Report for 2004UT44B: Alternative Decentralized Wastewater Treatment Systems for Utah Conditions

Publications

- Dissertations:
    - Hurst, Jenny. 2006. The use and management of alternative systems in Utah. M.S. Thesis, Department of Civil and Environmental Engineering, Utah State University, Logan, Utah.

Report Follows

Alternative Decentralized Wastewater Treatment Systems for Utah Conditions

Executive Summary

Increasing development of rural areas in Utah is resulting in demands for more options for treatment and disposal of wastewater, especially in areas not suitable for the use of the conventional septic tank – drain field system. Many of these alternative options are more complex treatment and disposal systems that require increased expertise in site evaluation, design, installation, management, operation, and maintenance. Also small communities that are facing growth pressures that impact water supply resources may be interested in decentralized wastewater treatment technologies that provide for beneficial reuse of the wastewater.

In this project, we surveyed, reviewed, and evaluated existing information on various wastewater technologies that would be protective of public health and the environment under Utah climatic, geological, and regulatory conditions, while at the same time addressing the pressures of population growth. Based on the information collected, we developed guidance materials for state and local decision-makers on decentralized treatment technologies and appropriate management strategies for those technologies.

Specific tasks include:

1. Survey and collect existing information on alternative decentralized on-site and wastewater reuse treatment technologies.

2. Evaluate information with regards to applicability of technologies to Utah's climatic, geological, and regulatory conditions – consider life cycle costs, treatment efficiencies, management requirements, reliability and failure rates, and potential for beneficial reuse of wastewater.

3. Develop guidance materials for state and local decision-makers concerning wastewater treatment technologies and management programs that will be protective of public health and the environment.

Statement of Critical State Water Problem

Populations are increasing in many rural and small municipalities in Utah, with housing developments expanding into areas that can only be served by on-site wastewater systems. Freshwater supplies in Utah are limited and must be kept free from contamination from untreated or poorly treated wastewater discharges. The need for effective wastewater treatment in these areas is a major concern for public health and environmental quality managers.

In many of these areas, site conditions such as steep slopes, shallow ground water or bedrock and local soil characteristics such as clayey or sandy soils may preclude the use of the conventional septic tank/drain field system. To accommodate growth in these areas, the use of more complex

systems that will provide equal or better treatment than that provided by the conventional system may be an option that will allow continued development. However, for these systems to be effective, they must be appropriate for Utah climatic and geological conditions, design, management and operating requirements must be known, and construction guidelines must be thorough.

Also as the drought in the western United States continues, the use of wastewater treatment technologies for individual homes or businesses or small communities that result in groundwater recharge or provide for beneficial reuse of treated wastewater is another goal of wastewater treatment.

In Utah at the present time, the opportunities to use more complex on-site wastewater treatment systems for individual homes and businesses and for small groups of homes and businesses is limited by prescriptive regulations. However, as population and growth demands increase, the options available need to also increase, but with adequate regulatory oversight and management programs. To ensure that Utah will make wise decisions in the use of complex on-site wastewater systems and systems in the future, in this project we are developing a rational scientific framework to evaluate potential technology options that will provide effective treatment and beneficial reuse while being protective of Utah's public health and environmental resources. The use of wastewater treatment technologies for small communities and individual households that provide adequate treatment are essential to maintain the quality of Utah's surface and groundwater supplies while adding to the sustainability of the water supply resources.

Statement of Benefits

The use of more complex on-site and small community wastewater treatment systems will allow continued development in Utah's more rural areas. By providing thorough and complete information on the range of technologies available, state and local decision-makers will be able to make wise decisions in the selection of technologies and will be able to ensure that appropriate siting, design, construction, installation, and operating and maintenance guidelines are implemented.

Nature, Scope, and Objectives

In this project, we surveyed, reviewed and evaluated existing information on various wastewater technologies that would be protective of public health and the environment under Utah climatic, geological, and regulatory conditions, while at the same time addressing the pressures of population growth. Based on the information collected, we developed guidance materials for state and local decision-makers on decentralized treatment technologies and appropriate management strategies.

Specific tasks included:

1. Survey and collect existing information on alternative decentralized on-site and wastewater reuse treatment technologies.

2. Evaluate information with regards to applicability of technologies to Utah's climatic, geological, and regulatory conditions – consider life cycle costs, treatment efficiencies, management requirements, reliability and failure rates, and potential for beneficial reuse of wastewater.

3. Develop guidance materials for state and local decision-makers concerning wastewater treatment technologies and management programs that will be protective of public health and the environment.

Methods, Procedures, and Facilities

To accomplish the project tasks, during the first year of the project we surveyed literature sources concerning alternative decentralized systems. We extensively utilized the resources associated with the National Small Flows Clearinghouse at West Virginia University (NSFC, 2004). We also obtained information on various technologies from environmental and health state agencies, with a focus on those states with climatic and geological conditions similar to those in Utah. Equipment vendors of wastewater technologies were also surveyed.

