Master's Project

Launching of a New Onsite Wastewater Treatment Technology

By

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Abstract

Through this paper, I aim to conduct a thorough evaluation of the market, regulatory environment and competition within the Onsite Wastewater Treatment Systems (OWTS) industry, with the intention to validate and determine the viability of launching a new onsite wastewater treatment technology known as the Water Effluent Treatment (WET) System.

Historically, US wastewater treatment has been performed by centralized wastewater treatment systems. However, these systems imply high infrastructure and maintenance costs, along with lacking the ability to adequately address storm surges and adapt to growing environmental issues and technological innovations.

As a solution, the industry is rapidly shifting towards OWTS. The U.S. market represents the largest and highest growth market for OWTS worldwide. On-Site U.S. sewage facilities collect, treat and release an estimated 4 billion gallons of treated effluent per day[8].

Increased frequency of storm surges, a decaying infrastructure, population increase and poor water treatment practices have created a national environmental crisis in water quality. There is a growing concern and recognition of the impact of inadequate wastewater treatment on ground and surface water quality.

Enhanced by the lack of budgets to improve wastewater treatment infrastructure, municipalities are faced with a major challenge in acquiring onsite wastewater treatment technologies that are cost efficient, environmentally sound, and adaptable to technology changes.

Preferred OWTS technologies used in the market include centrifuge and variations of belt press filters. After a thorough evaluation, which includes technical performance, health and a cost

competitive analysis of these systems versus the WET System, I conclude that the WET System is not only a viable option, but has significant competitive advantages which could make it a major player in the market.

Technical performance, environmental, health and cost advantages are further strengthened through the recommended plan to launch the system using Public Private Partnerships and financial lease models that accommodate the need for financing being faced by municipalities.

Prior to launching the system, recommendations are made to complete a formal business strategic plan, perform further testing of the system on municipal wastewater treatment, and enhance the automation features of the system.

Introduction

Almost every region in the U.S. will experience water shortages in the next 10 years[1]. Water prices are expected to rise well over inflation due to the need for capital-intensive expansion and needed renovations of water treatment systems, increasing population in areas of limited supply, and the increasing cost of energy to treat and transport wastewater[2]. The 2002 report issued by the U.S. Environmental Protection Agency (EPA) estimated the federal gap between investment needs and planned spending to be $140 billion for wastewater treatment systems[3]. As federal investment on water treatment infrastructure decreases, a greater share of infrastructure costs will need to be absorbed by state government, municipalities, and ultimately, end customers[4].

Centralized wastewater treatment facilities are increasingly burdened by storms, water shortages, and population increases, demanding that infrastructure keep pace with the associated impacts of developments. Centralized wastewater collection and treatment systems are not the most cost-effective and environmentally sustainable option in the market. They require a high capital upfront investment and high maintenance cost, which makes them infeasible or cost-prohibitive for rural and small municipalities[5]. Water bodies near urban areas are often exposed to pollutant discharge from centralized systems, which are highly susceptible to overloading during storms[6]. Increasing water pollution in surface and ground water is, in part, a result of inadequate wastewater treatment from a limited capacity, centralized water treatment infrastructure.

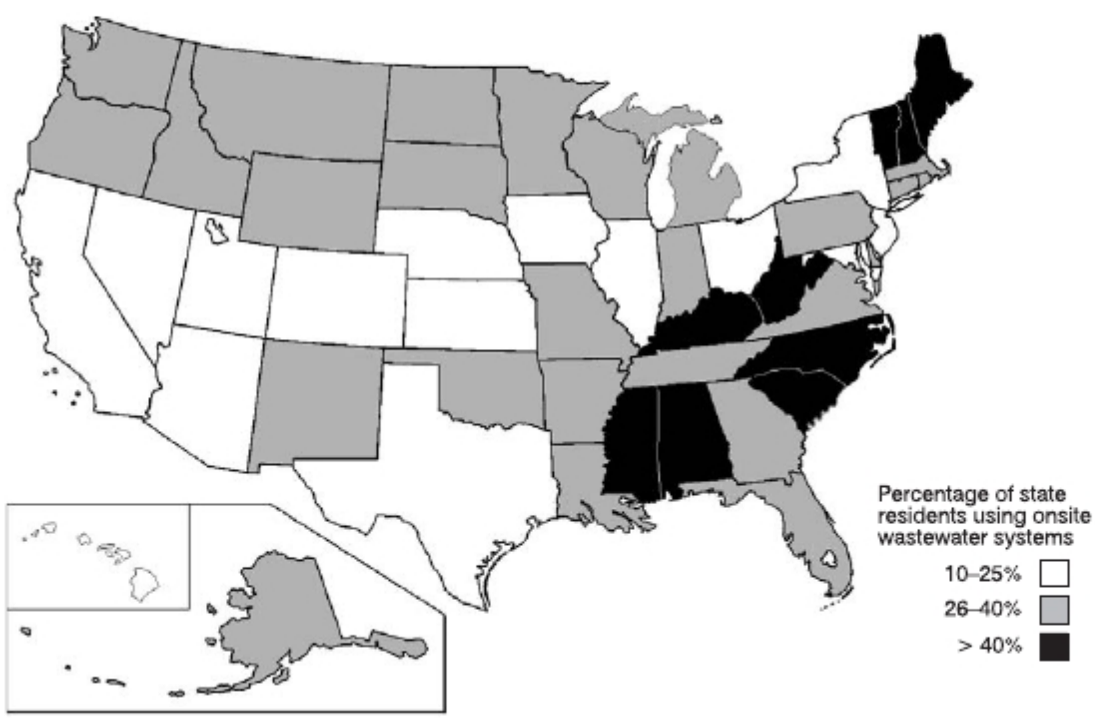
There is a growing need to conserve water in order to meet demand and support water resource management for both environmental and health purposes at a municipal level. The decentralization of water and wastewater treatment through the use of onsite wastewater systems offers a viable environmental and economical solution for municipal public water utilities.

Due to increased state and federal regulations in the treatment of wastewater, budget limitations, and increased demand, a large number of municipalities are encountering difficulties addressing the high investment required to expand the capacity of their wastewater facilities or extend lines to nearby urban locations[6]. Consequently, there has been a recent shift in interest among the industry and the public toward decentralized wastewater technologies, which can be environmentally compatible and cost-effective. According to the Consortium of Institutes for Decentralized Wastewater Treatment, the use of Onsite Wastewater Treatment Systems (OWTS) is one of the fastest growing markets within the U.S[7]. OWTS represent over 25% of domestic wastewater treatment in the U.S. and although most are made up of septic tank systems, the trend is moving toward scaled down versions of municipal centralized treatment systems[8]. Figure 1 shows the use of OWTS by State.

Onsite Waste Water Systems are used in the treatment of wastewater with the primary purpose of removing suspended solids and contaminants. If well designed, these systems provide several primary benefits, including lower capital investments needed to expand infrastructure to meet demand, the mitigation of peak treatment conditions through dispersed storage capacity, and a reduction of demand through discharge avoidance[6]. In addition, the design of onsite systems can enable primary or secondary treatment and may have further applications at the head works of the network. New technology can be incorporated to OWTS easier than other systems, representing large savings in infrastructure costs.

Dewatering systems are the primary cost driver of wastewater treatment. These systems are designed to separate solids from the wastewater, in preparation for further water treatment, sludge handling and disposal.

Fig. 1. OWTS Use by State[6]



Existing dewatering systems primarily use filter presses or centrifuges to remove suspended solids and contaminants. These systems offer important benefits but may involve high upfront capital investments, require high maintenance, are energy intensive and have moderate cost-effectiveness. A majority of the solutions in the market do not remove both chemical and organic pollutants from wastewater and require complementary processes and equipment to achieve regulatory compliance.

In 2012, my company ECO BCG Corporation formed a Joint Venture, which acquired the exclusive rights over a new onsite wastewater treatment technology known as Water Effluent Treatment System (WET System). The proprietary technology involves a Flock Reactor and chemical solution as a flocculation agent, which combined with other equipment, provide for a more cost effective and efficient system when compared to technologies being offered in the market today. The system has expectations of driving a lower final capital cost, lower maintenance costs, reduced energy consumption and higher efficiency ratios in the separation of bio-solids, including up to 92% separation of phosphates and 60% of nitrates.

The system seems to be the perfect solution for the problem being faced today, in that it offers an environmentally friendly and cost effective way to adapt existing wastewater treatment infrastructure to changing capacity and regulatory requirements. Nonetheless, further testing and market research needs to be completed in order to determine implementation strategies and formulate a business plan to launch this technology. Through this proposal, I aim to provide a sound analysis of the reasoning behind launching this technology, whilst providing for strategy and business plans to support the implementation if the technology is determined viable.

Objective

The objective of this paper is to determine if the WET system, as an alternative to existing dewatering systems for OWTS, has the necessary environmental and competitive advantages to justify a market launch and to formulate a strategic business plan that will enable long-term success.

Methods

In order to validate findings, I will conduct market research in the U.S. Municipality wastewater treatment industry, including a comprehensive application analysis, along with competitive market analysis and evaluations. Market research will involve quantifying market size and identifying target market segment within the OWTS industry. Furthermore, research will focus on identifying technical and health performance on the primary competitive solutions available today and carrying a cost benefit analysis of the WET System in comparison to these solutions.

I will be using third party independent testing to certify specifications and environmental regulatory compliance. Testing will be performed by a third party laboratory and will consist on certifying the constituent level of the influent and effluent water, prior and after treatment by the WET System. Third party testing is important to confirm theoretical technical estimations, along with measuring constituent levels of the effluent for both regulatory compliance and competitive analysis.

For regulatory and market information, I will be using the following resources:

Water Research Foundation (www.waterrf.org)

American Water Works Association (www.awwa.org)

National Association of Clean Water Agencies (www.nacwa.org)

U.S. EPA Office of Water (http://water.epa.gov/)

Water Environment Research Foundation (www.werf.org)

Consortium of Institutes for Wastewater Treatment (www.onsiteconsortium.org)

Expected Results

This paper will provide the fundamental analysis on market viability, along with a sound business strategic plan to launch this technology in the market.

