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Implementation of Low Pressure Dose Systems with Various Configurations

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SUMMARY

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 (TCEQ) indicated the need for local research to determine if design can be improved and suggested to test alternative configurations to the one currently approved in Texas. To answer these questions the Texas A&M University's On-Site Sewage Facility Team conducted a survey and a field experiment. 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.

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, during, and at the end of the project. 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.

AgriLife designed a survey form titled "*Survey to get your feedback for improving low-pressure dosing (LPD) design in terms of effluent distribution uniformity, and ability to maintain the system*". The survey was presented at the Texas Onsite Wastewater Association 2020 annual meeting (March 9-11), and later only shared as an electronic and/or online version due to the outbreak. Overall, 6,248 systems were represented in the received answers, where each answer is multiplied by the number of systems designed/installed/maintained/inspected/owned, and a system is counted for each problem indicated (some individuals indicated more than one problem). Results indicated orifice clogging and maintenance as the main issues experienced.

The field research experiment was designed and installed in December 2020. Continuous flow of 240 gpd was diverted from the Texas A&M RELLIS Campus wastewater line. 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). Specifications for treatment tank size and type were derived from the LPD design manual UNC-SG-82-03. 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. Loading of the drain field from the pump tank is controlled on demand. The pretreatment tanks are configured to allow wastewater to drain back to the RELLIS Campus wastewater line in case of highwater conditions. Both LPD tanks (septic and pump) have an effluent filter in between the two compartments

Three field distribution configurations were compared: Conventional trenches with holes in laterals facing down in gravel (design A); Trenches with holes facing up and protected by orifice shields in gravel (design B); Trenches with holes facing up and protected by leaching chambers (design C). The Team also designed and distributed a survey to identify problems reported by regulators, owners, and designers of LPD systems in Texas.

Field 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.

Weather in the study period was characterized by frequent precipitation events, with strong storms between the end of December 2020 and the beginning of January 2021, and in the summer, and by an exceptional cold front recorded in February 2021. Precipitation 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 from outside the drain field with additional drain relief network created around the area.

Water level inside the trenches quickly responded to rain and wastewater loading events. And overflowed occasionally after heavy storms (mostly in Block 1). Trenches had water most of the time, even after several dry weeks, and level was above the gravel (or top chamber) only for few days after rain events. Trenches with design C showed the lowest levels and were empty on few occasions, while other two configurations behaved similarly. Each configuration had a tendency for higher levels in Block 1 with respect to Block 2. Accidental overloading clearly affected water level in all trenches (April 9-13), with a rise of several inches.

Statistical analysis conducted on selected data (one level measure about every month a few days after a rain event), found that there was a statistically significant difference of water level among the three configurations: with respect to the average, water level was at +0.8, +2.1, and -3 inches, respectively in design A, design B, and design C. Results showed that there was a statistically significant difference between the two blocks, with water level higher than the average (+0.8 inches) and below the average (-0.8 inches), respectively in block 1 and block 2.

Configurations and blocks were also compared for water level change (absolute value of increase/decrease) in the trench, by analyzing four rain events (April 22-29, May 12-15, May 18-21, June 20-24). To have more comparable values, measured level change was corrected considering the inches of rain, the days after the rain event, and the level reached in the trench. The analysis determined that there was a statistically significant difference among design B (lower level change) and the other two configurations (greater level change). No statistically significant difference was found between the two blocks, but when only level increase was analyzed (excluding level decrease data), Block 1 had significant greater level increase compared to Block 2.

Pressure in the laterals was measured quarterly. Compared to December 17, 2020, values were significantly higher in April 20 (+ 0.57 in) and July 21 (+ 0.64 in), 2021. There were not statistically significant differences among configurations. As water rose in the transparent pipes added to the laterals turn ups, some sediment was observed in April and July, which could explain part of the increased pressure. Sediment was denser in trenches located toward the North side of the drain field, the farthest from the effluent source.

Pump tank effluent samples started to be collected on March 18, 2021, and were taken about once a week and analyzed for Total Suspended Solids (TSS) and 5-day Biochemical Oxygen Demand (BOD5). Values resulted quite low, with BOD5 ranging between 20 and 260 mg/L, and TSS between 9 and 26 mg/L. This could be explained by a good performance of effluent filters located in both septic and pump tank in between the two compartments.

Although not included in the monitoring plan, soil samples were collected to assess moisture content using the gravimetric method on November 24, 2020 to obtain preliminary information on the project area before altering it with construction. Samples were collected along the soil profile at 12 locations, and moisture calculated on dry weight. Results showed that the West portion of the field (Block 1, 14.2%) was slightly wetter than the East portion (Block 2, 12.6%), and resulted statistically different at 15-21 inches of depth.

Hourly soil moisture monitoring during the project was performed using Time Domain Reflectometer (TDR). Installation and setup were completed on February 9, 2021. One sensor not properly working was replaced at the beginning of the project under warranty, and throughout the experiment short interruptions were observed periodically, especially at the beginning of the project. Such issues were solved each time in the days following the problem, and appeared to be related to weather instability, factory defects (one time), and connections between the solar panel.

Overall, profiles behaved similarly, with moisture reaching saturation during the wet season, except for the most superficial locations, and started going down between end of July and begin of September. In most cases such decrease started in shallow sensors far from the trench. In September 2021, moisture at 32 inches of depth under the trenches decreased only in design C, which corresponds to these trenches getting dry; and moisture at 32 inches of depth near the trenches decreased only in Block 2, which corresponds to the observation made at installation that in these locations soil resulted harder (likely drier) compared to the rest of the area.

The overload event that occurred in April 2021 had an immediate effect on the driest portions of the soil close to the trench, but moisture variation was noticeable in most sensors. When selected data (one moisture measure about every month) where statistically compared, a lower moisture was found in design C with respect to the other two configurations at 8 (both distances) and 14 (far from the trench) inches of depth. This is consistent with water level, which resulted lower in this configuration. Results showed also that there was a statistically significant difference between the two blocks,

Soil physical and chemical characteristics were obtained from two profiles of soil samples collected in two locations in the drain field, one per block. Texture looks quite similar in the two locations, but Block 1 had consistently less sand and more silt and clay along the profile; especially in surface. Samples collected at 6-9 and 18-22 inches of depth where also used to conduct a clay detailed analysis, which indicated that the four samples are similar in mineral composition: dominated by smectite, then kaolinite, illite, quartz, and feldspars. This is the common clay mineral composition in the Brazos area. Results on cation exchange capacity (Sodium acetate/ammonium acetate extraction) and water soluble salts from saturated paste (SAR, soluble cations, electrical conductivity) did not show any differences between the two sampling locations.

Based on the results obtained from the activity reported, the project questions can be answered as follow:

1) What are the operational problems faced by the users and operators with the current LPD design in Texas? **ANSWER:** Based on the survey that was conducted, the main issues are related to orifice plugging and maintenance
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? **ANSWER**: Although a longer experiment is needed to properly answer this question, results showed that in the experiment conditions holes facing up did not present evident issues compared to holes facing down. In our analysis, design with holes facing up protected by orifice shield (design B) had significantly higher water level in the trenches, followed by design with holes facing down (design A) and design with holes facing up with leaching chamber (design C). The analysis indicated also that level change at rainfall events (increase/decrease) was significantly lower in design B compared to the other two configurations. Pressures in the laterals did increase significantly within the project period, but no significant differences were found among configurations. Longer testing is likely needed to have any indications on this regard. Our analysis showed also that a lower moisture was found in design C with respect to the other two configurations at 8 (both distances) and 14 (far from the trench) inches of depth. This is consistent with

water level, which resulted lower in this configuration. Overall, there is indication that, with respect to the control, design B could have an advantage in reducing the water level change during raining events (increase/decrease), and design C could have an advantage in keeping low the level in the trenches.

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? **ANSWER**: Based on the field experiment results, it appears that the smallest differences in site conditions (e.g., elevation, texture) had significant effect on most results, which indicates that soil evaluation has a key role in the at design phases and should be emphasized. As no major issues were identified with the alternative designs with holes facing up, such configurations should be considered for further testing and possible inclusion in the rules.

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 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).

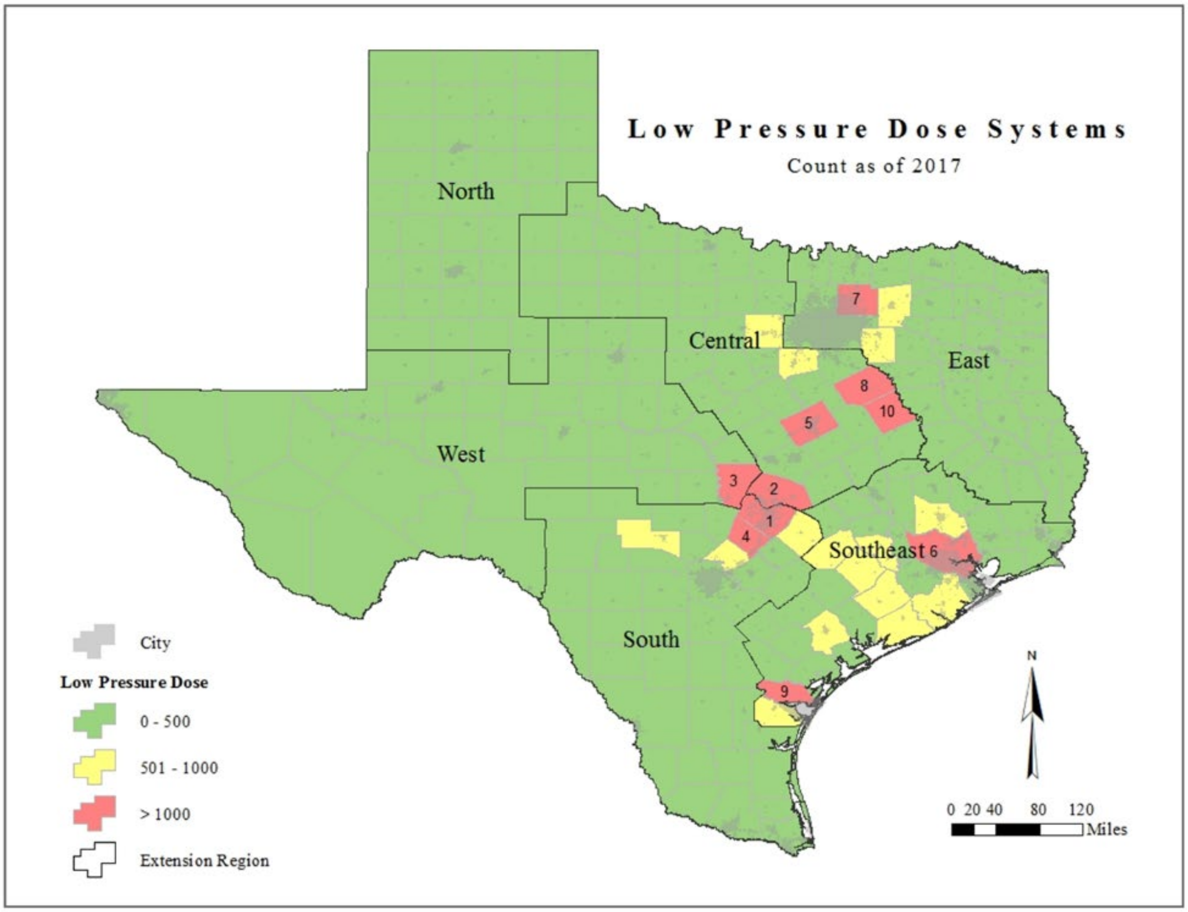

Figure 1. LPD systems are implemented in Texas mostly in the Central, South, and Southeast regions, especially in proximity of largest cities and along the Lower Colorado River

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.

