ONSITE WASTEWATER RESEARCH PROGRAM AT THE TEXAS A&M UNIVERSITY: LOW PRESSURE DOSING RESEARCH

Gabriele Bonaiti[1], Anish Jantrania[2], June Wolfe[3], Ryan Gerlich[4]

ABSTRACT

Low pressure dosing (LPD) systems offer an alternative to standard gravity or pumped drain field systems, thanks to uniform distribution of effluent, dosing and resting of the soil treatment area, and shallow placement of trenches to enhance aeration. In Texas, LPD systems are required to be installed according to design criteria in the North Carolina State University Sea Grant College Publication UNC-S82-03 or other publications. The Texas Commission on Environmental Quality indicated the need for local research to determine if design can be improved. The Texas A&M University's On-Site Sewage Facility Team designed and installed a field research experiment in December 2020. A standard septic tank was used for treatment of raw wastewater and three field distribution configurations were compared: Conventional trenches with holes in laterals facing down in gravel; Trenches with holes facing up and protected by orifice shields in gravel; Trenches with holes facing up and protected by leaching chambers. The Team also designed and distributed a survey to identify problems reported by regulators, owners, and designers of LPD systems in Texas. This paper will report field experiment description, including site characteristics, design features, and monitoring instrumentation (water level, laterals pressure, soil moisture); will discuss field preliminary results and experienced challenges; and will present survey design and input obtained from participants.

INTRODUCTION

Managed onsite water and wastewater systems play an important role in our nation's water infrastructure (US EPA Report to Congress, 1997). In Texas, it is estimated that about 20% of the dwellings use On-Site Sewage Facilities (OSSF) to manage their wastewater (Bonaiti, et. al., 2017). Research on OSSFs has been conducted in large part in the 80s' and discussed at the National Symposiums on Individual and Small Community Sewage Systems, which were periodically organized (ASAE, 1984, ASAE, 1987). In Texas, in the late 80s and early 90s, legislators debated and passed a law requiring the state's environmental regulatory agency to award competitive grants supporting applied research and demonstration projects regarding on-site wastewater treatment technologies. Funds were provided by a \$10 dollars fee collected from each OSSF permit. Due to the so called "sunset policy", the law was not renewed after 20 years in 2013, and state funding for onsite wastewater research stopped. Thanks to political lobbying efforts by the Texas Onsite Wastewater Association in 2017 the 85th Texas Legislative Session passed House Bill 2771 and renewed the law. As a result, the Texas Commission on Environmental Quality (TCEQ) in 2019 announced a Request for Grant Application (RFGA Number 582-19-93772), as part of the Texas OSSF Grant Program (TOGP). The RFGA called for research

[1] Gabriele Bonaiti, Ph.D., Extension Program Specialist, Texas A&M AgriLife Extension
[2] Anish Jantrania, Ph.D., P.E., MBA; Associate Professor and Extension Specialist, Texas A&M AgriLife
[3] June Wolfe, Ph.D., Research Scientist, Texas A&M AgriLife Research
[4] Ryan Gerlich, Extension Program Specialist, Texas A&M AgriLife Extension

addressing four topics: 1) black water non-potable reuse, 2) implementation of low pressure dose systems with various configurations, 3) dosing verses non-dosing in aerobic treatment units (ATU), and 4) adequacy of ATUs designs with higher strength wastewater. Texas A&M AgriLife was awarded three contracts to address all four research topics. This paper will describe the activity conducted under topic #2.

Low Pressure Dosing System (LPD) offers an alternative to a standard gravity or pumped drain field system that overcomes certain soil and site limitations for disposal and treatment of septic tank effluent. Three unique characteristics of the LPD system that help overcome soil and site limitations are: (a) uniform distribution of effluent, (b) dosing and resting of soil treatment area, and (c) shallow placement of trenches to enhance aeration. LPD systems are implemented in Texas mostly in the Central, South, and Southeast regions, especially in proximity of largest cities and along the Lower Colorado River (Figure 1). About 43,000 LPD permits (less than 5% of the total permits) have been issued since 1992 (On-Site Activity Reporting System website, https://www.tceq.texas.gov/permitting/ossf/on-site-activity-reporting-system, last visit August 27, 2021).

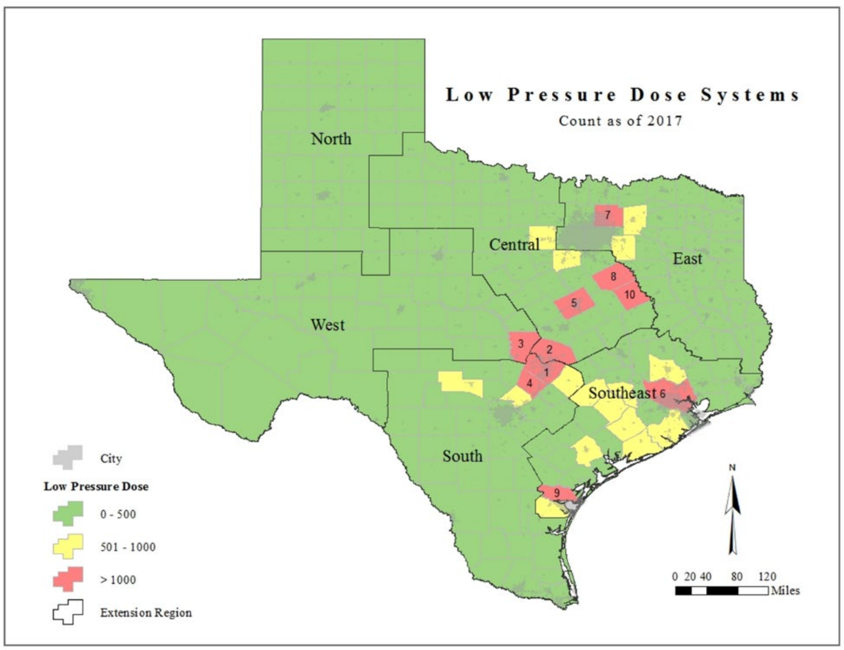

Figure 1. LPD systems are implemented in Texas mostly in the Central, South, and Southeast regions, especially in proximity of largest cities and along the Lower Colorado River

A properly designed, installed, and operated LPD system can overcome limitations associated with use of a standard system. However, field research is needed to determine if the commonly used design can be improved. TCEQ Solicitation questions the adequacy of North Carolina State Sea Grant College Publication UNC-SG-82-03 (Design and Installation of Low-Pressure Pipe Waste Treatment Systems, Cogger et al., 1982), currently used to aid in low-pressure dosing field design. The Solicitation suggests that research is needed into whether the design can be improved in terms of effluent distribution over time, and ability to maintain the distribution system. Two alternative field configurations are mentioned in the solicitation, which include distribution holes facing up (as opposed to the recommended set up with holes facing down) and protected with either orifice shields or with leaching chambers.

The project addressing LPD topic was designed to answer the following three main questions:

1) What are the operational problems faced by the users and operators with the current LPD design in Texas?
2) Can the current design with holes facing down be improved with holes facing up, to achieve better distribution of effluent and to allow for better maintenance of LPD systems?
3) Are changes required in the current design specifications of an LPD system in 30 TAC Chapter 285 (TCEQ, 2017), and if so, what changes are to be recommended?

To answer these questions a survey and a field experiment were conducted. Survey was distributed to OSSF license holders and LPD users to determine the type and magnitude of problems faced in Texas. The field experiment was set up to make observations and measure uniformity of effluent distribution and pressure in the trenches through observation ports, soil moisture probes, and pressure devices, and to periodically analyze water quality to ensure the strength is within the typical septic tank effluent range.

