, discussions suggest that CBP would be willing to discharge at a tipping fee of $.08/gal. If their transport costs are $.026/gal, then their disposal costs alone are at the highest $.054/gal. Assuming there is a profit incorporated into the $.054/gal, their actual disposal costs are probably lower.

Assumptions for Calculations			
	Category / Cost	Value	Units
W	Labor (includes workers comp., etc.):	$10.00	$/hr
T	Truck cost per mile (fuel, maint., depr.)	$0.35	$/mi
L	Ave. truck capacity (load)	2500	gal
D	Disposal costs, Land Application	$0.060	$/gal
D	Tipping costs, Compost	$0.125	$/gal
D	Disposal costs, CBP	$0.054	$/gal

Table 4 shows that that combined labor and truck costs range from a low of $14 to a high of $65 for a 2500 gallon load ($.0056 - $.026/gallon), while tipping/disposal costs run from $135 - $312 per 2500 gallon load ($.054 - $.125/gallon). However, because of the limited number of land application sites, the low cost disposal locations are highly limited and cover only 18.9% of the total trap effluent. The remaining quantity is split evenly between CBP and the composters, who generally have higher disposal or transport costs.

- Create a demand curve estimate based on the data.

The feasibility of a new trap effluent dewatering facility is based primarily on the quantity of trap effluent which is hauled to it. This quantity is based on competing prices for other existing disposal locations. As described in table 4, competing fees/costs for discharge range from $.054 - $.125/gallon, with hauling charges ranging from $.0056 - $.026/gallon. As the tipping fee at the proposed facility decreases, it will out-compete the fees/costs associated with existing operations.

Based on the data above, approximately 25 miles of driving results in an added penny per gallon cost to disposal. The roughly 15,000,000 gallons which are produced in Zone 1 are relatively easy to evaluate. Demand Curve 1 below shows the points at which existing haulers would switch to hauling to the proposed site. This curve incorporates the hauling cost to the existing facilities. For example, though McGill and Brooks both have the same tipping fee, haulers will switch from Brooks at $.145/gal because of the savings on transportation to the Brooks facility, but will switch from McGill at $.135/gal because it is closer to Raleigh.

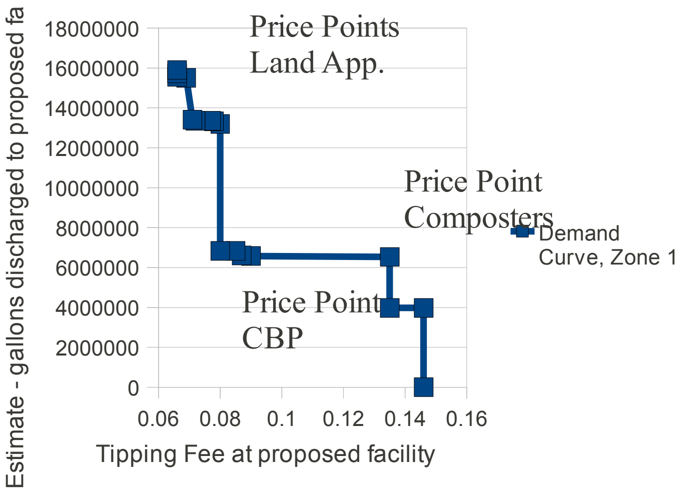


Illustration 2: Demand Curve 1

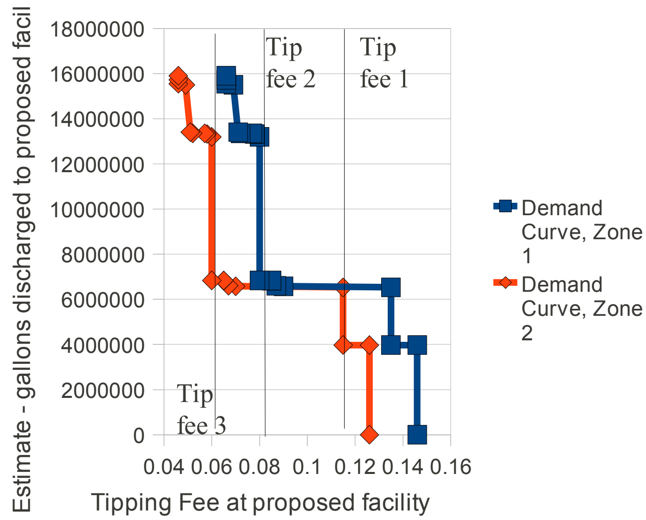


Illustration 3: Demand Curve 2

For Zone 2, the evaluation was outside of the scope of this study, because of the added complication of varying transportation costs and evaluation of other disposal locations outside of the Triangle. However, we would expect that haulers generally would be willing to pay their existing tipping fee minus $.02/gal, assuming their existing tipping location is within 25 miles of their pickup locations. For example, someone in Greensboro who is currently paying a tipping fee of $.12/gal plus $.01 for transportation (meaning they drive 25 miles to their disposal location) would be willing to pay $.10 tipping fee plus $.03 for transportation at the proposed Raleigh location (assuming they drive 75 miles to the proposed Raleigh location).