Environmental and Health Hazards

Environmental protection and public health agencies are becoming increasingly concerned about contamination from wastewater pollutants in ground and surface water. A significant number of OWTS lack adequate management oversight and maintenance, which results in inadequate pollutant treatment[6].

Toxic compounds, excessive nutrients, and pathogenic microbes are among the common environmental hazards and human health risks caused by contaminated wastewater discharge[6]. Most onsite system ultimately discharge treated water into the ground. However, these systems can fail to properly treat pollutants, allowing constituents to infiltrate ground and surface waters. Figure 1 depicts the commonly found pollutants in wastewater.

Fig 2. Waste Water Pollutants[9]	
Pollutant	**Reason For Concern**
Total Suspended Solids (TSS)	Suspended solids can lead to the sludge deposits that smother benthic macro-invertebrate and fish eggs and can contribute to benthic enrichment, toxicity, and sediment oxygen demand. Excessive TDS can lower the ability of aquatic plants to increase dissolved oxygen in the water column.
Biodegradable Organics (BOD)	Biological stabilization of organics depletes dissolved oxygen in surface waters, creating anoxic conditions harmful to aquatic life. Oxygen-reducing conditions may also generate taste and odor problems in drinking water.
Pathogens	Parasites, bacteria, and viruses causing disease through body contact or ingestion of contaminated water or shellfish. According to the USEPA, commonly found diseases in wastewater include gastroenteritis, salmonellosis, cholera, giardiasis, ameobiasis, conjunctivitis, hepatitis, gastroenteritis and typhoid fever. Transport distances of certain pathogens in discharged to recreational areas and fishing grounds can be significant. Viruses can survive in fresh water and sewage up to 120 days, while enteric bacteria from human and animal waste can survive up to 60 day.
Nitrogen	An aquatic plant nutrient that may lead to eutrophication and dissolved oxygen loss in surface waters. Algae and aquatic weeds can contribute to carcinogenic trinalomethane in chlorinated drinking water. Excessive nitrates in drinking water can cause methemoglobinemia in infants and pregnancy complications for women. Livestock can also suffer health impacts.
Phosphorus	An aquatic plant nutrient that can contribute to eutrophication of inland and coastal surface waters and reduction of dissolved oxygen.
Toxic Organics	Toxic organic compounds present in household chemicals and cleaning agents, which may interfere with biological processes and may be persistent in ground water. Can cause damage to surface water

	ecosystems and human health through ingestion of contaminated aquatic organisms.
Heavy Metals	Metals such as lead and mercury in drinking water can cause severe health problems. These can be hazardous to aquatic life and accumulate in fish and shellfish.
Dissolved Inorganics	Chloride and sulfide may cause taste and odor problems in drinking water. Boron, sodium, chlorides, sulfate and other solutes may limit treated wastewater reuse options.

TSS can result in the development of sludge layers harmful to aquatic organisms. Biodegradable organic material creates biochemical oxygen demand (BOD) which is a cause of dissolved oxygen concentrations in surface water, taste and odor problems in well water, and may cause leaching of metals from the earth into ground and surface waters[8]. Combined, TSS and BOD create additional problems in the form of pathogens, toxic pollutants, and other pollutants. OWTS, under proper conditions, can achieve removal rates greater than 95%.

Surfactants are the largest class of anthropogenic organic compounds found in domestic wastewater and originate from laundry detergents and other soaps[10].

Metals are primarily present in household water due to decaying plumbing systems that generate lead, cadmium, and copper[11]. Other sources for metals found in wastewater include human waste and vegetable matter. Industrial facilities are also major contributors to metals in wastewater.

OWTS may also reduce nitrogen and ammonia over 85%. Nonetheless, studies have detected in urban and rural ground water nationwide, levels exceeding the USEPA drinking water standard of 10mg/L. These compounds can change soil structure and alter wastewater infiltration behavior.

Regulatory Environment

The United States Environmental Protection Agency (USEPA) is the primary regulatory agency for water treatment, and also manages the majority of funding for water projects through the Clean Water State Revolving Fund and the Drinking Water State Revolving Fund. Other federal agencies involved in water regulation include the US Department of Agriculture (USDA), the Department of Energy (DOE), the Department of Homeland Security (DHS) and others. Furthermore, states and municipalities have responsibility for certain areas of water regulation within their jurisdictions and to manage federal programs.

An average home constituent mass loading is depicted in Figure 3. Water treatment facilities are designed to treat wastewater to negligible environmental and health hazards. Nonetheless, municipalities are having greater problems meeting discharge regulatory limits. Treated water with above permitted limits of contaminants is increasingly penetrating groundwater and wells.

The situation has become critical. As an example, the Report 305(b) issued by the State Water Resources Control Board finds:

- Over a third of the areal extent of groundwater in the state of California surpasses contamination limits to be safely used for all the purposes designated by State regulations.
- In addition, at least 40% of the areal extent groundwater is either impaired by pollution or threatened with impairment.

- Threats include salinity, organic compounds, pesticides, nutrients, metals, and others, which have been reported to exceed State and Federal set limits.

The situation being experienced across the vast majority of states and municipalities is causing a profound economic impact and need for a stricter regulatory environment and consequent search for feasible sustainable solutions. The San Fernando Valley is a good example on how critical the situation has become. The Los Angeles County grand jury had closed 54 of its 115 wells in the Valley as of 2009 due to high levels of contamination. Furthermore, of the remaining 61 wells, 44 had recorded various contaminants above MCLs established by the California Department of Public Health. As of 2010, the region was spending $174 million per year in importing water, up from $7.3 million in 2007 and a total of $850 million cleanup effort has been recommended. Without the investments, cities will be forced to stop withdrawing water from the Valley wells within 5 to 10 years[12].

Although, hydraulic fracturing and energy extraction, confined animal feeding operations, inadequate aquifer management and agricultural contamination are major contributors to surface and groundwater contamination, inadequate industrial and residential wastewater treatment remains the driving force behind the problem being faced today. Figure 3 shows the typical residential constituent mass loading.

Fig 3. Typical U.S. Residential Dwelling Constituent Mass Loading[8]

Constituent	**Mass Loading (gms/person/day)**	**Concentration (mg/L)**
Total Solids (TS)	115-200	500-880
Volatile Solids	65-85	280-375
Total Suspended Solids (TSS)	35-75	155-330

Volatile Suspended Solids	25-60	110-265
5-day Biochemical Oxygen Demand (BOD)	35-65	155-286
Chemical Oxygen Demand (COD)	115-150	500-660
Total Nitrogen (TN)	6-17	26-75
Ammonia (NH4)	1-3	4-13
Nitrites and nitrates (NO2-N; NO3-N)	<1	<1
Total Phosphorus (TP)	1-2	6-12
Fats, Oils, and Grease	12-18	70-105
Volatile Organic Compounds (VOC)	0.02-0.07	0.1-0.3
Surfactants	2-4	9-18
Total coliforms (TC)	-	10-10
Fecal coliforms (FC)	-	10-10

Direct discharges to surface waters require a permit issued under the National Pollutant Discharge Elimination System (NPDES) of the Clean Water Act. The process defines discharge performance requirements, including color and odor. Treated effluent discharge permits include limits for BOD, TSS, fecal coliforms, ammonia, nutrients, metals and other pollutants, including chemicals used to treat the wastewater, such as ferric chloride and chlorine. Limits vary based on the designated use of the water resource (swimming, aquatic habitat, recreation, potable water supply), state water classification scheme, and/or the sensitivity of aquatic ecosystems to eutrophication. Figure 4 shows the USEPA mandated Maximum Contaminant Levels (MCL) for drinking water and the potential negative health effects on exceeding established limits. Other types of discharges include atmospheric discharge or evaporation methods.

Fig 4. Maximum Contaminant Levels (MCL) for Drinking Water[13]

Contaminant	MCL(mg/L)	Potential Health Effects
Benzene	0.005	Anemia; blood platelets decrease, increase in cancer
Chlordane	0.002	Liver or nervous system problems; increased cancer risk
Chlorobenzene	0.1	Liver or kidney problems
2,4-D	0.07	Liver, kidney, or adrenal gland problems
0-Dichlorobenzene	0.6	Liver, kidney, or circulatory system problems
1,2-Dichloroethane	0.005	Increase risk of cancer
Dichloromethane	0.005	Liver problems, increased risk of cancer
Dioxin	0.00000003	Reproductive difficulties, increased risk of cancer
Ethyl benzene	0.7	Liver or kidney problems
Hexachlorobenzene	0.001	Liver / kidney problems; reproductive difficulty, cancer risk
Lindane	0.0002	Liver or kidney problems
Toluene	1.0	Nervous system, kidney or liver problems
Trichloroethylene	0.005	Liver problems, increased risk of cancer
Vinyl chloride	0.002	Increased risk of cancer
Xylenes (total)	10	Nervous system damage
Metals:		
Arsenic	0.06	Increase in blood cholesterol; decrease in blood glucose
Cadmium	0.005	Kidney damage
Chromium	0.1	Possible allergic dermatitis after long exposure
Copper	1.3 (al)	Gastrointestinal distress; liver or kidney damage
Lead	0.015 (al)	Child physical and mental developmental delays; Kidney problems; high blood pressure in adults.
Inorganic Mercury	0.002	Kidney damage
Nitrate-nitrogen	10.0	Methemoglobinemia (blue baby syndrome)

Nitrite-nitrogen	1.0	Methemoglobinemia (blue baby syndrome)
Selenium	0.05	Hair/fingernail loss; fingers numbness; circulation problems

Sludge management and disposal processes and technologies are becoming critical due to regulatory trends. New regulations are demanding adaptations to existing technology to comply with established limits. According to the USEPA, 16% or $52 billion of the total wastewater treatment investment need for the next 20 years, is driven by regulations (See Figure).