This paper reports a detailed description of the survey and the field experiment. Some preliminary results are reported, but focus is on presenting the work done and discussing technical issues and related solutions. Results, which more specifically refer to objectives 2 and 3, will be presented in another paper when analysis of data will be completed.

MATERIALS AND METHODS, PRELIMINARY RESULTS, AND DISCUSSION

Specific objectives of this project included the following: 1) Conduct interviews and surveys with regulators, owners, and license holders; survey should be designed based on preliminary interviews and finalized by a TCEQ approval; 2) Identify alternative LPD system designs and maintenance schemes based on literature review and surveys results; 3) Design the experiment and obtain approval from both TCEQ and the Brazos County Health District; 4) Construct and run the experiment, monitor waste distribution uniformity and maintenance requirements; 5) Analyze the data to compare performance of alternative configurations and the conventional design; and, 6) Submit final report documenting surveys and field demonstration results, recommendations for improving LPD design and maintenance, and suggested changes to Texas regulations. In this paper we will report mostly on objectives 1 through 4. Results, which more specifically refer to objectives 5 and 6, will be presented in another paper when analysis of data will be completed.

To receive input on survey and field design, two Texas OSSF Grant Program (TOGP) Committee Meetings were organized and held on the Texas A&M RELLIS Campus before the beginning of the experiment. A third and final meeting will be organized before reporting to TCEQ, to share results and discuss recommendations. Twenty-four attendees participated in both initial meetings representing academic institution, onsite wastewater industry, and regulatory agency. Useful comments and suggestions were received, which regarded the following: typos in the design (e.g., position of the lateral with respect the geotextile in section views of proposed alternative configurations); monitoring of weather parameters (rainfall, temperature and humidity were encouraged); monitoring of soil parameters (i.e., temperature, needed to improve reliability of soil moisture measure); monitoring instrumentation (i.e., advanced soil moisture sensors were encouraged); and survey audience (e.g., reflect the entire Texas conditions). Additional control in the planning phases was ensured by the compilation of a Quality Assurance Project Plan (QAPP), which was part of the contract and followed TCEQ and USEPA standards (EPA, 2001; TCEQ, 2014). Useful suggestions were also obtained from Steven Berkowitz, with the North Carolina Department of Health and Human Services (pers. com., 1/22/2020).

A major source of change in the planned activity was related to the Corona-19 virus outbreak. This affected particularly the field experiment, which was shortened from one year to about six months. Despite the emergency, all the main activities were accomplished. A no-cost extension of three months granted by TCEQ will allow AgriLife to better finalize the analysis and the reporting work.

Below are reported details for the project, including work plan, experimental design and monitoring, preliminary results, and discussion. The survey was distributed in all Texas at the beginning of the study period, both at in person events and online, and when possible it included follow up discussion in person, by phone or email. The field experiment was conducted at the AgriLife Waste Water Research Facility Center (Center), at Texas A&M RELLIS Campus, Bryan Texas.

Survey

AgriLife developed the "*Survey to get your feedback for improving low-pressure dosing (LPD) design in terms of effluent distribution uniformity, and ability to maintain the system*" form for OSSF license holders, regulators, and homeowners to determine the type and magnitude of problems faced in Texas with LPD systems. The 2-pages survey form asks information about the individual and the number of systems designed, installed, maintained, and inspected, and the observed problems and their frequency. Large space is provided to include comments and suggestions, and a final section provides contacts and background about the project. Once approved by TCEQ, the survey was presented at the Texas Onsite Wastewater Association 2020 annual meeting, and a total of 18 surveys were completed and received at the meeting and later by email.

Considering the extremely varying conditions in Texas, and the problem of reaching individuals during the outbreak, AgriLife decided to design and post an online version of the Survey. This version was built using the Qualtrics software and an invitation was sent out to all Texas Authorized Agents (AA) by email (Figure 2). As a result of this second effort, a total of 27 surveys were completed online, which is 11% of total emails sent. One of the difficulties was to obtain current addresses, which determined an undelivered rate of 22% of total emails sent. Eight out of 27 individuals submitting the online surveys (30%) included contact information, and were contacted for a follow up discussion.

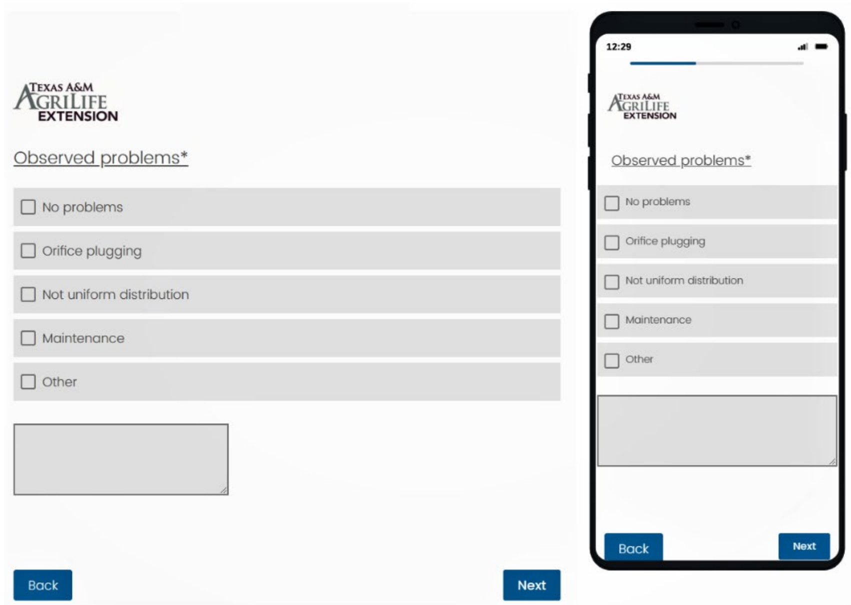

Figure 2. Example page of the online version of the "*Survey to get your feedback for improving low-pressure dosing (LPD) design in terms of effluent distribution uniformity, and ability to maintain the system*"

Summary results from all surveys received are reported in Figure 3. Overall, 6,248 systems are represented in this summary, where each answer is multiplied by the number of systems designed/installed/maintained/, and a system is counted for each problem indicated (some individuals indicated more than one problem).

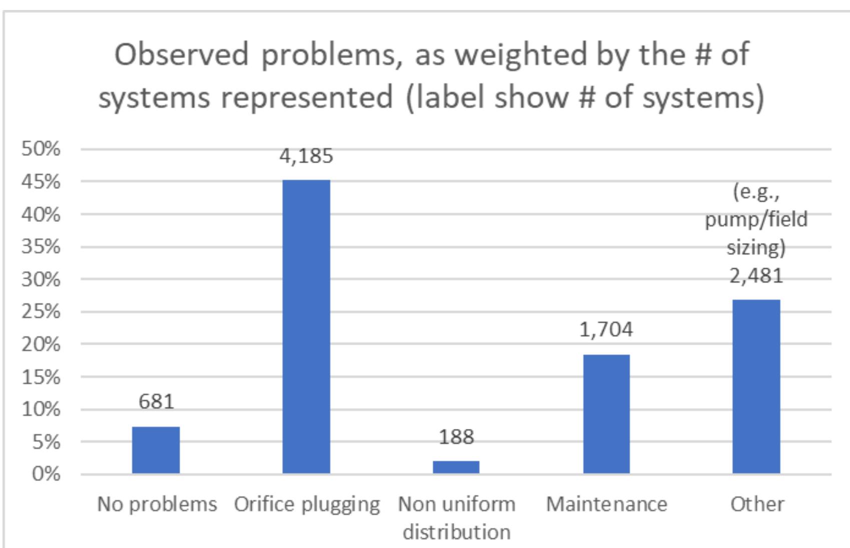

Figure 3 – Summary results from the LPD survey response. Results were weighted based on the number of OSSF designed/installed/maintained/inspected (count is reported on top of each bar)

Results suggested to put special focus on orifice clogging and maintenance. Such input, among other, affected our decision to select larger lateral holes, and to put special effort in monitoring any indicators that could be a result of orifice clogging (e.g., grass coloration).