To determine if technologies were appropriate for use in Utah, we defined those climatic and geological conditions that might affect the use of various technologies. We also developed a standardized format/matrix for evaluation of information, including:

- Treatment efficiencies anticipated in Utah's varying climatic and terrain conditions
    - Requirements to achieve predicted treatment efficiency (for example, residence time, loading rates, dose frequency, biomat effects, soil characteristics)
    - Dependence of technology on soil treatment
    - Dependence of technology on mechanical treatment

- Treatment efficiency expected through time

- Reliability of technology

- On-going monitoring, maintenance, and management requirements

- Projected life spans and failure rates of technologies

- Potential for:
    - Containment or removal of pathogens
    - Removal of nutrients (nitrogen and phosphorus)

- Life cycle costs
    - Site evaluation
    - Design
    - Installation and construction

- Operation, monitoring and maintenance
- Repair and replacement

- Beneficial reuse and groundwater recharge potential

Principal Findings

The alternative treatment systems that were selected for investigation as being promising for use in Utah included intermittent sand filters, peat filters, recirculating sand filters, textile filters, constructed wetlands, and aerobic treatment units. Drip irrigation was investigated as an alternative disposal technology.

Summaries of information on the technologies are presented in Tables 1 - 7. Additional information on these technologies and references for the information presented in the tables can be found on the project web site: [http://www.engineering.usu.edu/uwrl/training/onsitesystems/].

Table 1. Intermittent sand filters

	Intermittent Sand Filter
Residence time	Need finer media than in recirculating sand filters for longer residence time and greater contact with surfaces (USEPA, 2002)
Loading rates	The higher the loading rate, the more quickly the bed will clog (Venhuizen, 1998). 40.7 L/m2/d (Sievers, 1998) 0.8-5 gpd/ft^2 depending on if you want a high or a low rate (Gustafson et al., 2002d; Loudon et al., 2005; USEPA, 2002; Washington, 2000) 1.2 gpd/ft2 is in the rule, but it has been found to be too high for long term service (Washington, 2000). 0.05-0.1 gal/orifice (Loudon et al., 2005)
Organic loading rates	5 lb BOD_5/1000 ft^2-d (USEPA, 2002)
Dose Frequency	On-demand dosing or time dosed (which is more common) (USEPA, 2002) 4-24 doses/day (Ball, 1998; Hoover and Hampton, 1997; Loudon et al., 2005; USEPA, 2002; Washington, 2000).
Biomat effects	Effluent water quality improves as the biological maturity is increased with age (Vanlandigham and Gross, 1998)
Soil Characteristics	Can be built where the following are prevalent: Shallow soils, Very loose or very tight soils, and Fractured soils (Weaver et al., 1998)
Climate	High-rate sand filters are more common in warmer climates because they can be left open or one can easily remove the lid (Gustafson et al., 2002d) Cold weather not a problem. Cold weather design includes insulated tank lids and piping systems that drain between cycles (Norlin, 2005)

Table 1. (continued)

Credit	Must be 20 inches from the surface of the ground to a high water table or slower permeable soil conditions (BF Engineering, 2005); Must be 26-32 inches from a high permeable material or fractured rock (BF Engineering, 2005)
Dependence of technology on soil treatment	
Dependence of technology on mechanical treatment	Gravity fed system: Free access (Flows by gravity over the surface until it infiltrates, Pumps large quantity doses,Often produces odors, Biomat must be broken up periodically) Buried Gravity flow (Gravity flow from septic tank, Not dosed, Rests only between water use episodes, Lacks control and uniformity,More prone to clog up than pressure dosed systems) Pressure Dosed: Pressure distribution system (Uniform application, Longer time before clogging, Orifice spacing can help optimized the uniformity, Covered with pea stone or coarse stone layer instead of sod (for improved aeration), Pumps are not operated at times when there is no flow) (Loudon et al., 2005; Norlin, 2005)
Treatment efficiency expected through time	
Reliability of technology	
On-going monitoring, maintenance, and management requirements	Filters with high loading rates need regular cleaning (2-3 months) (Gustafson et al., 2002d) Inspect all components and effluent, clean, and repair when needed (Gustafson et al., 2002d) Lab analysis of the effluent may be necessary (Gustafson et al., 2002d)Flow meters and timers can be installed to be able to ensure the correct amount of the effluent is being pumped (Gustafson et al., 2002d)Monitoring ports can be installed to easily check for ponding (Washington, 2000) Maintenance visit per year (Loomis et al., 2004) Annual flushing, pump screen cleaning, and monitoring scum and sludge to optimize the pumping intervals (Norlin, 2005)
Projected life spans and failure rates of technolgy	Need to replace the sand in high-rate systems every 2-5 years (Gustafson et al., 2002d) Lower rate systems will operate longer than high-rate systems (Gustafson et al., 2002d) No operational complications reported in 4 years of operation (Loomis et al., 2004) 30 years or more when properly designed, operated, and constructed (Norlin, 2005)

Table 1. (continued)

Removal of pathogens and nutrients	Containment or removal of pathogens (disease-causing microorganisms) (Unsaturated flow enhances the inactivation of viruses (Vanlandigham and Gross, 1998) Virus Removal efficiencies 88.953% to 99.956% (Vanlandigham and Gross, 1998) 4 log reduction (Converse and Converse, 1998; Sievers, 1998) 3-4 log removal of Cryptosporidium oocysts (Logan et al., 2001) Better removal of fecal coliforms than recirculating filters due to finer media and lower hydraulic loading (USEPA, 2002)) Removal of nitrogen:TKN - 99.4% (Weaver et al., 1998), 34% (Converse and Converse, 1998), 15% (Loomis et al., 2004) NH3-N - 99.1% (Weaver et al., 1998), 98.7% (Sievers, 1998) Removal of Phosphorus: 40% (Loomis et al., 2004) Removal of BOD: 98.4% (Weaver et al., 1998), 98% (Converse and Converse, 1998), 99% (Sievers, 1998; Loomis et al., 2004)
Life cycle costs	Installation and construction:$11,000-$14,000 (which includes design, permitting, construction of ISF and drain field)$6,000-$8,000 (for just the materials)(Norlin, 2005); Operation, monitoring and maintenance: $150-$200/year, includes electricity and management visits (USEPA, 2002), $200-$500/ year, includes cleaning tanks, repairs, maintenance, and electricity (Gustafson et al., 2002d); $200/year for Inspection and Maintenance,$1.50/month for power (Norlin, 2005).
Beneficial reuse and groundwater recharge potential	