Regulation Type	**Microbial Regulations**	**Chemical Regulations**	**Total Regulatory Need**
Existing Regulations	$29.4	**$15.6**	**$45.0**
Proposed / Recently Promulgated Regulations	$3.6	**$3.3**	**$7.0**
Total Regulatory Need	**$33.0**	**$19.0**	**$52.0**

Figure 5. Regulatory Driven Wastewater Treatment Investment Needs- 20 Year Projection[10]. Number in U.S. Billions.

New technologies and innovative processes are being evaluated, as efficiency, and especially energy efficiency, is becoming more important. The overall market for water treatment technologies is undergoing a major shift in trends and requirements.

Wastewater Treatment Market

The 2010 global market for water-related equipment and operations is estimated at $483 billion and to surpass $600 billion by 2016. Equipment for wastewater collection and treatment is estimated at $82 billion, rising to $115 billion by 2016, with a compound annual growth rate (CAGR) of 5.6% p.a.[14]. The U.S market is the largest wastewater treatment global market at $107 billion. It is also the highest growth market amongst developed countries with an estimated 14.9% CAGR.

There are different estimates on the market for wastewater treatment equipment growth. These include:

- The 2008 Clean Watersheds Needs Survey estimates that $298 billion in wastewater treatment infrastructure will be needed by 2028.
- The USEPA's 2002 Clean Water and Drinking Water Infrastructure Gap Analysis estimated 20-year capital needs in the range of $204 billion to $590 billion.
- The Water Infrastructure Networks (WIN's) 2000 Clean and Safe Water for the 21st Century- A Renewed National Commitment to Water and Wastewater Infrastructure, estimates needs for $25 billion annually, or $503 billion until 2030.
- The 2010 US Conference of Mayors (USCM) in its Trends in Local Government Expenditures on Public Water and Wastewater Services and Infrastructure: Past, Present and Future report estimated total water project spending by governments to range between $2.5 to $4.3 trillion. In contrast to the other calculations, this last estimate includes investments for new infrastructure to meet population growth needs and maintenance.

According to the USEPA, the U.S. National Water Infrastructure, there are over 16,000 publicly owned wastewater treatment plants. 35.3% or $105.2 billion is estimated as investment needs over the next 20 years (see Figure 5).

Regardless of which source is used, it is evident that the U.S. market for wastewater treatment infrastructure is not only huge, but also growing at attractive rates.

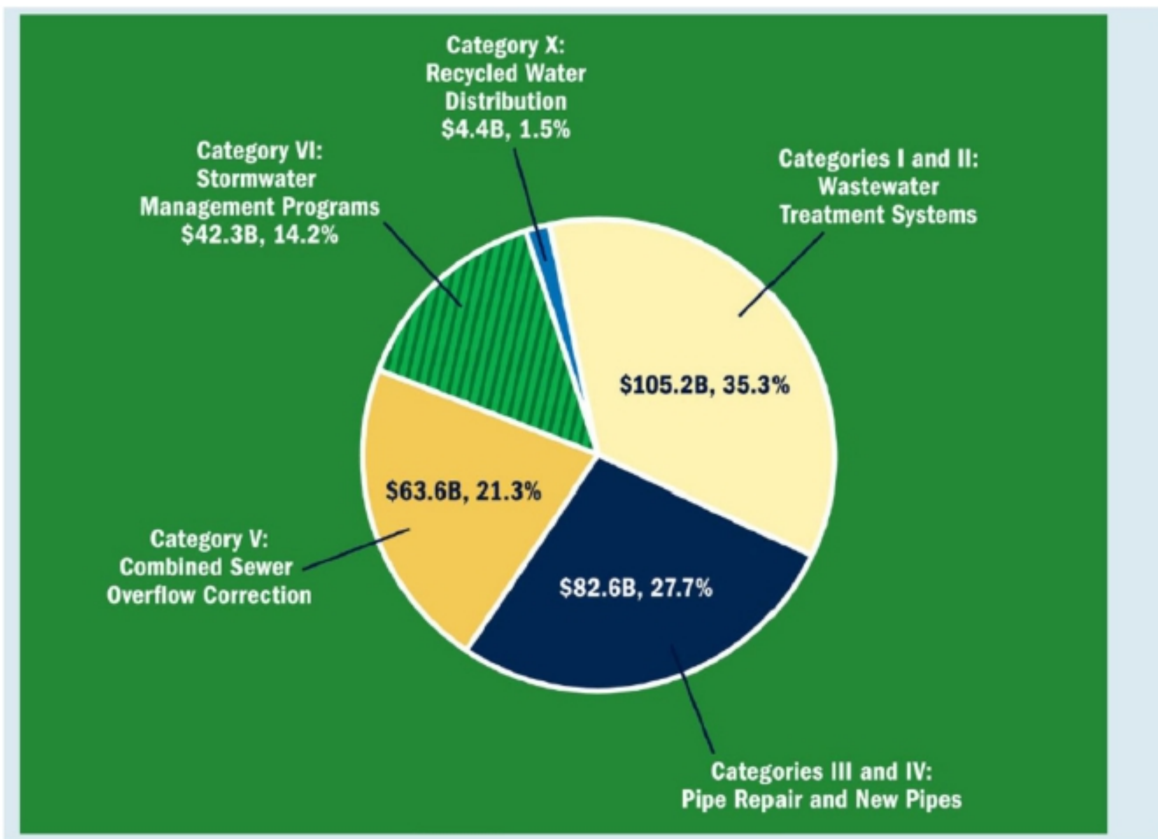


Figure 6. Largest Wastewater Treatment Investment Needs[11]

Wastewater treatment infrastructure needs have skyrocketed in the past decade due to the following drivers:

- *Decaying infrastructure.* Annual percentage of pipes that require replacement is expected to increase from less than 0.5% currently to nearly 2% by 2035.

- *Population increase.* Growth rate of 0.91% annually through 2016, mainly concentrated in urban areas.
- *Higher regulatory requirements.* In response to increasing pollutants in groundwater and applicable to secondary and tertiary wastewater treatment.
- *Emerging environmental issues*. Increased concerns on addressing storm water runoff in developed areas, phosphorous and nitrogen control, and other contaminants, such as endocrine compounds and pharmaceuticals.
- *Decreasing research and development.* Investment in new technologies has decreased due to lower venture capital availability, along with fewer government incentives, creating a growing technology gap in the water treatment industry.

Although the majority of the population served and investment required is concentrated in large and medium scale water treatment systems, a large opportunity exists in small community systems, which represent 82% of the systems available in the U.S. (refer to Figure below). A large number of available technologies are cost prohibitive or need higher economies of scale to make them viable.

Small community systems are being directly affected due to increasing capacity requirements, regulations and the limited availability of environmental and cost effective solutions in the market.

	CWS Need		Water Systems		Population Served	
System Size	$Billions	% of CWS Need	Number of Systems	% of Water Systems	Population Millions	% of Pop. Served
Large Community Water Systems (>100,000 persons)	$116.3	36%	584	1%	128.6	45%
Medium Community Water Systems (3,301 to 100,000 pers.)	$145.1	45%	8,749	17%	130.7	46%
Small Community Water Systems (3,300 and fewer pers.)	$59.4	19%	41,748	82%	24.1	9%

Figure 7. Market by Community Size[15]

Sludge handling, transportation and disposal costs are amongst the three major costs within a wastewater facility. The sludge dewatering system or solid separation system is the main driver on these costs and has been dominated by just a few equipment and solution options[16].

Historically, wastewater treatment facilities had inefficient vacuum filter systems, which eventually were replaced by early generation centrifuges and belt filter presses. By the 1990's belt filter presses were the most common dewatering equipment[10]. Over the past few years a number of variations and new technologies have been made available in the market.

Some of the most popular systems are:

Belt Filter Presses, amongst the most proven technologies, use a process that allows for a continuous sludge dewatering between two filter belts. The process uses a flocculator to produce a sludge-flocculants blend, which is distributed evenly throughout a filter belt. The flocculated sludge is then drained on a lower belt using gravity. After drainage of the freed-water by flocculation, the sludge is pressed between two filter belts. A progressive pressurization produces a solid known as the cake, which is then scraped off fro the surface of the two belts. Belt Filter press systems are commonly used and operator friendly but have a disadvantage in odor mitigation since it is an open process[10]. Belt Filter Presses can typically produce sludge with 18 to 23 percent solids content and may capture over 95 percent of the solids.

Centrifuge systems use a process based on the centrifugal force instead of gravity to force the separation of liquids and solids. The force is created in a conical-cylinder bowl that rotates at high speed and where the sludge particles are pressed against the bowl and conveyed out by a screw rotating at slightly slower speeds[11]. Centrifuges can generally produce cake solid concentrations similar to or higher than belt filter presses. The process requires for the cake solids to be returned to the liquid treatment process where the dewatered solids are captured and transported for disposal. With the use of polymers, centrifuges can typically produce sludge with 20 to 25 percent solids content and usually capture over 95 percent of solids.

Rotary Disk/Screw Press is a relatively new technology which feeds flocculated sludge between two parallel, rotating screens within each disc assembly and rotate slowly on a single shaft. Polymers are added to flocculate the solids in a separate flow-through process, which drop into a header box that allows the flocculated solids to move through a screw enclosed by an outer screen. Dewatering is then accomplished through gravity drainage where the bio solids are compressed and dewatered as the screw diameter decreases towards the outlet of the pipe. The process has a lower efficiency than belt filter presses and centrifuges; with less than 95 percent solids capture capacity.

Inclined Screw Press system involves feeding flocculated sludge into an inclined screw rotating inside a wedge wire screen.

Horizontal Screw Press, similar to the inclined screw press with the difference that it is configured in a horizontal arrangement. This system can be configured to stabilize the sludge with quick lime and steam to produce a Class A Bio-solids.

Frame Filter Press dewatering systems use a discontinuous process that works in batch cycles using the principle of filtration. Using a high-pressure pump, conditioned sludge is injected into filtration chambers. The water seeps out as the sludge fills each chamber.