LPD Plumbing Configuration and experiment design

As shown in Figure 4 (left part), the LPD experiment plumbing design included the following: a continuous wastewater flow supplied by the RELLIS Campus wastewater treatment facility to the existing lift station operating near the research facility; raw wastewater added to the existing 3,000-gallon common tank (feed tank) that supplies wastewater to all three research projects funded by the TCEQ Solicitation; a dedicated pump in the feed tank to supply raw wastewater to a septic tank for the LPD System, which is connected to a pump tank by gravity; one automatic sampler installed (Sampler #21) to collect weekly samples from the pump tank effluent; a pump tank used to dose the LPD field trough a 2-inches PVC SCH40 pipes supply line. Both LPD tanks (septic and pump) have two compartments, with a filter in between.

The drain field design included the following: trenches (12) sized according to 30 TAC Chapter 285 and based on UNC-S82-03 30, and excavated almost in parallel to the natural ground surface contours (i.e., 50 feet long, 18 inches deep, 24 inches wide, and 5 feet apart side to side); lateral lines (12) 1 inch in diameter, placed on top of 12 inches of pea gravel (or hanging on top of a 2-feet large leaching chamber), with 5/32-inch holes, spaced 5 feet.

The experimental design is a split plot design with three configurations (Figure 4, right part): A) holes facing down (control); B) holes facing up protected by orifice shields; and C) holes facing up protected by leaching chambers. Configuration trenches were grouped into two separate blocks. This generally ensure that the variability within blocks is less than the variability between blocks; therefore, the effect on results of any variance on soil uniformity and of any hydraulic interference among configurations are minimized. The decision was taken after observing that the West portion of the field was at lower level and more wet than the Eastern portion. Although four replicates were assigned by design to each configuration, trenches were also grouped in couples, to further reduce the possibility of hydraulic interference among configurations. On the other side this has the disadvantage that statistical analysis must be conducted differently according to the parameter observed, in some cases reducing the number of replicates to only two.

Monitoring of pump tank effluent and LPD field included the following:

- Septic tank effluent samples, taken about once a week, analyzed for Total Suspended Solids (TSS) and 5-day Biochemical Oxygen Demand (BOD5).
- Effluent distribution (i.e., water depth), measured through the inspection ports in each trench, once a week and after heavy rainfall events; inspection ports were built from PVC SCH40 pipes 4 inches in diameter, protected by a metal screen to prevent pea gravel from entering the pipe, and placed at the beginning and end of each lateral.
- Pressure at the end of distribution lines, measured each quarter as water column height with pump running, in transparent PVC SCH40 pipes installed at the end of the laterals.
- Soil moisture adjacent to the trench, measured with TDR (Time Domain Reflectometer) sensors continuously, and recorded automatically in a dedicated datalogger; sensors were placed in between trenches of the same configuration to minimize hydraulic interference, and at several depths and distance from the trench to study the wet front movements (Figures 5 and 6).

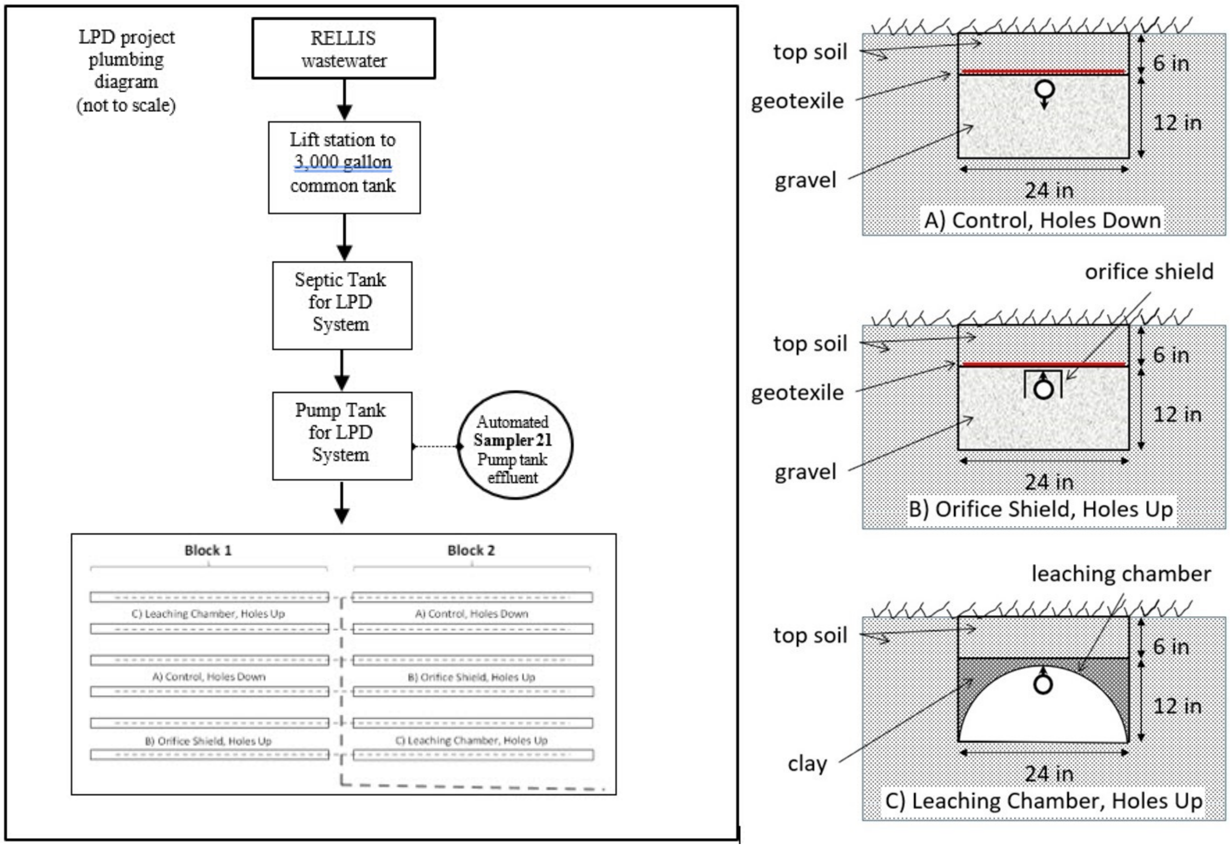

Figure 4. LPD experiment plumbing design (left), and cross-section view for three LPD Configurations (right)