Table 2. Recirculating sand filters

	Recirculating Sand Filter
Residence time	
Loading rates	2-5 gpd/ft2 (USEPA, 2002), 3-5 gpd/ft2 (Loudon et al., 2005; USEPA, 2002), 1-20 gpd/ft2 (most widely used 4-5 gpd/ft2) (Christopherson et al., 2002)
Organic loading rates	≤ 5 lb BOD5/1000 ft2-d (USEPA, 2002)
Dose Frequency	2-3 times per hour (USEPA, 2002), 48-96 doses/day (Loudon et al., 2005), 24-48 doses/day (Hoover and Hampton, 1997), 48 times/day or more (USEPA, 2002)

Table 2. (continued)

Dose Volume	Dose volume = Design flow (gpd) x (Recirculation Ratio +1)/ Number of Doses per day (USEPA, 2002), 0.1-0.5 gal/orifice (Loudon et al., 2005), 1-2 gal/orifice (USEPA, 2002)
Recirculation Rate	3:1 or 5:1 (USEPA, 2002), Ratio determined by dividing the recirculated flow by the influent flow (Loudon et al., 2005), 3:1 to 7:1 (Loudon et al., 2005), 3:1 to 5:1 – 4:1 most common (Ball and Denn, 1997), 2:1 to 10:1 – 4:1 min rate for acceptable treatment (Christopherson et al., 2002), 3:1 to 5:1 (Austin, 2001; Norlin, 2005), 2:1 to 5:1 acceptable (Hoover and Hampton, 1997; Loudon et al., 2004)
Biomat effects	
Soil Characteristics	
Climate	High level of nitrogen removal was maintained during the colder months (Jan-April) in Wisconsin. (Venhuizen et al., 1998), Used a modified at-grade, low-pressure-dosed trench for the drain field to accommodate for the the cold weather in Wisconsin (Venhuizen et al., 1998), Coarser media causes less heat loss (Roy and Dube, 1994), Extreme cold temperature caused only minimal disruption to the treatment efficiencies. Only nitrification rates seemed to be affected. (Martinson et al., 2001), cold weather not a problem, cold weather design includes insulated tank lids and piping systems that drain between cycles (Norlin, 2005)
Credit	
Dependence of technology on soil treatment	No dependence on soil for treatment (Christopherson et al., 2002)
Dependence of technology on mechanical treatment	Pressure Distribution to provide uniformity (Loudon et al., 2005), Pumps are run continuously regardless of inflow, odor problems occur when the pump is not continuously running (Norlin, 2005)
Treatment efficiency expected through time	
Reliability of technology	

Table 2. (continued)

On-going monitoring, maintenance, and management requirements	Inspect flow meters, pump, recirculation tank, recirculation pump, distribution systems, media and effluent quality(Christopherson et al., 2002), Clean and repair when needed (Christopherson et al., 2002), Lab analysis may be necessary (Christopherson et al., 2002), Periodically rake and/or remove and replace the top few inches of sand (Austin, 2001), Annual flushing, pump screen cleaning, and monitoring scum and sludge to optimize the pumping intervals (Norlin, 2005), Screen cleaning will be needed more often than an ISF due to recirculation (Norlin, 2005)
Projected life spans and failure rates of technolgy	
Removal of pathogens and nutrients	Containment or removal of pathogens (disease-causing microorganisms): Fecal Coliform Removal - 90% (Christopherson et al., 2001), less than in an intermittent sand filter because the coarser media is not as effective at removing the pathogens (Christopherson et al., 2002), 2-3 log reduction (Austin, 2001), more than 99% (Venhuizen et al., 1998) Nitrogen: Total Nitrogen - 40% (Christopherson et al., 2001), 70-80% - if an anoxic reactor is used ahead of the recirculation tank (USEPA, 2002), 30-70% (Christopherson et al., 2002), 30-80% (Austin, 2001), 60-90% (Venhuizen et al., 1998), 20% when the influent total nitrogen concentrations are high such as at schools and restaurants (Richardson et al., 2004), 25-84% (residential, club/casino, and commercial) (Loudon et al., 2004). NH3-N - 70-90% (Nitrification) (Austin, 2001) Phosphorus: 25% (Christopherson et al., 2001), 10-30% (Christopherson et al., 2002) BOD – Effluent concentration: < 10 mg/L (Richardson et al., 2004)
Life cycle costs	Installation and construction: $6,000-$10,000 (Christopherson et al., 2001), $8,000-$11,000 (USEPA, 2002), $7,000 (Austin, 2001), $6,000-$8,000 (for just the materials) (Norlin, 2005) Operation, monitoring and maintenance:$200-$500 per year (Christopherson et al., 2001; Christopherson et al., 2002) Power for pumping - $90-$120 per year (USEPA, 2002),$5-$10/month (Norlin, 2005). Management - $150-$200 per year (USEPA, 2002), $20/month Repair and replacement:$5/month (Austin, 2001), 20-year NPW - $10,502.22 (Austin, 2001)
Beneficial reuse and groundwater recharge potential	Lower effluent nitrate concentrations allow the water, after disinfection, to be land applied, used in drip irrigation or directly to a surface water body (Louden et al., 2004)