To adequately evaluate if the WET System technology is suitable for market launch, it needs to compare favorably to market available solutions.

WET Technology Overview

The WET System is an onsite solution for solid separation within the secondary treatment stage of municipal wastewater treatment. The system integrates market available equipment with a proprietary flocculating technology and trade secret process.

The primary equipment consists of "off the shelf" pumps, tanks, solids separators, and a solids concentrator. The unique and proprietary aspect of the WET system is the patent pending **Electrostatic Flocculating Reactor (EFR)**. The EFR alters the chemical charge of the solids while mixing the proprietary chemical/polymers, which results in the rapid agglomeration of the solids. The process uses analytical sensors that feed data to the programmable logic controller determining the polymer dose rate at specific injection points. The electrical charge generated by the EFR will also destroy in excess of 90% of all pathogens in the wastewater.

The flocculation agent that enables solids agglomerations is a proprietary chemical solution consisting of three well known and readily available chemicals. The amount of each chemical is determined by the solids makeup and volume of solids and phosphorous in the subject wastewater stream; the greater the concentration of solids requiring separation the greater the volume of chemical required. This chemical flocculent has been approved for safe application to agricultural land by the Canadian government authority.

Flocculants have a very high molecular weight and a varied ionic charge, which fixes the destabilized particles on their chain[17]. The particle size increases with the formation of flocs, which induces a release of water that can be eliminated through the dewatering step.

Figure 8. Visual effect of Flocculation [11]

In addition to the EFR, major components of the WET System are:

Solids Filtration Device – This device is a mechanical screen that captures 99%+ of all TSS solids and 80%+ of phosphorous and allows the cleaned water to pass through. The removed solids are conveyed into a compression screw for further dewatering as the wastewater continues to the next stage of processing.

Separated Solids Dewatering Device - Along with the separated solids remains a small amount of surface water that is effectively removed through the use of a compression screw that squeezes the surface water from the solids. The solids are then conveyed to the solids dryer or they are removed from the system. The water that is removed is returned to the head of the reactor where it is blended with the incoming effluent.

Activated Carbon Filtration –The final step in the treatment stage is to polish the discharge water by passing it through Activated Carbon that provides a number of functions including: removal of BOD, nutrients, and odor control. Activated carbon utilizes a technique known as adsorption to capture and hold pollutants. As the absorption capacity reaches a certain point it must be replaced or cleaned. Replacement is a very simple and quick process and cleaning can be done automatically.

Technology Process Description

The WET System uses a combination of mechanical (rotary screens) and chemical treatment steps to remove the bio-solids, Phosphorous (P), Nitrates (N) and other contaminants from wastewater.

The wastewater going into the system (influent) is initially treated with a rotary screen to remove the large solid particles. After the first rotary screen step, the wastewater is pumped into the EFR, which includes a chemical injection system and mixing chamber.

The EFR and the chemical process are proprietary. Certain chemicals are added in specific proportions and in series, then, mixed through a turbulence induction pipe layout, before being pumped into the bottom of the mixing tank. The chemical addition section of the WET system is shown in Figure 1. The mixing tank allows additional residence time between the chemicals and the wastewater. The process and the EFR bind small particles together from the wastewater into larger particles, allowing for mechanical removal of the coagulated particles. The rapid agglomeration forms larger particles (floc) that settle quickly and are then captured and removed by filtration. The filtered solids are then passed through a solids dewatering device that produces an end product that is 30% to 40% solids and 70% to 60% water. At this moisture content mix, the treated effluent can be cost effectively handled and further dried, which in many cases, allows it to be processed as a source of renewable energy or organic fertilizer.

Once the treated solid rises to the top of the mixing chamber, it flows to a second rotary screen. This last step separates de coagulated solids and discharges two remaining streams (treated water and separated solids). A detailed description of the process is included as an attachment.

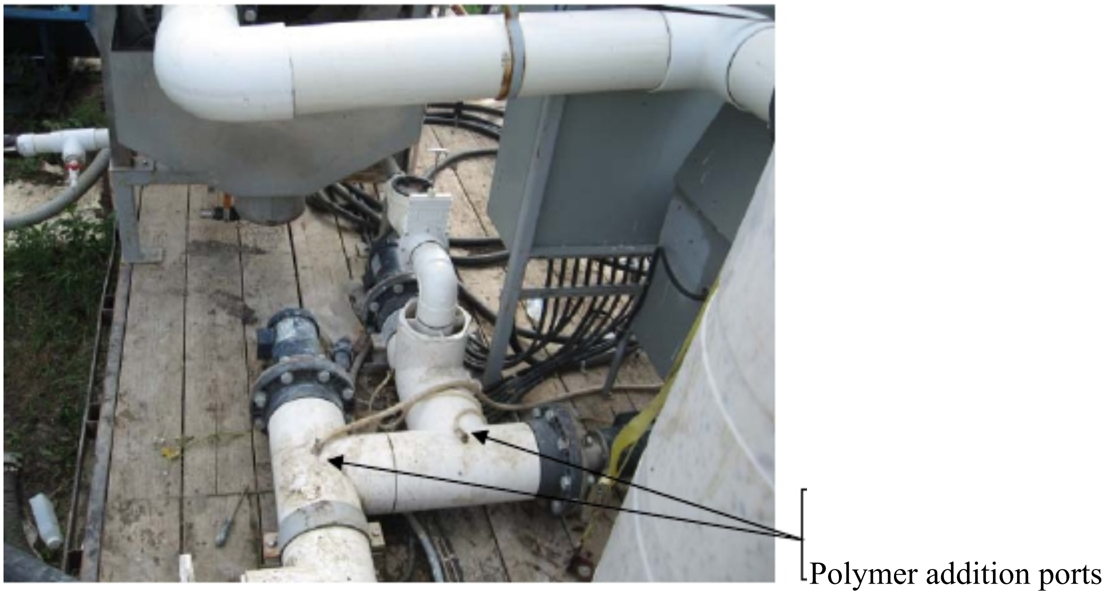


Figure 9. Technical Process

Technology Testing and Results

Independent third parties and laboratories have performed testing of the WET system. Samples have been analyzed by ALS Laboratories Inc. and the results included in Appendix I.

At this point, it is safe to state that the WET System meets regulatory requirements as a dewatering system. The discharge effluent has been certified to meet environmental regulations for agricultural use water. However, further testing in a municipal wastewater treatment facility is recommended. Additional testing under exposure to residential discharge and industrial wastewater will provide further evidence and confirmation of initial findings.

The visual effect of the wastewater treated by the WET system is shown in the next set of figures.

Figure 10. Wastewater influent sample

Figure 11. Treated wastewater effluent sample

Figure 12. Separated solids sample

Figure 13. Influent – Effluent – Separated Solids

Competition Analysis ,

In this section the best-known technologies (Belt Filter Press, Centrifuge and Rotary Screw Press) are compared with the WET System. Competitive analysis is based on three criteria: 1) general evaluation, 2) performance and health, and 3) Cost/Benefit analysis.

General Evaluation. Advantages and disadvantages on known and published characteristics of the different technologies.

Dewatering Alternative	**Advantages**	**Disadvantages**
Belt Filter Press	• Produces relatively dry sludge cake • High solids capture rate • Moderate energy consumption • Relatively low capital and operating costs.	• Complex conditioning equipment requiring future maintenance and replacement • Higher labor requirement • Large footprint • Skilled maintenance personnel required • Chemical mix generates additional disposal of solids mass • Higher odor problem
Centrifuge	• Good odor management • High cake solid concentration	• Scroll wear results in high maintenance

	• Low capital cost to capacity ratio • Continuous feed • Small footprint • Efficient start up and shut down • In-line sludge conditioning	• Skilled maintenance personnel required • Moderate solids capture rate • High energy requirements
Rotary Screw Press	• Good odor management • Limited skilled labor required • Low operating costs • Low energy consumption	• Low cake solids concentration and capture rate • Outer casing requires high maintenance • Few proven installations • Moderate footprint • Higher recycle rate
WET System	• Good odor management • Limited skilled labor required • Low operating costs • Low energy consumption • Small footprint • Continuous feed • High cake solid concentration • High solids capture rate	• Few proven installations • New technology

	• Pathogen elimination • High capture of nutrients	

Figure 14. General Evaluation

The WET system offers a great combination of the advantages present in the other solutions, including lower energy consumption and higher solids capture. Furthermore, the WET system has additional benefits related to pathogen and nutrient reduction.

Disadvantages related to few installations and the uncertainty related to new technologies should be addressed through intensive testing and onsite demonstrations.

Performance & Health. Criteria amongst chosen competitors for efficiency, physical and health standards, where red is worst and green is best.

Selection Criteria		Belt Filter Press	Centrifuge	Rotary Screw Press	WET System
Performance	**% Discharge Solids**	20	25	17-20	30
	Solids Capture Efficiency	>98%	95%	90-96%	>99%
	Skilled Operator Req				

		High	Low	Low	Low
	Maintenance	Medium	High	Low	Low
	Reliability	High	High	Low	High
Physical	**Footprint (sq.ft)**	406.6	43	228	92
Health	**Noise Potential**	Low	Medium	Low	Low
	Odor Potential	High	Low	Low	Low
	Operator Exposure	High	Low	Low	Low

Figure 15. Performance Health. Adapted from Brown and Caldwell Consultants. City of Sunnyvale: Sunnyvale Strategic Infrastructure Plan for the WPCP, Dewatering Alternatives. 2009[18]

The WET system represents by far the best performance options and together with the Rotary Screw Press represents the least health hazards to operators. Its footprint and required space requirements is comparable to the Centrifuge system. Overall, the WET system provides a competitive advantage in these areas.

Cost/Benefit Analysis. For the cost/benefit analysis (below) we used data and quotes from the Sunnyvale Wastewater Treatment Plant (WTP) evaluation of alternatives made in 2009. The

Sunnyvale WTP estimates 25,364 lb/day of total bio-solids to dewater and 101,376 gal/day. Furthermore, the city spends $0.2/kwh. Polymer costs estimated at $2.25/lb polymer and the existing contract for bio-solids handling and disposal is set at $44.69/wet ton.