MATERIALS AND METHODS, 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 local permitting authority; 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 right after contract signature, before the beginning of the field experiment, and at the end of the project (September 12, 2019, November 18, 2020, and November, 10, 2021, respectively). Twenty-four attendees participated in both initial meetings, and twenty-one in the third one. Attendees represented academic institution, onsite wastewater industry, and regulatory agency, and were involved to share and discuss plans and results. 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); survey audience (e.g., reflect the entire Texas conditions); and focus on results analysis. 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). QAPP was compiled in collaboration with TCEQ to define all details of the project, and was approved on October 1, 2020. 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, results, discussion, and conclusions and recommendations. 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.

Statistical analysis on data collected from the field experiment was conducted comparing data series with the T Test. This analysis returns the probability associated with a Student's t-Test, which determines whether two samples are likely to have come from the same two underlying populations that have the same mean.

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 form was submitted to TCEQ for approval on February 17, 2020, and was approved on February 28th. 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 (March 9-11), and a total of 18 surveys were completed and received at the meeting and later by email. A copy of the approved survey form is reported in Appendix A, together with all reported surveys (printed and online).

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.

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/inspected/owned, and a system is counted for each problem indicated (some individuals indicated more than one problem).

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).

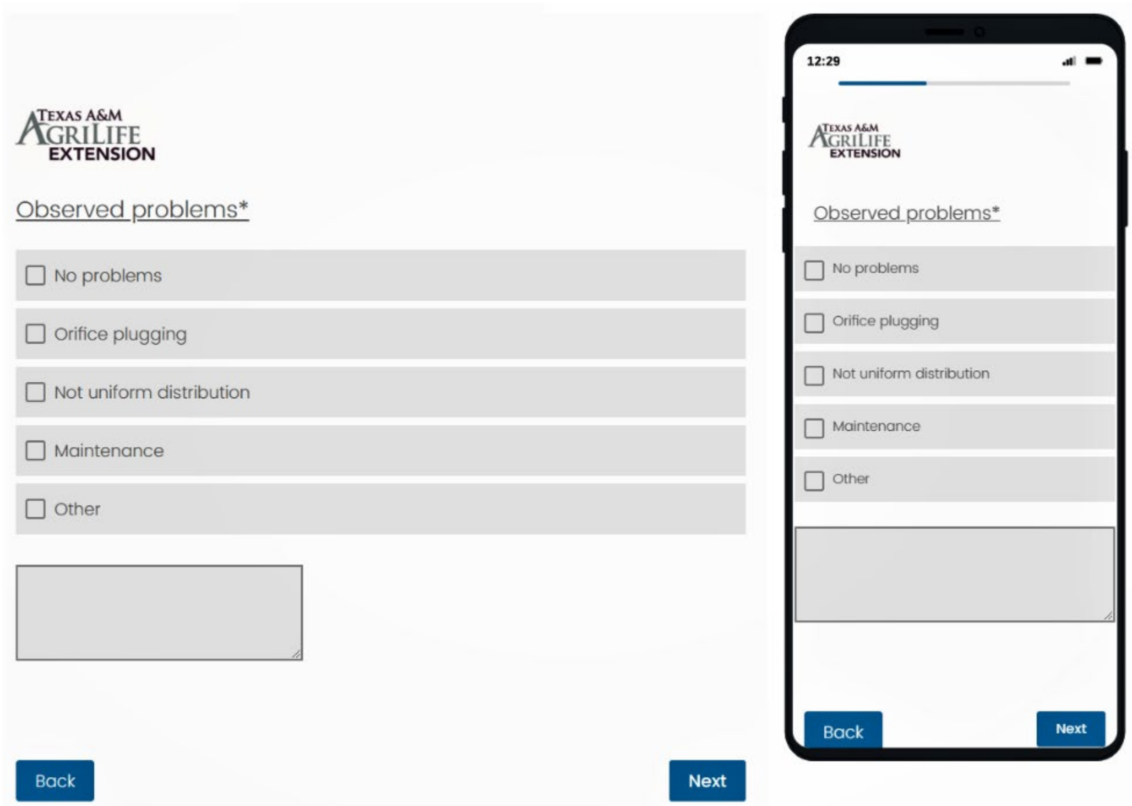

Figure 2. Example page of the online version of the "Survey to get your feedback for improving low-pressure dosing (LPD) design in terms of effluent distribution uniformity, and ability to maintain the system"

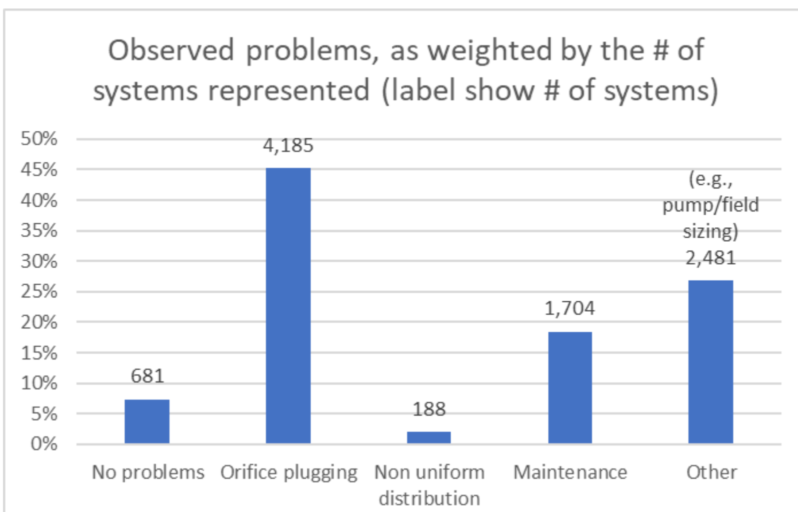

Figure 3. Summary results from the LPD survey response. Results were weighted based on the number of OSSF designed/installed/maintained/inspected/owned (count is reported on top of each bar)

Field experiment: LPD Plumbing Configuration and experiment design

LPD field 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; and a pump tank used to dose the LPD drain field (Figure 4). An aerial view of the AgriLife Waste Water Research Facility Center, at Texas A&M RELLIS Campus, Bryan Texas is shown in Figure 5. Indicated are all areas used for the TOGP Grant Application Number 582-19-93772, and details shown for the LPD field experiment, including plumbing design and planned drain field.

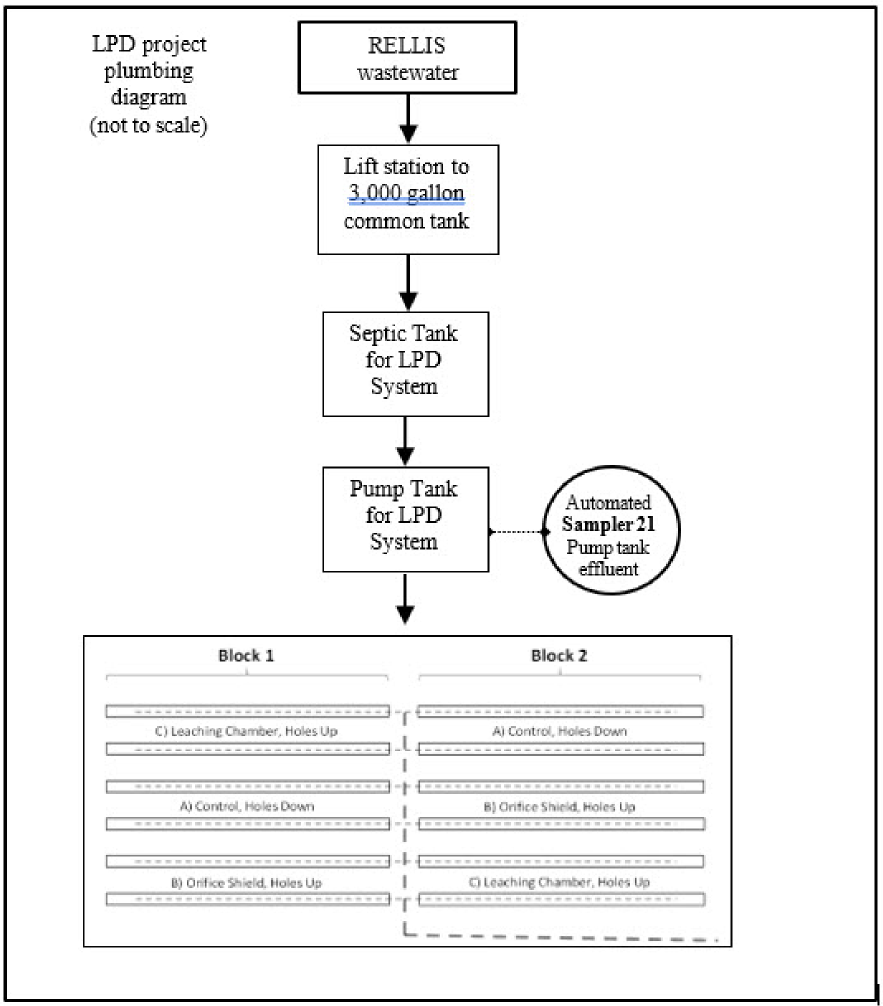

Figure 4. LPD experiment plumbing design

Figure 5. Aerial view of the AgriLife Waste Water Research Facility Center, at Texas A&M RELLIS Campus, Bryan Texas. Indicated are all areas used for the TOGP Grant Application Number 582-19-93772. Details are shown for the LPD field experiment, including plumbing design and planned drain field

Continuous flow of 240 gpd was 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). Specifications for treatment tank size and type were derived from the LPD design manual UNC-SG-82-03 (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. Pressure head is determined to be 5 ft, and minimum dosing volume 41 gal. 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. Both LPD tanks (septic and pump) have an effluent filter in between the two compartments. Drain field is fed with a 2-inches PVC SCH40 pipes supply line. The supply line and the manifold are positioned underneath the laterals (Figure 6) and are designed to be full all the time. This will guarantee a minimum dosing volume of 41 gal even with multiple doses per day.

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

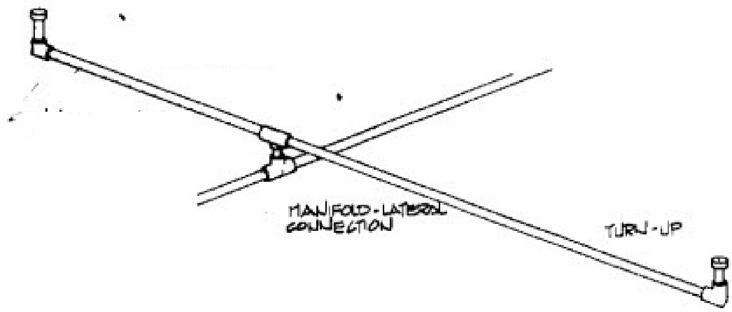

Figure 6. Schematic of the distribution system connection between manifold and lateral (extracted from North Carolina State University Sea Grant College Publication UNC-S82-03).

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 drain field. 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 drain field 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 drain fields 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 drain field 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.

The drain field design includes 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 washed pea gravel (1/8-3/8 diameter) or hanging on top of a 2-feet large leaching chamber, with 5/32-inch holes, spaced 5 feet. Laterals are connected to the manifold with 1/4-inch couplers and end with turn-ups. Ball valves are placed at the begin and end of each lateral. An air opening is placed at the begin of the supply line to avoid syphoning of water back to the pump tank, and a pressure relief valve is placed at the end of the manifold to release excess air.

The experimental design compares three configurations (Figure 7): 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 (Figure 8). 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 plan of pump tank effluent and LPD field included:

- 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 on the laterals turn-ups.
- Soil moisture along the soil profile adjacent and under 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 (Figures 9 and 10).

