Denali Emerging Energy Technology Grant:
"Improving Cold Region Biogas Digestor Efficiency"
Year 2 Quarterly Report, Y2Q3 – September 15, 2011

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i. Y2Q3 Summary

The project is nearing its final completion date on September 30, 2011, and all research obligations have been completed at this point. During the last quarter, research efforts focused primarily on analyzing gas and effluent samples collected over the course of the project and conducting a study on the economic feasibility of the technology in Alaska. In addition, researchers improved techniques for measuring gas flow at low rates of production in order to aid future biogas production research.

At the time of the last quarterly report, we were in the process of disassembling the major components of the biogas project at the Cordova High School research site. Reactor contents were not fully disposed of until July 18th, 2011 and the site has since been returned to it its original condition. The Conex used throughout the project (now vacant), was left at the high school for future use, with additional improvements of insulation, heat and electricity capacity upgrades. Re-usable reactor components remained with the Cordova High School Science Club for future use - no complete reactor assemblies remain at this time. The main 1000-L reactor vessels were disposed of by the Cordova Electric Cooperative. The gas collection system developed during the Y2-Q2 remains intact and is currently stored outside the ACEP building at the University of Alaska, Fairbanks.

UAF researcher Casey Pape gave a lecture presentation to the Fairbanks public on the project on June 21, 2011 for ACEP's June talk as part of their 'Community Energy Lecture Series'. Information regarding the talk can be found on ACEP's website and INE website (http://www.uaf.edu/acep/publications/).

Lastly, students as well as members of the research team plan to attend the Alaska Rural Energy Conference hosted in Juneau, from September 27-29th, where upon they will give a final presentation regarding their findings and experience(s) with the project. The project's Final Report will be submitted by September 30th, 2011, marking the completion of the project.

ii. Schedule and milestone information

The project continues to closely follow the original outlined plan:

- Construct Digestors for Phase 1 by December 15, 2009 – Completed January 21, 2010
- Commence Data Collection by February 1, 2010 – Achieved January 18, 2010
- June 25-27, 2010, project meeting onsite in Cordova (all team members present); High school student presentations
- Perform mid-term Analysis of Data by July 30, 2010 – Completed informally internally as a project team, and formally in Quarterly reports 2 and 3.
- Year 1 Q4 Report, December 15, 2010
- Phase II Scoping, deadline for revised report: Completed March 15, 2011
- Phase I Report, including analysis of all Phase I data: Completed March 15, 2011
- Year 2, Q1 Report: Submitted on March 15, 2011
- Scaling Report: Submitted [internally] April 15, 2011
- Year 2, Q2 Report: Completed June 29, 2011
- Year 2, Q3 Report: Due September 15, 2011(this report)
- Biogas Handbook: First draft due (August 7, 2011, submitted internally); Final draft due Sept. 30, 2011.
- Scaling Report: Final draft to Denali Commission September 30, 2011
- Final Report due September 30, 2011 [First draft Sep. 20, 2011]

ii.a) Personnel:

Cordova Electric Cooperative http://cordovaelectric.com/

Clay Koplin – Grant Administrator. Koplin has managed most of the financial aspects of the project thus far on behalf of the Cordova Electric Cooperative, serving as the project manager. Koplin also serves as a technical advisor to the project.

University of Alaska, Fairbanks http://www.alaska.edu/uaf/cem/ine/walter/

Katey Walter Anthony – Research Director. Walter Anthony acts as the primary investigator, and has spearheaded the scientific goals and directions of the project. She provides continual scientific expertise and project management. She contributed to the data analysis, interpretation and writing of this and all reports.

Casey Pape – Research Technician. Pape joined the project in early September, 2010, to assume the role of primary project research technician. Pape worked on-site in Cordova until March 2011, maintaining the digestor experiment, including data collection, analysis, and troubleshooting. Pape led the preparation of the current quarterly report with assistance from other team members. Pape relocated to Fairbanks on March 25, 2011 and will continue working on the project with closer access to lab instruments, consultation with Walter Anthony and ACEP. Pape travels intermittently to Cordova. Pape plans to remain with the project until its completion in September 2011.

Dane McFadden – Project Intern. Currently an undergraduate at Stanford University, Dane McFadden helped maintain digestor performance during August 2010. Job responsibilities included: maintaining daily gas data collection, feeding, chemistry measurements and gas sampling. McFadden used his experience with the project as his required internship at Stanford University.

Laurel McFadden – previous Research Technician. McFadden, served the project as Research Technician from the start of the project until August 2010, when she left to begin graduate school at UAA. McFadden was a key contributor to the project development and took the lead on organization and preparation for the initial construction and setup. McFadden completed the first draft of a Biogas Handbook for Alaskans, which will be submitted as a deliverable in final form to the Denali Commission by the end of the project.

Peter Anthony – Research Technician. Anthony consults on the project and continues to provide technical expertise to the maintenance and application of digestors. He participated in all on-site project meetings in Cordova and provided recommendations for simplification and winterization of the gas collection system in preparation for Phase II. In the UAF laboratory, Anthony conducted the gas chromatography analyses of biogas composition for the project.

Jeffrey Werner – State FFA Director. Werner is interested in using the effluent from anaerobic digestors as a liquid fertilizer for agricultural crops. Located at the horticultural center at UAF, Werner remains enthusiastic about the possibilities of the potential uses of the once thought of waste product.

Cordova High School http://blogs.cordovasd.org/chs/

Adam Low – Science Teacher. Low was integral in bringing in student involvement via classroom curriculum and extracurricular projects. Low was in charge of maintaining a consistent digestor feeding regime and guiding student involvement with the project. While Pape was away from Cordova, Low had the added responsibility of maintaining gas flow and chemistry measurements as well as general troubleshooting. Additionally, Low worked with science club students to set up a greenhouse experiment in which to test effluent samples for their potential use as a liquid fertilizer. Low also assisted in collecting and shipping effluent samples to other project colleagues in Germany in efforts to greater proliferate psychrophilic digestor technology.

On June 5, 2011, Low moved from his home in Cordova to Hawaii with his family and is no longer involved with the biogas project. He was an integral part of the research project, so the loss of participation is most regrettable.