Assuming this about Zone 2, we can make a second demand curve (Demand Curve 2), which is shifted by $.02 to the left. From this, three potential tipping fees are chosen. Tipping fee 1 has a total collection of 6,500,000 from Zone 1 and 6,500,000 from Zone 2, for a total of 13,000,000 at a tipping fee of $.115/gal. Tipping fee 2 has a total collection of 13,196,000 from Zone 1 and 6,500,000 from Zone 2, for a total of 19,696,000 at a tipping fee of $.08/gal. Tipping fee 3 has a total collection of 15,900,000 from Zone 1 and 13,196,000 from Zone 2, for a total collection of 29,096,000 gal at a tipping fee of $.06/gal. These tipping fees will be further evaluated in the Profitability Analysis section.

- Estimate water discharge fees.

Based on existing fees from the Raleigh WWTP and discussions with Tim Woody, the Reuse Superintendent for the City of Raleigh, the fee for waste water is as follows:

Raleigh Discharge limits and fees			
Measure	limit (in ppm)	cost per lb over limit	
BOD (biological oxygen demand)	300	0.65	$/lb
TSS (total suspended solids)	250	0.17	$/lb
TN (total nitrogen)	10	0.72	$/lb
P (phosphorous)	5	1	$/lb
FOG (fats, oils, and greases)	300		

Table 5: Raleigh Discharge limits and fees

Discharge of more than 25,000 gallons per day means that the facility will be considered a "Significant Industrial User" which is a $200 / year permit and requires some paperwork. In addition, the plant would have to receive a pretreatment permit. The city of Raleigh officials both indicated interest in working with a trap grease dewatering facility, as it would help reduce their sewer overflows by reducing FOG in the sewer system. Tim Woody stated that 2008 yearly report, 50% of overflows were due to grease blockages. He has also seen haulers who may not have the ability to discharge elsewhere dump directly into the sewer system.

The specific costs associated with disposal are dependent on the level of pretreatment and are covered in the Profitability Analysis section.

2. Competition

- City of Raleigh's trap effluent dewatering proposal.

Currently, the city of Raleigh WWTP is planning to install a site for trap grease haulers to discharge their trap effluent. They have recognized the need for this for some time, as trap haulers complain that there is simply not enough capacity to discharge in the Raleigh area. This has resulted in illicit discharges and sewer clogs, which cost the city significant amounts of money. The private market has not yet solved the problem, as it has in other cities like Winston-Salem which has a company which accepts trap effluent and cleans up the water using a flocculant. As a result, the city of Raleigh is planning to build its own trap effluent treatment on-site. Tim Woody, the Pretreatment Superintendent for the city of Raleigh's WWTP, stated that the city would actually prefer the private sector to provide this service. The city's long term plan (10+ years) is to install an anaerobic digester, which could handle the grease. However, they need a near term solution to the problems caused by grease, and are therefore moving forward. Furthermore, an anaerobic digester does not negate the value of a trap grease dewatering facility, but it does provide an alternative, lower cost disposal location.

The company which is providing the planning and engineering services for the project is Hazen and Sawyer LLC. Dan Peplinski was the main point of contact for the information gathered about this project. Hazen and Sawyer will be finishing a technical memorandum, which will outline several options for FOG removal from trap waste and ultimately FOG removal from their collection system. They are investigating the use of the recovered brown grease for landfill and methane gas, biodiesel production, and anaerobic digestion. If the city moves forward with a plan defined in the technical memorandum (late summer 2010 would be the earliest that contracts would go out, with the work finished by the end of the year). The facility will be 11,000 gpd (2.86 million gpy) to start and will be located at the Neuse WWTP on Battlebridge road (about 8 miles south east of the center of Raleigh). The municipality is not allowed to make a profit, and therefore will set a very low tipping fee, approximately enough to cover their costs. Dan suggested the tipping fee would be around $.05/gal. This will undoubtedly result in a huge amount of haulers wanting to tip, and only very few being able to actually do so.

• Stanley Environmental's trap effluent dewatering facility.

Jim Lanier is planning to build a trap grease dewatering facility in Stanley NC, according to an interview with him in the February edition of Pumper Magazine. He already has a fleet of trucks and provides trap effluent hauling services and land applies the waste. He has a dewatering box located in Durham, NC where he is discharging directly to the city after removing the concentrated grease. Frank Burt of BWI showed Jim his facility 2 years ago and Jim stated at the time that he was interested in building a facility to recover usable brown grease from his trap effluent. Though Stanley's primary location is near Charlotte, it is clear that he is interested in expanding and could provide more competition in the future in the Raleigh area.