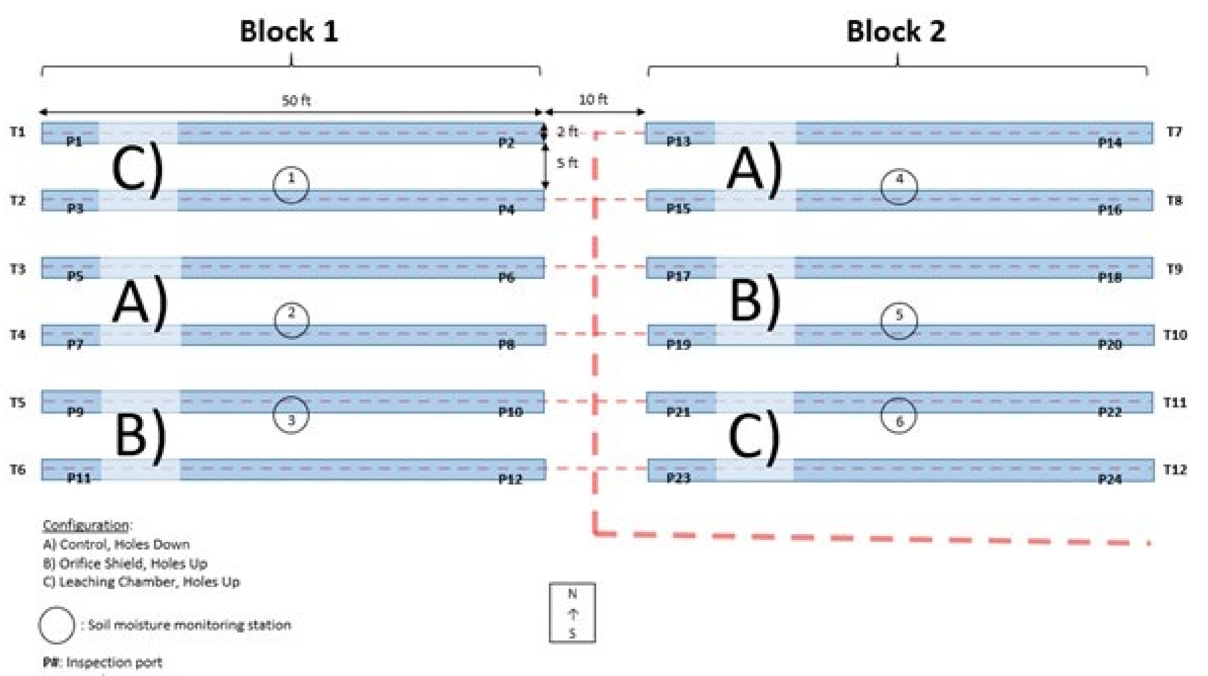

Figure 5. Details of experimental design for LPD project: Experimental design, location of TDR instrumentation installation, and location of inspection ports

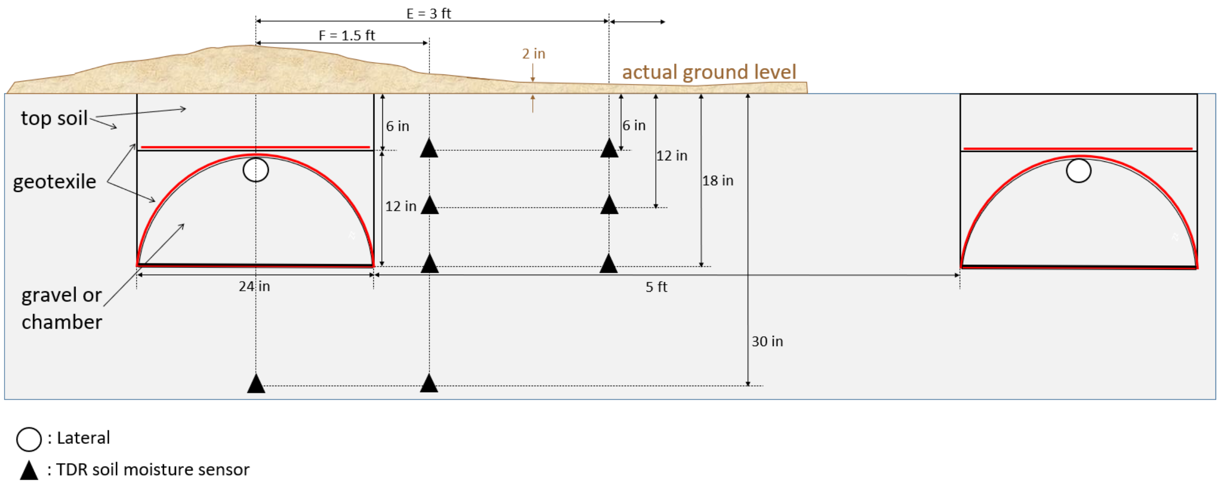

Figure 6. Details of experimental design for LPD project: Location of individual soil moisture monitoring sensors with respect to the trench section

Design Specifications and Construction

Permit to construct from Brazos County Health District

Authorization to construct was received on June 19, 2020 from the Brazos County Health District. Permit application requires specifications of the home (i.e., size, number of bedrooms, and type of home) and specifications for treatment tank size and type. Additionally, the application must include a soil profile evaluation, and site drawing indicating placement of home, OSSF treatment tanks, OSSF disposal field, all site features (including water wells) and property lines, and flood plain development permit.

A soil profile evaluation was performed on February 14, 2020 at the field North East corner and South West corner. In both locations, the profile identified a first layer (10 to 12 inches) with sandy clay loam texture, and a second layer silty clay up to 48 inches of depth. The inspection also excluded the presence of 100-year flood zone, seasonal high water table, adjacent ponds, streams, and water impoundments, existing or proposed water well in nearby area, and restrictive rock horizons.

The placement of home was not reported, because the new system was going to be installed for research purposes and not to serve any home. Rather, drawings showed the exact location where a continuous flow of 240 gpd was going be diverted from the Texas A&M RELLIS Campus wastewater treatment plant. This usage rate is the one reported for a single-family dwelling (three bedrooms), less than 2,500 square feet, with water saving devices, in the On-Site Sewage Facility Rules Compilation, TCEQ publication RG-472 (TCEQ, 2017).

Regarding specifications for treatment tank size and type, these were derived from TCEQ publication RG-472, which indicates to follow the LPD design manual UNC-SG-82-03 for most requirements (Cogger et al., 1982). Table 1 shows how size and type of the treatment tank where determined, including reference to the source used to determine maximum loading rates, wastewater usage rate, and criteria for effluent disposal systems. Table 2 reports copy of the criteria for effluent disposal systems, as extracted from TCEQ publication RG-472. Pretreatment consists of two existing two compartment 750-gallon concrete tanks connected by gravity. The first tank serves only as septic tank, while the second serves as a 500-gallon septic tank and 250-gallon pump tank. The pump tank is undersized in comparison to the current 30 TAC Chapter 285 rules, but is sufficient to allow a two-day retention in the first compartment with the 240 gallon per day flow or in the first septic tank. In the event of a highwater condition, the pretreatment tanks are configured to allow wastewater to drain back to the feed tank. The dosing from the feed tank to the pretreatment tanks is controlled by an electronic timer to ensure consistency. The feed tank also has an overflow pipe to return excess wastewater to the RELLIS Campus sewer main. These precautions will ensure wastewater will not breakout in the event of a malfunctioning pump or controller.

Table 1. Treatment tank size and type calculation

Parameter	Unit	Value	Method/Source
Effluent Loading Rate (Ra)	gal/sf/d	0.1	UNC-SG-82-03 LPD Design Manual
Wastewater Usage Rate (V)	gpd	240	TCEQ publication RG-472
Absorptive Area (A=V/Ra)	sqft	2400	
Trenches Spacing (side to side)	ft	5	
Width of the Excavation (w)	ft	2	
Depth of Media in the Excavation	ft	1	
Excavation Length (L=A/(w+2))	ft	600	TCEQ publication RG-472
Pumping Tank	gal	250	UNC-SG-82-03 LPD Design Manual (*)

(*) "*Size of septic and pumping tanks: Septic-tank volume is determined according to state and local regulations and is the same as a conventional system. The pumping tank should provide one day for emergency storage; thus, it should be at least twice the volume (V) of the daily waste flow.*" See text for justification on using a pumping tank smaller than recommended

Table 2. Criteria for Effluent Disposal Systems. Extracted from paragraph §285.33, TCEQ publication RG-472 (TCEQ, 2017)