Cordova High School Students – Volunteers. The students of Cordova High School have been highly involved with construction, feeding, maintenance, demonstration of the use of biogas in science fair projects for Phase II, and public presentations for the project. They include the seventeen Chemistry class students and Science Club students (Craig Bailer, Ben Americus, Adam Zamudio, Sophia Myers, James Allen, Eli Beedle, Josh Hamberger, Keegan Crowley, Kris Ranney, and Carl Ranney).

SOLAR Cities http://solarcities.blogspot.com/

Thomas "TH" Culhane – Biogas Expert. With an extensive history in biogas technologies, Culhane developed the water-pressure tank design and provided extensive technical knowledge to the engineering of the project at its outset. He worked with and advised the on-site construction in January 2010 and provided expert advice from his home base in Germany. In Nov. 2010, Culhane requested a 1-L sample of psychrophilic effluent in efforts to test the success of psychrophilic digestors in different locations in Europe, Asia and Africa with different weather patterns and climate regimes as part of a tangential outreach project that Culhane and Walter Anthony have, funded by the National Geographic Society and Blackstone Ranch.

Sybille Culhane – Co-founder of SOLAR Cities. S. Culhane assisted in initial construction efforts and managing financial aspects of SOLAR Cities involvement.

Chena Hot Springs http://www.chenahotsprings.com/

Bernie Carl – Owner of Chena Hot Springs. Carl has expressed interest in deploying a large scale biogas digestor at Chena Hot Springs, and has offered space for testing a digestor in his greenhouse.

Others http://www.cordovaenergycenter.org/

Brandon Shaw – Website Development. Shaw designed the CordovaEnergyCenter.org website, where the project is hosted. He also assisted at the initial construction site, and was integral in the assembly of the flow meter system.

Keywords: Biogas, anaerobic digestor, reactor, psychrophiles, mesophiles, methane, methanogens, Alaska, cold-climate, thermokarst lakes.

iii. Narrative summary of the project status and accomplishments to date, and addressing the following questions: is the project on schedule, is the project on budget, and what actions are planned to address any project problems.

iii.a) Notable Accomplishments:

Collection, passive compression, and usages of biogas – Phase II experiments to collect, store and utilize biogas successfully demonstrated that biogas technology is directly transferable for collectors utilizing psychrophilic cultures. Demonstration projects largely surpassed researcher expectation, and have all been completed at this time. A modified propane burner stove, 4-cycle combustion engine and gas-powered 1850 Watt generator were all demonstrated to work well on biogas produced from the experiment in Cordova. Optimal burn and device efficiencies are not known, but visual accounts confirmed high device performance.

Biogas production – Understanding of variables that limit biogas – One of the primary goals of this project was to determine if lake-bottom mud containing cold-tolerant methanogens could be used in an artificial environment to produce biogas. We observed production of flammable biogas from both psychrophilic and mesophilic microbes in this study, though psychrophiles tended to produce more biogas at cold temperatures.

An extensive dataset of daily biogas production from each of the tanks in the experiment was collected. At peak productivity under experimental 'cold temperature' conditions, production levels of flammable gas reached high quantities (between 30 – 345L/day per 1000L tank). The gas, shown to be safely and easily collectable using passive techniques, retained high flammability when exposed to spark or flame. Even at almost nominal pressures, the gas held continuous flame and burned cleanly with no visible soot or residue after combustion.

Biogas from conventional anaerobic digestors possess a methane content typically between 40-60%. We observed in this project that biogas produced on-site contained high concentrations of methane (50-82%).

Improvement on method for measuring biogas production rates – During the past quarter, Casey Pape made substantial progress on improving our capability of measuring biogas production and flow rates. He modified existing tipping cup technology, typically used for gauging rain fall, for use in measurement of a range of gas flow rates in submerged settings.

Determination of nutrient concentrations in digestor effluent – We analyzed samples of biogas digestor effluent for nutrient concentration. High levels of bioavailable phosphate were found in the effluent. This could explain our observation of enhanced growth of greenhouse plants fed with effluent from the digestors, and suggests that biogas digestors have the added benefit of nutrient-rich organic fertilizers from effluent in addition to producing methane gas.

Student education – This project has the good fortune to involve High School students in rural Alaska in scientific research. Cordova High School students have had the opportunity to see some of the technical aspects and complications that go along with research. The science club and chemistry class provided an excellent platform to organize student involvement. Students had the opportunity to troubleshoot and take the lead on feeding procedures for the project resulting in implementation of several very clever and innovative ideas.

The students of Cordova High School made multiple public presentations of the project progress and results. They were received well with each new appearance. The students demonstrate a thorough understanding of the issues involved with conducting new technology research as well as the factors that contributed to lessons learned during this project. In 2010 and 2011, CHS students and teacher Low presented biogas projects for the Alaska State science fair. Student results, reports and photographs from the biogas demonstrations are available (please refer to Y2Q2 report).

Community outreach – High school students and UAF researchers were given the opportunity to present on project ideas and preliminary results at meetings with the Alaska Power Association and Alaska state legislators in Juneau, and at a variety of conferences, including the Alaska Rural Energy Conference (April 27-29th, 2010) and the Alaska Forum on the Environment (February 7-11th, 2011). Most recently, the project research was featured during ACEP's lecture series for the month of June 2011. The talk, given by Casey Pape, was hosted at the Blue Loon in Fairbanks. Slides as well of video of the speech can be found online (web link in section i). Titles of our project presentations and other public dissemination documents are:

Walter Anthony, K., Culhane, TH., Koplin, C., McFadden, L., Low, A. "Improving Cold Region Biogas Digestor Efficiency." McFadden, L. Alaska Forum on the Environment. Anchorage, Alaska. February 8-12, 2010.

Walter Anthony, K., Culhane, TH., Koplin, C., McFadden, L., Low, A. "Improving Cold Region Biogas Digestor Efficiency." Low, A., Hess, E., Allen, J., Americus, I., Americus, B., Zamudio, A. Alaska Rural Energy Conference. Fairbanks, Alaska. April 27-29, 2010.

Pape, C. and the Project Team, "Energy from Psychrophilic Bacteria: A Cold-Region Alternative for Biogas", ACEP Community Energy Lecture Series, Fairbanks, Alaska, June 21, 2011.