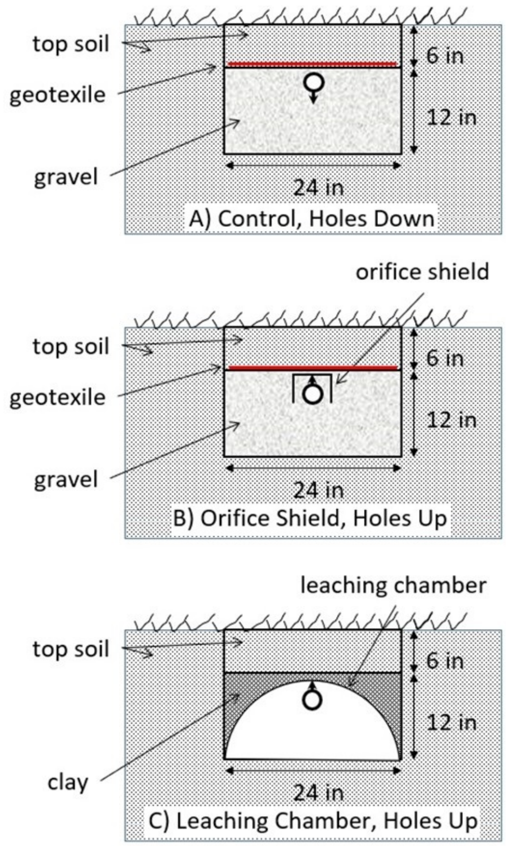

Figure 7. Cross-section view for three LPD Configurations

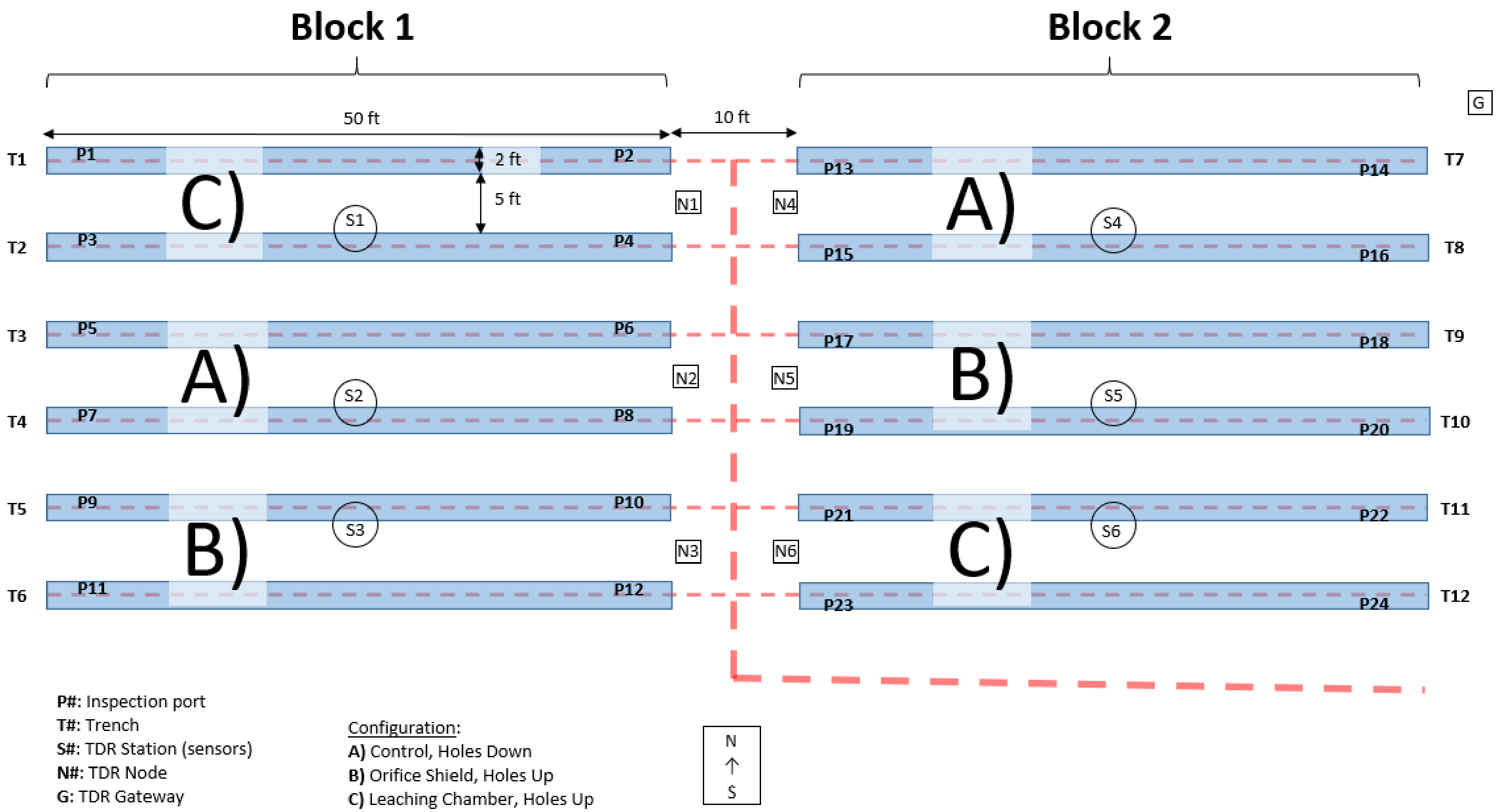

Figure 8. Experimental design, and location of monitoring activity (inspection ports and TDR stations)

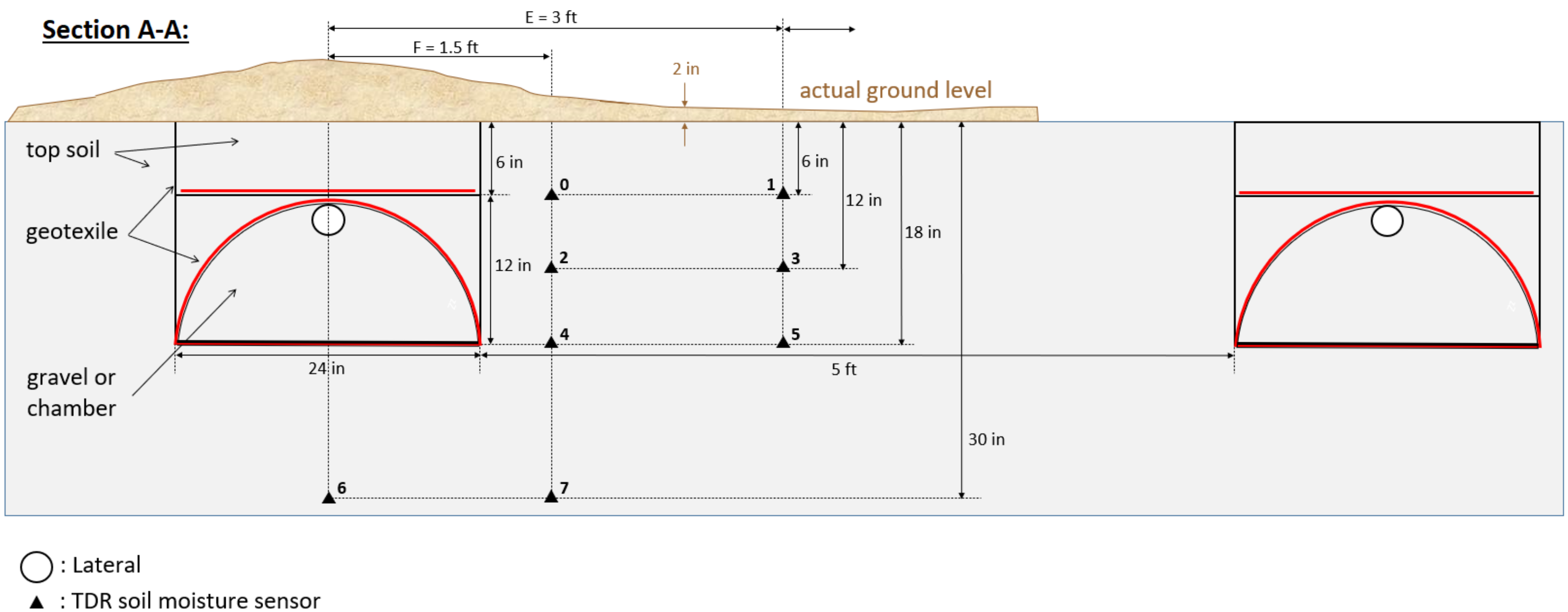

Figure 9. Location of individual soil moisture monitoring sensors with respect to the trench section

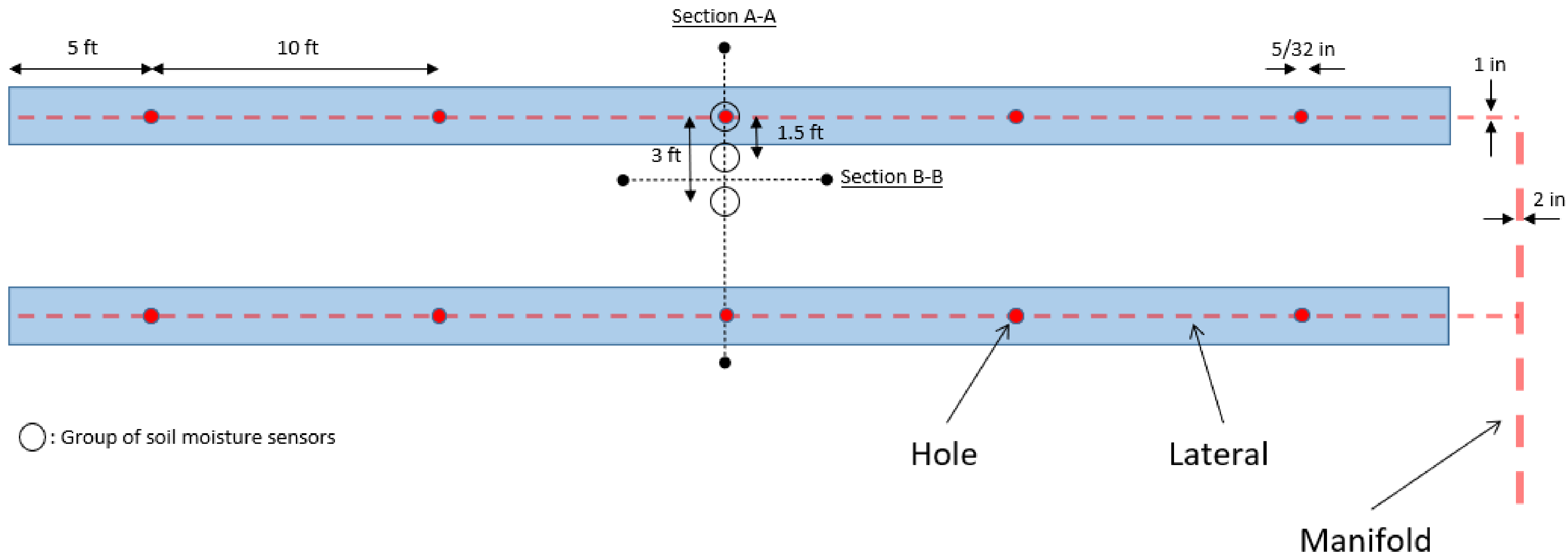

Figure 10. Distribution line and soil moisture monitoring sensors installation details.