Section	Content
§285.33	CRITERIA FOR EFFLUENT DISPOSAL SYSTEMS
(d)	Nonstandard disposal systems. All disposal systems not described or defined in subsections (b) and (c) of this section are nonstandard disposal systems. Planning materials for nonstandard disposal systems must be developed by a professional engineer or professional sanitarian using basic engineering and scientific principles. The planning materials for paragraphs (1) - (5) of this subsection shall be submitted to the permitting authority and the permitting authority shall review and either approve or disapprove them on a case-by-case basis according to §285.5 of this title (relating to Submittal Requirements for Planning Materials). Electrical wiring for nonstandard disposal systems shall be installed according to §285.34(c) of this title (relating to Other Requirements). Upon approval of the planning materials, an authorization to construct will be issued by the permitting authority. Approval for a nonstandard disposal system is limited to the specific system described in the planning materials for the specific location. The systems identified in paragraphs (1) - (5) of this subsection must meet these requirements, in addition to the requirements identified for each specific system in this section.
(1)	Low-pressure dosed drainfield. Effluent from this type of system shall be pumped, under low pressure, into a solid wall force main and then into a perforated distribution pipe installed within the drainfield area.
(C)	**Pressure dosing systems** shall be installed according to either design criteria in the North Carolina State University Sea Grant College Publication UNC-S82-03 (1982) or other publications containing criteria or data on pressure dosed systems which are acceptable to the permitting authority. Additionally, the following sizing parameters are required for all low-pressure dosed drainfields and shall be used in place of the sizing parameters in the North Carolina State University Sea Grant College Publication or other acceptable publications
(i)	The low-pressure dosed drainfield area shall be sized according to the effluent loading rates in §285.91(1) of this title and the wastewater usage rates in §285.91(3) of this title. The effluent loading rate (Ra) in the formula in §285.91(1) of this title shall be based on the most restrictive horizon one foot below the bottom of the excavation. Excavated areas can be as close as three feet apart, measured center to center. All excavations shall be at least six inches wide. To determine the length of the excavation, use the following formulas, where L = excavation length, and A = absorptive area.
(I)	If the media in the excavation is at least one foot deep, the length of the excavation is L = A/(w+2) where: (-a-) w = the width of the excavation for excavations one foot wide or greater; or (-b-) w = 1 for all excavations less than one foot wide.

Construction phases

Construction started on November 3, 2020, and field distribution and plumbing were finalized on November 20. Figure 8 shows some key features of the installation, such as pea gravel size, leaching chamber installation and location of lateral, orifice shields in gravel trench, inspection port location, and connection of laterals to manifold. Superficial soil was moved separately and used to cover back the top of the trenches, while the deeper layers were not used anymore and replace by the gravel or the leaching chamber. Final grading was performed to avoid low spots vulnerable to ponding and to let the area drain after rain events; in particular, excess soil was placed on top of the trenches to allow for some compaction of moved ground. Each trench was built not exactly along contour lines, as these cut the field diagonally; therefore, to keep the bottom horizontal, it was decided to assign the design depth to the West end of the trench. As a result, the East end of the trench resulted deeper by about 1-3 inches. AgriLife completed construction on December 12, 2020, including pump installation. On December 17 head pressure was tested, and head resulted uniform for all 12 laterals. Pump outflow was then regulated to ensure at least 5 feet pressure. A fence was also installed all around the distribution field, to prevent wildlife from entering the area and vandalism.

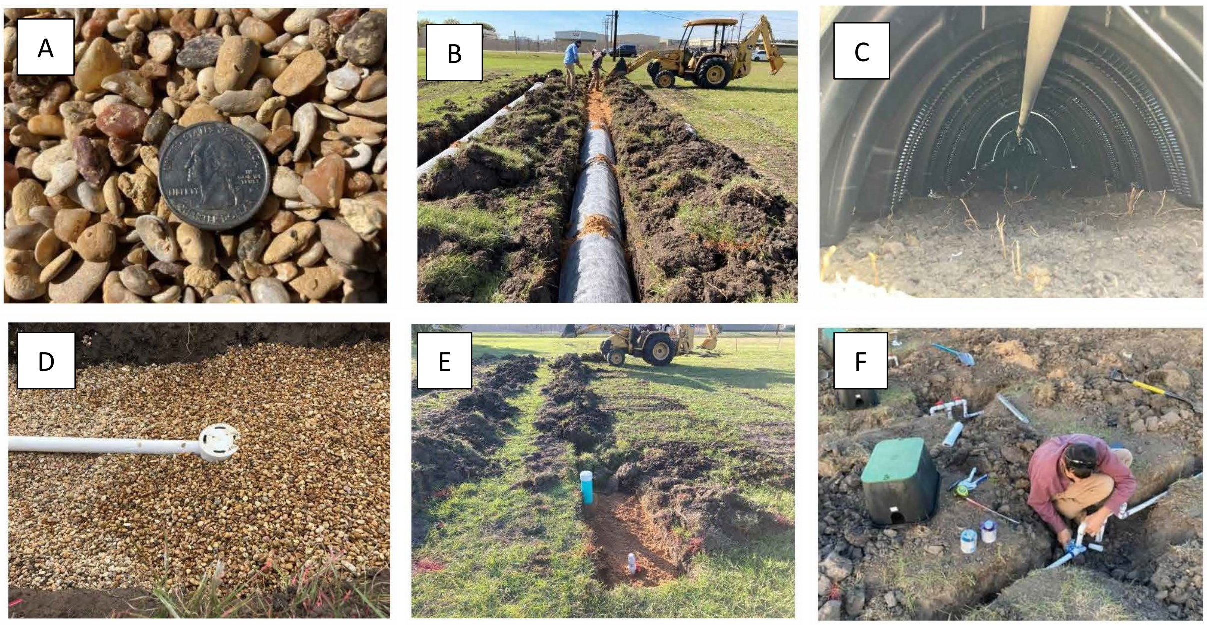

Figure 8. Images of the installation process: A) pea gravel, B) Leaching chamber installation, C) Location of lateral under leaching chamber, D) Orifice shields in gravel trench, E) Closing of a gravel trench, showing inspection port and valve, F) Connection of laterals to manifold

Construction of the distribution field resulted quite labor intensive. Difficulties included high percent of clay, distance and obstacles between the tanks and the drainfield (e.g., sidewalk), and complexity of building an experimental setup.

Wastewater distribution and monitoring

After some weeks of inclement weather and monitoring of ports with only rainfall water, on February 24, 2021 LPD pump started to distribute wastewater to the field. AgriLife had calibrated inflow from the feed tank to the LPD septic and pump tanks. Flow rate from feed tank pump was set up to run 1 minute every hour, for an estimated 8.5 gal/run, which means 8.5 gal/h and 8.5*24 = 204 gal/d; this is 85% of the design load (240 gal/d), which it was determined to be an acceptable real-world condition. Pump in the LPD pump tank was then setup with floats to work on a demand basis, with the electrical panel providing number of cycles and run time in hours and minutes. According to the following days monitoring, LPD pump was running on average 3 times/d, at 51.4 gal/dose. Based on design, and considering that supply lane and configurations 2 and 3 laterals (holes up) remain full at all time, such value respected the minimum dosing volume recommended by the UNC-SG-82-03 LPD Design Manual (41 gal for this project).

On April 9, a failure in the feeding calibration loaded the drain field with an estimated >600 gal/d for four (4) consecutive days. The feed tank pump was turned off on April 13 to restore an equilibrium. By April 20, the pump calibration method was improved with a more robust approach and loading was resumed. The new approach consisted of adding a calibration tank in between the feed tank and the septic tank. The calibration tank is closed, and has a device made of calibrated communicating pipes that while the feed tank pump is running allows for storage of the desired volume and drains back to the feed tank the excess volume; about a minute after the timer stops the loading from the feed tank, a Jandy valve controlled by a second timer opens, and the stored volume is discharged by gravity towards the septic tanks. After the changes were made, daily flow was estimated again and determined to be 9.2 gal/run (221 gal/d). On May 18, following high water levels observed in the trenches (due to high rainfall), the daily load was reduced to ~109 gal/d. The usual load was resumed on May 20.