III. Production and use of brown grease

3. Evaluate the current brown grease market

• Potential users and uses in and around Wake County

Currently, the largest users of brown grease are the dewatering plants themselves who burn it in their boilers. Boiler applications require the least amount of pretreatment and are most forgiving in terms of high soap, MIU (Moisture, Insolubles, and Unsaponifiables), and other contaminants. Kline Services runs a modified 150hp steam boiler for process heat, which they say is over-sized but effective. They also run brown grease to heat their buildings. In 2009, there was a $.50/gal credit for burning biomass for heat which added to the profitability of using this material as boiler fuel. In 2010, this credit was delayed, but eventually reinstatedby by March. The credit is only in effect for 1 year, and should be considered to be temporary.

The boiler modifications required to convert a typical diesel or multi-fuel boiler are very similar to those performed at Piedmont Biofuels in order to run acid fatty acid esters. The fuel holding tank and lines to the boiler should be heated and the fuel should be recirculated to keep material from settling. Any copper and brass in contact with the fuel should be replaced, as both will degrade in the presence of vegetable oil. Furthermore, the fuel pump wetted parts should be checked for compatibility with both vegetable oil and acidic environments. The spray nozzle may need to be changed, as ash can build up around the nozzle. The oil should be preheated to at least 170F before passing through the spray nozzle. These modifications are best done by a company with experience in the field.

In the Wake County area there are many large boiler facilities who, given a consistent supply of low-cost alternative fuel, could modify their boiler systems to run the material (this may also require re-permitting for large boiler systems which have air permits). Triangle Brick in Apex runs thousands of gallons of diesel fuel per month through boilers. Luckstone, the rock quarry near Sanford, also runs thousands of gallons of diesel fuel per month through boilers. Smaller operations, like Piedmont Biofuels, run 1000 gallons per month through an already up-fitted system. Finally, if local buyers are unable to absorb the quantity of grease available, there are oil traders who consolidate oil from smaller producers and sell them to larger buyers. Based on the current cost of off-road diesel fuel to that of brown grease, selling brown grease is fairly easy.

The primary problem with brown grease for use with biodiesel is its high sulfur content, though this is certainly not the only hurdle to overcome. If a brown grease could be produced with low sulfur content, its use in the biodiesel industry could be expanded. The resulting demand could increase the price of brown grease towards that of yellow grease, which is currently $.25/lb. However, it will probably always remain cheaper than yellow grease due to its more limited use in feed and high FFA.

4. Evaluation of brown grease separation technologies

• BWI process

The process developed by Frank Burt of Burt's Waste Incorporated was developed over the course of the last 11 years. Frank Burt is a trap grease hauler and developed the system for his own use. Only in the last few years did he decided to sell his system to others. Some description of the system is available on his website (http://bwiequipment.com/Home_Page.html). Basically, it has an initial screening of "trash" (larger particulates) which occurs as the truck is pumping off the material. At the same time, it is being heated through a heat exchanger which is running a steam line from the boiler, which itself runs off of brown grease. The material is then sent into a heated settling tank where the brown grease is pulled off the top and the remaining waste water is decanted off the bottom. The system does not use a centrifuge. It also does not treat the waste water – it is a filtration/gravity separation system.

Two existing users of the system, Eddie from Ft. Lauderdale FL and Shawn from Kline Services in PA were reached by phone. Both were very pleased both with the system and with Frank Burt's technical support during construction. Shawn runs 25,000 – 50,000 gallons per day of trap effluent at Kline Services. Over the past year, they have run their boiler system in multiple buildings off of the resulting brown grease. Because they also run their own waste water treatment plant, they have collected good data on the process. Shawn claims that the trap effluent contains about 2% usable brown grease, and that the resulting waste water has between 5000 – 7000 ppm BOD (Biological Oxygen Demand).

Eddie from Ft. Lauderdale has less information, but only had good things to say about the system. He has sold brown grease at $.10/lb to buyers who then sell it for boiler fuel applications. He is located in the middle of the city and has worked with the Ft. Lauderdale WWTP to be able to discharge the resulting water directly into the sewer at $.005/gal. Using concentrated grease trap waste (some from traps which were skimmed, not fully cleaned, and therefore more oil dense), the resulting fractions were 12% brown grease, 79% water, and 5.7% concentrated particulates. The particulates he tips at the local WWTP, and which adds an additional $.005/gal to the processing costs (which is consistent with a tipping cost of $.10/gal for the concentrated material). He claims that the city is happy to work with him because his business will reduce the amount of FOG influent into the WWTP by driving costs for haulers down and reducing illegal discharges into the ocean and sewer locations. Finally, he will also begin accepting trap effluent from other haulers, and says he can easily make money and be competitive at $.10/gal tipping fee.

