COLD CLIMATE HOUSING RESEARCH CENTER
CCHRC

Final Report to
The Denali Commission

Sustainable Northern Shelters Sewage Treatment Plant: Award No. 01162-00

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510 L Street, Suite 410
Anchorage, AK 99501

DENALI COMMISSION
ALASKA

Cold Climate Housing Research Center
P.O. Box 82489
Fairbanks, AK 99708

Telephone: 907.457.3454
Fax: 907.457.3456

www.cchrc.org

Sustainable Northern Shelters Sewage Treatment Plant

Cold Climate Housing Research Center

written by:

Lawrence Bowman, Ryan Colgan, Aaron Cooke, Colin Craven, Kristie Hilton, Kate Huber, David Karabelnikoff, Michael Lilly, Nate Mohatt, Ron Paetzold, Bob Tsigonis

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Background

Having a sufficient quantity of clean water and reliable sanitation service is an important factor in quality of life, especially by reducing infection and disease transmission. In rural Alaska sufficient clean water and reliable sanitation services are not available to a significant portion of the population. For example, 23% of rural Alaska homes are without in-house water and sanitation services (USARC, 2012). The funding necessary to reach unserved populations and replace infrastructure in served areas may be untenable, as the shortfall between funding availability and need has grown from $339 in 2007 to $658 million in 2012 (USARC, 2012). The cost to operate and maintain the existing water and wastewater infrastructure in rural Alaska is estimated at $100 million annually, however, the true cost is not known due to nature of system replacement and emergency repairs (Colt et al, 2003). All these considerations have led to a desire to explore and understand alternatives to the status quo.

In addition to these challenges, Alaska's landscape continues to change due to natural disasters, melting permafrost, and increasing risk of catastrophic storm events. This further motivates the identification of infrastructure approaches that are more adaptable and scalable, which may be increasingly desirable for communities directly confronted by these risks. Through this project, CCHRC and partners worked to address some of these challenges by examining the application and performance of an on-site sewage treatment plant (STP) as an approach for meeting sanitation needs in rural Alaska.

Figure 1. Members of the project team meet at the STP installed at Anaktuvuk Pass. From left to right, Bob Defoe (TNHA), Larry Burris (homeowner), Bob Tsigonis (Lifewater Engineering), and Jack Hebert (CCHRC). Photo by Mike Lilly, July 26, 2010.

The Denali Commission funded the Cold Climate Housing Research Center (CCHRC) to conduct the Sustainable Northern Shelters Sewage Treatment Plant project for the purpose of implementing, refining, and demonstrating on-site wastewater systems as a means of reducing the costs and improving the effectiveness of wastewater treatment systems in rural Alaska communities. Specifically, the work focused on reducing the energy demand of an on-site sewage treatment plant (STP) system, with a target of 50% reduction in electricity demand. CCHRC worked with several project partners to carry out work on this project, including Lifewater Engineering Inc., the community of Anaktuvuk Pass, Tagiugmiullu Nunamiullu Housing Authority (TNHA), the Burris family, and GW Scientific.

Objectives

CCHRC and the Denali Commission identified three main components for the Sustainable Northern Shelters Sewage Treatment Plant project scope:

1) Evaluate the wastewater treatment needs of participating communities in order to provide feedback for the design, installation, and modification of treatment systems

2) Develop remote monitoring for optimizing performance and maintenance

3) Demonstrate the effectiveness and efficiency of on-site wastewater treatment systems for use in rural Alaska

Village Wastewater Systems and Needs

Access to adequate supplies of clean water and healthy sanitation service is a large concern in rural Alaska communities. One of the main hindrances to providing more complete access is cost. The installation of an above-ground connection to sewer and water in the villages of Anaktuvuk Pass, Atqasuk, and Point Lay (all located in the North Slope Borough) is approximately $80,000-100,000 per home. Below-ground connections can cost up to $200,000 per home depending on the location of the water and sewer mains (personal communication, Brett E. Goodwin, Utilities Water and Sewer Manager, North Slope Borough Department of Public Works, 07/12/11).

Anaktuvuk Pass

Village sewer access was a key component of the decision to implement an on-site treatment system in the Anaktuvuk Pass prototype home. The potential occupants of the home was another factor in the decision process. If the people living in the home were going to be an elderly couple, how much system maintenance would be required of the home owners? In terms of building space utilization, would the fill and haul system be more prudent or a standalone STP unit? Another consideration with the water and sewer systems was the timeline. Some systems proposed wouldn't be in service before winter. A series of charettes held in Anaktuvuk Pass resulted in several potential design issues regarding the water and the sewer system.

The community was concerned about access to water since the water delivery truck had problems reliably getting potable water to the homes, so CCHRC looked into the possibility of a centralized or individual wells. However, the delivery truck was chosen as the most practical and cost-effective method. The community was also concerned with preventing damage since water utilities and tanks have the potential to cause moisture problems in the house that can lead to mold and other problems that can be costly to fix. Community members wanted to have space and plumbing available for a washer/dryer unit, although they were concerned with the cost of buying and operating the units. Separate showers and baths were another a concern of the community. The houses are crowded and people have multiple needs at similar times. The community was also hoping that prudent design would limit the amount of piping required. Short piping runs are not only easier to manage if they burst, but are also economical and energy-efficient (especially when heat tape is necessary). By clustering and centralizing the wet facilities, short piping runs could be utilized. For example, the bathroom and kitchen could share a wall for plumbing runs if placed centrally. CCHRC was hoping to reduce water and waste demand by using seasonal water catchment and water recycling. If an on-site STP was used it would need to be able to accommodate spikes in use, reflecting the social events or loading from biological waste such as from butchering of animals. Conversely, an on-site STP would need to be able to sustain extended periods of little or no use resulting from occupant time away from the prototype home, for instance due to hunting.