Section A-A: **Section B-B:**

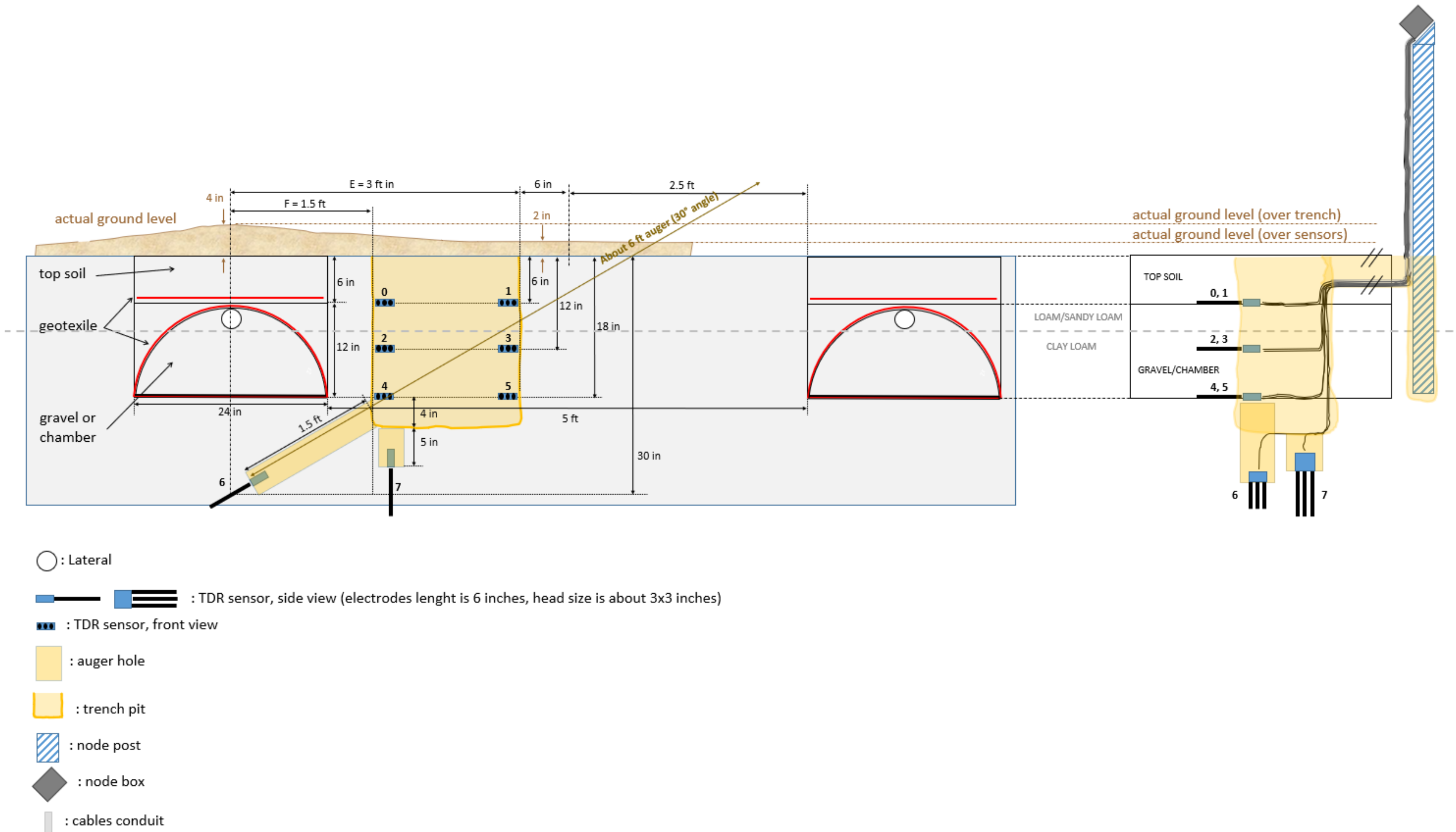

Figure 10 (cont.) Distribution line and soil moisture monitoring sensors installation details. Orange area indicate soil movement.

Top view (zoom in):

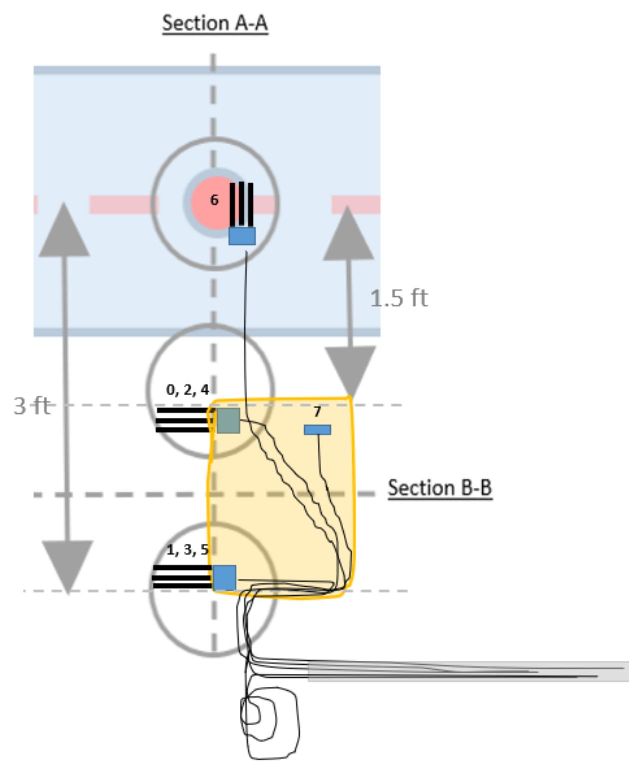

Figure 10 (cont.) Distribution line and soil moisture monitoring sensors installation details. Orange area indicate soil movement.

Construction

<u>Permit to construct from Brazos County Health District</u>

Permit application was submitted on June 18, 2020 to the Brazos County Health District, and authorization to construct was received on June 19th. 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.

The placement of a 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. 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. Figures 11 and 12 show results and phases of the soil profile evaluation.

OSSF Soil & Site Evaluation **Date Performed: 2/14/2020**

Site Location: <u>Onsite Wastewater Training Center – RELLIS Campus</u>
Proposed Excavation Depth: <u>18"</u>

Soil Boring # 1				
Depth (inches)	Soil Class	Soil Texture	Groundwater/ Water Table	Topography
0 – 10"	III	Sandy Clay Loam	No	Flat
10 – 48"	IV	Silty Clay	No	Flat

Soil Boring # 2				
Depth (inches)	Soil Class	Soil Texture	Groundwater/ Water Table	Topography
0 – 12"	III	Sandy Clay Loam	No	Flat
12 – 48"	IV	Silty Clay	No	Flat

FEATURES OF SITE AREA

Presence of 100 Year Flood Zone ☐ Yes ☑No
Presence of Seasonal High Water Table ☐ Yes ☑No
Presence of Adjacent Ponds, Streams, Water Impoundments ☐ Yes ☑No
Existing or Proposed Water Well in Nearby Area (within 150 feet) ☐ Yes ☑ No
Restrictive rock horizon ☐ Yes ☑ No
Ground Slope <u>0.8</u> %

I certify that the findings of this report are based on my field observations and are accurate to the best of my ability.

(Signature of person performing evaluation) 2/21/2020 (Date) OS0031317 Registration Number and Type

Figure 11. Results of the soil profile evaluation performed on February 14, 2020

Figure 12. Phases of the soil profile evaluation performed on February 14, 2020, by Ryan Gerlich, TCEQ Certified Site Evaluator

<u>Construction phases</u>

Construction originally planned for the spring 2020 was postponed. This delay was anticipated due to COVID19 epidemic field activities restrictions, and was communicated to TCEQ by email on March 24, 2020. Construction and experiment start where later further postponed, as communicated to TCEQ by email on August 14, 2020. Construction started on November 3, 2020, and field distribution and plumbing were finalized on November 20. On December 10th a fence was installed all around the distribution field to prevent wildlife from entering the area and vandalism, and construction was completed 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 drop of about 10 inches total (0.8% slope) was found from the North East corner to the South West corner of the drain field area. 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 (Figure 13).

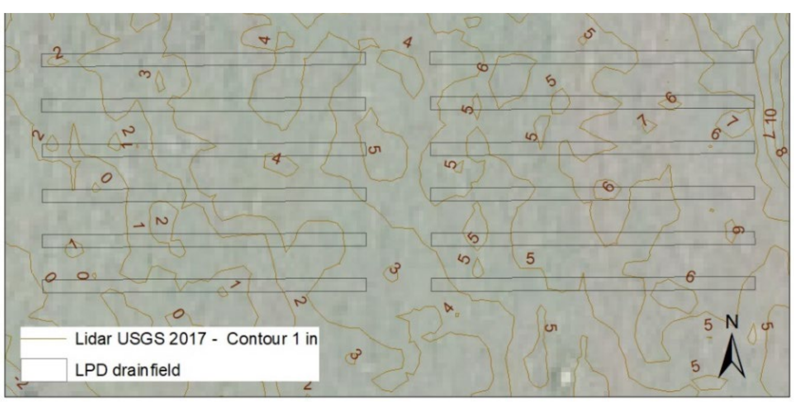

Figure 13. Lidar USGS contour elevation isolines (at 1 inch interval) in the drain field area. Elevation is referred to the lowest point (South West corner)

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

Figure 14 shows some key features of the installation (pea gravel size, leaching chamber installation and location of lateral, orifice shields in gravel trench, inspection port location, and connection of laterals to manifold). An image of the LPD drain field completed, as it looks at the end of the experiment on November 2021, is reported in Figure 15.

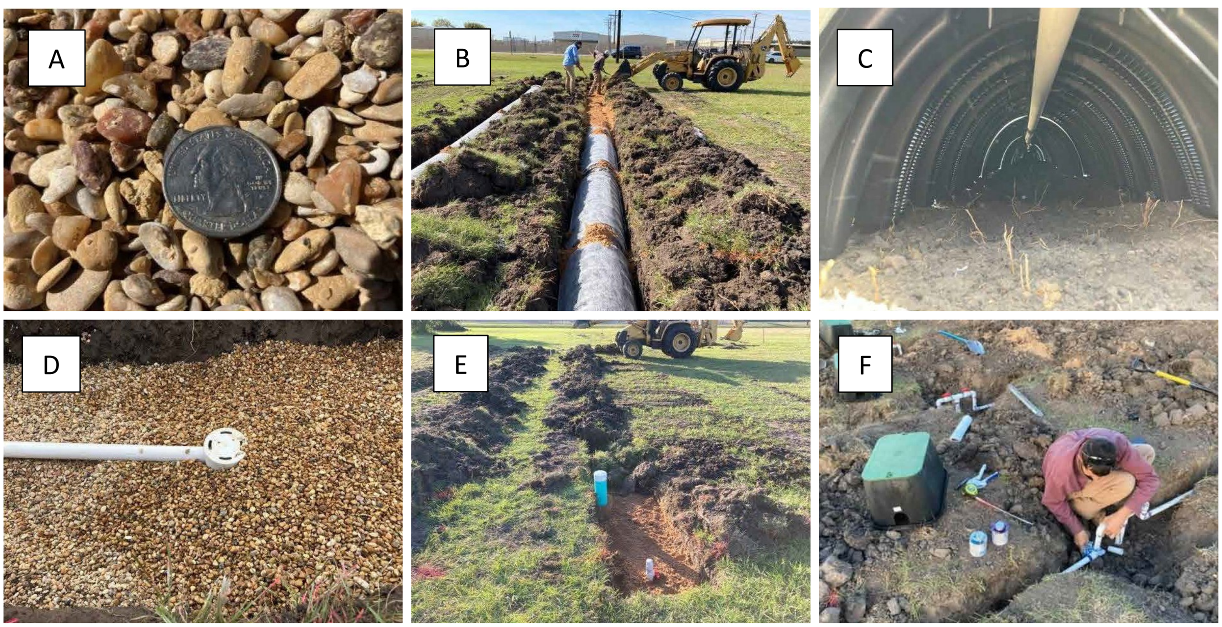

Figure 14. Images of the installation process: A) pea gravel, B) Leaching chamber installation, C) Location of lateral under leaching chamber, D) Orifice shields in gravel trench, E) Closing of a gravel trench, showing inspection port and valve, F) Connection of laterals to manifold

Figure 15. Image of the LPD drain field as it looks at the end of the experiment, on November 2021. Highlighted are the location of trenches and configurations in the experimental design

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), and effluent pumped to the drain field at an average of 65.1 gal/dose (a little more than 3 times/d). Figures 16 and 17 shows a detail of the calibration tank.