- Affordable Bio Feedstock (ABF) process

John Haslow, an ABF partner, was contacted for information. Affordable Bio Feedstock uses the BWI separation unit on their front-end, which pre-heats as the material comes off the truck and separates most of the solids. Then, they heated settle the water from the brown grease and separate the two streams. Finally, lime is used as a filtration agent in conjunction with other treatments to reduce the BOD of the discharge water. These solids are being investigated for use in their boilers, and he believes they may also be used as animal feed (though it would take significant testing before a trap grease effluent cake could be used in the feed market, as it is not currently legal). In their Florida plant, ABF discharges to the sewer which flows to the local WWTP.

ABF does not run a trap effluent hauling fleet, but it charges $.12/gal tipping fee to haulers in the area. This is competitive with other discharge locations near the ABF facility. William Windsor, another ABF partner, claims that he could reduce his tipping fee to $.10/gal, but would not reduce it much further. They are currently running 50,000 gallons per day of trap effluent.

The system sold by ABF would cost $1.2 million for a 5 day a week plant, running 40,000 gallons per day, or 1.6 million for 100,000 gallons of trap waste per day. John also claimed that if the BOD reduction aspect of the plant was not purchased, the cost would be reduced to closer to 400,000 (this essentially represents the portion purchased from BWI). They are looking to enter the North Carolina market and generate electricity from the brown grease and the solids waste on-site, either through gasification or as boiler fuel for a steam generator. This may result in no brown grease being sold, as all of it would be used on-site for electricity production. However, there are not currently any other facilities running their technology.

5. Brown grease for use with biodiesel

- Investigation of the technology for brown grease biodiesel production.

Brown grease conversion requires an acid esterification front-end, which is well understood but adds an extra step to the process and some added variable, capital, and operating costs. In addition, brown grease has a very high gel point, and like any new biodiesel plant will require extensive physical filtration for effective on-road use. Even with this consideration, winter use may be limited to very low blends, as many biodiesel buyers now shy away from high gel point biodiesel. Brown grease biodiesel tends have high sulfur (300 – 400ppm), and can often fail distillation temperature and carbon residue, two tests which must be passed to sell biodiesel as an on-road fuel. While these hurdles may be able to be overcome, reducing sulfur to on-road levels (15ppm) is very difficult, and very few companies have developed the processes to achieve this. Black Gold Biofuels is the only company I am aware of which has legitimate claims to be able to make on-road biodiesel from brown grease. They have a facility in Philadelphia PA, and are currently looking to commercialize their process. However, it is very capital intensive, and probably does not make sense for the relatively small quantities estimated from the Raleigh area (200,000 – 400,000 gal per year). Alicia Chakrabarti of the The East Bay Municipal Utilities District found that distillation was the most effective method for reducing sulfur, but only distillation plus activated carbon was sufficient to break the 15ppm threshold required for on-road fuel sale[1]. Ultimately, the process used by Chakrabrti is too costly and probably not feasible on a commercial scale. Any brown grease to biodiesel facility which intends to sell on road fuel from brown grease alone would be considered experimental.

It is more feasible to sell brown grease in small quantities to existing biodiesel producers who are already set up to do esterification. However, this would be relatively small quantities, probably less than 5% of their overall production, as any more than that would cause them to exceed the ASTM specification for sulfur.

- Feasibility of on-site production.

It would be simpler to convert the brown grease to biodiesel and run the material in off-road uses where some of the ASTM specifications do not apply, or to blend the material down in on-road uses.. In this case, because you are not selling the product as biodiesel, you do not need to pass the normal specifications for carbon residue or distillation temperature – however, sulfur still applies. Furthermore, sulfur specifications are continually getting tighter, so a long term strategy using cheap, high sulfur fuel in off-road engines may be threatened by changing regulations. Therefore, while this may be an acceptable, short term option and could save the facility money on off-road diesel costs, it is probably not a long term solution for all of the brown grease produced. In addition, there may be warranty issues associated with running fuel which does not comply with ASTM specifications. The East Bay Municipal Utilities District (EBMUD) did produce biodiesel from their own collected brown grease in a pilot program. They produced roughly 100 gallons per day and ran the material in the EBMUD's dump trucks without significant problems. However, a private fleet is unlikely to consume the quantities collected in the Raleigh area. Finally, a private fleet will not be able to acquire the $1 per gallon tax credit, as that is available only to biodiesel being sold on the market which passes ASTM specifications.

On-site production may also be feasible if the location was taking large quantities of higher quality fats and oils to dilute the brown grease. However, this would be a significant undertaking, requiring a full scale biodiesel facility of several million gallons per year.