The design results from these considerations resulted in a gravity-fed water tank for cool potable water, in-line pump for pumped hot water and a Lifewater Engineering ExtremeSTP unit for sewage treatment. The STP unit chosen was the

XST500 model, costing approximately $18,950 in Fairbanks. The system is a residential version sized for a four-bedroom home and serves up to eight people, treating 500 gallons of domestic sewage per day. The unit was installed outdoors to minimize the indoor footprint, which required insulating the system adequately to maintain internal temperatures within operating limits. Although the system does not have a need for a building enclosure, the design team decided to add extra insulation over the STP exterior with the same polyurethane foam that was spray-applied to the house during construction. This appears to have reduced the energy required to maintain the internal temperature within the desired range, while also reducing the risk of freeze-up in case of power outages. Inputs to the STP unit include the toilet and the sink. After treatment from the STP is complete, effluent disposal occurs periodically on the tundra surface. The choice of an on-site sewage treatment system cost $30,000 to $50,000 less than connecting to the North Slope Borough sewage treatment grid. These design decisions also removed the need for connection to community water lines and the cost of additional contractors and subcontractors. The Anaktuvuk Pass prototype home demonstrates the possibility of making virtually any accessible lot buildable without regard to the availability of municipal utility services, beyond that of the electrical service connection and access for water delivery trucks.

Point Lay

Point Lay has multiple difficulties in providing water service to homes. Currently, the water is obtained from a lake near the community, treated, and stored for delivery. Households have water delivered to domestic tanks, which allows for running water in the kitchen. It would cost approximately $50,000 apiece for homes to be hooked up to piped water and sewer systems. There have been issues related to the water and sewer lines causing extreme subsidence where the pipes melt the permafrost layer. Frost heaving is another significant problem the village encounters. Some of the houses have plumbing while others use honey buckets. Family members in houses without plumbing often go to a home with plumbing to meet their washing needs. This means that the plumbing loads will be higher than calculated by single occupancy. This can be a challenge for designing on-site wastewater treatment systems, as some units are susceptible to hydraulic overloading, where wastewater inputs in excess of design capacity lead to inadequate treatment.

Point Lay has also had problems with moisture inside of homes. Mold is a widespread problem; in the spring there are reports of the walls ‘sweating’ due to the excessive moisture. When the door to the outside is opened, the fog is created instantaneously. Similar to Anaktuvuk Pass, residents prefer deep sinks for the processing of subsistence foods. The draining of grease has become a problem and is another consideration for plumbing and effective on-site sewage treatment. The wastes from processing subsistence foods could lead to spikes in organic loading that exceed the STP’s treatment capacity. The washer/dryer unit is another important concern. The washateria at Point Lay is the only working washateria on the North Slope. Tokens are $20 to wash and another $20 to dry.

Atqasuk

The water for the Atqasuk community is obtained from Imakrua Lake. It is treated and available at a watering point or by delivery. Most homes have tanks, which enables the kitchen to have running water. The residents feel that a larger water tank is needed per household, at least 500 gallons or more. The majority of homes, facilities, and the school have running water and a flush system. The North Slope Borough provides sewer for a connection fee.

Consultants for CCHRC found significant permafrost issues in Atqasuk that require consideration in the design of a community prototype house. There is a concern that when the active layer begins to freeze, it could push water and lead to potential frost heaving of the house. The consultants emphasized the need to favor vegetated areas in site selection over areas without vegetation, as dry soil can have a deeper active layer than vegetated soil due to lower heat capacity and less shading of the surface from solar gain.

Monitoring and Demonstration of On-Site Wastewater Treatment Systems

CCHRC and project partners established three project sites that served as the platform for working with communities on design, monitoring performance, optimizing design, testing design improvements, and demonstrating the use of on-site sewage treatment systems. To provide insight into the operation and performance of each system, CCHRC and project partners installed monitoring packages to measure various aspects of system conditions at each of the three sites.

Project Site #1: CCHRC Research and Testing Facility

The first project site was at CCHRC's Research and Testing Facility (RTF) in Fairbanks. The on-site sewage treatment system installed at the RTF is a Lifewater Engineering Extreme STP 900, which is designed to treat up to 900 gallons of sewage per day. This on-site STP was installed in 2006 and became operational in 2007. An illustration of the STP system components is provided in Figure 2, and a photo of the STP installed at the RTF in Figure 3. The primary treatment in the STP is a Fixed Activated Sludge Treatment (FAST®) media, made by Bio-Microbics, Inc, housed within an aeration tank. In the FAST® system, the media remain submerged while air diffusers provide circulation and oxygen to the liquid as it flows through the media. The only moving parts of the STP are the air blower motor and discharge pump. Prior to release of the effluent, final treatment is provided by UV disinfection. Discharge dosing is achieved by periodic pumping from the final treatment chamber. This periodic discharge strategy is designed to keep the discharge pipe free of ice without the need for heat tracing.

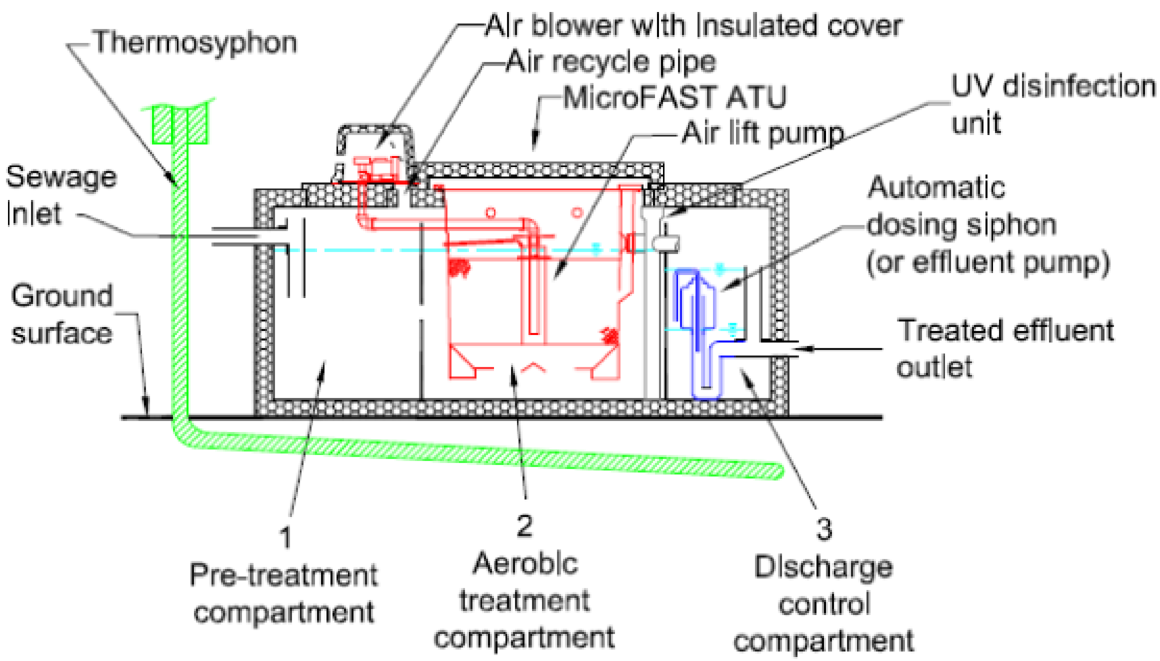


Figure 2. Cross section view of a Lifewater Engineering Extreme STP (Lifewater Engineering Company, 2004). The thermosyphon shown is recommended when placing the STP outdoors on soils with permafrost.