New Scientist article featuring this project: 'Cold climates no bar to biogas production'. November 4, 2010. <http://www.newscientist.com/article/mg20827854.000-cold-climates-no-bar-to-biogas-production.html>

The project was featured by Alaskan Dispatch Magazine in an article on rural Alaska entitled, 'Biogas could bring new energy to rural Alaska'. January 17, 2011. <http://www.alaskadispatch.com/article/biogas-could-bring-new-energy-rural-alaska?page=0,0>

Low, A. "Youth Participation: Improving Cold Region Biogas Digestor Efficiency." Low, A., Bailer, C., Allen, J., Americus, B., Zamudio, A. Alaska Forum on the Environment. Anchorage, Alaska. February 8, 2011.

Walter Anthony, K., Culhane, TH., Koplin, C., Low, A., Pape, C. "Improving Cold Region Biogas Digestor Efficiency." Low, A., Bailer, C., Allen, J., Americus, B., Zamudio, A. Denali Commission Public Forum on the Emerging Energy Technology Grant. Juneau, Alaska. February 14-15, 2011.

The project was also mentioned in Senator Lesil McGuire's recent press release on the 'Deadline for Emerging Energy Technology Fund Grant Applications Approaching'. Released March 3, 2011. <http://www.aksenate.org/mcguire/030311EmergingEnergyFund.pdf>

Last year, the chemistry students took a class trip to the Alaska Power Association in Feb. 2010. Students C. Bailer, D. Hess, C. Morrissett, J. Smyke, S. Lindow, and T. Kelley presented on the project and it was received well among those who attended the meeting. The project team intends to present at this years' Alaska Rural Energy Conference in Juneau, Sept. 27-29, 2011.

Website development- Website developer Brandon Shaw designed a site (www.cordovaenergycenter.org) for the Cordova Energy Center, the venue at which the biogas experiment has been conducted. The website provides a venue for students and community members to obtain information about the project and how to get involved. It is important to update the website often as a means to show visitors that the project is still underway, that is still producing results and that people are still encouraged to get involved.

iii.b) Project Status

iii.b.1) Gas Sample and Effluent Analysis

As specified in the initial project proposal, researchers at the University of Alaska, Fairbanks were charged to analyze samples collected from the Biogas project and report on the relative gas and nutrient composition levels of each reactor used during the experiment. During the last quarter of the project, liquid and gas chromatographs were run on gas and effluent samples collected and cataloged from the Cordova site. These tests were employed to reveal the heat content of biogas produced (BTU rating) as well as the presence of usable nutrients found within detectable quantities from samples of the reactor effluent. The results are as follows:

Gas Chromatograph

Gas chromatography is a powerful analytical technique used to determine the composition and relative gas concentrations in a sample. Throughout the experiment, several samples of biogas, collected from the project site were analyzed by GC and revealed high concentrations of methane, as much as 82% in some cases (Figure 1). At the time, it was suspected that the observed high levels of methane, uncommon in typical anaerobic digestors (AD) (typically 40-60%), was due, likely in part to decreased feeding regime which shifted the balance between fermenting bacteria and methanogenic anaerobes (see Y1Q3 report). Once a feeding schedule by students resumed on a regular basis with the onset of the new school year, methane levels began to decrease slightly, more closely resembling that of other anaerobic digestor systems of similar type and scale (Figure 1). The last set of samples taken in June of this year, revealed a range in methane content between 61-69% among all actively producing tanks in the experiment (Tanks 1, 4, and 5 respectively; Tank 6's activity was observed, but could not be isolated in order to obtain a sample). At the time the samples were taken, each of the tanks had been incubated at a temperature of approximately 35°C on average. Therefore, it is unknown at this time whether the cause of the change in methane concentration was primarily due to changes in feeding regime or temperature since the tanks had not been given additional food material since April of that year (see Y2Q2 report). However, previous samples obtained from earlier in the year suggest that the methane content of biogas was similar to that of typical anaerobic digestor systems commonly cited throughout the scientific and other related literature.

In addition to methane content, other gases were measured as well for their relative abundance within the collected biogas. Most notably worth mentioning here is that all trace gases (i.e. CO_2, N_2, O_2, etc.) decreased since the last set of samples were run in September 2010 (Appendix I). The likely explanation for the decrease in atmospheric molecules (O_2 and N_2) was that leaks were since identified and fully repaired. Once repaired, oxygen and nitrogen levels decreased to nominal levels which otherwise would only be expected to be present in any quantity within a reactor where air contamination has occurred (Appendix 1).

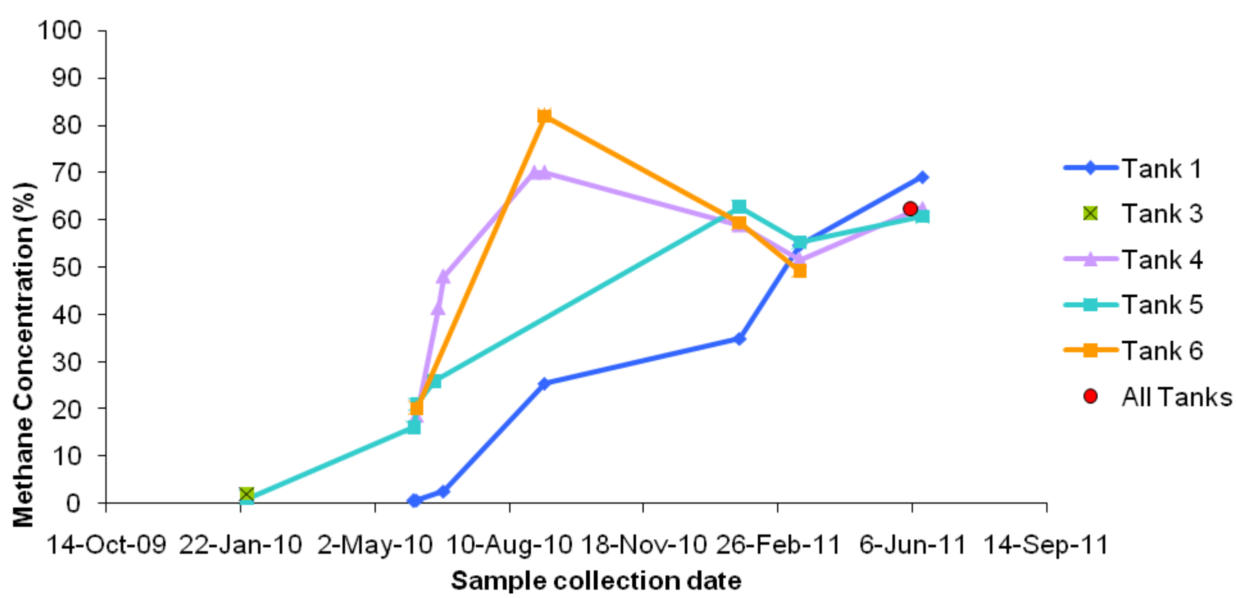

Figure 1. Methane (CH_4) concentration in biogas samples determined on a Shimadzu 2014 gas chromatograph equipped with FID and TCD. Concentration of gases are presented as percent by volume. It should be noted that 70% CH_4 in Tank 4 shown for Aug. 28 and Sep. 5 was calculated as a correction to lower concentrations measured in samples due to a leak in the sampling system. Both the samples from August/September Tank