Figure 16. Detail of the calibration tank design. Left: at experiment start (with calibration tags); Right: at experiment end (noticeable the deposit where level has been controlled)

Figure 17. Calibration tank phases. Left top: loading; Left center: draining surplus; Left bottom: calibrating (loading ended); Right: Jandy valve open to send calibrated volume to the septic tank

On May 17, at 1:30 PM, 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 at 2 PM. A second intentional interruption (no flow) was imposed for the same reason on June 3, at 2 PM, and ended on June 7 at 3 PM. Minor power outages were observed time to time. In general, these had minor effects on the experiment as power was reestablished within few hours. The longest outage was observed on July 16, from around 10 AM to 4 PM. This outage was intentional and was needed to complete some electrical connections at the Center. Overall, excepted for the initial period of calibration, short intentional interruption before heavy storms, and minor power outages, loading was quite uniform throughout the experiment (Table 3).

Table 3 - Average daily load (gal/d) and factors affecting regular loading

Month	Weighted average daily load (gal/d)	Notes
Feb 2021	204	
Mar 2021	154	
Apr 2021	220	Overload (>600 gal/d) on April 9-13 due to calibration failure; pump turned off April 13-20 (new calibration method)
May 2021	210	Daily load reduced (~109 gal/d) on May 17-20, due to heavy rain forecasted
Jun 2021	190	Daily load reduced (no flow) on June 3-7, due to heavy rain forecasted
Jul 2021	214	Power turned off (~8 hours) on July 16, for electrical work
Aug 2021	221	
Sep 2021	221	

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 on November 15, 2020. 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 (Figure 18). 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 NOAA 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.

Precipitation was 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.

Precipitation events were quite frequent, with strong storms end of December 2020 beginning of January 2021, and in the summer. Temperature was characterized by an exceptional cold front 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 (Figures 19 and 20). The tipping bucket did not work properly between February 14 and 22, as water froze, and the mechanism resulted blocked.

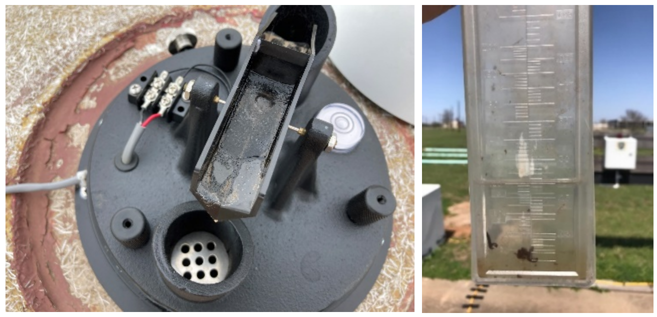

Figure 18. Rain gauges installed at the Center. Left: Tipping bucket (with ice blocking the mechanism, in February 2021); Right: existing manual gauge

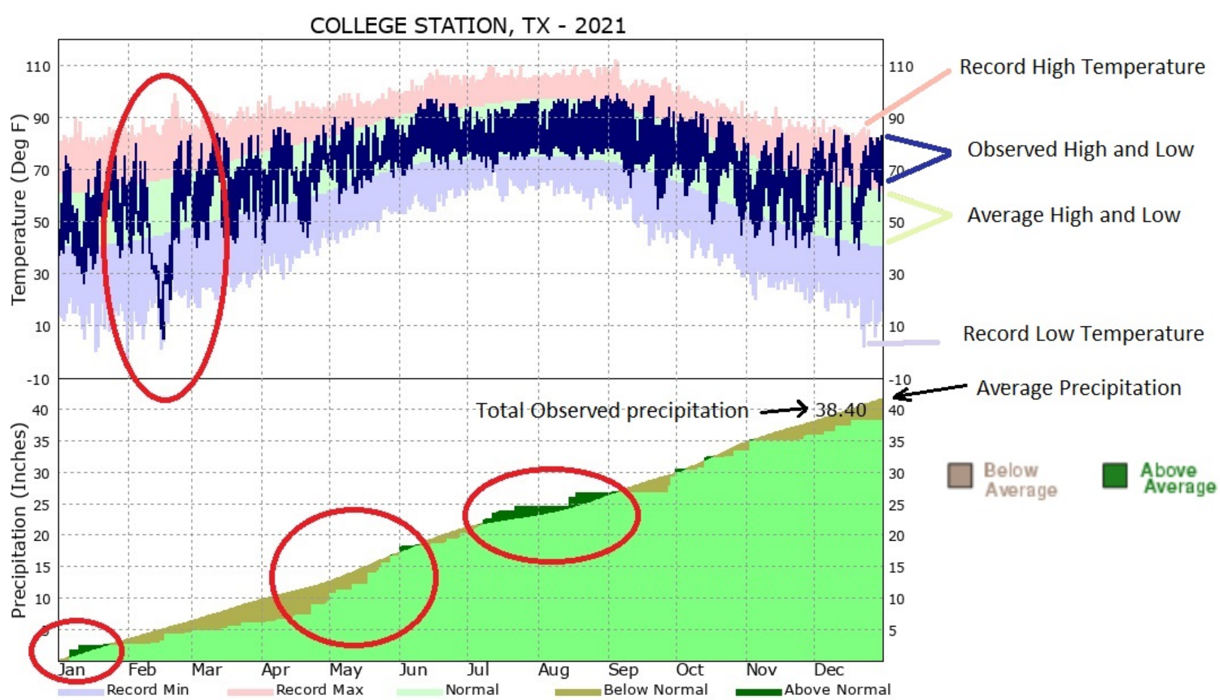

Figure 19. Temperature and precipitation data and long term records, recorded at the nearby NOAA Station (KCLL) in 2021. Red circles show freezing or high precipitation conditions observed during the project period.

Figure 20. Snow deposit after the exceptional cold front recorded in February 2021

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. Monitoring consisted in the measurement of the distance between the port top and the water level. As elevation of the port top and the trench bottom had been determined previously, this value could be converted to water level (Figure 21).

Figure 21. Inspection port monitoring consisted in the measurement of the distance between the port top and the water level, converted to water level based on elevation of the port top and the trench bottom

An anomaly was observed in these first monitoring period, after the strong rainfall events in December and January. 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 relief network (approximate section of 2 ft x 6 inches) was built around the distribution field to divert most runoff away from the field. After the intervention the issue did not present anymore. Figure 22 shows the location of the drainage relief network, together with the Lidar USGS contour elevation isolines for the surrounding area.

Figure 22. Location of the drainage relief network and Lidar USGS contour elevation lines (at 1 inch interval). Elevation is referred to the lowest point of the drain field (South West corner)

Figure 23 shows the estimated wastewater daily load, the average water level, and the daily precipitation. Wastewater load is reported as water height (inches/day) in the trench, and is calculated using the following formula:

Estimated daily load (inches/day) =
Average daily flow since last reading (gpd)/7.481/total trench surface area (sqft) *12

Where the average daily flow since last reading is the daily loading from the feed tank to the septic tanks, 7.481 is the factor to convert gallons to cubic feet, total trench surface area is the excavation length * width of the excavation (600 ft * 2ft = 1,200 sqft), and 12 is the factor to convert feet to inches. The water level reported in figure is the average of the four observations available for each configuration in each block (two ports x two trenches). The precipitation is the daily average value obtained from the tip bucket gauge.

The figure shows that the water level quickly responded to rain and wastewater loading events. And overflowed occasionally after heavy storms (mostly in Block 1). Trenches had water most of the time, even after several dry weeks, and level was above the gravel (or top chamber) only for few days after rain events. 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. Each configuration had a tendency for higher levels in Block 1 with respect to Block 2. The choice to split the experiment in two blocks was therefore successful in addressing this different behavior within the area. Driving factors could be both the difference in slope and in texture. Accidental overloading clearly affected water level in all trenches (April 9-13), with a rise of several inches. Figure 24 shows details of effects on water levels of the overload and the intentional interruptions in May and June. The overload was estimated as 0.9 inch per day.

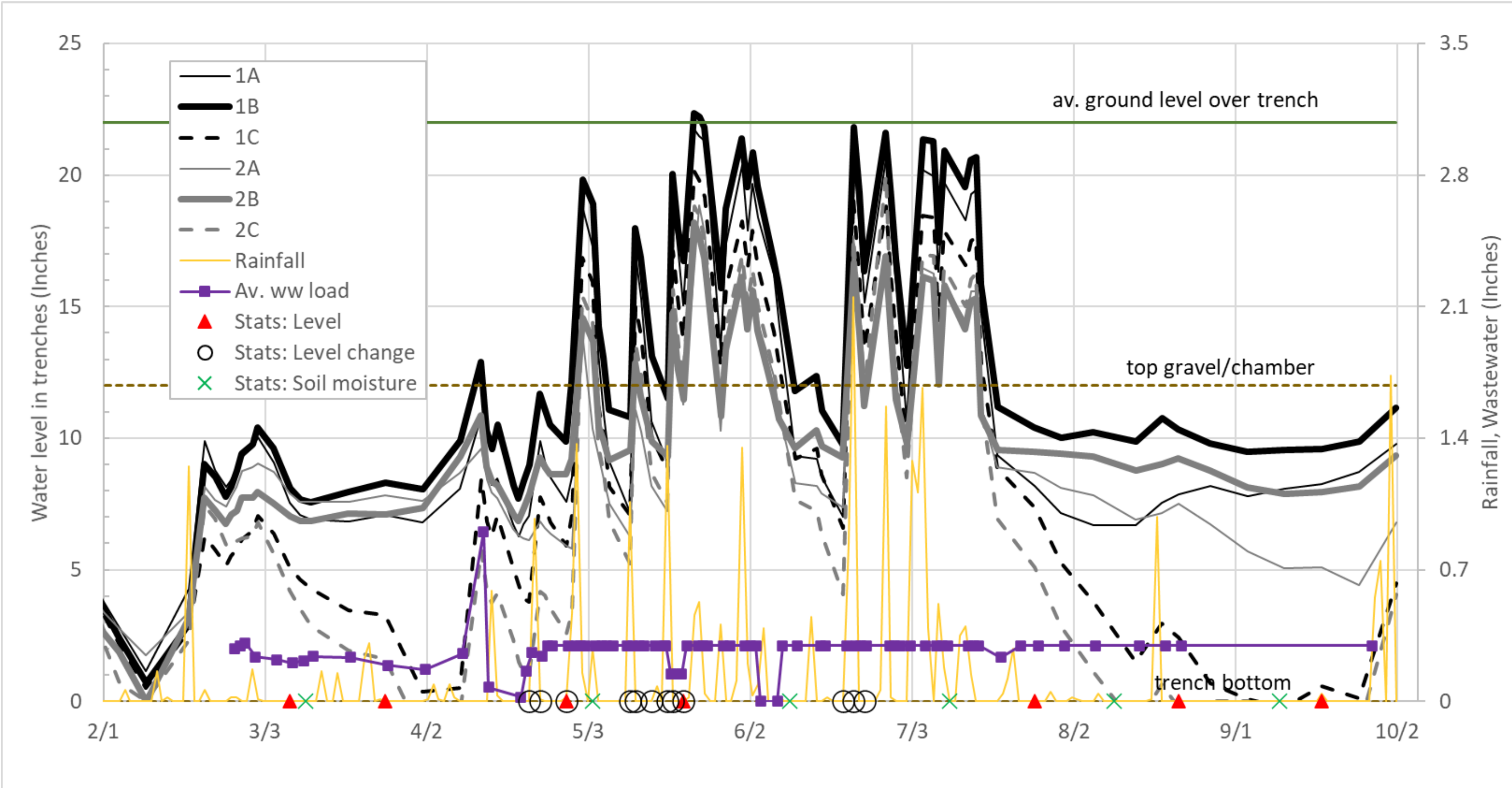

Figure 23. Estimated wastewater daily load, average water level (average of the two trenches in each block, measured from the bottom of the trench), and daily precipitation. Also indicated are levels for trench bottom and top (either gravel or chamber), ground level over the trench (including the soil added to ensure drainage off the trench), dates used for statistical analysis (water level, water level increase/decrease, and soil moisture)