Table 3. Peat filters

	Peat Filters
Residence time	36-48 hours (Bord Na Mona Products, 1999)
Loading rates	300 L/day/bedroom (Patterson, 2004); 1 gal/sq. ft./day (Gustafson et al., 2002b); 360-480 gpd (Lindbo, 2001); Loading rates are designed for a four bedroom home with loading to 450 gpd per unit. You can twin two units together for more. (Festa, 2004); No more than 4 bedrooms served by 1 peat filter (Ecoflo, 2004)
Dose Frequency	60 L pumped at a time (Patterson, 2004); 30-40 L per dosing (Premier Tech, 2003)
Biomat effects	
Soil Characteristics	Works well in highly permeable soils over light sandy clays and in soils with low cation exchange capacity (Patterson, 2004); Areas with:Compacted, cut, or filled soil, Shoreline areas, Shallow bedrock areas, Aquifer recharge areas, Wellhead protection areas (Gustafson et al., 2002b); Works with all soil types (Bord Na Mona Unlimited, 2004); If Group I or II soil, a level base percolation area is recommended (Bord Na Mona Products, 1999); If Group III or IV soil, piping the effluent to remote trenches is recommended (Bord Na Mona Products, 1999);The system will work in any soil that has a percolation rate and with drip irrigation it can work in moderate clay with proper sizing (Festa, 2004); Soil has to pass the perc test for a sand mound (Ecoflo, 2004)
Climate	Until 1993, confined to cool temperate climates with relatively long winters and mild summers (O'Driscoll, 1998); The effectiveness is not subject to significant seasonal variation with ambient air temperature fluctuations (Born Na Mona Products, 1999); All climates are acceptable. The system was tested from Maine to Florida with the same results (Festa, 2004); Approved for use in Alabama, Arizona, Georgia, Iowa, Massachusetts, Michigan, North Carolina, Ohio, Pennsylvania, South Carolina (Ecoflo, 2004)
Credit	30% reduction in adsorption area (Festa, 2004); 40% smaller adsorption area than for a sand mound (Ecoflo, 2004)
Dependence of technology on soil treatment	Soil can act as tertiary treatment or as a polishing, but is not required (Patterson, 2004); Since the peat filter is not 100% effective, soil is still needed as the final step (Lindbo, 2001)
Dependence of technology on mechanical treatment	Gravity flow: water may pond on top of the peat and compress it (Gustafson et al., 2002b); Pressurized distributions system (Patterson, 2004): applied evenly over the peat surface (Gustafson et al., 2002b)
Treatment efficiency expected through time	Performance after 10 years: Percent removal of BOD (96+), TSS (95+), NH_3-N (90+), Total Coliforms (99.9+) (Born Na Mona Products, 1999)

Table 3. (continued)

Reliability of technology	
On-going monitoring, maintenance, and management requirements	Add lime yearly to maintain P-sorption (Patterson, 2004); Low maintenance compared to other technologies (Patterson, 2004; O'Driscoll, 1998); Yearly to quarterly maintenance: Inspection of component, flow meter, and effluent (Gustafson et al., 2002b), De-sludge when needed (Bord Na Mona Unlimited, 2004), Make sure the systems are water tight to avoid infiltration (Lindbo, 2001); Experience has shown that after five years it is good to add two extra bags of loose peat and after ten years replace all the peat in the unit (Festa, 2004)
Projected life spans and failure rates of technology	10 year life span (saturates with phosphorus in about 7 years) (Patterson, 2004); 10-15 years (Gustafson et al., 2002b; Bord Na Mona Unlimited, 2004); Life span depends on homeowner use (Festa, 2004); 8 years (Ecoflo, 2004; Premier tech, 2003)
Removal of pathogens and nutrients	Containment or removal of pathogens (disease-causing microorganisms): 99.7% removal (Patterson, 2004), 93% removal (O'Driscoll, 1998), 99% removal (Bord Na Mona Unlimited, 2004; Lindbo, 2001; Premier Tech, 2003); Removal of Nitrogen: Ammmonia-N is oxidized to Nitrate-N in the aerobic zones of the peat: 275% increase in nitrate-N (Patterson, 2004), Ammonia nitrogen removal 96% (O'Driscoll, 1998), Nitrate-N is reduced in the anaerobic zones: 53.9% loss of nitrate-N (Patterson, 2004), Measured to be 4.5 mg/L (which is below the MCL of 10 mg/L) (Lindbo, 2001), 70-90% reduction of NH_3 levels (Bord Na Mona Product, 1999); Removal of Phosphorus: 74.6 % removal (Patterson, 2004), 58-96% reduction (Lindbo, 2001); Removal of BOD, 90% reduction (Lindbo, 2001), 95% reduction (Bord Na Mona Product, 1999; Premier Tech, 2003)
Life cycle costs	Site evaluation: Depends on contractor (Festa, 2004); Design: Depends on contractor (Festa, 2004); Installation and construction: Easier to install in small lots (Gustafson et al., 2002b), Cost is higher where peat is not commonly found (USEPA, 2001), Standard ST-650 Biofilter: $3,895.00 (USEPA, Sept. 2004),Total materials and installation $11,808 (USEPA, Oct. 2004); Operation, monitoring and maintenance: Low energy inputs (Patterson, 2004); Yearly costs: $200-$500/year (included pumping, repairs, maintenance, and electricity) (Gustavson et al., 2002), A maintenance contract is recommended at of fee of $150 to $175 yearly (Festa, 2004), Costs to maintain or operate have not been standardized (USEPA, 2001), Present Value total O&M $12,604 (USEPA, 2004a), Total over life of system $24,412 (USEPA, 2004a), Monthly averaged over the life of the system $150 (USEPA, 2004a); Repair and replacement: If the peat itself is replaced and added, the system as a whole should not ever need to be placed (Festa, 2004)