Sunnyvale City received three quotes as follows[16]:

	Manufacturer	**Model No.**	**Power Req (hp)**	**Total Cost**
Belt Filter Press	BDP Industries	2.0 meter Model 3DP	35	$1,195,500
Centrifuge	Westfalia Separator	UCD536	100	$1,588,800
Rotary Screw Press	FKC Co.	BHX 1250X7000	7.5	$1,510,740

To enable a proper assessment of the quotes, it is important to add other components, such as polymer/chemical needs, energy consumption costs, maintenance, real estate footprint, handling and disposal, alternate equipment and engineering. Below is a chart comparing these technologies to the WET System for the same scenario.

	Belt Filter Press	**Centrifuge**	**Rotary Screw Press**	**WET System (Est)**
Installed Dewatering Equipment Cost	$1,195,500	$1,588,800	$1,510,740	$950,000
Polymer Mixers/ Flocculation Tanks	$18,404	NA	$40,160	NA
Polymer Mix Feed Units	$69,320	$46,380	$69,320	$38,000
Feed Pump to Dewatering System	$138,090	$92,060	$138,090	$92,060
Cake Handling System	$228,200	$228,200	$228,200	$228,200
Dewatering Building To House Equipment ($250/ft2)	$5,841,000	$1,026,000	$2,702,700	$2,193,023
Engineering (Est. 15% of cost)	$1,123,577	$447,216	$703,382	525,192
TOTAL Capital Cost	**$8,614,000**	**$3,429,000**	**$5,393,000**	**$4,026,475**
Maintenance ($/yr)	$80,000	$80,000	$40,000	$30,000
Energy Consumption	$32,585	$62,067	$6,983	6,000

($/yr.)				
Polymer Costs ($/yr.)	$104,151	$312,453	$104,151	82,000
Est. Contract Bio solids Handling and Disposal ($/yr.)	$1,013,648	$786,094	$982,618	775,000
TOTAL Annual O&M Cost	**$1,230,000**	**$1,241,000**	**$1,134,000**	**$893,000**

A 10-year projection using the above equipment and maintenance costs, along with 2% p.a. inflation rate and a 5% p.a. interest rate generate the following results:

	Belt Filter Press	**Centrifuge**	**Rotary Screw Press**	**WET System**
Maintenance	$684,469	$684,469	$342,235	$256,675
Energy Consumption	$278,795	$531,039	$59,742	$51,332
Polymer Cost	$891,102	$2,673,305	$891,102	$701,581
Contract Bio solids Handling and Disposal Cost	$8,672,636	$6,725,718	$8,407,147	$6,630,811

TOTAL O&M Life Cycle Cost	$10,527,000	$10,615,000	$9,700,000	$7,640,399
Total Capital Cost	$8,614,000	$3,429,000	$5,393,000	$4,026,475
TOTAL Project Cost	**$19,141,000**	**$14,044,000**	**$15,093,000**	**$11,666,874**

Financially, the WET System remains the better option. Primary drivers are the low energy and polymer consumption, lower maintenance, coupled with a high solid extraction rate. Due to the lower energy consumption, reduced transportation of solids and lower polymer consumption, the WET System has a lower carbon footprint and is the most viable environmental solution amongst the analyzed options.

It is noteworthy that the above comparison does not take into consideration nutrient removal or pathogens elimination. Financial viability may further improve when incorporating these variables into the mix.

Competitive Advantages

Primary competitive advantages of the WET system identified to date are:

1. The WET system can replace part or all of the primary and secondary services. The Primary treatment can be done without the addition of land and in fact would produce excess land; at a capital cost that is approximately 60% less than any competitive system in the market, with at least a 50%+ reduction in energy requirement, a 1/6th reduction in the volume of residual solids. Energy consumption efficiency is a growing concern and

key element in choosing amongst competition. According to the California Energy Commission (CEC), water-related energy use surpasses 20% of the total electricity consumed in the State.

2. Replace existing solids separation and sludge dewatering equipment (filter press and or centrifuge). The replacement will produce approximately a 30% savings in capital cost, at least a 50% savings in energy cost, reduce polymer usage by approximately 25%t and produce residual solids that is 1/6th more dry matter.
3. Install at the point of water discharge for the purpose of removing phosphorous and other nutrients and thus allowing the facility to meet discharge regulations. This type of addition is very cost effective and will produce a valuable by-product in the form of phosphorous and other nutrients that will enhance the value of solids residuals as a fertilizer.
4. Installation is possible at a satellite location, such as a primary lift station or at the location of a major waste water producer, for the purpose of reducing volume being transferred and treated at the central treatment facility
5. Allows the installation of an Infrared Dryer to dry the dewatered solids from 30% dry matter to 90% dry matter. This installation will easily pay for itself in reduced transportation and disposal costs. As an example 2,200 pounds of liquid sludge (3% dry solids) results in 220 pounds of dewatered sludge (30% solids) and after further drying, in 68 pounds in dried sludge (>90% dry solids). A municipality with a population of 500,000 would need more than 30 large silo trucks to transport liquid sludge (3% dry solids), but only one truck to transport fully treated sludge (>90% dry solids) per day[19].

6. When compared to other systems, the WET System can further eliminate phosphates in excess of 90% and eliminate over 90% of pathogens without the need for additional equipment or processes.

Financial Viability

A very reputable U.S. engineering firm will be responsible for manufacturing. Furthermore, efforts are under way to improve automated capabilities for the system.

The EFR is the highest cost component of the WET System. For confidentiality purposes, the detailed Capital Investment Cost for the system is not presented. However, based on the above pricing, the gross margins for the company will be over 300%, making it a very profitable solution.

Considering that the initial investment to launch the WET System technology in the market involves current and future cash needs of an estimated $1.5 million for the first two years, a total of 5 systems would need to be sold during the same period to achieve profitability. In consideration that over a dozen municipalities have shown interest in the solution, this situation is likely to occur.

Business Model & Opportunity

The WET System presents strong competitive advantages when compared to Belt Filter Presses, Centrifuge Systems and Rotary Screw Presses. The system provides a cost effective system to address the needs of small community wastewater treatment needs. Nonetheless, these same municipalities are facing diminished federal funding and local budgets. Even though the sale of the equipment provides for a very profitable margin, the question remains on how the municipality will be able to pay for the investment.

As an alternative opportunity, the proposed business model involves the creation of Public Private Partnerships (PPP). The USEPA recommends PPP's as an alternate financing option through which the private sector may finance public wastewater treatment needs[20]. One approach to a PPP is a Build Operate and Transfer (BOT) option, whereby the private company designs and constructs the system (Build), installs and manages it (Operates) and transfers ownership after a time period (Transfer). During this time, the private company may charge service fees resulting from savings generated, performance, or both. An as example, Tampa Bay Water (TBW), selected Veolia Water North America to build a new surface water treatment plant under a BOT, enabling TBW to sign with one single supplier and operate it under a long term agreement[21].

Similar to a BOT, is a Lease Purchase Option. Defined as an installment-purchase contract, whereby the private company finances and builds the wastewater treatment facility and then is leased to the public agency, which accrues ownership over time[20].

Due to greater solid capture rates and dewatering efficiency, the WET System generates lower sludge handling and disposal costs (primarily transportation). The savings generated from the use of the WET System can be destined to amortizing the cost of the system. Under this scenario, the public agency will not have to make any upfront investment and its current budget would not be impacted, since all payments will come from cost savings generated by the program.

The ability for the WET system to further capture and sequester nutrients, along with eliminating most of the pathogens, also provides greater savings in equipment and chemicals required.

Overall, the system can be positioned as part of a sustainable solution to wastewater treatment, which pays for itself on cost savings.

By offering a 10-year BOT and/or lease option, the system can be integrated as part of a solution, which includes drying, post-waste treatment and the sale of polymers as a package, thus increasing revenue potential.

The largest hurdle identified is the need for financing options. Considering that the risk revolves around both the technology performance, and the municipality credit risk (ability to pay), it is important to partner up with a reputable engineering, procurement, and contracting (EPC) company. Several options are being evaluated based on experience, financial strength and the ability to issue performance bonds.

Conventional financing options are most likely out of the question given the deteriorating credit risk of the majority of municipalities. Given the high margins, it is probable that a partnership with an investment fund would be most attractive. This type of financing is expensive, but readily available in the market.

For a successful market launch of the WET Technology, a Business Strategic Plan will need to be completed. The Business Strategic Plan will include the mission, vision and values statements, organization design, communication plan (including sales and marketing), and budgets.

Business Expansion Opportunities

There are several by-products derived from the wastewater treatment process, including energy extracted from anaerobic digestion, biodegradable plastics, phosphorous and nitrogen recovery, amongst others.

If properly dried and treated, the sludge can be converted to biogas or syngas through the use of anaerobic digestion. This application is profitable in regions where the KWHr is over 14 cents. Such is the case of Mexico and Chile, where the price per KWHr from renewable sources ranges around 18 cents per KWHr.

Phosphorous recovery from wastewater is a growing opportunity. Phosphorous is a finite and rapidly declining nutrient globally. As a result, the market price for Phosphorous has increased six-fold over recent years. Global resources are projected to last 90 years, while U.S, inventories are expected to deplete within 40 years. Phosphorous can be removed and reclaimed from wastewater processing and poses an opportunity for sludge management and alternate income.

Nitrogen requires a large amount of energy to fix it into a form that can be chemically utilized in industrial and agricultural applications. The nitrogen within wastewater is fixed and represents a large energy savings, along with a lower carbon footprint.

In all cases mentioned, the drying process is critical in achieving a solid mass, which can be further treated or processed.

A further expansion opportunity lies in the oil and gas industry, for hydro fracking operations and within confined animal herd production facilities. Because of the high efficiency in solid separation, the system is a potential solution to these industries where an energy efficient and environmentally friendly solution is required.