4 had the same methane/carbon dioxide ratio - =4.4 Based on a review of the other biogas samples, this should put the methane level of the biogas at ~65-70%, after correcting for presumed dilution from air contamination. The fact that the two samples had the same ratio of these gases, despite a two-fold difference in the methane level, is a good indication that the low reading is due to dilution by atmospheric air in the sample collection stage.

Based on the samples gathered, sufficient information now exists in order to rate the quality and BTU equivalent of the biogas produced during the experiment. Referring back to the "Phase 1 Data report", the highest observed production rate of any given 1000L tank within a twenty-four hour period was 345L. Combining the observed production rate(s) with the average methane concentration of biogas collected from the site (~69% CH_4 by volume), a good estimate of heat production value can be determined at this time. Based on the information available, gas collected at the end the project, which at the time of the last report was used to run a generator and boil water (see Y2Q2 report), had an equivalent BTU rating of approximately 8.4 btu day^{-1} L^{-1} (Equation 1).

It is important to note, that this BTU rating is helpful in calculating possible efficiencies of combustion across a range of gas powered devices, but should not be viewed as a static number as the quality of produced biogas has been demonstrated to change over time and should therefore be viewed only as a helpful approximation of gas heat content (Figure 1).

Equation 1. Rating BTU content of biogas

$$\frac{Production\ Rate \times Gas\ Composition\ \% \times Density\ of\ CH_4\ @\ 1bar}{100} = g\ CH_4$$

$$g\ CH_4 \times \frac{1\ mol}{16.042g} CH_4 = moles\ of\ CH_4\ per\ daily\ output$$

$$n\ Mols\ CH_4 \times \frac{891kJ}{mol} CH_4 = n\ kJ\ per\ day*$$

$$1\ kJ \cong 0.95\ BTUs\ \therefore equivalent\ measure\ of\ gas\ energy\ content$$

* MSDS for Methane (source: encyclopedia.airliquide.com)

High Pressure Liquid Chromatography

The research team also ran tests on the relative nutrient content of reactor effluent collected throughout the experiment. Similar to GC analysis, high pressure liquid chromatography (HPLC) is another analytical technique which can be used to determine the composition of a material when the material of interest is in the liquid form as opposed to a gas. The same concept applies in both cases were individual components and their concentrations are determine based on the amount of time it takes them to travel through a charged column, know as retention time. Here, the retention times of the sample are compared to a set of 'standards' (i.e. prepared samples of known concentration) which are used in order to determine the sensitivity and accuracy of the instrument and therefore quality of the results for samples run (Figure 2).

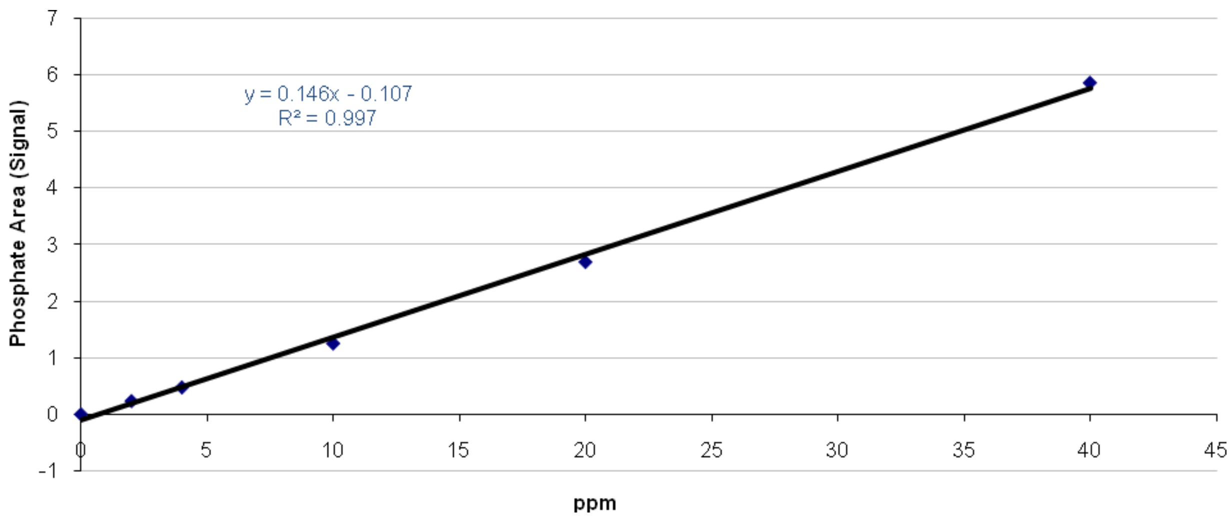

Figure 2. The calibration curve for phosphate. The linear relationship observed in the calibration curve was used to determine concentration of phosphate in digestor effluent samples based on the magnitude of the peak signal that occurred at the retention time of phosphate. All liquid chromatography testing was performed on a Dionex LC 20 HPLC with automatic feeding and sample control. All concentrations are reported in ppm.

Upon sampling, effluent samples were stored refrigerated until analysis on a Dionex LC 20 with Chromeleon software package was performed on April 18, 2011. The instrument was programmed to determine the relative levels of fluoride, phosphate, nitrate, nitrite, and chloride. Some species of interest (e.g. potassium, ammonium, ammonia, etc.) could not be determined due to unavailability of instrumentation needed to perform these analyses. A cataloged list of frozen samples still exists, in case further analysis is desired in the future.

Perhaps, most surprising was the low, mostly undetectable, levels of nutrient and mineral content within the samples run. Indeed, aside from chloride, which had very high levels due to the use of tap water in the experiment, only phosphate was detectable in any measurable quantity among samples run. Nitrate and nitrite were below the detection limit of the instrument; however, we suspect that most nitrogen found within the tanks would likely be in some other usable form (e.g. ammonia, ammonium, etc.) (House, 1978).