IV. Profitability analysis

1 http://www.pprc.org/BrownGreaseSymposium/docs/Waste_Grease_Biodiesel_Production.pdf

6. Economic analysis of potential dewatering plant.

Based on the demand curve described previously, the three tipping fees were used to analyze the profitability of the ABF and BWI technologies, based on the information provided by the producers of the equipment and existing facilities running that equipment. The primary difference between the two is that BWI does not reduce the BOD in the discharged waste water – as a result, it is assumed here that they will be discharging to the city of Raleigh and paying the appropriate rate based on how much their BOD is over the limit. In addition, the ABF system is slightly larger capacity (100k gallons per year) and costs significantly more.

The capacity of the BWI is low and can fulfill the estimated demand only at the highest price point ($.115/gal). ABF however can take more capacity, and was therefore analyzed at all three tipping fees. The payback on investment for BWI is very short at roughly 1 year, while the paybacks in all of the ABF scenarios are significantly longer (6 – 9 years). It should be noted that these were initial estimates from both companies. Further negotiation on price and system capabilities may result in changes in price and payback on investment.

The two graphs show the cumulative profitability of all 4 scenarios over time, both including and excluding depreciation. All assets are assumed to depreciate to zero in 8 years. However, given the type of equipment, the value of the equipment after full depreciation will still be significant. Therefore, the cash only graph shows cash flow over that same period.

Based on information from ABF's John Haslow, the on-site treatment for BOD reduction runs approximately $.035 per gal ($.015 for labor and $.02 for consumables – because labor was included as a per gallon number, it is absent from the fixed cost portion of Table 6). This is more expensive than the assumed cost for discharge to the city of Raleigh based on 5500 ppm BOD without on-site treatment. As a result, it does not make sense to do on-site treatment in this case. If the cost to discharge or the BOD loading of the discharged waste water were to increase, on-site treatment may become more attractive.

Description of Analysis Points	
ABF .06	ABF technology at tipping fee 3
ABF .08	ABF technology at tipping fee 2
ABF .115	ABF technology at tipping fee 1
BWI .115	BWI technology at tipping fee 1

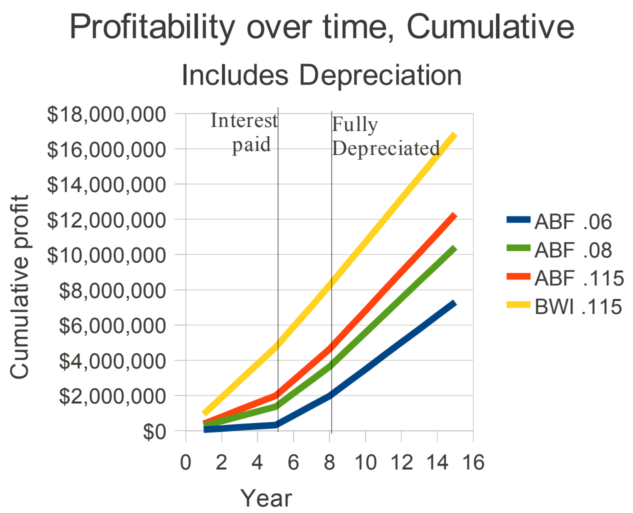
Raleigh Discharge limits and fees			
Measure	limit (in ppm)	cost per lb over limit	
BOD	300	0.65	$/lb
TSS	250	0.17	$/lb
TN	10	0.72	$/lb
P	5	1	$/lb
FOG	300		

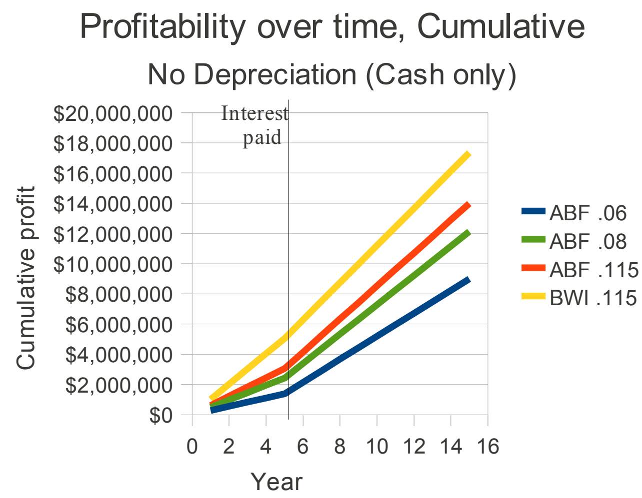
Raleigh WWTP Discharge costs calculations	ABF .06	ABF .08	ABF .115	BWI .115	
BOD limit	300	300	300	300	ppm
BOD plant	100	100	100	6000	ppm
BOD above limit	0	0	0	5700	ppm
% BOD	0.00%	0.00%	0.00%	0.57%	wt%
BOD cost/lb	$0.65	$0.65	$0.65	$0.65	$/lb
Discharge cost	$0.00	$0.00	$0.00	$0.031	$/gal
Treatment cost	$0.035	$0.035	$0.035	$0.00	
License Fee	$0.01	$0.01	$0.01		
Yearly Capacity (based on demand curve)	26,000,000	19,696,000	13,000,000	13,000,000	gal/yr
Discharge and treatment cost/yr	$1,170,000.00	$886,320.00	$585,000.00	$400,212.91	$/yr