CONCLUSIONS

Existing wastewater treatment market conditions are ripe for the introduction of new onsite wastewater treatment technologies. These conditions include:

- *Pressure from existing and new regulatory requirements*. Water quality concerns have prompted stricter regulatory initiatives and enforcement on wastewater treatment facilities.
- *Increased environmental awareness*. Growing concern amongst the public in surface and ground water quality and the effects of contamination from wastewater discharge.
- *Growing capacity requirements*. Increasing population, specially in small to medium municipalities and suburban locations.
- *Storm surge management*. Storm frequency and intensity due to climate change over burden existing infrastructure and add complexity to storm water and sewage separation.
- *The need for infrastructure adaptability to new technological solutions*. Centralized wastewater treatment systems are capital intensive and have a rigid infrastructure. On site systems, if well designed, can have greater flexibility in incorporating future adaptations.
- *Investment and budgetary constraints at a municipal and state level*. Municipal and state governments in charge of wastewater treatment infrastructure have a

deteriorating financial condition, enhancing an already existing gap in wastewater treatment infrastructure investment.

- *Decaying Infrastructure.* Wastewater treatment infrastructure is outdated and in need for a major overhaul. Existing infrastructure is a contributor of heavy metal contamination in water discharge.

This present situation represents an opportunity for new technologies that offer a solution to prevailing challenges.

The highest cost for on-site wastewater treatment facilities relates to sludge separation, treatment and disposal. Dewatering systems are the main cost driver of these processes. Primary dewatering technologies available in the market today include centrifuges, filter belt presses and rotary screw presses, amongst others. In general, these systems are not very efficient, are capital intensive, or are energy-inefficient.

In order to validate and evaluate the launch of a new onsite wastewater treatment technology known as the WET System, a comprehensive analysis was performed to compare the system with other popular solutions in the market. Results show that the WET System presents clear technical out performance, improved environmental and health benefits and greater cost-benefit ratios.

Third party lab testing performed on the influent and effluent treated by the WET System validated constituent levels achieved for regulatory purposes and efficiency performance of the system used in the comparison with other similar solutions. Furthermore, analytical evaluations proved the WET System has strong competitive advantages when compared to the most popular dewatering systems in the market today. These advantages include:

- *Higher total solids separation rates*. With over 99% separation rate and a 30% solid discharge rate, the WET System proved to be a better solution to improving efficiency in this critical cost driver area.
- *Additional benefit of over 90% phosphate removal*. This benefit is critical to meeting regulatory guidelines and represents a direct capital savings over other solutions, which require and depend on additional equipment or processes.
- *Higher energy efficiency*. Because the WET System does not need pumps, belts and pressure filters, energy consumption proved to be the lowest amongst systems compared.
- *Pathogen removal*. Due to the electrical charge applied, the system further presents the benefit of over 90% of all pathogens removed.
- *Lower polymer / chemicals consumption*. Due to the trade secret process of polymer application, the amount and cost associated with polymers or chemical applications is reduced.
- *Efficient CAPEX cost*. The WET System proved to be up to 50% cheaper than other systems, such as Belt Filter Presses. When other characteristics are considered, such as maintenance, polymers, energy, etc, the system has a higher return on investment.
- *Adaptability*. The WET system can be easily adaptable to existing wastewater treatment infrastructure and can be used in primary or secondary treatment.

Overall, the WET System proved to be the best alternative amongst solutions compared.

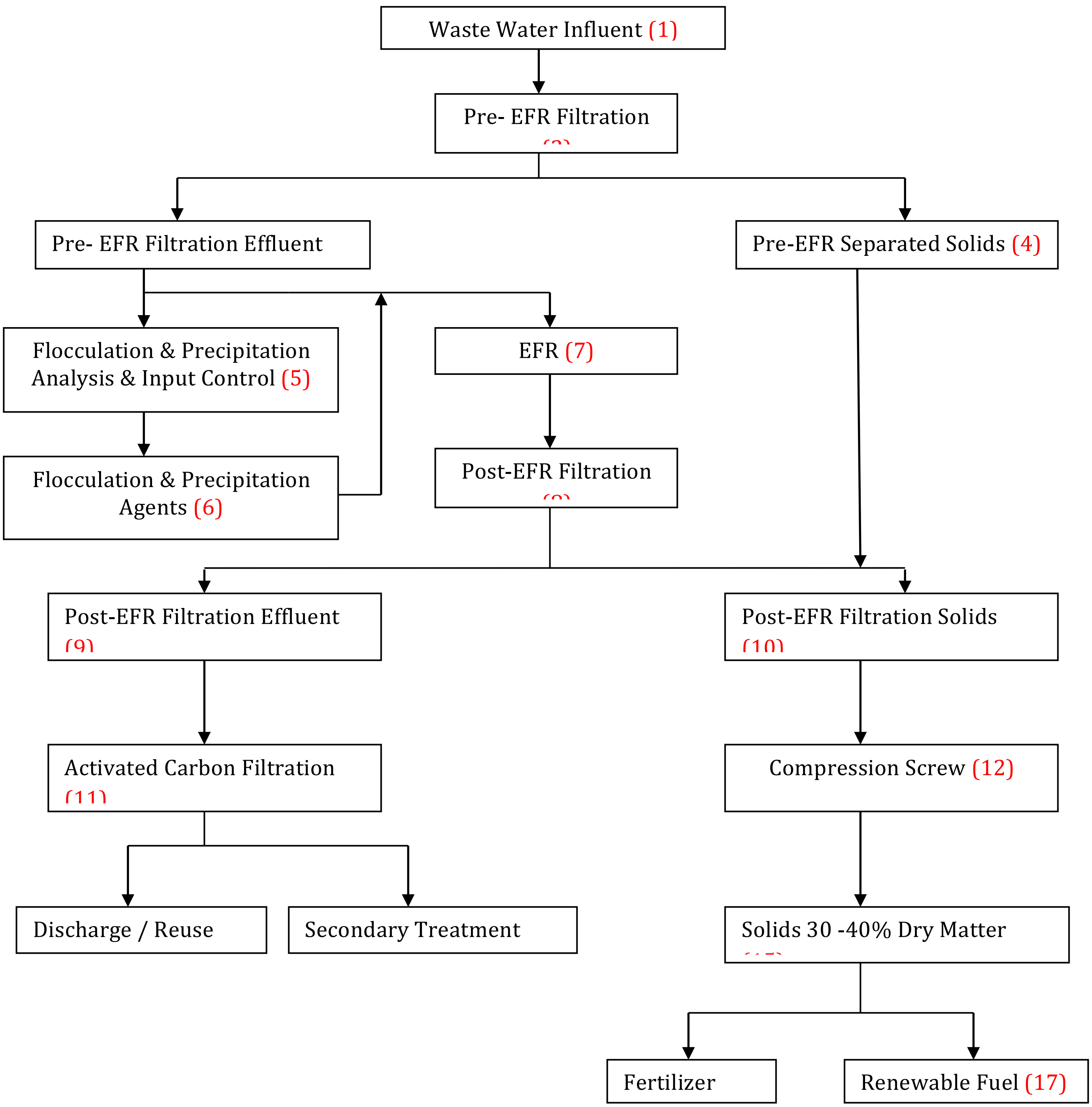
By incorporating a business model which offers alternative financing options to municipalities and state governments through the use of Public Private Partnerships and Build, Operate and Transfer 10 year term options, the technology becomes a very attractive option in the market.

Precautionary steps should be taken to further validate the third party testing under continuous wastewater flow in a municipal water treatment facility. Furthermore, being a new technology with only one unit built is a major weakness in the selling process and should be strengthen by developing a strong business strategic plan, along with partnering with a well known and experienced Engineering, Procurement and Construction (EPC) company. With these steps completed, I strongly recommend the launch of the WET System into the market.

APPENDIX

WET Municipal Waste Water Process Flow Diagram

Please see page 2 for explanation of each step in the flow diagram



See following page for notes

(1) **Waste Water Influent**: The proposed water to be treated – can consist of municipal waste water. industrial waste water, and agricultural waste water

(2) **Pre-Electrostatic Flocculating Reactor (EFR) Filtration:** This device is used to remove as much of the suspended solids as possible prior to the effluent feeding into the EFR. With municipal waste water this could remove approximately 40-50% of the suspend solids without the use of flocculating polymers or chemicals

(3) **Pre-EFR Effluent**: The liquid effluent from the pre-EFR filter of which a very small sampling flows Compression Screw (12)into the Flocculation & Precipitation Analysis and Input Control device with the remainder flowing into the EFR

(4) **Pre-EFR Separated Solids**: These are the solids separated by the Pre-EFR filter that will eventually merge with the solids from the Post-EFR Filter before flowing into the Compression Screw ((12)

(5) **Flocculation & Precipitation Analysis and Input Control Device:** This device analyses the influent from the Pre-EFR Filter (2) to determine the level of TSS, Phosphorous, Nitrogen, pH and water temperature (analysis happens every three minutes) that then signals the appropriate pumps for the various polymers and precipitant (6) to increase or decrease the flow so as to meet the proper dosing rate that will result in the removal of the various polluting constituents

(6) **Flocculation and Precipitation Agents:** Each agent, as prescribed by the Flocculation & Precipitation Analysis and Input Control Device (5) is pumped into the EFR.

(7) **EFR:** Within the proprietary and patent pending EFR, at prescribed placement electrostatic charge is combined with the flocculating and precipitating constituents

to rapidly interact with the TSS, Phosphorous and Nitrogen to cause their rapid flocculation into larger, combined particles that are then easily separated from the water by the Post-EFR Filtration device.

(8) **Post-EFR Filtration**: This device has holes through which only the water and TDS (total dissolved solids) will flow through leaving the flocculated solids to be removed and delivered to the Compression Screw (12). The liquid effluent is pumped to the Activated Carbon Filter

(9) **Post EFR Filtration Effluent**: This water is free of approximately 99.7% of TSS, 80%+ of Phosphorous, and 12%+ of Nitrogen.