During the design phase, CCHRC had to decide whether to place the unit indoors or outdoors. Installing the STP outdoors requires the unit be insulated and have heat trace on the line between the building and the STP, but outdoor placement frees up significant indoor floor space for other purposes. Placing the STP indoors eliminates the need for insulation, heat trace, provides the STP with warm intake air, and made it a more accessible demonstration of the technology during building tours in the winter. Placing the unit indoors also requires consideration of the weight of the system in foundation design. The elevation of the STP within the RTF was an important consideration due to the desire to minimize the need for pumps in moving effluent outside for disposal.

Figure 3. The Lifewater Extreme STP900 installed in the basement of CCHRC's Research and Testing Facility.

Sizing of the STP unit for the RTF created unique design challenges not experienced at the residential scale. The STP handles all the wastewater from the RTF, which includes eleven sinks, eight toilets, two showers, a low-flow washing machine, and flue condensate drainage from a condensing boiler. The use is variable based on occupancy load and usage pattern. The usage pattern in the RTF is much heavier Monday through Friday, and within those days between 7 am and 6 pm. Additionally, CCHRC often hosts classes, tours, and events, all of which can spike input. When first put into service, the RTF STP was well within its design capacity of 12 regular occupants. However, the RTF occupancy has since dramatically increased beyond its specified capacity. In 2010, the RTF regularly had 20 or more regular occupants, and as of early 2012, the number had increased to approximately 30 regular occupants. This loading in excess of design specifications is not an unfamiliar phenomenon for rural systems, and provides an opportunity for testing an on-site sewage treatment system under similar conditions.

In-Situ Effluent Monitoring

In addition to testing RTF STP for performance under loads in excess of design capacity, the STP also served as a test bed for establishing real time, in-situ monitoring of treatment efficacy and effluent quality. In the spring of 2010, dissolved oxygen (DO) sensors were tested as a potential proxy for the proper functioning of the aerobic treatment process. Lifewater Engineering modified the STP to include two new monitoring tubes, and provided recommendations for sensor placement. A Campbell Scientific CS511 DO sensor was deployed in various sectors within the STP to characterize the state of the treatment process and determine the best sensor location. Monitored locations included the aerobic treatment chamber above the fixed activated sludge treatment membrane, in the pipe for the UV lamp feed downstream of the aerobic treatment chamber, and in the third chamber that serves as an effluent discharge reservoir after UV irradiation.

Figure 4 shows the DO concentration in the wastewater feed of the UV lamp on a typical day (Thursday March 11, 2010). Grey water entering the STP at the start of the day, such as from showers, sends a plug of water with high relatively DO concentration into the STP. Additional 'doses' of high DO water are injected throughout the day from such activities as dish washing. This is quickly consumed in the sewage digestion process. The DO concentration drops steeply after normal business hours and returns to an essentially flat baseline under one part per million (ppm) DO by around midnight. There is no activity in the RTF of significance in the early morning hours and the blower motor is delivering air continuously. This should provide time for the system to recover from the organic loading over the day, but the DO concentration remains flat, indicating the aerobic digestion process is starved for oxygen.

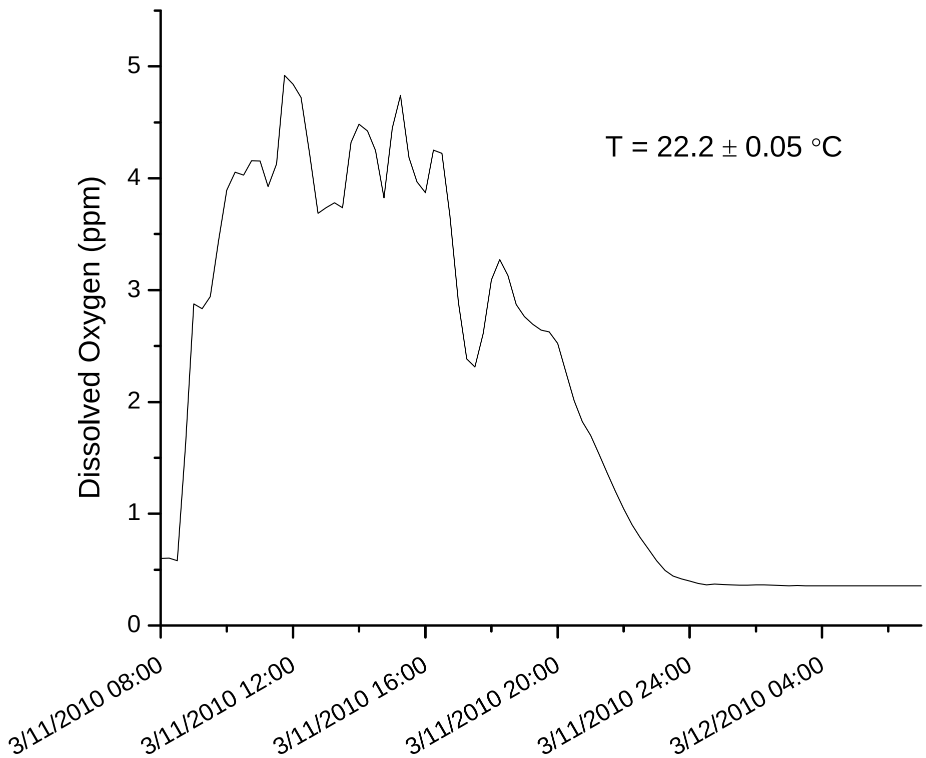


Figure 4. One daily profile of the RTF STP dissolved oxygen concentrations in March 2010. Measurements were taken in the feed pipe to the UV lamp downstream of the aerobic treatment chamber.