Table 3. (continued)

Beneficial reuse and groundwater recharge potential	

Table 4. Textile filters

	Textile Filter
Residence time	
Loading rates	15-30 gpd/ft2 (Bounds, 2002), single pass = 10 gpd/ft2 (design), 30 gpd/ft2 (peak) (Crites et al., 1998), recirclating = 30 gpd/ft2 (design), 45 gpd/ft2 (peak) (Crites et al., 1998)
Organic loading rates	
Dose Frequency	
Dose Volume	
Recirculation Rate	(Leverenz et al., 2004), can be single-pass application (Bounds, 2002)
Biomat effects	
Soil Characteristics	
Climate	
Footprint	20-40 square feet (OWDP, 2005)
Credit	
Dependence of technology on soil treatment	
Dependence of technology on mechanical treatment	Utilizes mechanical filtration to physically remove matter (Bounds, 2002)
Treatment efficiency expected through time	
Reliability of technology	Variations in performance of different textile filter units (Wren et al., 2004), Only filtrate is discharged, no matter if there are problems earlier in the treatment process. Therefore only high quality effluent will be discharged (Bounds, 2002)

Table 4. (continued)

On-going monitoring, maintenance, and management requirements	2 scheduled maintenance visits per year (Loomis et al, 2004), Easy access makes means cleaning and servicing can be done in less than an hour (Bounds, 2002), Low maintenance – Annual maintenance visit: Inspect - effluent clarity (turbidity, grease and oil films, foam, color, etc.), odor; Clean - pump filters, distribution piping (Bounds, 2002)
Projected life spans and failure rates of technolgy	No operational complications in four years (Loomis et al, 2004), Indefinite life (durable and biodegradation resistant polymers (Orenco, 2003)
Removal of pathogens and nutrients	Containment or removal of pathogens (disease-causing microorganisms): 3.1-3.4 log removal of fecal coliform (Loomis et al, 2004) Nitrogen: 44-47% (Loomis et al, 2004) Phosphorus: 0-2% (Loomis et al, 2004) BOD: 99% (Loomis et al, 2004), 80% (cBOD) within the first day of operation (Bounds, 2002), Treats to secondary standards (Orenco, 2004) TSS: 95-98% (Loomis et al, 2004), Treats to secondary standards (Orenco, 2004)
Life cycle costs	Installation and construction: Lightweight medium and smaller filter size reduce the cost to install (Bounds, 2002; OWDP, 2005), $4,500 (AX20 with telemetry, but without tank, installation and drainfield) (Orenco, 2004) Operation, monitoring and maintenance: Annual operating cost - $40/year (Loomis et al, 2004), Annual inspection and maintenance costs - $250/year (Loomis et al, 2004), Low energy consumption - 32-96 cents/month for energy (Bounds, 2002), $1-2/month (Orenco, 2004)
Beneficial reuse and groundwater recharge potential	Effluent quality is superior and may be ideal for water-reuse applications (Bounds, 2002), Effluent can be used for irrigation (Orenco, 2004)

Table 5. Constructed wetlands

	Constructed Wetlands
Residence time	2-3 days (Lenning et al., 2005; Lesikar, 2005), 10-13 days (Gustafson et al., 2002c), >2 days (White and Shirk, 1998)
Loading rates	
Organic loading rates	BOD: 1.6 g/m2-d (for 20 mg/L effluent) – 6 g/m2-d (for 30 mg/L effluent) (USEPA, 2006a), TSS: 20 g/m2-d (for 30 mg/L effluent)
Dose Frequency	
Dose Volume	
Recirculation Rate	
Biomat effects	
Soil Characteristics	Good for sites where soil conditions are limiting (White and Shirk, 1998)
Climate	In colder climates: liquid depth may be lowered (Lenning et al., 2005) (Lesikar, 2005), vegetation may appear to be dead in the winter (Lenning et al., 2005), can insulate with mulch, but may reduce oxygen transfer (Gustafson et al., 2002c), snow cover positive factor in avoiding freezing the system (Henneck et al., 2001), reed-sedge peat can be used as insulation (Henneck et al., 2001)
Footprint	
Credit	
Dependence of technology on soil treatment	
Dependence of technology on mechanical treatment	
Treatment efficiency expected through time	
Reliability of technology	
On-going monitoring, maintenance, and management requirements	Passive O&M (Lenning et al., 2005), Manage as a rock garden (Lenning et al., 2005) (Lesikar, 2005), May need to remove and/or replant vegetation (Lenning et al., 2005) (Gustafson et al., 2002c), Must keep pores open (Lenning et al., 2005), 3-4 times a year to inspect the systems and make any adjustments (USEPA, 2006a), Control the water level so that it remains below the media surface (Lesikar, 2005), 1-4 times a year (Gustafson et al., 2002c)