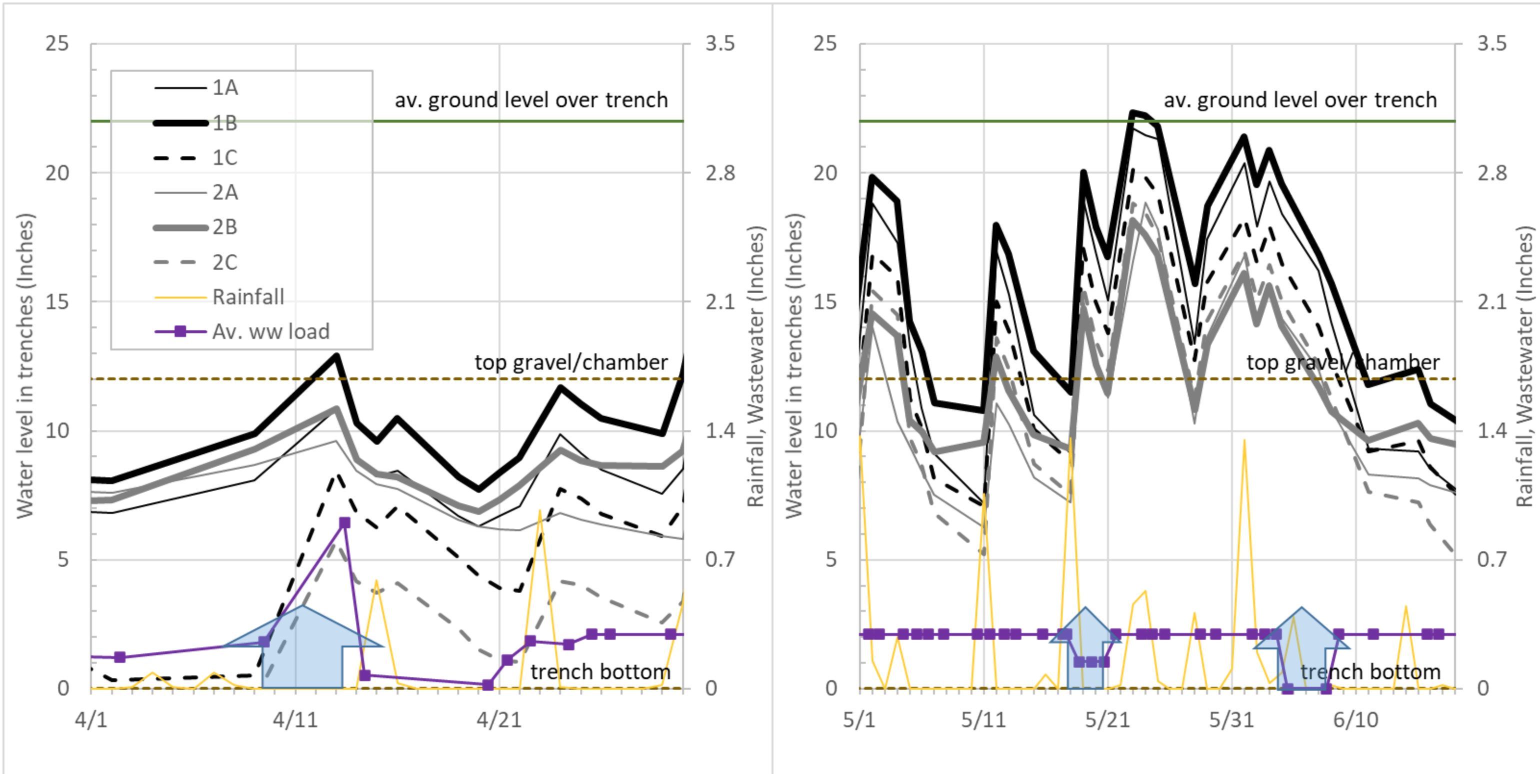

Figure 24. Estimated wastewater daily load, average water level, and daily precipitation. Effect on water levels of overloads (April 9-13) and intentional interruptions (May 17-20, June 3-7). Width of the arrows identifies the length of the event

A statistical analysis was conducted on selected events (see Figure 23), to compare configurations and blocks in terms of water level and water level change at rain events. Data used in this analysis was again the combination (average) of the four observations available for each configuration in each block (two ports x two trenches), for a total of six measures in a day (1A, 1B, 1C, 2A, 2B, and 2C). The rationale is that these four adjacent measures are too dependent from each other. Considering that as a result we would have only two replicates per configuration (e.g., 1A and 2A), we also used the repeated measures in time as our replicates. This requires to only pick selected events, making sure they are spaced out enough among each other to reduce dependency.

In the case of water level, dates were chosen about every month a few days after a rain event. Values compared were not the actual measured level, but the difference of the level with the overall average of the day. As also shown in Figure 25, results of this analysis determined that there was a statistically significant difference among the three configurations: with respect to the average, water level was at +0.8, +2.1, and -3 inches, respectively in design A, design B, and design C. Results showed that there was a statistically significant difference between the two blocks, with water level higher than the average (+0.8 inches) and below the average (-0.8 inches), respectively in block 1 and block 2. All differences were very highly significant ($P<0.001$).

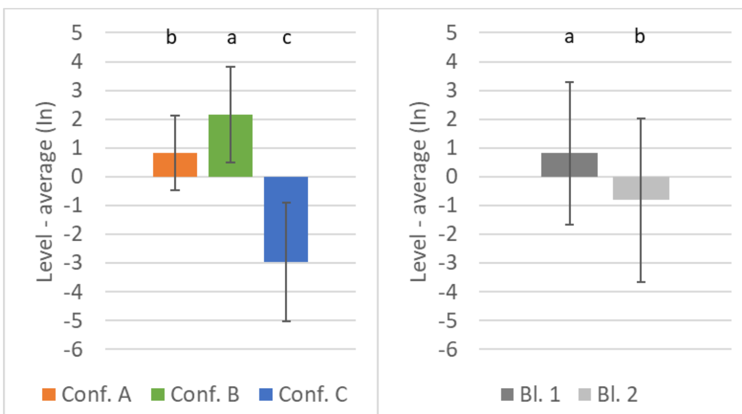

Figure 25. Average water level in the trench from events chosen about every month a few days after a rain event, and expressed as inches above or below the overall daily average. Bars indicate standard deviation, and letters show if configurations (left) or blocks (right) are significantly different among each other with the T-Test.

In the case of water level change, four rain events were chosen: April 22-29, May 12-15, May 18-21, and June 20-24. Differently from the previous analysis, the events in May were quite close to each other as it was determined that the level change was less dependent from a nearby rain event. The absolute value of the level change (increase or decrease) during and after the rain event was used for analysis.

To have more comparable values for the statistical analysis, the change was corrected, considering the inches of rain, the days after the rain event, and the level reached in the trench:

Corrected increase = absolute increase/inches of rain

Corrected decrease = absolute decrease/(days interval/3)/(water level right after rain/12)

Where 3 is a coefficient that standardizes the interval with respect to 3-days after the rain, and 12 is a coefficient that standardizes the water level in the trench with respect to 12-inches. As also shown in Figure 26, results of this analysis determined that there was a statistically significant difference among configurations: Corrected water level change was 4.5, 4.7, and 4.9 inches, respectively in design A, design B, and design C, respectively. Difference A vs B was very highly significant ($P<0.001$), while C vs B was highly significant ($P<0.01$). No statistically significant difference was found between the two blocks, but there was a tendency to have higher water level change in block 1 (4.7 inches) than in block 2 (4 inches).

Significance among configurations did not change if increase or decrease are considered separately, but the overall average for corrected level increase was higher (5.1 inches) than the one for corrected level decrease (3.6 inches). Difference between blocks became highly statistically significant ($P<0.001$) when considering only corrected level increase (5.9 and 4.3 inches respectively in block 1 and block 2).

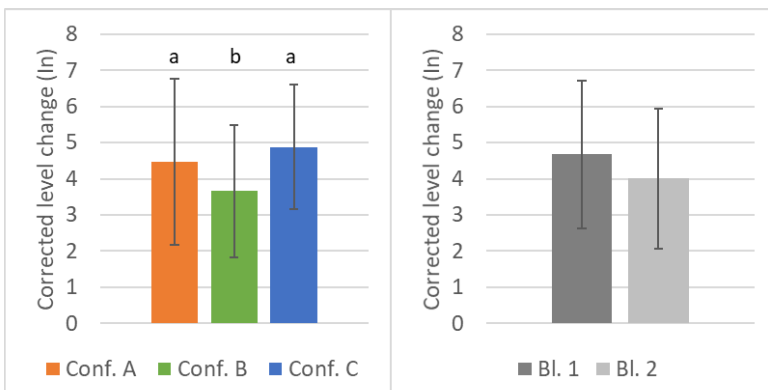

Figure 26. Water level change (increase/decrease) in the trench during four rain events (April 22-29, May 12-15, May 18-21, June 20-24), expressed as corrected absolute level change. Correction of the level change considers the inches of rain, the days after the rain event, and the level reached in the trench. Bars indicate standard deviation, and letters show if configurations (left) or blocks (right) are significantly different among each other with the T-Test.

Pressure on laterals was measured quarterly and showed to be quite uniform within the field. As shown in Figure 27, values measured on April 20, 2021 resulted higher compared to the one conducted on December 17, 2020, while a smaller/no increase was observed on July 21, 2021. As water rose in the transparent SCH40 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. There were not statistically significant differences among configurations, although variability increased in design B. Pressure increased significantly with time (+ 0.6 in between December 2020 and July 2021).

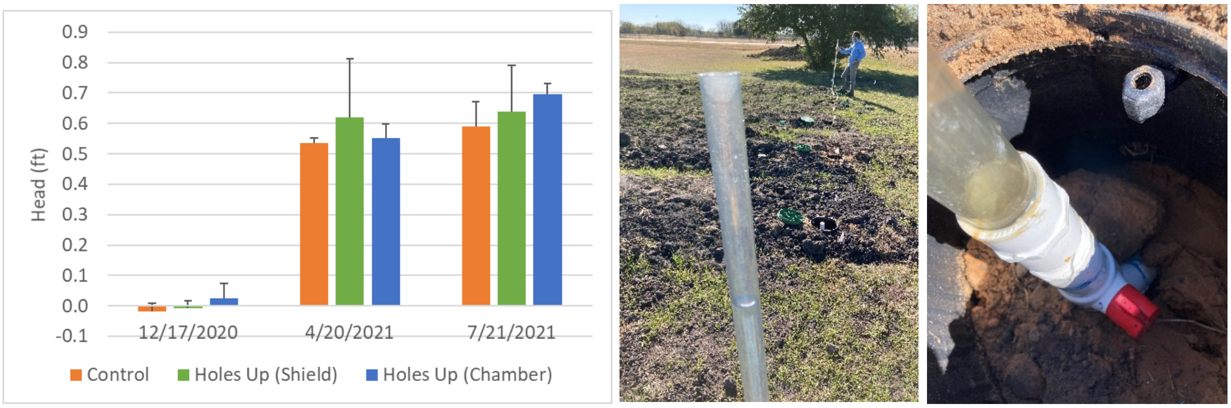

Figure 27. Pressure on laterals as measured at the beginning of the experiment (December 17, 2020), and on April 20 and July 21, 2021. Head reported in the chart is the increase with respect to the average of December 2020 observations, and is referred to a common reference level in the drainfield. Left: Columns show the average value for each configuration, while error bars indicate the standard deviation value. Right: images of the reading through transparent PVC SCH40 pipes inserted in the turn-up at the end of the laterals

Grab samples for quality purposes started to be collected on March 18, 2021. Sampling was conducted from the pump tank as shown in Figure 28. An automatic sampler was installed for ease of operation, but it was operated manually. As shown in Figure 29 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 28. Wastewater quality (BOD5 and TSS) during the experiment months, as measured from grab samples collected from the LPD pump tank