This hypothesis is further supported by the DO concentrations measured in the discharge chamber shown in Figure 5. Set on the bottom of the third tank, the DO sensor is exposed to the atmosphere when the tank is emptied by the discharge pump. These events are visible in Figure 5 by the spikes up to about 11 ppm DO. The sensor signal returns to the low DO value as the effluent level rises and submerges the sensor. Note the DO concentration returns to this low baseline overnight, such as from 21:00 on March 19 (Friday) through 12:00 on March 20 (Saturday). The high DO values overnight on March 18 are likely due to the sensor remaining in contact with the atmosphere since relatively little effluent would be expected to recharge the chamber at that time. Just as in Figure 4, this steady-state value of less than one ppm indicates the aerobic digestion process is starved for oxygen.

The dissolved oxygen concentrations in the RTF STP revealed that the unit was overloaded. All locations tested showed a DO concentration below one ppm when not influenced by incoming grey water with higher DO content. Lifewater Engineering confirmed the assessment of the dissolved oxygen data and status of the STP. Based on these findings, it was determined that the RTF STP could not be used to experiment decreased blower motor duty cycles as a means to reduce energy consumption.

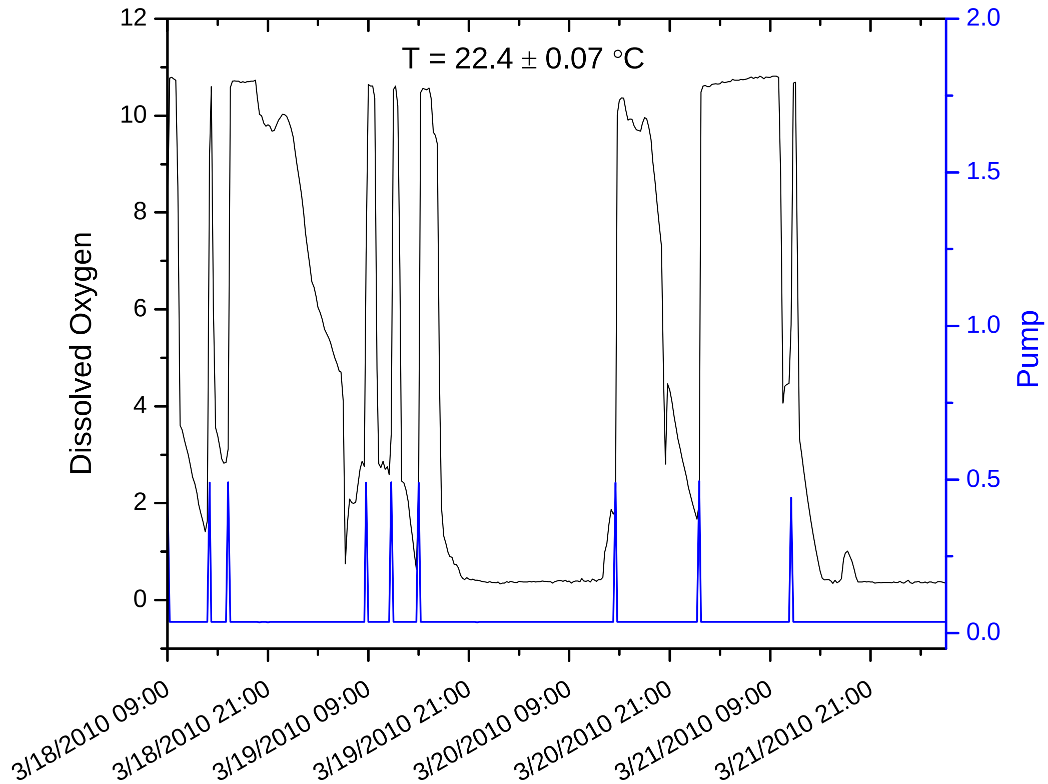


Figure 5: Several days of monitoring the RTF STP dissolved oxygen concentrations. Measurements were taken in the third or discharge tank showing the DO concentrations in ppm (black) and the pump electrical current draw as a on/off signal (blue).

Effluent Sampling and Analysis

Based on the indication of STP overloading from the dissolved oxygen monitoring, CCHRC collected samples for laboratory analysis to more conclusively determine the effluent quality. Effluent aliquots were collected in a bucket from the outfall pipe by manually triggering the STP unit to discharge. The effluent was immediately transferred to sample containers and then transported to Pollen Environmental, LLC for analysis of five day biological oxygen demand (BOD), total suspended solids (TSS), and fecal coliform bacteria. A summary of the sample results is provided in Figure 6.

	Biological Oxygen Demand (mg/L)	**Total Suspended Solids** (mg/L)	**Fecal Coliform** (cfu/100 ml)
Thursday afternoon (3/29/12)	38.6	47.0	>6,000
Monday morning (4/2/12)	28.9	12.0	>6,000

Figure 6: Effluent sample results from the RTF STP.

These analyses are the common metrics for determining compliance with Alaska Department of Environmental Conservation (ADEC) wastewater discharge requirements. While compliance with ADEC requirements is met by an engineering plan review or determined by specific permit requirements for multiple samples over specific timeframes, these samples were collected solely as an indication of wastewater treatment efficacy for the purposes of research. The “30/30 secondary treatment standards” (30mg/L TSS and 30mg/L BOD) will be used here as a reference framework. A more complete analysis would include samples characterizing the influent characteristics to allow for a better understanding of the treatment efficacy.

The RTF STP effluent was close to the 30/30 secondary treatment standards during the March and April 2012 sampling events. These BOD and TSS results are within the range of previously published test results for Lifewater Engineering residential-sized STPs (Lifewater Engineering Company, 2004), however, the fecal coliform results appear to be more typical of STPs without UV disinfection. The Monday morning sample had lower BOD and TSS concentrations than the sample from Thursday afternoon. Unlike the in-situ DO monitoring, this indicates that the STP is able to recover somewhat over the weekend when minimal influent input allows the system to catch up with the sewage loaded into the system. A more thorough sampling protocol would be necessary to establish this conclusively.

In light of the monitoring results, CCHRC plans to increase the size of its on-site wastewater treatment system during construction of an addition to the RTF in 2012 and 2013. The renovated system will benefit from the innovations discussed later in the report, but will be a highly customized installation since a complete, pre-fabricated STP can't be moved into the RTF basement. Further information about the RTF system will be made available as construction of the RTF addition proceeds.