Variable Costs Revenue calculations	ABF .06	ABF .08	ABF .115	BWI .115	
Rated Capacity	26,000,000	26,000,000	26,000,000	15,600,000	
Yearly Capacity (based on demand curve)	26,000,000	19,696,000	13,000,000	13,000,000	gal
Brown grease %	2.00%	2.00%	2.00%	2.00%	%
Brown grease consumption (boilers)/yr	52000	39392	26000	26000	gal
Brown grease produced	520000	393920	260000	260000	gal
Brown grease sold	468000	354528	234000	234000	gal
Price, brown grease	$0.80	$0.80	$0.80	$0.80	$/gal
Revenue, brown grease	$374,400	$283,622	$187,200	$187,200	$/yr
Tipping Fee	$0.060	$0.080	$0.115	$0.115	$/gal
Revenue, tipping fee	$1,560,000	$1,575,680	$1,495,000	$1,495,000	$

Profit and Loss Estimate				
Capital Costs	**ABF .06**	**ABF .08**	**ABF .115**	**BWI .115**
Equipment (system installed cost)	$1,700,000	$1,700,000	$1,700,000	$500,000
Land	$500,000	$500,000	$500,000	$500,000
Fixed Costs (per year)				
Labor (plant operators)	$0	$0	$0	$48,000
Depreciation	$212,500	$212,500	$212,500	$62,500
Interest + principle on Capital (5yr, 3.75%)	$483,223	$483,223	$483,223	$219,647
Permitting (air, stormwater, zoning, significant industrial user waste water, pretreatment, etc.)	$2,000	$2,000	$2,000	$2,000
Variable Costs (per year)				
waste water discharge and treatment	$1,170,000	$886,320	$585,000	$400,213
electricity	$1,800	$1,800	$1,800	$1,800
Income				
brown grease	$374,400	$283,622	$187,200	$187,200
tipping fee	$1,560,000	$1,575,680	$1,495,000	$1,495,000
Profit	$64,877	$273,459	$397,677	$948,040
Cash only	$277,377	$485,959	$610,177	$1,010,540

Table 6 – Profitability Analysis based on selected tipping fee



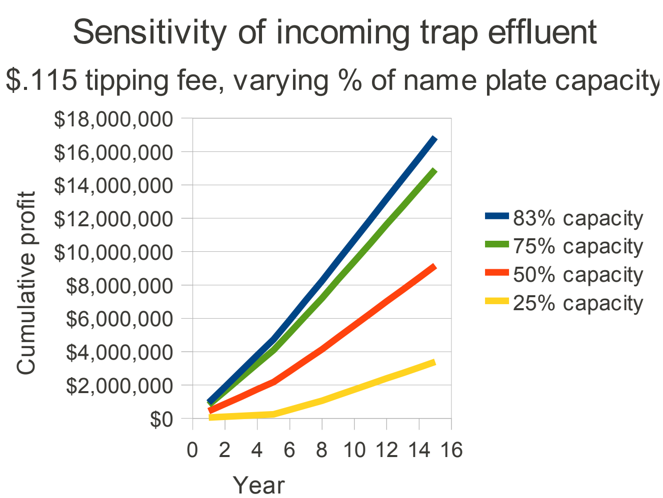


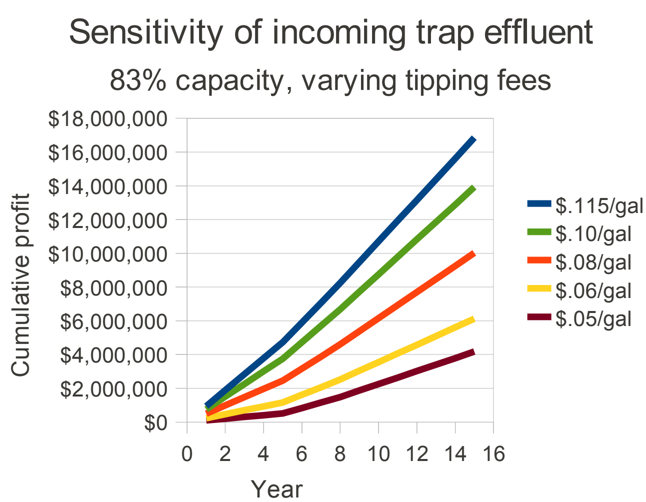
Illustrations 4 and 5: Profitability over time

* Raleigh fees are standard fees for discharge to the Raleigh WWTP. Fees were obtained from Tim Woody, Pretreatment Superintendent at the Raleigh WWTP.