Table 5. (continued)

Projected life spans and failure rates of technolgy	
Removal of pathogens and nutrients	Containment or removal of pathogens (disease-causing microorganisms): Fecal coliform - 99-99.9% reduction (Lenning et al., 2005), less than 10,000cfu/100 mL (Gustafson et al., 2002c) Nitrogen: Insignificant removal (Lenning et al., 2005), small percentage due to anaerobic conditions (USEPA, 2006a) Phosphorus: small percentage due to anaerobic conditions (USEPA, 2006a) BOD: <30 mg/L (Lenning et al., 2005) (Gustafson et al., 2002c), 20-30 mg/L depending on the organic loading rate (USEPA, 2006a) TSS: <30 mg/L (Lenning et al., 2005; USEPA, 2006a), <25 mg/L (Gustafson et al., 2002c)
Life cycle costs	Installation and construction: $20/ft2 (USEPA, 2006a), $6650/400ft2 (excluding final disposal) (Henneck et al., 2001), $8325 (excluding labor and final disposal) (Henneck et al., 2001), For 53 m2 wetland: Materials = $3200, Installation = $2500 (White and Shirk, 1998) Operation, monitoring and maintenance: $100/year (USEPA, 2006a), $200-$500/year (includes pumping, repairs, maintenance, and electricity) (Gustafson et al., 2002c)
Beneficial reuse and groundwater recharge potential	

Table 6. Aerobic treatment units

	Aerobic Treatment Units
Residence time	
Loading rates	Rate that will pass through the device (Seabloom and Buchanan, 2005), must provide sufficient retention time (Seabloom and Buchanan, 2005), washouts can occur on laundry day (Seabloom and Buchanan, 2005), 250 gal/day (McCarthy et al., 2001), Based on home square footage and/or number of bedrooms (Lesikar, 2005), Can treat 500 gal/day (Lesikar, 2005)
Organic loading rates	More bugs than food (Seabloom and Buchanan, 2005)
Dose Frequency	Intermittent flow (Seabloom and Buchanan, 2005)
Dose Volume	
Recirculation Rate	
Biomat effects	
Soil Characteristics	Have been approved in areas with low soil permeability and shallow seasonal soil saturation (Wallace and Louden,, 2004), Compacted, cut or filled soil (Gustafson et al., 2002a), Poor soil (PATH, 2005)
Climate	Works better the warmer the temperature (USEPA, 2000b; McCarthy et al., 2001)
Footprint	
Credit	Soil depth and sizing reductions are permitted depending on the quality of effluent (Lenning et al., 2005), May allow for a reduction in drainfield size (USEPA, 2000b) (PATH, 2005), May be allowed in environmentally sensitive areas such as near lakes, in shallow bedrock areas, aquifer recharge areas, and well head protection areas (Gustafson et al., 2002a) (PATH, 2005), May allow reduction in 3-foot separation between system and limiting soil layer (Gustafson et al., 2002), High groundwater/bedrock (PATH, 2005)
Dependence of technology on soil treatment	Works well in shallow soils that will not provide enough depth for sufficient treatment (Seabloom and Buchanan, 2005)
Dependence of technology on mechanical treatment	Mechanical aeration (Seabloom and Buchanan, 2005), Sensors and controls that can detect failure (Seabloom and Buchanan, 2005)
Treatment efficiency expected through time	

Table 6. (continued)

Reliability of technology	Need backup for power source (Seabloom and Buchanan, 2005)
On-going monitoring, maintenance, and management requirements	Easy access for easy maintenance (Seabloom and Buchanan, 2005), Sludge in the ATU must be removed every 6-9 months (Seabloom and Buchanan, 2005), Operators should inspect 2 times a year (Seabloom and Buchanan, 2005), Inspections every 2 months (USEPA, 2000b), 12-48 man-hours/year (USEPA, 2000b), Maintenance checklist: Inspect alarm system, Check effluent for odor and color, Inspect clarifier, Inspect test port cover, Check and clean aerator filters, Inspect water level in clarifier, Check disposal field area (Wallace and Louden, 2004)
Projected life spans and failure rates of technolgy	Should last longer than a conventional system because it produces cleaner wastewater (Gustafson et al., 2002a)
Removal of pathogens and nutrients	Containment or removal of pathogens (disease-causing microorganisms): Properly operating ATU – 10,000 cfu/mL fecal coliform (Gustafson et al., 2002a), <104/100 ml (Lenning et al., 2005) Nitrogen: Not good at nitrogen removal (Seabloom and Buchanan, 2005), Reduces ammonia discharged (USEPA, 2000b), May release more nitrates (USEPA, 2000b), ammonia removal 0-31 % (Christopherson et al., 2004), TKN removal 0-23 % (Christopherson et al., 2004), Better nitrification in the summer (McCarthy et al., 2001) Phosphorus: Not good at phosphorus removal (Seabloom and Buchanan, 2005), 1-53 % removal (Christopherson et al., 2004) BOD: Properly operating ATU – 30 mg/L (Gustafson et al., 2002a), Works well in wastewater with high BOD loads due to too much organic load and/or wastewater from bakeries or dairies(Seabloom and Buchanan, 2005), 5-60 mg/l (Lenning et al., 2005), 70-90% removal (USEPA, 2000b), 20 mg/L (USEPA, 2000b) 42-92% removal (Christopherson et al., 2004) TSS: Properly operating ATU – 25 mg/L (Gustafson et al., 2002a), 5-60 mg/l (Lenning et al., 2005), 20 mg/L (USEPA, 2000b), 41-62 % removal (Christopherson et al., 2004)