Project Site #2 - Anaktuvuk Pass Prototype House

The second project site was at the Sustainable Northern Shelter prototype house built in Anaktuvuk Pass in 2009, shown in Figure 7 below. Anaktuvuk Pass is a Nunamiut community of 312 located in the Brooks Range, accessible only by plane. It is located above the Arctic Circle at 68° N. This is a very cold location with an average winter temperature of −14°F (-25°C) and an average summer temperature of 50°F (10°C) (State of Alaska, 2011).

Figure 7. The Anaktuvuk Pass prototype house.

To guide the design process, CCHRC held a design charette in Anaktuvuk Pass to gather ideas from the community about what kind of housing suited its needs. The CCHRC design team developed a building site and floor plan based on these criteria. The design incorporated innovative building technologies, a roof truss system designed to hold solar panels, and spray polyurethane foam insulation for the walls, floor, and roof.

Construction took place over the summer of 2009. The 800-square-foot prototype house was bermed with soil and provided with a traditional *qingok* (passive venting system) in response to community interest in reestablishing select building traditions. The foundation is made up of two feet of gravel fill topped with a synthetic waterproof membrane that supports the home's light frame, which is filled with spray foam insulation. Polyurethane foam insulation was sprayed onto plywood from the outside, unlike typical construction where insulation goes on the inside, to a depth of nine inches, for an approximate R-value of 60 $ft^2 \cdot °F \cdot hr/BTU$. All insulation was covered with an elastomeric coating for weather-proofing. The roof was also covered with nine inches of foam, topped with sod, and vegetated.

The on-site STP servicing the Anaktuvuk Pass prototype home is a Lifewater Engineering XSTP 500, which is designed to treat up to 500 gallons of sewage per day. The unit was installed outdoors on the north side of home and encased in polyurethane spray foam and clad in a spray-applied elastomeric coating, mirroring the insulation and weather-proofing system used on the prototype home. The STP unit cost $18,950. The cost for freight was incalculable because the materials for the entire home were designed to fit on a single plane flight, and therefore the shipping cost was independently driven. Installation was performed primarily by students and teachers from Illisagvik College engaged in workforce development training. For comparison, the estimate to connect the home to the local utility was between $80,000 - $100,000.

Figure 8 shows the STP system installed outside of the Anaktuvuk Pass prototype house. The effluent is rated for direct surface discharge and is now supporting a small wetland during summer months. The soils underlying the discharge area are predominantly sandy gravel, providing good drainage in the active layer. The management of discharge water is an important design consideration in Arctic climates.

Figure 8. The STP system at the Anaktuvuk Pass Arctic Prototype House.

This project site provided the setting to understand the design considerations associated with applying on-site sewage treatment in a rural setting. This project site also enabled CCHRC to experiment with the installation and operation of a STP by applying a new insulation strategy for outdoor use, using ventilation exhaust from the home to provide supply air to the STP, evaluating a lower duty cycle on the aerobic treatment air supply system to reduce energy use, and testing a remote monitoring system. The STP installed at the Anaktuvuk Pass prototype house was instrumented with a monitoring package that measures outdoor air temperature, temperatures at several locations within the STP, and electrical current demand from major STP system components.

Energy Use Monitoring

One of CCHRC's primary concerns with the STP unit as an on-site sewage treatment option was the amount of energy necessary for its operation. CCHRC monitored the prototype home in Anaktuvuk Pass for several parameters relating to energy use. The data collection systems are intended to help demonstrate operations of the prototype design and to provide feedback for design improvements. The initial estimate for the STP was 350 watts of continuous electricity demand, mainly attributable to the blower motor that provides air for the aerobic treatment process. This could dramatically increase the electrical load for the prototype house. To test the potential for reducing this energy demand for on-site sewage treatment, the STP was set up with the blower motor operating at a 50% duty cycle instead of 100%. In other words, the blower motor would cycle on and off at regular intervals; the rate of air delivery when the blower motor is activated does not vary.

Because energy use of the STP was a significant topic of interest, the total prototype home electricity demand was monitored, including the portion attributable to the STP (see Figure 9). The monthly energy demand profile illustrates the consistency of the STP energy requirements. The relative spike in energy demand in January 2010 was attributed to the discharge pump running continuously during a system freeze up prior to occupants moving into the prototype home. The minimal energy demand values in June and July 2010 were due to the homeowners turning off the STP while traveling. Throughout the monitoring period illustrated in Figure 9, the STP averaged approximately 132 kilowatt hours (kWh) per month or around 12% of the total house electricity demand (Garber-Slaght, 2011). This fraction of total household electricity use may be relatively low compared to other households, as the prototype home had much higher electricity use than the Alaska average of 661 kWh per month (US EIA, 2009).