** BOD Plant for BWI was obtained from Klein's Services of PA, who has tested their resulting waste water from their BWI process. BOD Plant for ABF was obtained from William Windsor, owner and operator of their FL dewatering plant.

***All ABF and BWI data was taken from the owner operators (Frank Burt and William Windsor) or from plants which are functioning and using their respective technology. Brown grease cost, boiler fuel usage, etc. are from these discussions. It is assumed that ABF would require another operator (and therefore higher labor costs) due to the added waste water treatment function. ABF did not respond to the variable cost of the waste water treatment system (reduction of BOD), therefore it is assumed to be $.01/gal.





Illustrations 6 and 7: Sensitivity to price and quantity fluctuations

Sensitivity Analysis

These numbers are highly sensitive to the cost of waste water discharge for BWI and the cost of waste water treatment (BOD reduction) for ABF. The crux of the comparison is the price to discharge to the city as compared to the price to treat on-site. If the city provides low cost or no cost discharge, then the BWI system is much more profitable. If the city does not, then the ABF system would be preferable.

In terms of changes in expected plant capacity, or changes in tipping fee, Illustrations 5 and 6 show the variability associated with those factors using the BWI system. At 83% capacity, the lowest tipping fee to maintain profitability throughout the project is slightly less than $.05/gal. At a tipping fee of$.115/gal, the lowest capacity to maintain profitability is slightly less than 25% of the nameplate capacity (equal to 3.9 million gallons per year). This shows a large variability in price and capacity while still maintaining profitability. Because labor is such a small portion of overall costs, adding additional labor also does not significantly affect the picture.

Though several tons per day of solids would be produced at the ABF plants which could be burned, this is not included in the analysis because of the uncertainty associated with burning the material. If this is burned on site, then the brown grease which is assumed to be burned for heat would then be sold. This would add an additional 26,000 – 52,000 gallons of brown grease for sale, increasing yearly brown grease revenues by approximately 10%.

There is also significant sensitivity around transportation of trap effluent from long distances, particularly in the case of ABF because the system will be pulling effluent from 75 miles away from Raleigh. Firstly, if there is upward pressure on wages or truck costs, (increased diesel prices, wages or taxes on wages, etc.), then haulers coming from farther away may switch back to more local discharge points where these costs are minimized. In addition, as dewatering/separation technologies spread and other cities or companies install similar systems in cities like Greensboro and Fayetteville, those customers will be able to discharge at the same tipping fee without driving to Raleigh. These threats disproportionately affect a larger system like ABF's due to its dependence on haulers coming from longer distances.

Finally, the increased use of indoor grease skimmers could change the constituents in the trap grease, and the quantity hauled. As trap regulations change to require larger and more expensive traps for new restaurants, many new installations are choosing to use indoor skimmers in conjunction with smaller outdoor traps.. These continuously skim for grease and reduce the size of traps and the frequency of cleaning. While this will not be an immediate effect, it may affect the quantity of trap effluent and percent brown grease over the next 10 – 20 years.

V. Conclusions

The profitability of dewatering trap effluent is still primarily related to the tipping fee charged and cost of waste water disposal. However, recovering brown grease adds significantly to revenues (12.5% - 25%) with some additional capital costs, but very little added variable costs. The two systems described here have proven success in recovering brown grease from trap effluent in the real world, with several years and multiple operations worth of data in the case of BWI. The brown grease market is also well developed, so selling product will not be difficult.

The Raleigh WWTP is looking for a solution to reduce FOG buildup in their collection system and so far no private company has fulfilled that demand. An opportunity exists to work with the city of Raleigh to build a private business around collecting trap effluent, removing the FOG, and discharging the waste water. Though they are currently moving forward with their trap effluent collection point, their preference is that a private company provide the service.

As a side-benefit, lowering the cost of trap effluent disposal in Raleigh will make the hauling business healthier, as smaller haulers will be able to compete more effectively with larger scale operations. This will be good for restaurants, and reduce the development of local hauling monopolies which can charge high prices and provide poor quality service.

The long term threats to this plan would be competition from other haulers, like Stanley's Environmental. A dewatering facility which is pulling trap effluent from far away is in danger of losing business to local competitors and increased hauling costs.

Overall, this appears to be a good 10 year investment with relatively fast payback, especially for the BWI system, and a significant yearly return on investment.

VI. Future Work

- More work should be put in to investigating specific sites in the Raleigh area which may be good locations for the facility.
- A few key pieces of information were not collected in this study: the true cost of the waste water treatment portion of the ABF equipment (it was assumed to be $.01/gal, but that may be too low); the true quantity of trap grease collected by Carolina Byproducts, and a more accurate assessment of their disposal costs; and the ability to see actual cost and revenue numbers for an existing operation to make sure that our cost estimates are correct. These would be helpful to increase the accuracy of the study.
- This study was limited to only a few equipment providers – quotes and information from other equipment providers should be acquired. Those quotes and information can be plugged into the framework (demand curve, cost calculation) used in this study.
- It is necessary to see some of of the existing operations first hand – Burts Waste Incorporated, Affordable Bio Feedstock, and Kline's Services.
- Zone 2 should be evaluated more thoroughly, so that a more accurate demand curve can be created for that area.