Table 6. (continued)

Life cycle costs	Installation and construction: Packaging easy for easy installation (Seabloom and Buchanan, 2005), $2,500 - $7,000 + for the unit (Lenning et al., 2005), $2,500 - $9,000 installed (USEPA, 2000b), $5,700-$14,000 (Christopherson et al., 2004), $3,200-$5,000 (PATH, 2005) Operation, monitoring and maintenance: Maintenance contract - $350/year (USEPA, 2000b), $200-$500/year (Gustafson et al., 2002a), $50-75/year (PATH, 2005); Electrical cost - $4/month (PATH, 2005)
Beneficial reuse and groundwater recharge potential	Treat water well enough to be used with spray systems if it contains a disinfection component (Lesikar, 2005)

Table 7. Drip irrigation

	Drip Irrigation
Residence time	Longer residence time enhances denitrification in the soil (Beggs et al., 2004)
Loading rates	Water application rate should not exceed the water absorption capacity of the soil (Geoflow, 2003): rate should be less than 10 percent of the saturated hydraulic conductivity (Geoflow, 2003), design for saturated events (rainfall) by including a safety factor of 10 or 12 (Geoflow, 2003); Design based on nitrogen loading rates: Lower for sandy soils, Higher for fine soils (Beggs et al., 2004)
Dose Frequency	Once-daily pulse application is better for nitrification/denitrification than smaller daily pulses (Beggs et al., 2004); Frequent, small doses are better than large doses once or twice a day (USEPA, 2002); Rule of Thumb: dose volume equals five times the network volume (USEPA, 2002)
Biomat effects	
Soil Characteristics	Should not be built in flood plain or bottom of a slope where excessive water may collect after rain (Geoflow, 2003); Must be classified as either well drained or moderately well drained (BF Environmental, 2005); Percolation test should be between 3 and 90 minutes per inch (BF Environmental, 2005); Slope 0-25% (BF Environmental, 2005)
Climate	No operational problems were found in cold temperatures (soil temperatures of -12°C) when properly designed aind installed (Bohrer and Converse, 2001); Less problems in cold weather if drip lines are buried 6" or more below the surface or a winter grass can be planted to provide insulation (Lesikar and Converse, 2005); In colder climates, the dripline should be buried deaper. Mulching the area the winter after construction (and the winter afterward) can help insulate the dripline (USEPA, 2002)

Table 7. (continued)

Credit	Must be 20 inches from the surface of the ground to a high water table or slower permeable soil conditions (BF Engineering, 2005); Must be 26-32 inches from a high permeable material or fractured rock (BF Engineering, 2005)
Dependence of technology on soil treatment	It is used as a polishing treatment and to get rid of the water
Dependence of technology on mechanical treatment	
Treatment efficiency expected through time	
Reliability of technology	
On-going monitoring, maintenance, and management requirements	Clean filter cartridges (Geoflow, 2003); Flush the field (Geoflow, 2003); Check the pressure in the drip field (Geoflow, 2003)
Projected life spans and failure rates of technolgy	10 year warranty for root intrusion, workmanship and materials (Geoflow, 2003); Durable with a long expected life (Geoflow, 2003)
Removal of pathogens and nutrients	Nitrogen removal by plant roots (Austin, 2001)
Life cycle costs	Installation and construction: Drip line $0.51-1.16 per foot (Geoflow, 2004), Controler $807.00-2,420.00 (Geoflow, 2004), Headworks $550.00-4,396.00 (Geoflow, 2004), Accessories $10.00-500.00 (Geoflow, 2004), System, installation (includes controls and alarm) $15,000 (Austin, 2001); Operation, monitoring and maintenance: Energy costs $0.47/month (Austin, 2001), O&M maintenance contract $45/month (Austin, 2001); Repair and replacement: 4.17/month (Austin, 2001)
Beneficial reuse and groundwater recharge potential	Irrigation of crops and Irrigation of landscapes

Based on the information collected, evaluated, and assessed, during Year 2 of the project we prepared guidance materials that summarized the effectiveness and appropriateness of various decentralized technologies for use in Utah. By considering population growth, climate, and system monitoring issues specific for Utah, suggestions were made as to which alternative systems are suitable for Utah.

Utah is recognized nationally as a desirable place to live, which is resulting in rapid population growth. The population is expected to increase about fifty percent during the next two decades, going from 2.2 million people in 2002 to a projected 3.2 million by 2020 (Utah Governor's Office, 2000). Many places that could be built upon are limited by the lack of a central sewer system but may also not be suitable for conventional onsite systems due to slopes, high water table or inadequate separation from bedrock, and unsuitable soils, as well as housing density issues. Many alternative decentralized systems are not as dependent on soil for treatment as are conventional systems. This reduced dependence makes it possible to build in areas with high water tables or bedrock and in soils where the wastewater moves through either too slowly or too quickly.