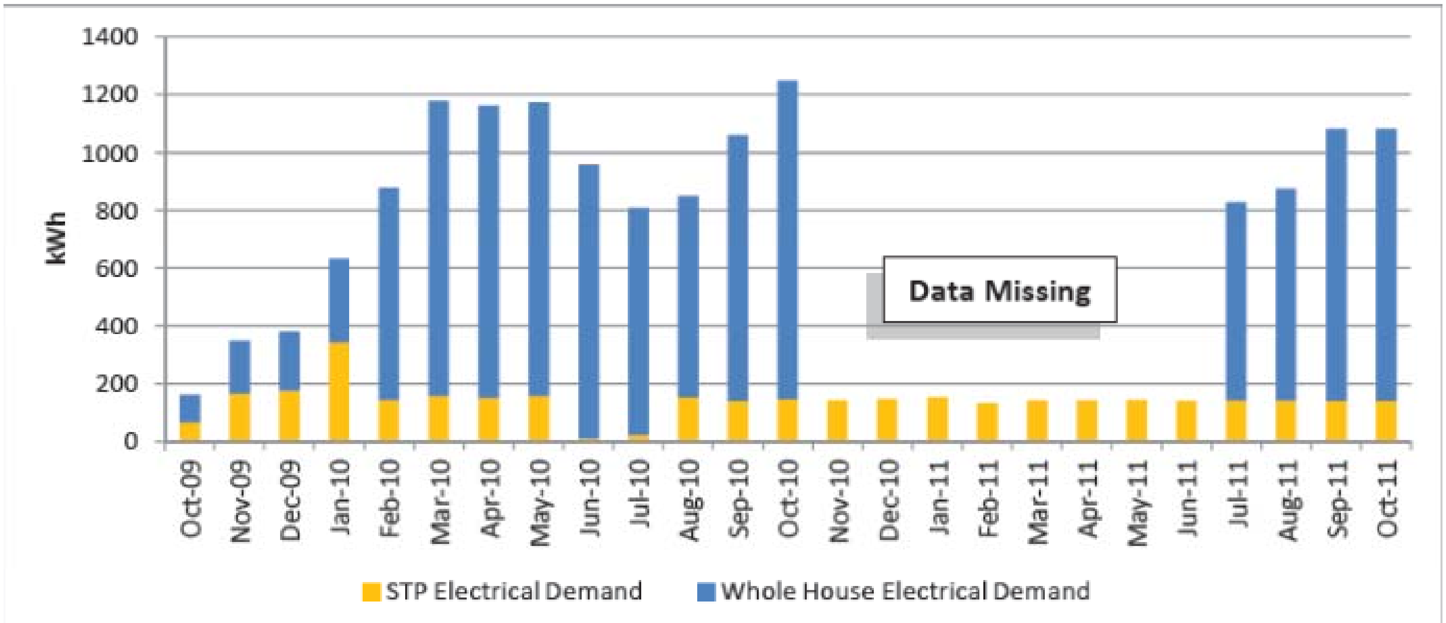


Figure 9. Electrical energy demand in kilowatt hours (kWh) for the Anaktuvuk Pass prototype home. The blue bars represent the total electricity demand for the month, and the yellow section of the bars represent the portion of the total attributable to the STP energy demand (from Garber-Slaght, 2011).

If the blower motor was kept at 100% duty cycle, the anticipated energy demand would be approximately 260 kWh per month. The average energy demand for the Anaktuvuk Pass STP therefore corresponds very well to simply halving the 350 W original estimate, confirming that installed energy performance of the STP is very close to design specifications.

A different purpose for the monitoring data is provided in Figure 10, which shows electrical current demand for various STP system components. The most striking feature of the electrical current data is its regularity; relatively few deviations are noticeable over the several month time period. This allows for changes in system behavior to be readily apparent, such as the outage of water in late 2010 and early 2011 that manifested in a reduced number of discharges from the STP (discharge pump not operating) without affecting air delivery to the aerobic treatment chamber (blower motor) and UV disinfection (UV lamp). Various frequencies of current monitoring allow for different diagnostic capabilities. The two-minute average data illustrate the cycling of the blower motor on and off, whereas the hourly average data show convergence around an average of 1.5 amperes for the 50% motor duty cycle.

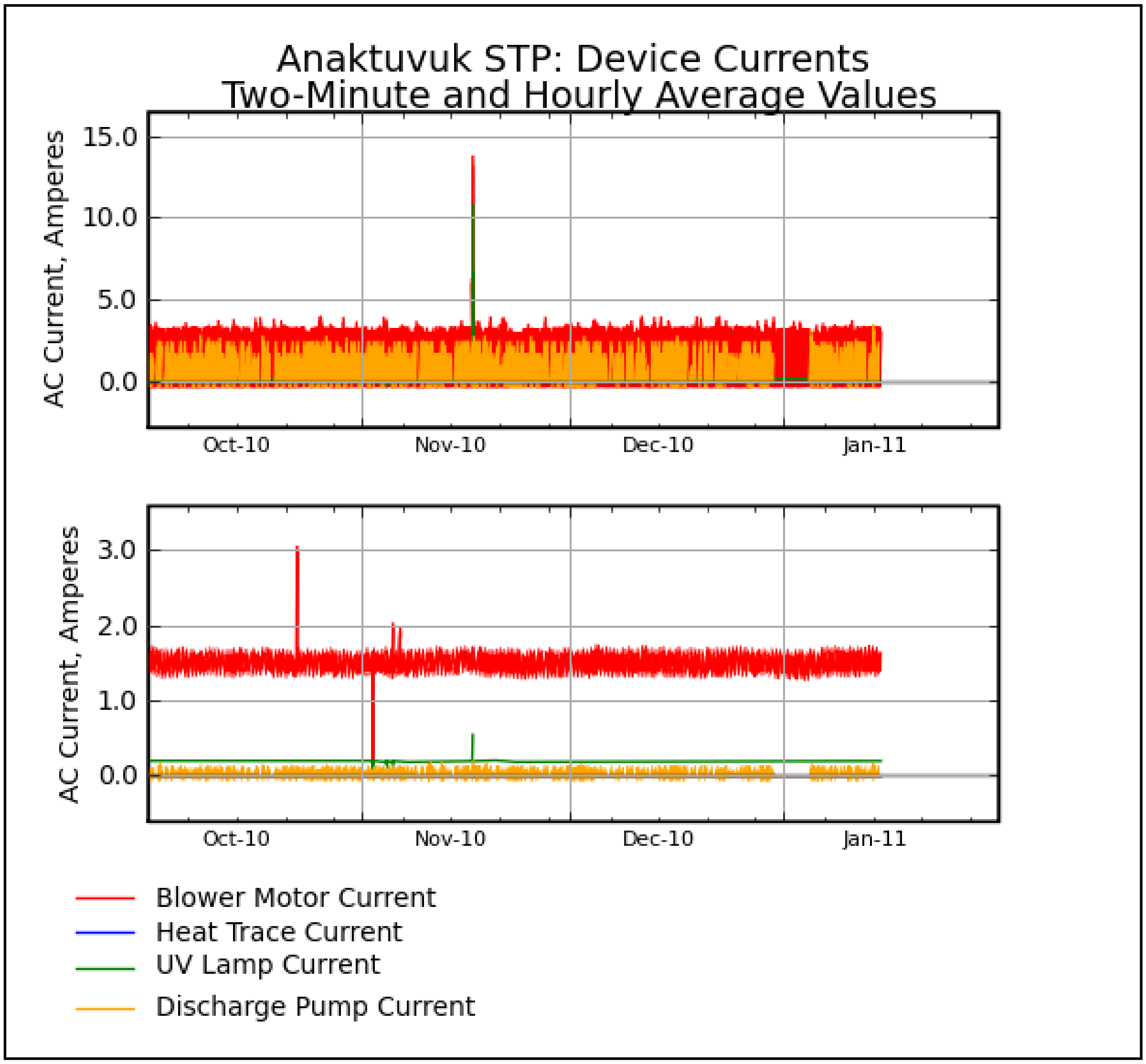
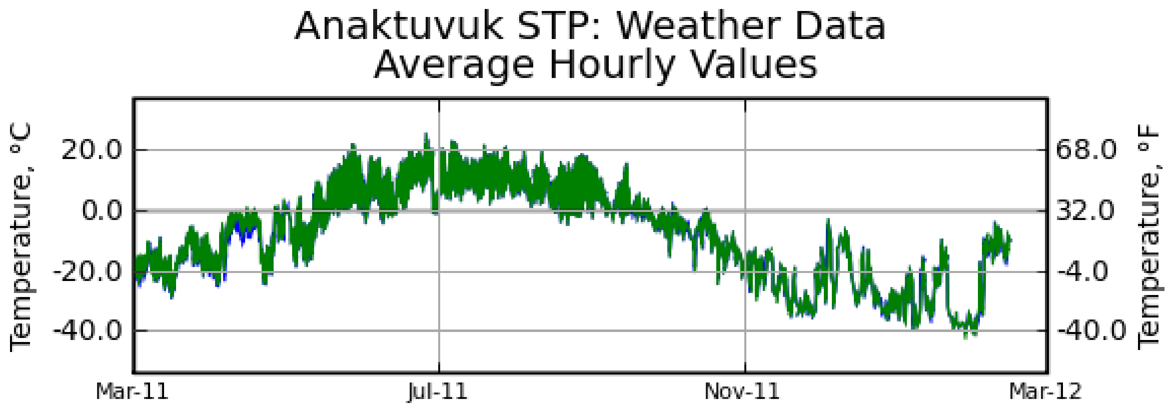