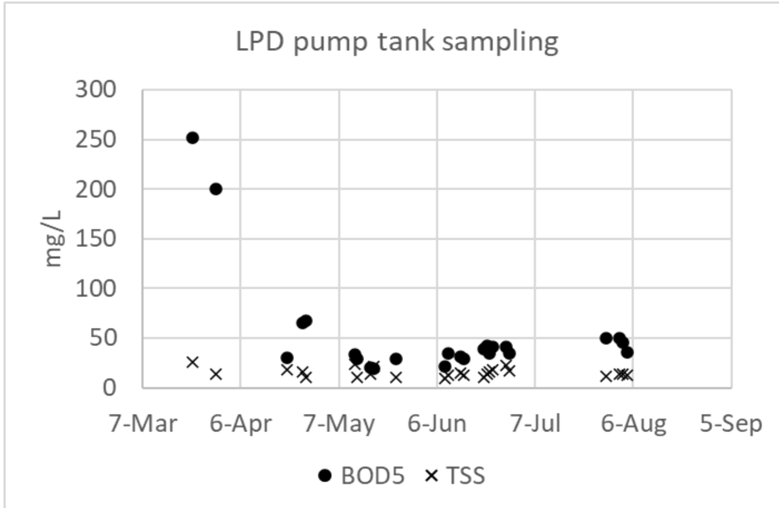

Figure 29. Wastewater quality (BOD5 and TSS) during the experiment months, as measured from grab samples collected from the LPD pump tank

Soil monitoring

Preliminary gravimetric moisture. Although not included in the monitoring plan, soil samples were collected to assess moisture content using the gravimetric method on November 24, 2020. This was decided to obtain preliminary information on the project area before altering it with construction, also because as mentioned above a drop of about 10 inches total was found from the North East corner to the South West corner. 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), using a probe soil sampler, with a diameter of ¾ inches. Samples were stored in plastic bags hermetically closed, and weighted and oven dried for 48 hours at 105 degrees C at the lab on the same day (figure 30).

Moisture content was calculated on dry weight, and results confirmed that the West portion of the field (assigned to Block 1) was slightly wetter than the East portion (overall average of 14.2% and 12.6% respectively). Differences were more evident at greater depths, as shown in Figure 31. Statistical analysis identified a highly significant difference between Block 1 and Block 2 at 15-21 inches of depth (average of 16.7% and 14.4% respectively, $P < 0.005$). Results did not indicate any significant differences among configurations. Individual samples are reported in Figure 32. From these charts it can be noticed that the driest locations are at 6 inches of depth in profiles 2B and 2C.

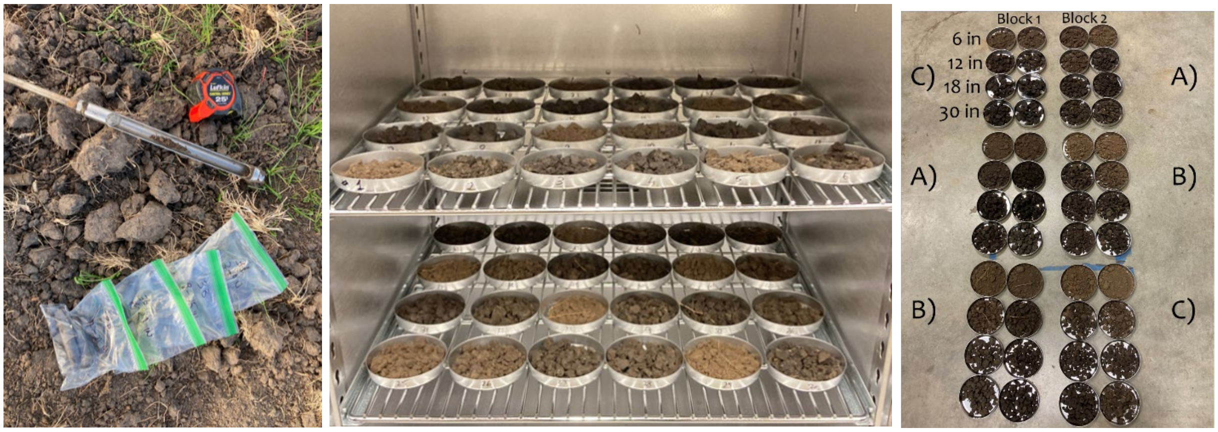

Figure 30 Soil moisture measured with the gravimetric method from core samples collected before the experiment start, on November 24, 2020. Left: field sampling; Middle: oven detail; Right: dried samples

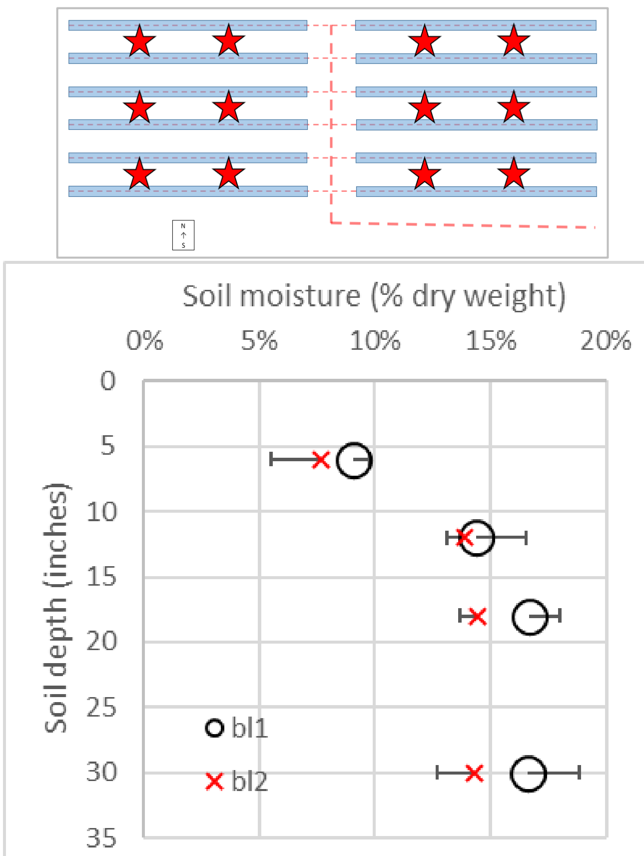

Figure 31. Soil moisture measured with the gravimetric method from samples collected with probe soil sampler before the experiment start on November 24, 2020. Top: Location of sampling (stars); Bottom: Average moisture on dry weight for all samples in each block at each depth, and bars indicating standard deviation (shown only on one side to facilitate representation)

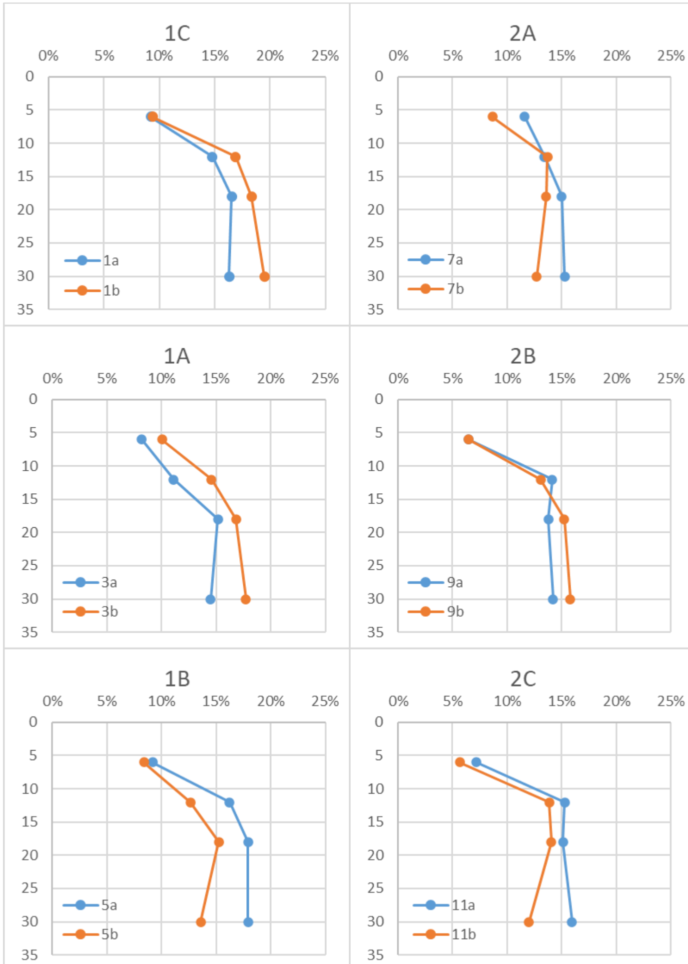

Figure 32. Soil moisture measured with the gravimetric method from samples collected with probe soil sampler before the experiment start on November 24, 2020: Moisture on dry weight for all collected samples, and organized as in the actual drain field (Block 1 on the left and Block 2 on the right, configurations in the same location). Legend indicates the number of the trench located North of the profile (1, 3, 5, 7, 9, 11), and the location along the trench (a = 1/3 from West, b = 2/3 from West)

<u>Hourly Time Domain Reflectometer moisture</u>. Hourly 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.

Instrumentation was configured for 60 minutes measurement interval and 4 hours upload interval. Installation and setup started on February 3, 2021 and were completed on February 9, 2021. Soil conditions did not allow for earlier field work, initially planned for end of December 2020. 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. Soil at 30 inches of depth was particularly hard (likely drier) in stations 2A and 2C. Monitoring started as soon as sensors were installed. Figures 33-35 show some phases of sensors configuration and installation.

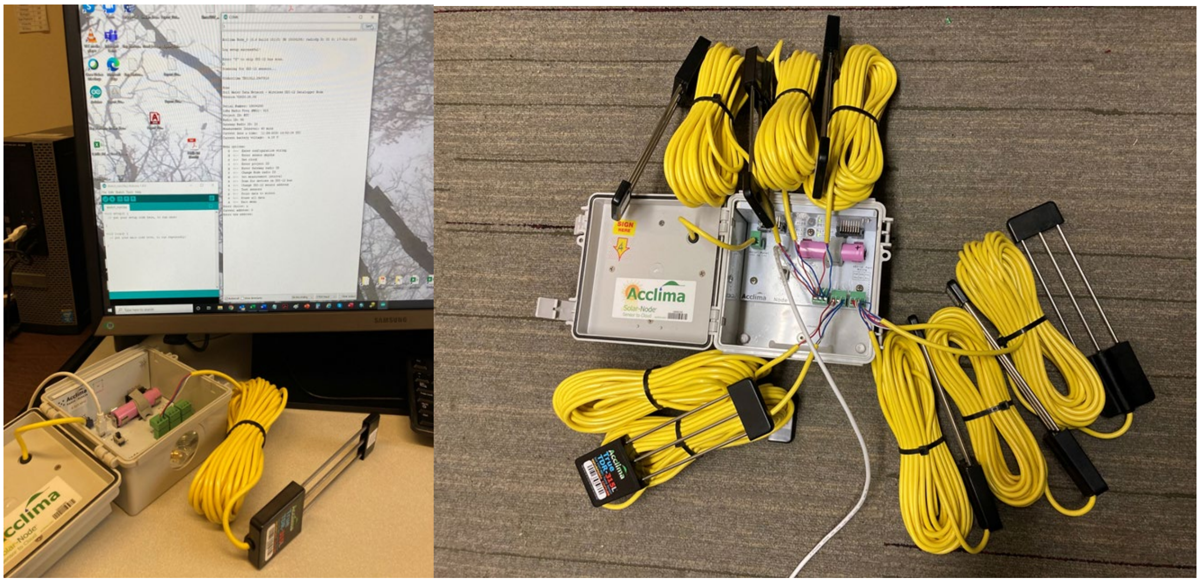

Figure 33. Time Domain Reflectometer (TDR) sensors configuration before installation

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. Both these issues were solved by updating the firmware (weather instability) and wiring again the solar panel. No issues were observed during the exceptional cold days in February 2021.