Monitoring included weather, water level, water pressure, water quality, soil moisture, and soil physical and chemical properties.

<u>Weather data</u>

A tipping bucket rain gauge was installed in the middle of the Center at about 100 feet from the drain field. The tipping bucket was set to measure rain with a 0.01-inches resolution and at a 5-minutes interval. Additional rainfall data continued to be gathered manually from an existing gauge at the Center. As this second gauge was meant to be a backup dataset, readings were sometimes performed few days after the rain event, and only cumulated values recorded. Other weather parameters were obtained from the nearby College Station Easterwood Field (KCLL) airport weather station, which is about 7 miles from the project area. The station is part of the Houston/Galveston, TX Weather Forecast Office (WFO), and located at Latitude 30° 34' N, Longitude 96° 22' W. Available data include precipitation, air minimum and maximum temperature, wind average and maximum speed. Data were downloaded as daily averages from the NOAA National Weather Service (NWS) website. Figure 9 shows the collected weather data for the study period.

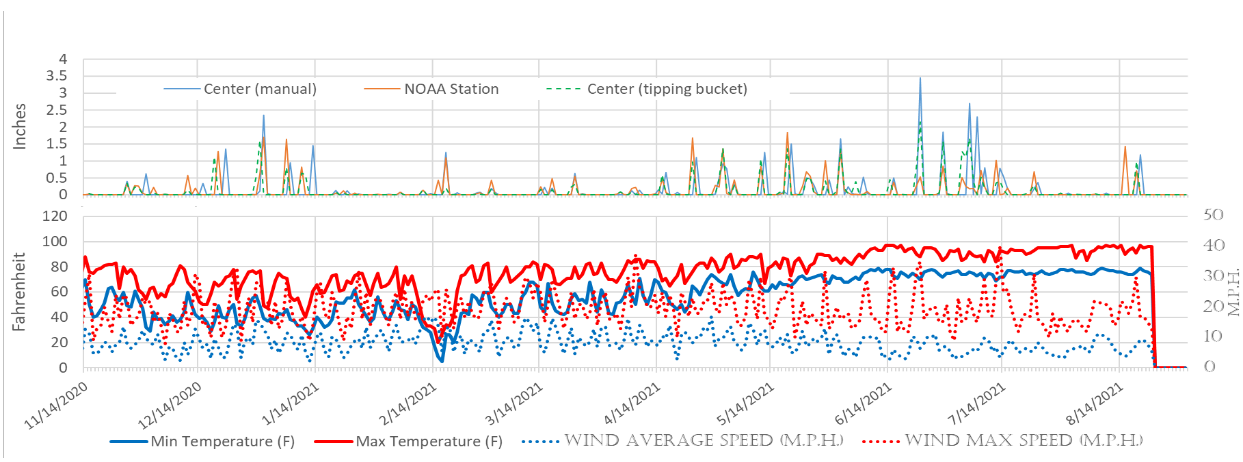

Figure 9. Weather data. Top image: precipitation from manual gauge, College Station Easterwood Field (KCLL) airport weather station, and tipping bucket. Bottom image: minimum and maximum temperature and average and maximum wind (KCLL weather station)

Precipitation was mostly consistent among the three different sources, excepted for the summer 2021, when the KCLL weather station recorded significantly less rain volumes compared to the Center (7.7 and 13.7 inches, respectively). This was due to a different behavior of local storms, and likely did not significantly affected other weather parameters. Also, the tipping bucket recorded consistently about 80% the amount measured with the manual gauge. This might be related to interference from nearby buildings and vegetation, or a calibration issue; or again, to the relatively small dimensions of the manual gauge opening (3 x 2 inches). A calibration will be conducted on the tipping bucket before the end of the project, and correction of data conducted if needed.

Weather was quite wet in the study period, especially at the end of December 2020 and beginning of January 2021. Additionally, an exceptional cold front was recorded in February 2021, with minimum temperatures constantly below freezing from February 12 to 20, and maximum temperatures constantly below freezing from February 14 to 16. Consequently, the tipping bucket did not work properly between February 14 and 22.

Water level, pressure, and quality

Measure of water level from inspection ports begun on January 7, 2021. Monitoring was performed more frequently than planned in the first two months (every 1-2 days) to collect as much information as possible in the early project stages. Figure 10 shows the average water level, together with daily precipitation and estimated wastewater daily load.

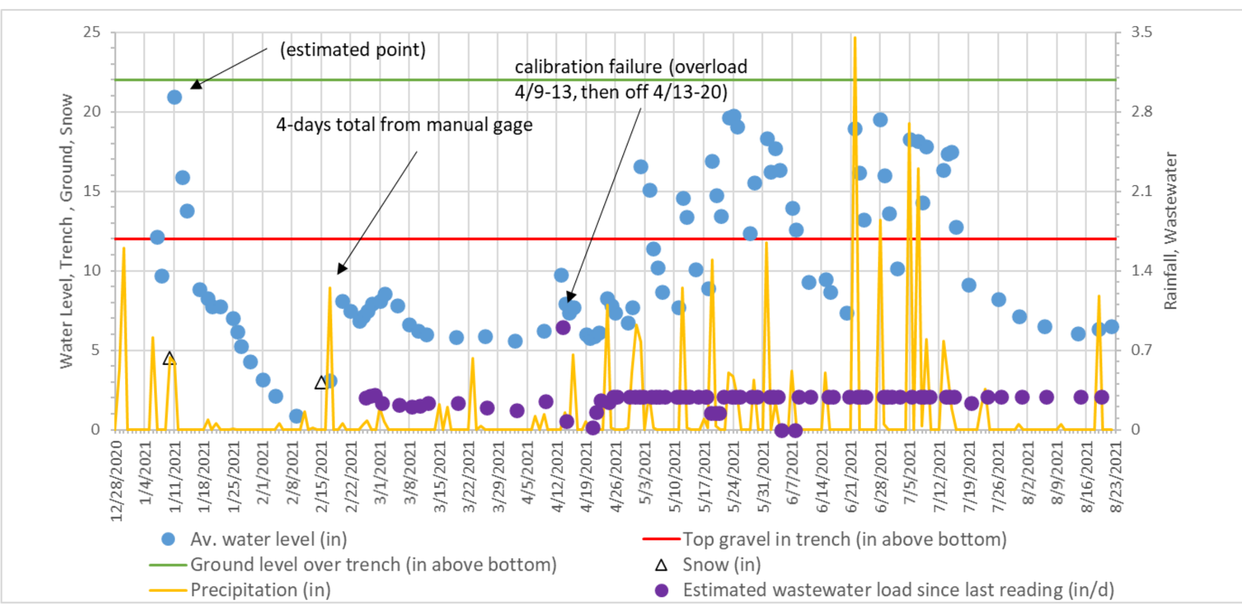

Figure 10. Average water level measured from all 24 inspection ports, daily totals of rainfall events measured at the manual rain gauge, estimated wastewater daily load, and bottom and top levels for the average trench (top indicating either gravel or chamber)

The figure shows that the water level quickly responded to rain and wastewater loading events. Trenches had water most of the time, even after some dry weeks, and level was above the gravel (or top chamber) only for few days after rain events. Preliminary results showed some differences among the compared configurations (data not shown). Trenches under configuration with holes up and leaching chamber showed the lowest levels and were empty on few occasions, while other two configurations behaved similarly. Two times in May 2021, levels were recorded also at 10 minutes intervals right after a wastewater loading. It was observed that level rose right after application (+10 minutes reading) and then started going back. Results show also that the increase was larger in the two alternative configurations (about 1 inch) compared to the control (about ¼ inch). Regarding the two blocks, each configuration had a tendency for higher levels in Block 1 with respect to Block 2. The experimental design choice demonstrated therefore successful in addressing this different behavior within the area; such effect could be related to both the difference in slope and texture.