Figure 10. Real-time reporting example for electrical current draw for the STP system in Anaktuvuk Pass. The upper graph shows the two-minute current draw averages and the lower graph the hourly current draw averages.

Additional strategies employed to reduce the energy demand for the STP included plumbing exhaust air from the home to the unit and over-insulating the STP exterior. Using warm house air for the STP aerobic treatment instead of ambient air was intended to reduce the energy that would need to be supplied to maintain the internal STP temperature. After the installation, the warm air from the home and the internal heat generated by the STP digestion and internal components provided nearly all of the energy needed to maintain the internal temperature. The STP internal temperature monitoring (Figure 11 below) showed that the system temperature largely followed the trends in ambient air temperatures. A power outage in late 2011 and early 2012 is apparent in the sharp drop of the STP internal temperature, however, the system never approached freezing during the year of monitoring data shown in Figure 11 despite such interruptions. This integration of the STP into the house ventilation system improved the energy efficiency of the home, however, this approach made the house susceptible to back drafting of sewer odors during times when the blower motor was not on.



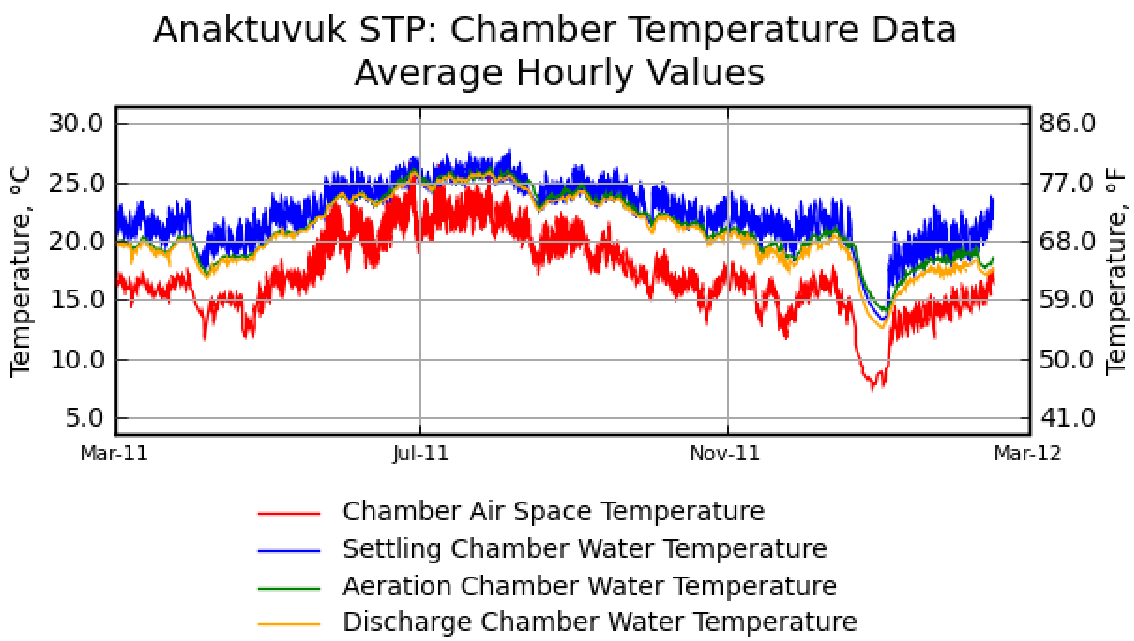


Figure 11. Top figure shows the outdoor air temperatures in Anaktuvuk Pass at the prototype home. The bottom figure shows the temperature data from within various chambers of the STP.

Effluent Sampling

It is important to establish whether the reduced electricity demand of the Anaktuvuk Pass STP has maintained the level of treatment previously demonstrated by ExtremeSTP systems. As was performed for the STP at the RTF, the Anaktuvuk Pass STP effluent was sampled for BOD, TSS, and fecal coliform bacteria in late March 2012.

	Biological Oxygen Demand (mg/L)	**Total Suspended Solids** (mg/L)	**Fecal Coliform** (cfu/100 ml)
50% Duty cycle on aeration system (3/28/12)	69.8	49.0	>6,000

Figure 12: Effluent sample results from the Anaktuvuk Pass STP.