Housing density is also an important issue with a growing population. To avoid contaminating groundwater, the density of decentralized on-site systems must be considered. Many alternative decentralized systems remove contaminants to a greater degree than conventional septic tank/drain field systems and their use may not have as great an impact on the groundwater as conventional systems.

The climate in Utah is overall dry and cold. Utah receives an average of 13 inches of precipitation per year, which is the second lowest annual precipitation in the US, behind Nevada (State of Utah Natural Resources, 2001). Although the precipitation has been above normal the last two years, the southeastern parts of Utah are still abnormally dry or have moderate drought conditions (Drought Monitor, 2006).

Arid conditions can actually be helpful with alternative decentralized systems that are open to the environment, such as intermittent and recirculating sand filters. As precipitation decreases, so does the volume of added rainwater that needs to be treated in the system. Also, disposal of final effluent from the alternative decentralized systems can result in groundwater recharge or provide for beneficial reuse as irrigation water due to the higher quality of effluent, especially taking into account nutrient and pathogen removal.

The coldest temperatures in Utah usually occur in the month of January. The average low temperatures in Logan, Salt Lake, and St. George are 10° F, 18° F, and 27° F, respectively. Many of the alternative systems investigated were found to function in Minnesota where the average low temperature in January is 5° F (Country Studies, 2003; University of Minnesota, 2005). At these colder temperatures, overall performance will decrease because the microorganisms that are an active part of the treatment do not thrive at lower temperatures as they do at more moderate temperatures. All the technologies may require insulation of components, especially if there is no or very little snow cover in the winter (USEPA, 2002). Drip irrigation and the two types of sand filters can have their pipes buried deeper and/or be designed to include insulation

for cold weather so as to avoid freezing (Bohrer and Converse, 2001; Lesikar and Converse, 2005; Norlin, 2005; USEPA, 2002). However, it has been found that nitrogen removal in alternative systems is reduced in colder temperatures (Martinson et al., 2001; Venhuizen et al., 1998)

Alternative decentralized systems require more monitoring and maintenance than conventional systems, which in turn requires the use of a comprehensive management plan. A private sector business could act as a management entity providing required inspection and maintenance activities. A business built on entrepreneurship means creating a company of long-term value that has a durable cash flow (Timmons, 2001).

In this project we developed a business plan for a company targeting the management of on-site systems in Utah under current regulatory conditions. When starting a new business, writing a business plan can be an important part of starting the venture. A business plan is used to determine what topics need to be researched and how to organize ideas for starting a business. It is also commonly used to present to a potential investor to try to persuade him/her that this would be a profitable venture to contribute to. A business plan includes subjects such as a description of the industry, a market analysis, the economics of the business, a marketing plan, the design and development, an operations plan, possible risks, a financial plan, and a proposed offering (Timmons, 2001). The example business plan developed in the project can be found on the project web site: [http://www.engineering.usu.edu/uwrl/training/onsitesystems/]

Based on the results of the project, packed bed systems (intermittent and recirculating sand filters, peath and textile filters) appear to be the most desirable options for Utah. They can be used in areas where the soils or slope are restrictive for conventional systems. These systems would continue to work well during Utah's cold winters, especially the recirculating sand filters. They do require monitoring and maintenance. Subsurface flow constructed wetlands would also be a viable option for Utah. The design, including the vegetation, would have to be site specific and should take into account the cold weather during the winter months.

Drip irrigation has been found to be a useful way to distribute the treated wastewater for beneficial reuse. The quality of the water that will be distributed will need to be maintained at a higher level than for a conventional drain field so as to protect public health and the environment. Once again, the design would have to take into account cold weather. At this time, it appears that aerobic treatment units should not be considered an option for use in Utah due to their many mechanical parts that need to be managed and maintained at a more rigorous level than what the State of Utah is prepared to require at the present time.

Management entities need to include three main components in order to be successful. These components are to: (1) educate the public, (2) secure enforcement mechanisms, and (3) tailor the details of the entity to the specific needs of the community. When educating the public, it is important to stress the need to protect a resource of value, whether that is public health, the environment, or a rural way of life. Also, the public should be educated on how valuable it is in the long run to be part of a management program. Legal enforcement gives the program an option for those who choose not to comply. Although the enforcement action, whatever it may be, may only be used for a few people, it will send a message to the rest of the public that may

not have been convinced by education. Lastly, the program needs to be structured so as to meet the needs of the community, taking into consideration public health, the environment, the onsite technologies used, and the people themselves. The U.S Environmental Protection Agency management models are helpful to use as a guide, but creativity and adjustments should be used as needed.

Population growth in Utah has resulted in increased development. This growth and development has been restricted in some locations by the lack of a centralized sewer system or the soil and landscape are restrictive for conventional onsite wastewater treatment systems. Alternative onsite technologies offer more options to develop in such areas. Management of these systems is an important tool to ensuring that the treatment is sufficient.

The information developed in this project will be used by state and local decision-makers as they develop programs to utilize alternative decentralized systems. Information from this project will also be used to develop a workshop on the use of packed bed filter technologies (sand, gravel, peat, and textile filters) and drip irrigation in Utah will be given in the fall of 2006 to local health department and Utah Department of Environmental Quality staff and to private service providers responsible for system operation and maintenance.

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