(10) **Post EFR Filtration Solids**: The solids contain all of the above TSS, Phosphorous, and nitrogen but they also include a small amount of free water. These solids will be conveyed into the Compression Screw (12) to remove the free water thereby producing solids with approximately 35% dry matter.

(11) **The Activated Carbon Filter**: This Filter will remove part of the small amount of TSS that could be remaining in the effluent and it will also remove most of the odor from the effluent.

(12) **The Compression Screw**: The Compression Screw compresses the solids thereby squeezing out the remaining free water.

(13) **Discharge or Reuse Water**: Following the Activated Carbon Filter the water, in some regions will be acceptable for discharge to a ground water source or it could be reused. If, it will not meet discharge regulations then it will be pumped to Secondary Treatment (14).

(14) **Secondary Treatment**: With Secondary treatment the effluent will be subjected to additional treatment that could include 1 or more additional methods of treatment including: Anion / Cation Resins, Ozonation, Advanced Oxidation, and UV light treatment. The extent of treatment will be determined by its end use.

(15) **The Solids**: The solids can then be used as a feedstock for fertilizer (16) or renewable energy (17)

Prairie Agricultural Machinery Institute
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Date Received: 25-JUL-12
Report Date: 01-AUG-12 15:25 (MT)
Version: FINAL

Client Phone: 204-239-5445

Certificate of Analysis

Lab Work Order #: L1184053

Project P.O. #: 30914
Job Reference: Z1611D
C of C Numbers:
Legal Site Desc:

Paul Nicolas

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ALS ENVIRONMENTAL ANALYTICAL REPORT

Sample Details/Parameters	Result	Qualifier*	D.L.	Units	Extracted	Analyzed	Batch
L1184053-1 BDT - I21							
Sampled By: CLIENT on 25-JUL-12							
Matrix: LIQUID MANURE							
Liquid Manure Package ML2							
Ammonium - N in Liquid Manure - as rec'd							
Ammonia, Total (as N)	13.5		1.0	lb/1000gal	31-JUL-12	31-JUL-12	R2408476
Total N in Liquid Manure -as rec'd							
Total Nitrogen	25.2		1.0	lb/1000gal	31-JUL-12	31-JUL-12	R2409234
Total P,K,S & Na -Liquid manure-as rec'd							
Phosphorus (P)	3.1		1.0	lb/1000gal	30-JUL-12	30-JUL-12	R2408064
Potassium (K)	9.4		1.0	lb/1000gal	30-JUL-12	30-JUL-12	R2408064
Sulfur (S)	1.7		1.0	lb/1000gal	30-JUL-12	30-JUL-12	R2408064
Sodium (Na)	4.9		1.0	lb/1000gal	30-JUL-12	30-JUL-12	R2408064
Total Solids in Liquid Manure							
Total Solids	1.03		0.10	%	31-JUL-12	31-JUL-12	R2408170
% Moisture	99.0		0.10	%	31-JUL-12	31-JUL-12	R2408170
pH and Conductitivity of Liquid Manure							
pH	6.54		0.10	pH	31-JUL-12	31-JUL-12	R2408499
Conductivity (EC)	10400		10	uS/cm	31-JUL-12	31-JUL-12	R2408499
L1184053-2 BDT - I22							
Sampled By: CLIENT on 25-JUL-12							
Matrix: LIQUID MANURE							
Liquid Manure Package ML2							
Ammonium - N in Liquid Manure - as rec'd							
Ammonia, Total (as N)	13.8		1.0	lb/1000gal	31-JUL-12	31-JUL-12	R2408476
Total N in Liquid Manure -as rec'd							
Total Nitrogen	26.0		1.0	lb/1000gal	31-JUL-12	31-JUL-12	R2409234
Total P,K,S & Na -Liquid manure-as rec'd							
Phosphorus (P)	3.3		1.0	lb/1000gal	30-JUL-12	30-JUL-12	R2408064
Potassium (K)	9.5		1.0	lb/1000gal	30-JUL-12	30-JUL-12	R2408064
Sulfur (S)	1.7		1.0	lb/1000gal	30-JUL-12	30-JUL-12	R2408064
Sodium (Na)	4.9		1.0	lb/1000gal	30-JUL-12	30-JUL-12	R2408064
Total Solids in Liquid Manure							
Total Solids	1.14		0.10	%	31-JUL-12	31-JUL-12	R2408170
% Moisture	98.9		0.10	%	31-JUL-12	31-JUL-12	R2408170
pH and Conductitivity of Liquid Manure							
pH	6.50		0.10	pH	31-JUL-12	31-JUL-12	R2408499
Conductivity (EC)	10600		10	uS/cm	31-JUL-12	31-JUL-12	R2408499
L1184053-3 BDT - I23							
Sampled By: CLIENT on 25-JUL-12							
Matrix: LIQUID MANURE							
Liquid Manure Package ML2							
Ammonium - N in Liquid Manure - as rec'd							
Ammonia, Total (as N)	13.3		1.0	lb/1000gal	31-JUL-12	31-JUL-12	R2408476
Total N in Liquid Manure -as rec'd							
Total Nitrogen	20.3		1.0	lb/1000gal	31-JUL-12	31-JUL-12	R2409234
Total P,K,S & Na -Liquid manure-as rec'd							
Phosphorus (P)	3.4		1.0	lb/1000gal	30-JUL-12	30-JUL-12	R2408064
Potassium (K)	9.6		1.0	lb/1000gal	30-JUL-12	30-JUL-12	R2408064
Sulfur (S)	1.7		1.0	lb/1000gal	30-JUL-12	30-JUL-12	R2408064
Sodium (Na)	4.9		1.0	lb/1000gal	30-JUL-12	30-JUL-12	R2408064
Total Solids in Liquid Manure							
Total Solids	1.05		0.10	%	31-JUL-12	31-JUL-12	R2408170

* Refer to Referenced Information for Qualifiers (if any) and Methodology.

ALS ENVIRONMENTAL ANALYTICAL REPORT

Sample Details/Parameters	Result	Qualifier*	D.L.	Units	Extracted	Analyzed	Batch
L1184053-3 BDT - I23							
Sampled By: CLIENT on 25-JUL-12							
Matrix: LIQUID MANURE							
Total Solids in Liquid Manure							
% Moisture	98.9		0.10	%	31-JUL-12	31-JUL-12	R2408170
pH and Conductitivity of Liquid Manure							
pH	8.83		0.10	pH	31-JUL-12	31-JUL-12	R2408499
Conductivity (EC)	10600		10	uS/cm	31-JUL-12	31-JUL-12	R2408499
L1184053-4 BDT - E21							
Sampled By: CLIENT on 25-JUL-12							
Matrix: LIQUID MANURE							
Liquid Manure Package ML2							
Ammonium - N in Liquid Manure - as rec'd							
Ammonia, Total (as N)	11.8		1.0	lb/1000gal	31-JUL-12	31-JUL-12	R2408476
Total N in Liquid Manure -as rec'd							
Total Nitrogen	20.6		1.0	lb/1000gal	31-JUL-12	31-JUL-12	R2409234
Total P,K,S & Na -Liquid manure-as rec'd							
Phosphorus (P)	<1.0		1.0	lb/1000gal	30-JUL-12	30-JUL-12	R2408064
Potassium (K)	8.6		1.0	lb/1000gal	30-JUL-12	30-JUL-12	R2408064
Sulfur (S)	1.4		1.0	lb/1000gal	30-JUL-12	30-JUL-12	R2408064
Sodium (Na)	11.5		1.0	lb/1000gal	30-JUL-12	30-JUL-12	R2408064
Total Solids in Liquid Manure							
Total Solids	1.06		0.10	%	31-JUL-12	31-JUL-12	R2408170
% Moisture	98.9		0.10	%	31-JUL-12	31-JUL-12	R2408170
pH and Conductitivity of Liquid Manure							
pH	8.75		0.10	pH	31-JUL-12	31-JUL-12	R2408499
Conductivity (EC)	10600		10	uS/cm	31-JUL-12	31-JUL-12	R2408499
L1184053-5 BDT - E22							
Sampled By: CLIENT on 25-JUL-12							
Matrix: LIQUID MANURE							
Liquid Manure Package ML2							
Ammonium - N in Liquid Manure - as rec'd							
Ammonia, Total (as N)	11.9		1.0	lb/1000gal	31-JUL-12	31-JUL-12	R2408476
Total N in Liquid Manure -as rec'd							
Total Nitrogen	26.2		1.0	lb/1000gal	31-JUL-12	31-JUL-12	R2409234
Total P,K,S & Na -Liquid manure-as rec'd							
Phosphorus (P)	<1.0		1.0	lb/1000gal	30-JUL-12	30-JUL-12	R2408064
Potassium (K)	8.9		1.0	lb/1000gal	30-JUL-12	30-JUL-12	R2408064
Sulfur (S)	1.4		1.0	lb/1000gal	30-JUL-12	30-JUL-12	R2408064
Sodium (Na)	12.4		1.0	lb/1000gal	30-JUL-12	30-JUL-12	R2408064
Total Solids in Liquid Manure							
Total Solids	1.20		0.10	%	31-JUL-12	31-JUL-12	R2408170
% Moisture	98.8		0.10	%	31-JUL-12	31-JUL-12	R2408170
pH and Conductitivity of Liquid Manure							
pH	8.85		0.10	pH	31-JUL-12	31-JUL-12	R2408499
Conductivity (EC)	10700		10	uS/cm	31-JUL-12	31-JUL-12	R2408499
L1184053-6 BDT - E23							
Sampled By: CLIENT on 25-JUL-12							
Matrix: LIQUID MANURE							
Liquid Manure Package ML2							
Ammonium - N in Liquid Manure - as rec'd							
Ammonia, Total (as N)	11.9		1.0	lb/1000gal	31-JUL-12	31-JUL-12	R2408476

* Refer to Referenced Information for Qualifiers (if any) and Methodology.