Phosphate, which is an important nutrient used in agriculture, was found in concentrations as high as 55 parts per million (ppm) (Appendix I). Soils containing phosphate levels below 14 ppm are considered ‘phosphorous deficient’ so reactor effluent can be considered as good source of liquid fertilizer (Swift, 2009).

iii.b.2) ACEP Cost Benefit Analysis, Performed by ISER

This section of the report briefly outlines the work performed in the last quarter on evaluating the feasibility and cost benefit analysis of this project. This portion of the project was performed in order to make recommendations regarding the future of the technology for Alaskans interested in installing a reactor of similar scale within an individual home.

The Institute of Social and Economic Research (ISER) is currently in the process of evaluating the Cordova Biogas project in order to determine the technology's level of marketability to Alaskan communities at large. Working in conjunction with ACEP, research associate Sohrab Pathan at ISER has been reviewing the project throughout the last quarter in order to determine if small, household-scale anaerobic digestor projects, like those assessed in this study, have any future potential to Alaska residents interested in biogas technology.

In early July of this year, the UAF research team, along with ACEP and ISER met to discuss what an economic feasibility study would likely look like. It was determined at that time, and reaffirmed in later meetings at ACEP in August, that a Cost Benefit Analysis would be the most appropriate form of analysis as this project did not fall under the same parameters of other studies under the Emerging Energy Technology Grant (EETG) and should therefore not be evaluated along the same baselines of measure.

The study is currently underway and should be finalized before the project's termination date on September 30, 2011. For more information regarding the details of the report, please contact:

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iii.b.3) Wet-cup Flux Trap and Low Biogas Production Monitoring

A critical limitation to determining gas production rates during Phase I and Phase II of this study was the lack of a manageable and reliable method of measuring gas flow rates (Y1Q4, Y2Q1-2). Much information was lost during the first year of the project with respect to daily gas production rates of individual reactor vessels due to improper calibration of the Sierra Top-Track 820 mass flow meters installed on site (see Y1Q4 report). The issue arrose because the flow meters could not distinguish significant quanties of gas movement across the flow tranducer (calibrated at ~3 SLPM) and therefore gave faulty readings. Later in the project, this issue was remedied for short-term flow determinations by closing off reactor valves in order to let the tanks accumulate gas pressure over 6-8 hour periods (Y2Q1-2), thereby releasing the gas at high enough rates of flow in order for the meters to detect the mass movement (see Y1Q4 report). This method improved the accuracy and understanding of daily biogas production rates, but was too costly and inefficient to to be employed on the long term. In general, it was determined that other, less costly methods must be developed in order to reliably determine flow rate and daily biogas production levels.

In effort to improve biogas data collection methods, UAF researchers worked during the last quarter to improve upon the design of existing flux trap technology for better gas flow measurements. Improvements made to the technology now allow for reliable low and high-level gas flow rate monitoring.

In the last quarter, at the sugestion of PI Katey Walter Anthony, a new method of gas production monitoring was developed by researcher Casey Pape, et al. using 'wet-cup gas meters'. The idea has been used before in experiments similar to that of the Cordova biogas project, though never in this exact application, and was therefore not commercially available (Massé, 1997). Figure 3, component 7 illustrates the underlying principle of the wet-cup gas flow meter. The mechanism is operated by a double-walled typing cup which is balanced at a single, central pivot point. When the leading cup fills with gas, its moment of inertia changes once it reaches a certain constant volume, causing the cup to tip while at the same time, orienting the cup opposite into the proper position to collect gas until it fills and tips - restarting the cycle. This is very much the way in which a typical rain gauge operates, the only difference being the cup and gauge is inverted in this case, being held in place by the bouyancy of the material, rather than gravity (Figure 2). As the cup begins to empty, losing its contents and orienting in the adjacent position, a small magnet placed in the middle ot the mechanism travels past a magnetic proximity switch which triggers a data logging device to record the event.

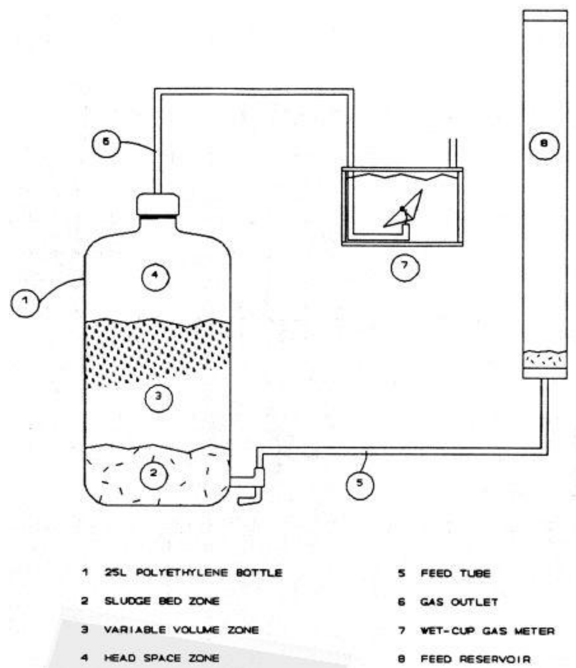

Figure 3. Illustration of the 'wet-cup gas meter' used to develop a method to measure gas flux at low rates of production (from Massé, 1997).

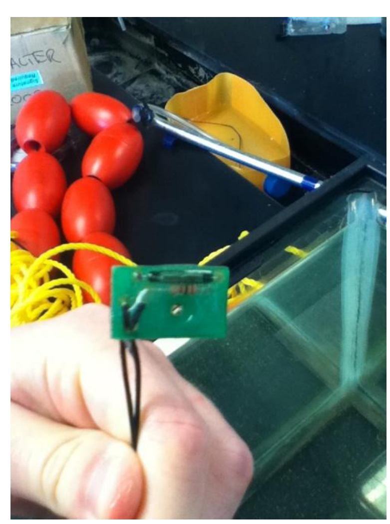

Figure 4. The internal working mechanism of the wet-cup flux trap (Left). Set screws can be used to adjust the relative position and tipping volume of each event. The magnetic switch delivered from the manufacture does not have adequate waterproofing and needs additional treatments of epoxy or equivalent in order to be deployed in an aquatic environment (Right).