An anomaly was observed after the strong rainfall events in December and January, when trenches located in the northern side filled much more than the others. As large deposits were observed on top of these trenches, it was interpreted that this could have be related to runoff coming from upstream the Center; likely worsened by the fact that trenches were new and porosity in the topsoil was still quite high. As a response, a drainage network was built around the distribution field to divert most runoff away from the field. After the intervention the issue did not present anymore.

Pressure on laterals was measured quarterly and showed to be quite uniform within the field. As shown in Figure 11, values measured in April 2021 resulted slightly higher compared to December 2020, while a smaller/no increase was observed in July. Values were still around 5 ft, which was the pressure set by design at installation. As water rose in the transparent PVC pipes added to the end of laterals, more sediment was observed (not measured) in April and July with respect to December, which could explain part of the increased pressure. As shown in figure, there were not apparent differences among configurations.

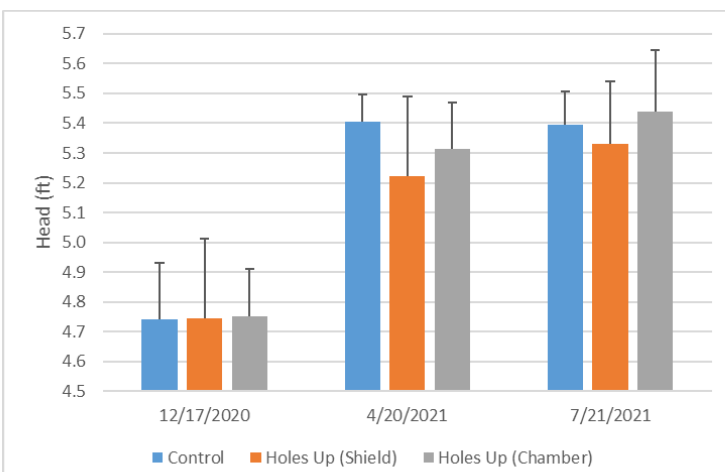

Figure 11. Pressure on laterals as measured at the beginning of the experiment (December 17, 2020), and on April 20 and July 21, 2021. Columns show the average value for each configuration, while error bars indicate the standard deviation value

Grab samples for quality purposes started to be collected in March 18, 2021. As shown in figure 12 values resulted quite low, with BOD5 ranging between 20 and 260 mg/L, and TSS between 9 and 26 mg/L. The this was the result of having effluent filter in both septic and pump tank, in between the two compartments.

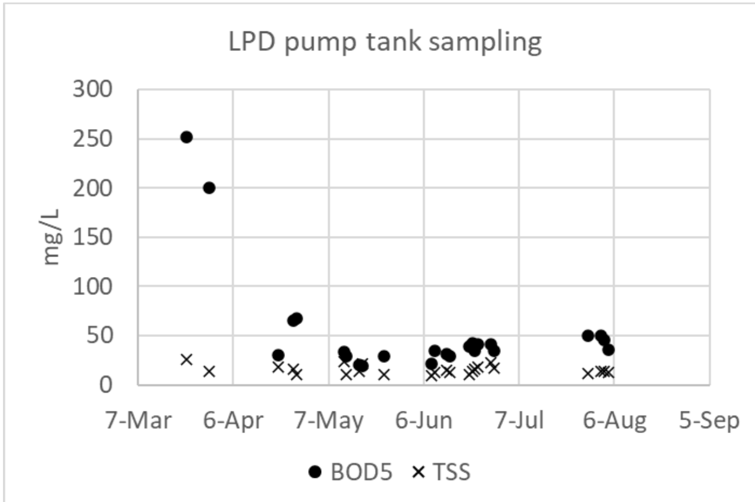

Figure 12. Wastewater quality (BOD5 and TSS) during the experiment months, as measured from grab samples collected from the LPD pump tank

<u>Soil monitoring</u>

To obtain preliminary information on the project area before altering it with construction, soil samples were collected to assess moisture content (November 24, 2020). This was also because as mentioned above a drop of about 10 inches total (0.8% slope) was found from the North East corner to the South West corner. The drop was assessed with a laser before construction, and it was confirmed by a more detailed contour elevation map generated using Esri ArcGIS Software from USGS Lidar (LIght Detection And Ranging) image. The previous months had been quite dry with respect to the local long-term average (7.5 vs 17 inches since July 1), especially the last two months (0.5 vs 8 inches). Samples were collected in between trenches of the same configuration at 1/3 and 2/3 of the trench length; therefore, at 12 locations. At each location a sample was collected at the approximate depth where TDR sensors were going to be located (3-9, 9-15, 15-21, 27-33 inches of depth), stored in plastic bags hermetically closed, and weighted and oven dried for 48 hours at 105 degrees C at the lab (same day). Moisture content on a dry weight basis was determined with the gravimetric method, and results confirmed that the West portion of the field (assigned to Block 1) was slightly more wet than the East portion (overall average of 14.2% and 12.6% respectively). Statistical analysis identified a significant difference between the two blocks at 15-21 inches of depth (average of 16.7% and 14.5% respectively). Results did not indicate any differences among configurations.

Continuous soil moisture monitoring during the project was performed using Time Domain Reflectometer (TDR). In particular, the ACC-TDR-315L TDR Single-ended Sensor (sensor), produced by Acclima, Inc., appeared to be the best option for the experiment conditions. Each sensor has three 6 in-long rods and is connected to an ACC-AGR-NODE-II-915 Acclima sensor node (node), which communicates wireless to a ACC-AGR-GTWY-II-915 Acclima SDI-12 sensor data gateway (gateway). The gateway communicates wireless with a SD card with the Hologram website, from which data can be downloaded via Internet. Selection of the instrumentation, configuration and field installation procedures had been defined following recommendations from Dr. Steven Evett, with USDA-ARS, Bushland, Texas.

TDR was configured for 60 minutes measurement interval and 4 hours upload interval. Installation and setup were completed on February 9, 2021. Installation was quite labor intensive, particularly when installing sensors at the deepest levels and under the trenches, and when filling back the holes ensuring to recreate the bulk density existing before installation. Monitoring started as soon as sensors were installed. Figure 13 shows some phases of installation.

Figure 13. Phases of Time Domain Reflectometer (TDR) installation. Left image: Picture 1: 4-inches soil layers are removed and stored separately for later correct refilling of the hole; Picture 2: Depths are referred to a common ground level; Pictures 3-8: Installation of sensor below the trench; Picture 9: Sensor installed vertically at 30 inches of depth. Right image: Picture 1: Installation of one of the horizontal sensors (6, 12, and 18 inches of depth) using a plastic guide; Picture 2: Installation of all six horizontal sensors; Pictures 3-6; Typical cables placement inside the hole; Picture 7: Electrician's putty used to plug the entrance of the conduit; Pictures 8-9: Final sensors set up and connection to the node

One sensor not properly working was replaced at the beginning of the project under warranty. On May 1, node #4 (configuration A, block 2) stopped working for four (4) days, and then stopped working again on May 11. It was determined with factory support that the issue could have been the result of a factory defect and/or some damage caused by thunderstorms. The node was sent for repair and monitoring for the node resumed on May 28. Other short interruptions were observed

periodically, especially at the beginning of the project. Such issues appeared to be related to weather instability and connections between the solar panel and the main board not properly made inside the nodes. No issues were observed during the exceptional cold days in February 2021. Results of soil moisture monitoring are not presented here, as their processing and analysis require also careful consideration of all available information on soil physical and chemical properties.
Soil texture was measured again, this time in the lab, from samples collected on March 5, 2020. Locations were nearby the ones chosen for the soil profile evaluation conducted in February, i.e., the South-West corner (Block 1) and the North-East corner (Block 2) of the LPD drain field, near the corresponding TDR sensors. Depths were 0-6, 6-9, 12-16, 18-22, 22-26, 26-30, and 30-34 inches. Results were consistent with the February estimate, showing a superficial layer loam (Block 1) and sandy loam (Block 2) extending to about 10 inches of depth, and a deeper layer clay loam (Figure 14). The slightly difference in texture between the two blocks, together with the difference in elevation could explain the higher moisture observed in Block 1.