ALS ENVIRONMENTAL ANALYTICAL REPORT

Sample Details/Parameters	Result	Qualifier*	D.L.	Units	Extracted	Analyzed	Batch
L1184053-6 BDT - E23							
Sampled By: CLIENT on 25-JUL-12							
Matrix: LIQUID MANURE							
Total N in Liquid Manure -as rec'd							
Total Nitrogen	15.6		1.0	lb/1000gal	31-JUL-12	31-JUL-12	R2409234
Total P,K,S & Na -Liquid manure-as rec'd							
Phosphorus (P)	<1.0		1.0	lb/1000gal	30-JUL-12	30-JUL-12	R2408064
Potassium (K)	8.8		1.0	lb/1000gal	30-JUL-12	30-JUL-12	R2408064
Sulfur (S)	1.4		1.0	lb/1000gal	30-JUL-12	30-JUL-12	R2408064
Sodium (Na)	12.3		1.0	lb/1000gal	30-JUL-12	30-JUL-12	R2408064
Total Solids in Liquid Manure							
Total Solids	1.12		0.10	%	31-JUL-12	31-JUL-12	R2408170
% Moisture	98.9		0.10	%	31-JUL-12	31-JUL-12	R2408170
pH and Conductitivity of Liquid Manure							
pH	8.81		0.10	pH	31-JUL-12	31-JUL-12	R2408499
Conductivity (EC)	10700		10	uS/cm	31-JUL-12	31-JUL-12	R2408499
L1184053-7 BDT - S21							
Sampled By: CLIENT on 25-JUL-12							
Matrix: LIQUID MANURE							
Liquid Manure Package ML2							
Ammonium - N in Liquid Manure - as rec'd							
Ammonia, Total (as N)	19.6		1.0	lb/1000gal	31-JUL-12	31-JUL-12	R2408476
Total N in Liquid Manure -as rec'd							
Total Nitrogen	46.3		1.0	lb/1000gal	31-JUL-12	31-JUL-12	R2409234
Total P,K,S & Na -Liquid manure-as rec'd							
Phosphorus (P)	41.2		1.0	lb/1000gal	30-JUL-12	30-JUL-12	R2408064
Potassium (K)	11.3		1.0	lb/1000gal	30-JUL-12	30-JUL-12	R2408064
Sulfur (S)	5.6		1.0	lb/1000gal	30-JUL-12	30-JUL-12	R2408064
Sodium (Na)	12.7		1.0	lb/1000gal	30-JUL-12	30-JUL-12	R2408064
Total Solids in Liquid Manure							
Total Solids	9.32		0.10	%	31-JUL-12	31-JUL-12	R2408170
% Moisture	90.7		0.10	%	31-JUL-12	31-JUL-12	R2408170
pH and Conductitivity of Liquid Manure							
pH	8.27		0.10	pH	31-JUL-12	31-JUL-12	R2408499
Conductivity (EC)	8520		10	uS/cm	31-JUL-12	31-JUL-12	R2408499
L1184053-8 BDT - S22							
Sampled By: CLIENT on 25-JUL-12							
Matrix: LIQUID MANURE							
Liquid Manure Package ML2							
Ammonium - N in Liquid Manure - as rec'd							
Ammonia, Total (as N)	15.7		1.0	lb/1000gal	31-JUL-12	31-JUL-12	R2408476
Total N in Liquid Manure -as rec'd							
Total Nitrogen	29.2		1.0	lb/1000gal	31-JUL-12	31-JUL-12	R2409234
Total P,K,S & Na -Liquid manure-as rec'd							
Phosphorus (P)	19.9		1.0	lb/1000gal	30-JUL-12	30-JUL-12	R2408064
Potassium (K)	10.3		1.0	lb/1000gal	30-JUL-12	30-JUL-12	R2408064
Sulfur (S)	3.2		1.0	lb/1000gal	30-JUL-12	30-JUL-12	R2408064
Sodium (Na)	13.3		1.0	lb/1000gal	30-JUL-12	30-JUL-12	R2408064
Total Solids in Liquid Manure							
Total Solids	5.83		0.10	%	31-JUL-12	31-JUL-12	R2408170
% Moisture	94.2		0.10	%	31-JUL-12	31-JUL-12	R2408170
pH and Conductitivity of Liquid Manure							
pH	8.56		0.10	pH	31-JUL-12	31-JUL-12	R2408499

* Refer to Referenced Information for Qualifiers (if any) and Methodology.

ALS ENVIRONMENTAL ANALYTICAL REPORT

Sample Details/Parameters	Result	Qualifier*	D.L.	Units	Extracted	Analyzed	Batch
L1184053-8 BDT - S22							
Sampled By: CLIENT on 25-JUL-12							
Matrix: LIQUID MANURE							
pH and Conductitivity of Liquid Manure							
Conductivity (EC)	8830		10	uS/cm	31-JUL-12	31-JUL-12	R2408499
L1184053-9 BDT - S23							
Sampled By: CLIENT on 25-JUL-12							
Matrix: LIQUID MANURE							
Liquid Manure Package ML2							
Ammonium - N in Liquid Manure - as rec'd							
Ammonia, Total (as N)	15.9		1.0	lb/1000gal	31-JUL-12	31-JUL-12	R2408476
Total N in Liquid Manure -as rec'd							
Total Nitrogen	30.2		1.0	lb/1000gal	31-JUL-12	31-JUL-12	R2409234
Total P,K,S & Na -Liquid manure-as rec'd							
Phosphorus (P)	20.7		1.0	lb/1000gal	30-JUL-12	30-JUL-12	R2408064
Potassium (K)	10.2		1.0	lb/1000gal	30-JUL-12	30-JUL-12	R2408064
Sulfur (S)	3.3		1.0	lb/1000gal	30-JUL-12	30-JUL-12	R2408064
Sodium (Na)	13.1		1.0	lb/1000gal	30-JUL-12	30-JUL-12	R2408064
Total Solids in Liquid Manure							
Total Solids	5.86		0.10	%	31-JUL-12	31-JUL-12	R2408170
% Moisture	94.1		0.10	%	31-JUL-12	31-JUL-12	R2408170
pH and Conductitivity of Liquid Manure							
pH	8.53		0.10	pH	31-JUL-12	31-JUL-12	R2408499
Conductivity (EC)	8940		10	uS/cm	31-JUL-12	31-JUL-12	R2408499

* Refer to Referenced Information for Qualifiers (if any) and Methodology.

Reference Information

Test Method References:

ALS Test Code	Matrix	Test Description	Method Reference**
N-TOT-LECO-AGL-SK	Manure	Total N in Liquid Manure -as rec'd	RMMA A3769 3.3

The sample is introduced into a quartz tube where it undergoes combustion at 900 C in the presence of oxygen.
Combustion gases are first carried through a catalyst bed in the bottom of the combustion tube, where oxidation is completed and then carried through a reducing agent (copper), where the nitrogen oxides are reduced to elemental nitrogen.
This mixture of N_2, CO_2, and H_2O is then passed through an absorber column containing magnesium perchlorate to remove water. N_2 and CO_2 gases are then separated in a gas chromatographic column and detected by thermal conductivity.

Reference:
Reference: Wolf, A., Watson, M. and Nancy Wolf. 2005. In: John Peters(ed.) Recommended Methods for Manure Analysis. Method 3.3

ALS Test Code	Matrix	Test Description	Method Reference**
NH4-AGL-SK	Manure	Ammonium - N in Liquid Manure - as rec'd	RMMA A3769 4.1

Ammonium is determined by steam distillation into boric acid followed by titration with standard acid.

Reference: Wolf, A., Watson, M. and Nancy Wolf. 2005. In: John Peters(ed.) Recommended Methods for Manure Analysis. Method 4.1

ALS Test Code	Matrix	Test Description	Method Reference**
NUTR-PART-AGL-SK	Manure	Total P,K,S & Na -Liquid manure-as rec'd	SSSA (1996) P.931
PH/EC-AGL-SK	Manure	pH and Conductitivity of Liquid Manure	RMMA A3769 7.5/8.5

The sample is analyzed directly using a calibrated pH/Conductivity meter.

Reference: Wolf, A., Watson, M. and Nancy Wolf. 2005. In: John Peters(ed.) Recommended Methods for Manure Analysis. Methods 7.5 and 8.5

ALS Test Code	Matrix	Test Description	Method Reference**
SOLIDS-TOT-AGL-SK	Manure	Total Solids in Liquid Manure	RMMA A3769 2

Sample is heated at 110C until dryness. Weight loss is determined gravimetrically.

Reference: Wolf, A., Watson, M. and Nancy Wolf. 2005. In: John Peters(ed.) Recommended Methods for Manure Analysis. Method 2

** ALS test methods may incorporate modifications from specified reference methods to improve performance.

The last two letters of the above test code(s) indicate the laboratory that performed analytical analysis for that test. Refer to the list below:

Laboratory Definition Code	Laboratory Location
SK	ALS ENVIRONMENTAL - SASKATOON, SASKATCHEWAN, CANADA

Chain of Custody Numbers:

GLOSSARY OF REPORT TERMS
Surrogates are compounds that are similar in behaviour to target analyte(s), but that do not normally occur in environmental samples. For applicable tests, surrogates are added to samples prior to analysis as a check on recovery. In reports that display the D.L. column, laboratory objectives for surrogates are listed there.
mg/kg - milligrams per kilogram based on dry weight of sample
mg/kg wwt - milligrams per kilogram based on wet weight of sample
mg/kg lwt - milligrams per kilogram based on lipid-adjusted weight
mg/L - unit of concentration based on volume, parts per million.
< - Less than.
D.L. - The reporting limit.
N/A - Result not available. Refer to qualifier code and definition for explanation.

Test results reported relate only to the samples as received by the laboratory.
UNLESS OTHERWISE STATED, ALL SAMPLES WERE RECEIVED IN ACCEPTABLE CONDITION.
Analytical results in unsigned test reports with the DRAFT watermark are subject to change, pending final QC review.

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