Table 2. Calibration table of a wet-cup flux trap for gas flow measurements.

	Trap Calibration		
Trial	**Trap 2 (5mL)**	**Trap 3 (10mL)**	**Trap 1 (40mL)**
#		**(mL)**	
1	6	10	39
2	6	8	34
3	6.5	10	35
4	6	8	36
5	6	10	37
6	5	7	39
7	6.25	10	38
8	5	9	39
9	5	10	37
10	5	7.5	37
Average	**5.7**	**9.0**	**37.1**
STDEV	**0.6**	**1.2**	**1.7**
Mode	**6.0**	**10.0**	**39.0**

Since both cups are identical, once calibrated, a total volume of gas evolved from the system can be ontained by simply multiplying the number of events recorder by the amount of gas required to cause a tipping event (Table 2). Since each event is given a time stamp, information regarding rates of flow and daily production are still retained and can be calculated based on the slope of the gas production graph (Figure 4). This method is ideal for studies where high resolution flux data is prefered because the individual tipping cup's capacity is on the order of hundreths of a liter per tipping event. Most gauges tip at 20 ml or less. Initial efforts to monitor gas flow in the six Cordova digestors using the wet-cup method were challenged by inadequate (non-standardized) tipping cup apparatus as well as by shorting out of electronics for data logging (Figure 5). The improvements made during the past quarter seem to have resolved these problems. In addition to laboratory testing and calibration, the wet-cup flux traps were deployed and tested in the field to monitor the gas flow rate from methane seeping in a thermokarst lake. Results suggest that the method would work well as a gas flow monitoring technique for anaerobic digesters as initially intended for this project (Figure 5).

For the average consumer interested in developing an anaerobic digestor of their own, this tipping cup method presents a cheap and simple way to closely monitor gas production. Gauges of this type can be obtained and adapted for for the wet-cup application for around $100 USD.

Figure 5. Installation and deployment of the wet-cup flux traps at the Cordova digestor site earlier in the project. Automated bubble traps were installed on 10/15/2010 in an effort to monitor total gas flux from digesters 1, 4, 5, and 6 in a to the Sierra Top-Trak 820 Mass Flow meters

iii.b.4) Final Project Site Breakdown

Research technician Casey Pape traveled to the Cordova site from May 28, 2011 to June 16, 2011 in order to finalize Phase II demonstration of gas collection and utilization. He also led the breakdown of the digesters at the Cordova field site. Pape and other project team members from CEC began disassembly on June 14, 2011. Each of the reactor vessel's contents was evacuated using an industrial garbage pump into a secondary storage container which was used to screen out most of the sediment and heavy solids that were located within each of the tanks. The remaining liquid was discharged into the local storm water runoff drain as it contained no chemically harmful material. In order to finish evacuating all of the tank contents, each tank had to be cut and the bottom sludge layer agitated in order to loosen the remaining material of each tank, allowing them to drain more easily. The remaining tank components were disposed of at the local bailer waste compactor site and all instrumentation was returned either to CHS or UAF labs when Pape returned to Fairbanks. The project Conex is now vacant as of June 27th 2011, and aside from the R-10 foam insulation and updated electrical system provided by the project, the Conex was returned to the school in its original condition prior to the onset of this project. Spare materials (e.g. construction materials, garbage cans, water pumps, pipe fittings, ball valves, and spare tubing), along with the converted Husky generator and stove instruments were left at the Cordova High School Energy Center for future use by students and teachers. Field-based activity at the Cordova field site ceased as of July 18, 2011. Pictures of the final breakdown are available at the end of this report (Appendix II).

iii.c) Health and Safety

Conventional small-scale anaerobic digestors are generally considered to be non-hazardous when given proper ventilation and maintenance. Still anaerobic digestors are used for the synthesis of combustible gases and have some safety concerns associated with them. As of April 18, 2011 the project Conex was locked and given a "standby" status upon discussing the project with UAF Environmental Health and Safety workers. EH&S had expressed some concern over proper project ventilation and the intrinsic safety of some of the equipment used on-site. With decrease supervision, coinciding with Pape's relocation to Fairbanks, it was determined that the best plan was to minimize access to the inside of the Conex, cease feeding experiments, increase the temperature and open all valves in order to react all remaining organics within the reactors. Upon revisiting the project in June 2011, researchers consulted with EH&S in order to follow the best procedures for finalizing the gas collection, demonstration of gas utilization, and site breakdown. No health problems or accidents were ever reported during the course of this project.

Electrical and Power: The project site is maintained by electrical heat and power supply. At present, that electricity has been provided by extension cords that run from inside the school and out to Conex. The CEC recently renovated the electrical system and increased the power capacity of the site. The project Conex electrical system now complies with all state and federal building and transmission codes and is wired for both 120V and 240V AC power.

Flammability: Biogas is very flammable and it is important that measures be taken to prevent any undesirable fires that may cause explosion. No open flame was allowed within the Conex and students handling biogas were instructed to wear appropriate eye protection at all times. Students conducting experiments with biogas were required to wear eye safety glasses and proceed under adult or teacher supervision. No injuries due to fire or explosions occurred during this project though several fire alarms were been triggered when demonstrating biogas flammability was conducted without proper ventilation.

Ventilation: The build-up of certain gases in an enclosed space can be toxic. Biogas digestors produce methane, carbon dioxide, hydrogen sulfide, and other gases which can be deadly at high concentrations. It is apparent to anyone entering the Conex which houses the experiment that a noticeable "barn-like" smell can be detected. The smell is due to volatile organics. Methane is odorless. This smell was significantly reduced once the new tank gas outlets were installed. Tanks were monitored daily and were not thought to pose any threat to human health. The air was cycled daily to a certain extent when the Conex container was opened for daily download of the gas flow data. Tubes are connected to the tanks to allow lighter than air constituents escape the container. H_2S tags were located in the Conex throughout the duration of the experiment to visually monitor H_2S levels in the Conex. They never reached any level of concern. The Cordova fire department visited the site and tested it for noxious gases. The results of the fire departments' testing came up negative for any toxic gases.

iii.d) Schedule of project

The project is still on schedule as defined by the original project outline. Phase I is complete and Phase II is in its final stages. Throughout the rest of the project research efforts will focus final data synthesis, writing of reports and information for public dissemination, and public presentation at the Alaska Rural Energy Conference.

iii.e) Project budget

We anticipate that the budget is on target. At this time, the budget is not expected to exceed the grant, and the matching contribution is expected to significantly exceed the grant requirement. Clay Koplin will provide more details on the budget in the Final Report.

iii.f) Hurdles and solutions

Project problems and solutions were outlined in previous progress reports. The remaining hurdles to which we found solutions during the past quarter were finding a reliable method for measuring gas flow rates (see *iii.b.3) Wet-cup Flux Trap and Low Biogas Production Monitoring*), and building and employing a suitable gas collection system for biogas produced among the digestors (see Y2Q2).