The effluent was above the 30/30 treatment standards, and the BOD and TSS results are toward the high range of previously published test results for Lifewater Engineering residential-sized STPs (Lifewater Engineering Company, 2004). As with the RTF STP, the fecal coliform results appear to be more typical of STPs without UV disinfection. This one effluent sample result does not rule out aerobic system duty cycles under 100% for STPs, however, it strongly indicates that a 50% duty cycle is insufficient for the installation at Anaktuvuk Pass. Considering these sample results, a combination of higher duty cycles for the blower motor and effluent sample monitoring would help to identify the appropriate balance between energy efficiency and completeness of sewage treatment. There are multiple setting options available on the STP control board, including options between the 50 and 100% duty cycle. Further research could provide insight on an practical optimization protocol for rural STP implementations.

Project Site #3: Lifewater Engineering Inc. Manufacturing Plant

The third project site was in Fairbanks at the manufacturing site for Lifewater Engineering Company, who independently developed a next-generation STP that substantially reduced energy use and also improved the quality of effluent, which already met ADEC standards. Systems prototypes were instrumented to measure electrical power demand and effluent samples were analyzed to determine treatment efficacy.

In February of 2010 Lifewater Engineering tested the Prototype I (SST600A) in a new line of sewage treatment plants. The primary goal for the SST line was reduced power consumption while minimizing maintenance requirements in an effort to provide a beneficial solution to wastewater treatment needs in rural areas of Alaska. Using monitoring equipment provided by CCHRC and GW Scientific, Prototype I was monitored to determine the power consumption of various system components. The SST600A consumed approximately 400 W of power and successfully met 30/30 secondary treatment standards.

Figure 13. Lifewater Engineering's prototype SST600C sewage treatment plant under testing in its Fairbanks, Alaska, manufacturing facility. This prototype uses less energy than prior STP models while providing increased treatment performance.

In August of 2010 Lifewater Engineering installed Prototype II (SST600B) of the SST line of residential wastewater treatment systems that targeted increased treatment performance and a further decrease in electrical consumption. The Prototype II discharged effluent under 10/10 (10mgl/L TSS and 10mg/L BOD) and frequently produced effluent of 5mg/L TSS and 5mg/L BOD with fecal coliform bacteria under 2 cfu per 100ml effluent. The SST600B used an average 112 W, which includes the average hourly power consumption for the air blowers, control timer, alarm relays, UV disinfection, and the effluent pump. This reduced power requirement combined with effluent quality capable of meeting 10/10 makes the SST600B model of sewage treatment more cost-effective as a rural Alaska wastewater treatment option. The system has been operating in the Lifewater Engineering office for six months treating the wastewater from a four person office, three to four person apartment, and three person shop.

Shortly thereafter, Prototype III (SST600C) shown in Figure 13 was created to reduce end-user costs by reducing fabrication labor and material costs as well as simplifying the aeration cycle. While the original plan was to install and monitor this prototype unit in Point Lay, that housing project was delayed. Instead the Prototype III was monitored at the Lifewater Engineering facility. Figure 13 shows the SST600C in a testing environment at the Lifewater Engineering manufacturing facility in Fairbanks. The Prototype III was hooked up to apartments at Lifewater facilities, allowing Lifewater staff total access to the new prototype design, allowing testing, validation, and improvements to be made at an accelerated pace. The controlled “field” test allowed the project team to learn more with less travel. The testing and improvements in the SST600 series prototype systems at the Lifewater Engineering in Fairbanks led to the fine-tuning of the system design, which will consume less energy than their previous STP model.

Homes being built in Atqasuk by TNHA are using some of the new system design concepts learned during the project. The Sustainable Sewage Treatment Plant (SST600 series) systems are being installed inside the envelope of these homes, which will not only eliminate the need for heat trace, but also makes winter maintenance easier. The project team met throughout the project to exchange ideas and information that helped improve wastewater treatment systems and their integration into new northern shelter designs.

Conclusion

In rural Alaska, reliable sanitation services are not available to a significant portion of the population. While there has been considerable progress in improving access over the past several decades, the costs of establishing additional sewer connections and maintaining existing systems have led to a desire to explore and understand alternatives. In this project, the Denali Commission funded CCHRC and partners to implement, refine, and demonstrate on-site sewage treatment systems as a means of reducing the costs and improving the effectiveness of wastewater treatment in rural Alaska communities. Specifically, this project focused on reducing the energy demand of an on-site sewage treatment plant (STP) system.

Several North Slope Borough communities were engaged as part of CCHRC's Sustainable Northern Shelters program to understand their water and wastewater treatment needs, which helped inform the design, installation, and modification of STP systems in these communities. The systems monitored included several Lifewater Engineering STP models. The system at CCHRC's Research and Testing Facility (RTF) was used to study a STP installed indoors with most of the system input occurring during normal business hours at a rate in excess of design capacity. The RTF STP was used as a test bed for an in-situ monitoring method using dissolved oxygen (DO) measurement as a proxy for treatment efficacy. The DO monitoring revealed that the system is overloaded due to increasing occupant loads at the RTF, however, effluent samples analyzed for biological oxygen demand (BOD) and total suspended solids (TSS) were close to the "30/30" secondary treatment standards and within the range of previously published results from Lifewater Engineering STPs. The STP at the Anaktuvuk Pass prototype home was studied as an outdoor installation with a reduced duty cycle on the blower motor that is responsible for most of the system energy demand. While cycling the motor achieved the targeted 50% reduction in energy demand, limited effluent sampling indicated BOD, TSS, and fecal coliform bacteria in excess of treatment goals. A different approach to meeting these goals was undertaken by Lifewater Engineering in the testing of new STP prototype designs that use more efficient means of delivering oxygen to the aerobic treatment chamber. Testing of the prototypes at the Lifewater Engineering manufacturing facility provided promising results for reducing energy demand while delivering superior treatment capabilities.

The testing of STPs in multiple locations helped identify important considerations for incorporating on-site sewage systems into new housing designs. On-site systems such as the Lifewater Engineering STPs use biological treatment strategies that require a balance of inputs in order to meet treatment requirements. In the case of the Anaktuvuk Pass STP, the goals of simultaneously providing sufficient oxygen supply to the STP and exhaust ventilation for the prototype house, while meeting an energy efficiency target, proved difficult to balance simultaneously. Fundamental system refinements of the STP design by Lifewater Engineering in combination with lessons learned from the studied installations demonstrate that on-site sewage treatment is an option that can be effective and energy efficient. These are important advancements that provide promising options for continued improvement of rural Alaska sanitation at lower capital costs than conventional scenarios.

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