Appendix A

Because the the UWGRA's estimation of trap effluent availability included waste water treatment plant (WWTP) influent FOG numbers, data was pulled from the narrative portion of the study to separate the FOG and trap effluent estimates. This is outline below for each of the locations investigated. Sometimes the UWGRA did not explicitly separate FOG from trap effluent – in those cases no data was retained. Only explicit mentions of trap effluent were included.

In addition, the UWGRA sometimes only stated the refined brown grease. In those cases, the actual trap effluent quantity was then back-calculated. The UWGRA assumes 10% usable brown grease in trap effluent, which is significantly above what was found to be reasonable in this study (2 – 4%).

Data pulled from Urban Waste Grease Resource Assessment			
Trap grease estimation only (no WWTP FOG)			
Metropolitan Area	hauled trap grease (gal)	hauled trap grease (lbs)	population
Sacramento, CA	914945		1481102
Olympia, WA	na		
Provo-Orem, UT		3000000	263590
Denver, CO	3700000		1848319
Lincoln, NE	629925		213641
Bismark, ND	na		
Bloomington, IL		1600000	129180
Battle Creek, MI		2000000	135982
Mansfield, OH		370000	126137
Elmira, NY	na		
Boston, MA		36000000	1950855
Altoona, PA	na		
Hagerstown, MD	na		
Washington, DC	na		
Fayetteville, NC	na		
Florence, SC	na		
Greenville-Spartanburg	1141380		640861
Lexington-Fayette, KY	na		
Decatur, Alabama		3000000	131556
Macon-Warner Robins, GA		9000000	281103
Lakeland-Winter Haven	na		
Bradenton, FL	na		
Baton Rouge, LA	na		
Shreveport, LA	400000		334341
Beaumont-Port Arthur, TX		5000000	361226
Bryan College Station,	85000		121862
AVERAGE	**1145208**	**7496250**	**572840**
Convert lbs to gal (7.3lb/gal)		**1026884**	
Total gal		**2172092**	
Gal of trap grease/person/year			**3.79**

Table 7: Data from the UWGRA

Appendix B

Raleigh was defined by longitudinal and latitudinal coordinates, selected to include Raleigh and the majority of its suburbs (see below):

Raleigh, Long/Lat Coordinates		
Top, left	35.914339000	-78.888702000
Top, right	35.914339000	-78.501434000
Bottom, left	35.669272000	-78.888702000
Bottom, right	35.669272000	-78.501434000

Table 8: Raleigh area, coordinates

The coordinates of each of the major disposal/recycling locations were also known via information from NCDENR and Google maps (see below):

Firm Name	Latitude	Longitude
East Coast Resources	35.631944444	-79.017777800
Boswell & Son Septic Tank Service	35.899444444	-77.735555600
B & D Septic Tank	35.993611111	-78.381666700
David Brantley & Sons	35.919166700	-78.270000000
David Brantley & Sons	35.927600000	-78.253200000
Gerald Temple Septic Tank Service	35.318333333	-78.844722200
Marlin's Waste Management	35.223888889	-79.548055600
Cheek Plumbing and Backhoe	35.625000000	-79.571944400
Eastside Septic Cleaning Service	35.649166667	-78.600833300
Eastside Septic Cleaning Service	35.649166667	-78.597777800
Stallings Septic Service	35.619444444	-78.591666700
Mitchells Septic Tank Cleaning Service	35.657222222	-77.804444400
Creech's Septic Tank Cleaning Serv.	35.595555556	-78.074166700
Dean Brooks	35.546874000	-79.390640000
McGill	35.637869000	-79.009724000
Carolina Byproducts	35.030470000	-78.862438000

Table 9: Disposal location coordinates

From these coordinates, 2700 random points (the estimated number of traps in Raleigh and the surrounding suburbs) with a longitude and latitude within the Raleigh coordinates described above were created in an excel spreadsheet. Then the distance from each random point was calculated to each disposal location – this was performed by subtracting the longitude form the latitude and calculating the hypotenuse of the resulting triangle. Because this represented a straight line "as the crow flies" distance, the distance was then multiplied by 1.11 to get a more accurate "driven" distance, represented as the variable "miles to raleigh, road". Then, to determine an estimated drive time, the straight line distance was multiplied by 1.35, represented as the variable "time (min) to disposal loc). Both multipliers 1.35 and 1.11 were determined by choosing 10 random locations in the Raleigh area and calculating the ratio of straight line distance to driven distance and driving time using Google maps.