References:

House, David. (1978) *The Complete Biogas Handbook*. (Alternative House Information, United States), 52.

Massé, D.I., Droste, R.L., Kennedy, K.J., Patni, N.K., and Munroe, J.A.(1997) *Potential for the psychrophilic anaerobic treatment of swine manure using a sequencing batch reactor*. Canadian Agricultural Engineering. Vol. 39, No. 1. pp. 25-33.

Swift, C.E. (2009) *Colorado State University area extension agent, horticulture, Tri River Area, Grand Junction*; and J. Self, CSU extension specialist – soil testing, soil, water, and plant pesting lab manager, Colorado State University, Fort Collins. Revised 2/09. <http://www.ext.colostate.edu/pubs/garden/07611.html>

Appendix I. (Chemical Data Supplement)

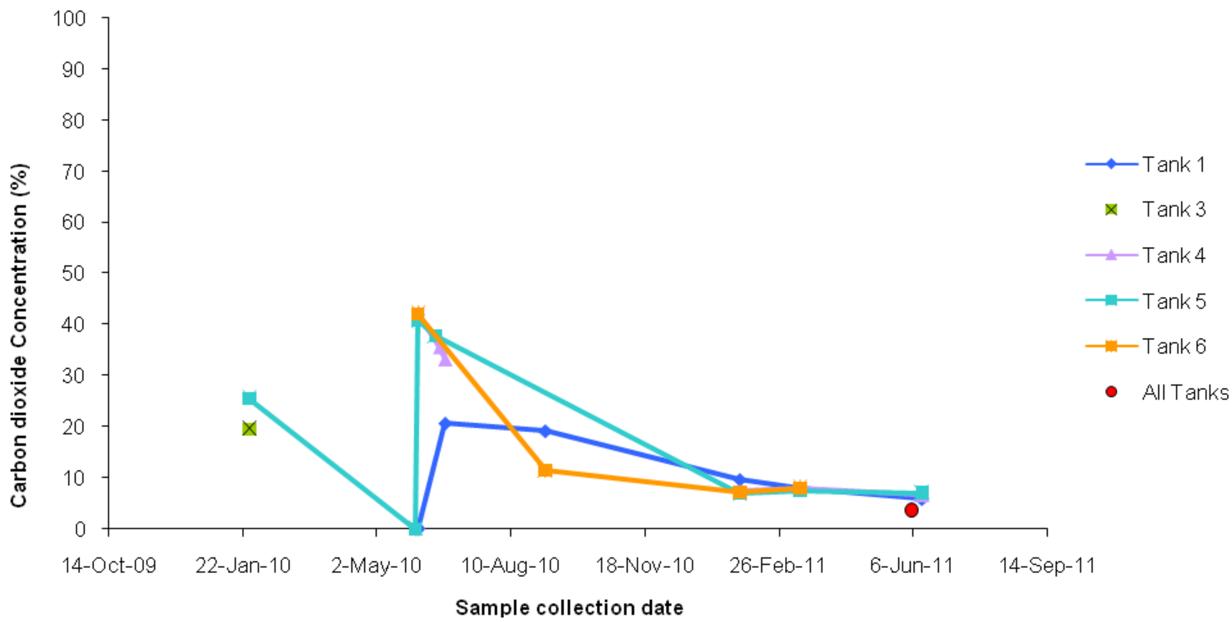

Figure 5. Concentration of carbon dioxide in digesters, presented as percent by volume.

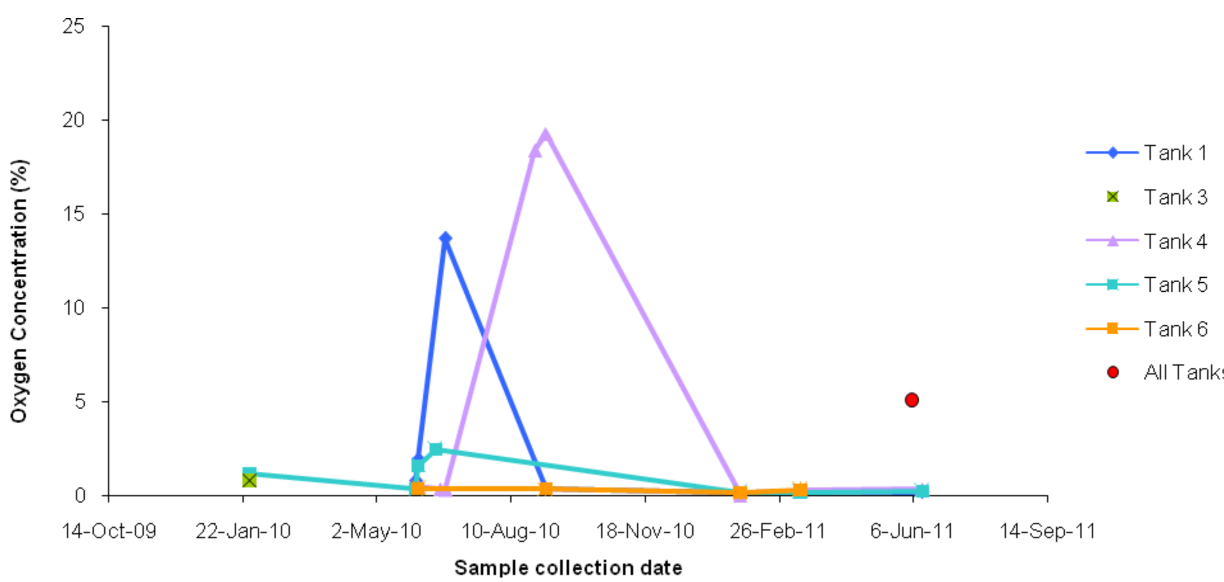

Figure 6. Concentration of oxygen gases are presented as percent by volume. Data label "All Tanks" is suspected to be above other measured gas samples due only to not being fully evacuated prior to collecting and storing gas produced from the other tanks in the experiment.