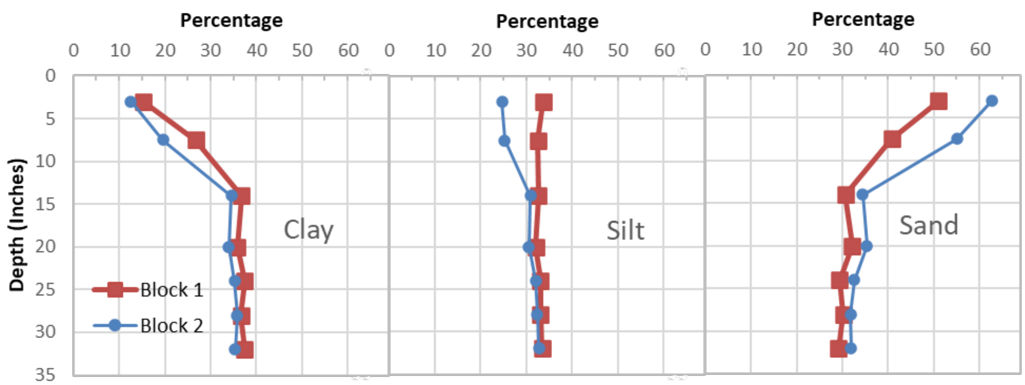

Figure 14. Soil texture observed at the South-West side (Block 1) and the North-East side (Block 2) of the LPD drain field, near the corresponding TDR sensors

The samples collected on March 2020, were also used to determine chemical characteristics (PSD basic, water-solution Cations/EC from saturated paste, Cation Exchange Capacity (CEC)), and clay detailed analysis (X-ray diffraction and Fourier transform infrared). Results (not presented) did not show significant differences between the two locations but will be useful in the final interpretation of moisture results. Finally, on August 11 and 20, 2021 undisturbed soil samples were collected to measure soil hydraulic properties at each TDR station and each TDR depth. A total of 24 samples were collected and are still being processed to determine parameters such as moisture, bulk density, field capacity determined with Tempe cell, and wilting point determined with Pressure plate.

CONCLUSIONS

The project was carefully planned by preparing a Quality Assurance Project Plan (QAPP), approved by TCEQ, and collecting suggestions and recommendations from license holders, regulators, and homeowners. Such useful recommendations were collected by organizing a committee that met before (and will meet again after) the project, and by designing and sharing a survey at events and by email. The Corona-19 virus outbreak affected somewhat the planned timeline, but although field activity was shortened by a few months all the main activities were accomplished.

Experimental design focused on reducing as much as possible the effects of hydraulic interference and soil variability among the configurations being compared in the small area. To address hydraulic interference, some of the trenches assigned to the same configuration were located next to each other; as a result, some replicates could not be used for the statistical analysis of parameters that are strongly affected by location (e.g., wastewater level). To address the observed soil variability (i.e., texture and moisture), configurations were grouped in two separate blocks, which resulted a successful setup.

Field construction was facilitated by using existing septic tanks but was overall slower than planned due to the clay texture, particularly inclement weather, presence of various obstacles (e.g., walkway), and the setting up of field monitoring instrumentation. Design specifications followed current Texas rules, excepted for the pump tank, which resulted undersized. To address this issue, a second septic tank was used upstream to ensure a two-day retention, and both tanks were configured to return excess wastewater to the RELLIS Campus sewer main in the event of a highwater condition.

Wastewater loading calibration needed some initial adjustments but ended up being very reliable in distributing the desired daily amounts to the pretreatment tanks, and in documenting the on-demand dosing to the field. A failure (overdosing for few days) and some intentional reductions on loading during heavy rain events acted as real-word situations. Storm events caused power loss in some days, but the loading was always restored promptly.

Rain data was collected from two local rain gauges and one at a nearby NOAA weather station, while other weather parameters were obtained from the NOAA station. The use of multiple devices was successful in ensuring data also during the exceptional freezing conditions occurred in February 2021. Initially, water level rose to quickly in some trenches due to run off from adjacent area. This issue was solved by intercepting run off with additional grading around the drain field.

Preliminary results showed that pressure in the laterals was uniform in all trenches. Pressure slightly grew toward the end of the experiment, but no significative differences were found among configurations. Wastewater level was above the gravel (or chamber) only few days after heavy rainfall, but rarely trenches resulted empty (few days in the configuration with leaching chamber). Level was also generally higher in one of the two blocks: the one with lower elevation and higher clay content. It was observed that, in the 10 minutes right after wastewater application level rose more in the two alternative configurations, which had holes facing up, opposed to the control that had holes facing down. Soil moisture and chemical analysis data are currently being processed.

LITERATURE CITED

American Society of Agricultural Engineers (ASAE) 1984. On-Site Waste Water Treatment. Proceedings of the Fourth National Symposium on Individual and Small Community Sewage Systems: December 10-11, 1984, Hyatt Regency New Orleans, New Orleans, Louisiana.

American Society of Agricultural Engineers (ASAE) 1987. On-Site Waste Water Treatment. Proceedings of the Fifth National Symposium on Individual and Small Community Sewage Systems, December 14-15, 1987 Hyatt Regency Chicago, in Illinois Center Chicago, Illinois

American Society of Civil Engineers (ASCE) 2017. 2017 Infrastructure Report Card. https://www.infrastructurereportcard.org.

Bonaiti, G., Karimov, A.K., Gerlich, R., and Jantrania, A. 2017. Knowing the source of On-Site Sewage: Methodologies and Challenges to Manage a Real-Time Spatial Database. Written for presentation at the 2017 ASABE Annual International Meeting. Sponsored by ASABE. Spokane, Washington, July 16-19, 2017. DOI: 10.13031/aim.201700469, Paper Number: 1700469

Cogger, C., Carlile, B.L., Osborne, D., Holland, E. 1982. Design and Installation of Low-Pressure Pipe Waste Treatment Systems. North Carolina State Sea Grant College Publication UNC-SG-82-03, North Carolina State University, Department of Soil Science, Triangle J Council of Governments

Texas Commission on Environmental Quality (TCEQ) 2014. Guidance for Assessing and Reporting Surface Water Quality in Texas, June 2015. TCEQ. Retrieved from https://www.tceq.texas.gov/assets/public/waterquality/swqm/assess/14txir/2014_guidance.pdf

Texas Commission on Environmental Quality (TCEQ) 2017. On-Site Sewage Facility Rules Compilation. Publication RG-472 (Revised May 2017). Includes: Health and Safety Code, Chapter 366 On-Site Sewage Disposal Systems (Updated February 7, 2017), On-Site Sewage Facilities, Title 30, TAC Chapter 285 (Effective December 29, 2016), Occupational Licenses and Registrations, Title 30, TAC Chapter 30, Subchapters A and G (Effective September 29, 2016)

United States Environmental protection Agency (EPA) 2001. EPA Requirements for Quality Assurance Project Plans. EPA QA/R-5. Washington, D.C.: US Environmental Protection Agency. Retrieved from https://www.epa.gov/sites/production/files/2015-06/documents/g5-final.pdf