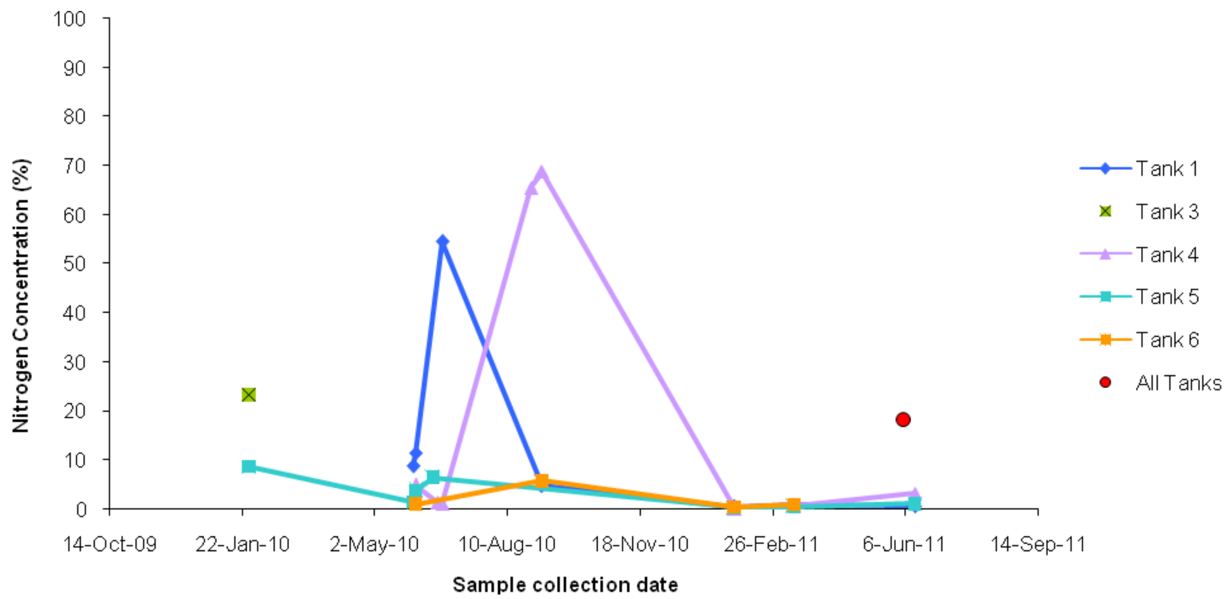

Figure 7. Concentration of nitrogen in digestors presented as percent by volume. Data label “All Tanks” is suspected to be above other measured gas samples due only to not being fully evacuated prior to collecting and storing gas produced from the other tanks in the experiment.

Table 1. Liquid chromatography table for phosphate in all effluent samples collected over the course of the experiment. The samples were all run with a 1:5 dilution; therefore actual concentrations are reported in the right-most column. All samples were run on a Dionex LC 20 chromatograph with Chromeleon data processing software package.

Run Date: 04/18/2011

Sample Name (Tank #)	Sample Date	Sample No.	Sample Name	Ret. Time min Phosphate	Area (µS*min) Phosphate	Dilution (1:5) standard/sample concentration [ppm]	Actual [ppm]
		Standards					
		1	lrb	n.a.	n.a.	0	0
		2	standard 1	9.777	0.2337	2	10
		3	**standard 2**	**9.794**	**0.4751**	**4**	20
		4	standard 3	9.78	1.2506	10	50
		5	standard 4	9.757	2.6897	20	100
		6	standard 5	9.734	5.8526	40	200
lrb		7	lrb	n.a.	n.a.		
ccv2		8	ccv 2	9.597	0.4688	3.93	20
1	7/13/2010	9	1	n.a.	n.a.		
2	7/13/2010	10	2	9.61	0.0481	1.06	5
3	7/13/2010	11	3	9.64	0.2332	2.32	12
4	7/13/2010	12	4	n.a.	n.a.		
5	7/13/2010	13	5	n.a.	n.a.		
6	7/13/2010	14	6	9.587	0.8266	6.37	32
1	7/28/2010	15	7	n.a.	n.a.		
2	7/28/2010	16	8	9.627	0.1051	1.45	7
3	7/28/2010	17	9	9.63	0.3635	3.21	16
4	7/28/2010	18	10	n.a.	n.a.		
5	7/28/2010	19	11	n.a.	n.a.		
6	7/28/2010	20	12	9.617	0.9359	7.11	36
1	8/4/2010	21	13	n.a.	n.a.		
2	8/4/2010	22	14	n.a.	n.a.		
blank		23	15	n.a.	n.a.		
4	8/4/2010	24	16	n.a.	n.a.		
blank		25	17	n.a.	n.a.		
6	8/4/2010	26	18	9.577	0.8746	6.70	33
lrb		27	lrb	n.a.	n.a.		
ccv2		28	ccv 2	9.603	0.4769	3.98	20
1	8/27/2010	29	19	n.a.	n.a.		
2	8/27/2010	30	20	9.58	0.0462	1.05	5
3	8/27/2010	31	21	9.597	0.2684	2.56	13
4	8/27/2010	32	22	n.a.	n.a.		
5	8/27/2010	33	23	n.a.	n.a.		
6	8/27/2010	34	24	9.563	0.7137	5.60	28
1	3/23/2011	35	25	9.57	0.1452	1.72	9
2	3/23/2011	36	26	9.54	0.4405	3.74	19
3	3/23/2011	37	27	9.59	0.7037	5.53	28
4	3/23/2011	38	28	9.543	1.1275	8.42	42
5	3/23/2011	39	29	9.544	0.7703	5.98	30
6	3/23/2011	40	30	9.527	1.4953	10.93	55
lrb		41	lrb	n.a.	n.a.		
ccv2		42	ccv 2	9.567	0.4737	3.96	20

Appendix II. (Final Project Breakdown)

Final project site as of July 18, 2011. Insulation and lighting arrays remain to be removed at the school districts discretion. Photo credit: Clay Koplin.

Evacuated tanks had to be cut with a sawz-al in order to be removed and their remaining contents disposed of properly. Photo credit: Clay Koplin.

Empty tanks.

The project site, when viewed from the outside. Final project site remains undisturbed since July 18, 2011.
Photo credit: Clay Koplin.