Soil moisture readings, expressed as volumetric moisture, together with precipitation height, are shown in Figure 36 for all sensors, configurations, and blocks. Overall, profiles behave similarly, with moisture reaching saturation during the wet season, except for the most superficial locations, and started going down between end of July and begin of September, except for under the trench in configurations A and B. Such decrease starts in shallow sensors far from the trench.

Figure 34. Phases of Time Domain Reflectometer (TDR) installation. 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

Figure 35. Phases of Time Domain Reflectometer (TDR) installation. 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

In the wet season, the lowest moisture at 8 inches of depth is found in 2B and 2C; this is consistent with the soil moisture profiles observed before installation of the drain field. Moisture at 32 inches of depth near the trench appears lower than saturation in 2A and 2C at the beginning of the experiment; this is consistent with the observation of a hardest soil found at installation in these two locations, which did not have a different texture. As mentioned above, moisture at 32 inches of depth under the trenches decreased only in configuration C, which corresponds to these trenches getting dry. Moisture at 32 inches of depth near the trenches decreased only in Block 2.

A detail of the overload event that occurred between on April 9-13 and its effect on soil moisture are shown in Figure 37. It is evident an immediate effect on the driest portions of the soil close to the trench, but moisture variation is noticeable in most sensors. Figure shows also soil moisture in correspondence of intentional interruptions (May 17-20, June 3-7). No effects are evident from the figure. It is possible that the frequent rainfall events observed in May and June masked minor changes. Sensors 2A did not record any data on May 10-29, as node 2A was out for repair.

A statistical analysis was conducted on selected events (periods) to compare soil moisture among configurations and blocks at each sensor location (eight). As done with water level analysis, considering that we would have only two replicates per configuration (e.g., 1A and 2A, at 8 inches of depth near the trench), we also used the repeated measures in time as our replicates. This required again to only pick periods spaced out enough among each other to reduce dependency. As shown in figure 23, a period of about ten days was picked every month, in the middle of the month. In our analysis, soil moisture for a given period and a given configuration and block is expressed as difference between the period average and the period average among all configurations and blocks, then normalized for the period range among all configurations and blocks (moisture – average, normalized).

As also shown in Figure 38, results of this analysis determined that there was a statistically significant difference among the three configurations for some of the sensors locations, especially for the shallow ones: at 8 and 14 inches of depth, soil moisture follows the ranking design A>design B>design C; excepted at 14in NEAR, where the ranking is C>B>A. Difference A vs B is statistically highly significant ($P<0.01$) only at 8in FAR; A vs C is very highly significant ($P<0.001$) at 8in FAR, and significant ($P<0.05$) at 8in NEAR and 14in NEAR. B vs C is very highly significant ($P<0.001$) at 14in NEAR, and significant ($P<0.05$) at 14in FAR. A lower moisture in C at 8 (both distances) and 14 (far from the trench) inches of depth is consistent with water level, which resulted lower in this configuration. At 20 and 32 inches of depth, differences are smaller, with a tendency for C to have greater moisture (excepted at 32in NEAR). Differences are statistically significant ($P<0.05$) for A vs B at 32in NEAR, and A vs C at 20in FAR and at 32in NEAR. Results showed also that there was a statistically significant difference between the two blocks, with moisture always higher in Block 1 with respect to Block 2. Difference was very highly significant ($P<0.001$) at 8in FAR, not significant at 14in, and significant ($P<0.05$) at all other sensor locations.

Additional data recorded with TDR instrumentation included soil temperature and electrical conductivity from each sensor, and air temperature and solar voltage from each node. These data are reported in Appendix C..

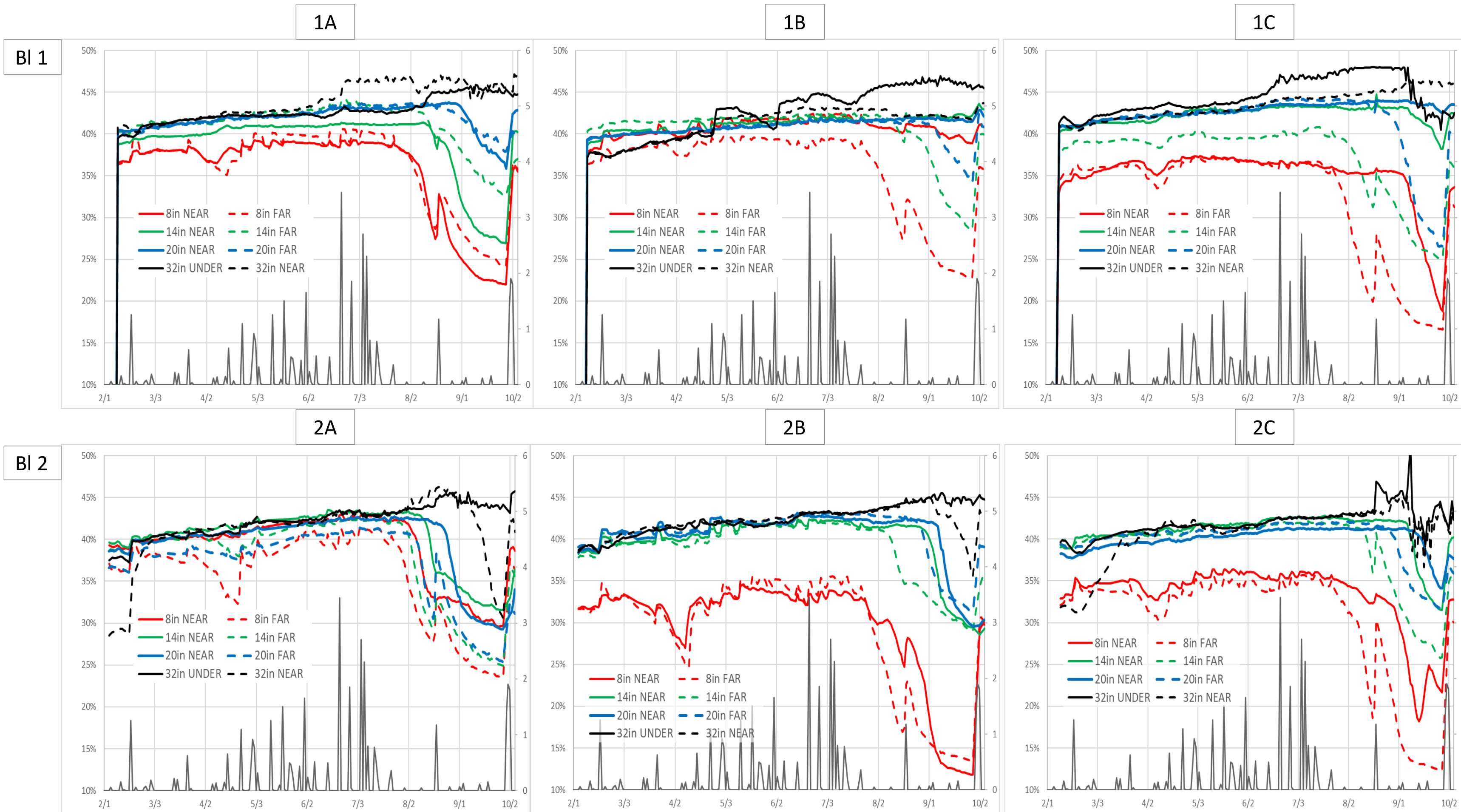

Figure 36. Soil moisture readings, expressed as volumetric moisture, together with precipitation height. Readings are reported for all individual TDR sensors. Sensors are abbreviated as #in<LOCATION>, where # is the depth of the sensor, “in” stands for inches, and LOCATION can be NEAR (6 inches from the trench wall vertical), FAR (2 feet from the trench wall), or UNDER (under the trench)

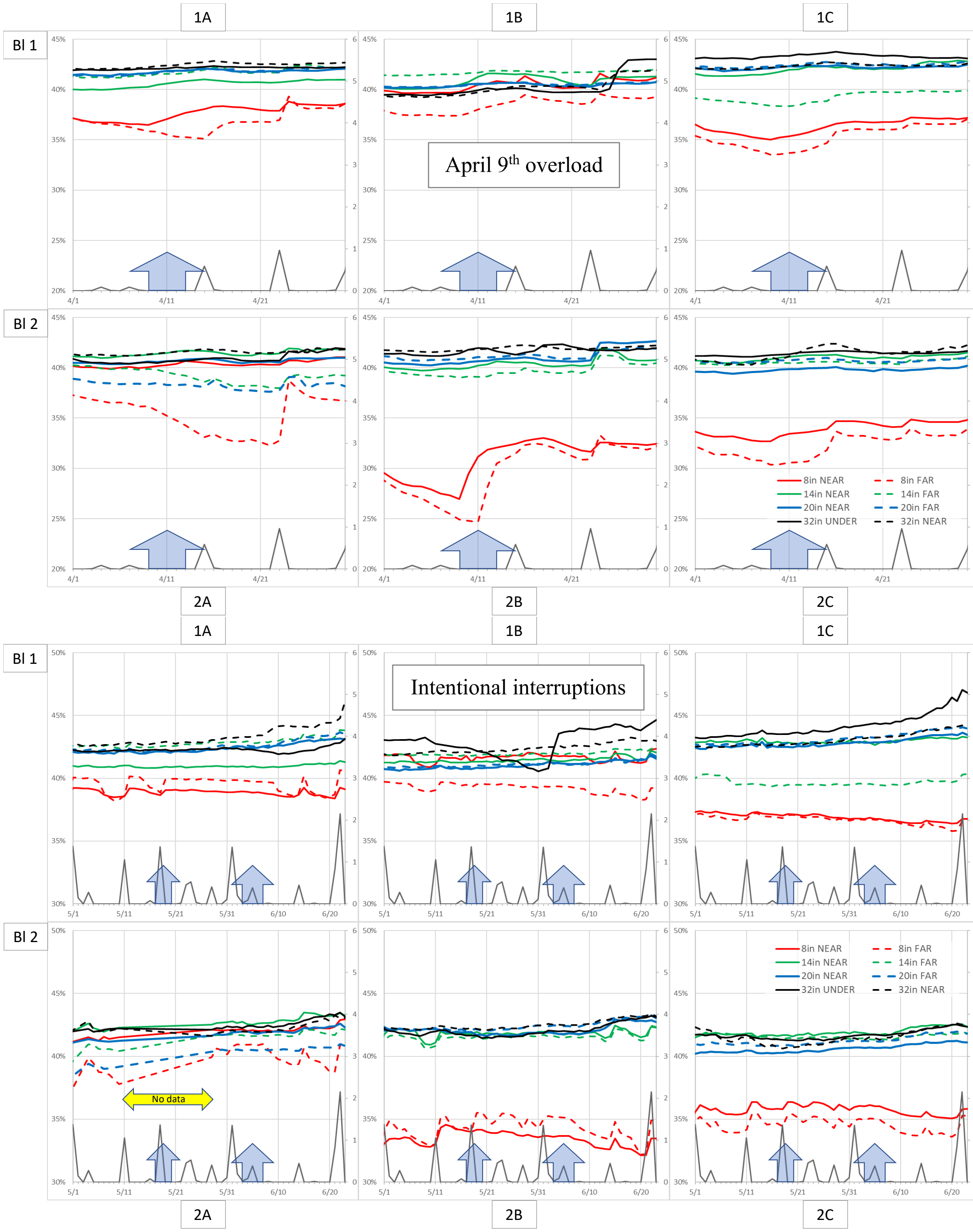

Figure 37. Effect of overload and intentional interruptions on soil moisture readings, expressed as volumetric moisture. Width of the arrows identifies the length of the event. Top: Overload on April 9th and the following days; Bottom: intentional interruptions on May 17-20 and June 3-7. Sensors 2A did not record any data on May 10-29, as node 2A was out for repair

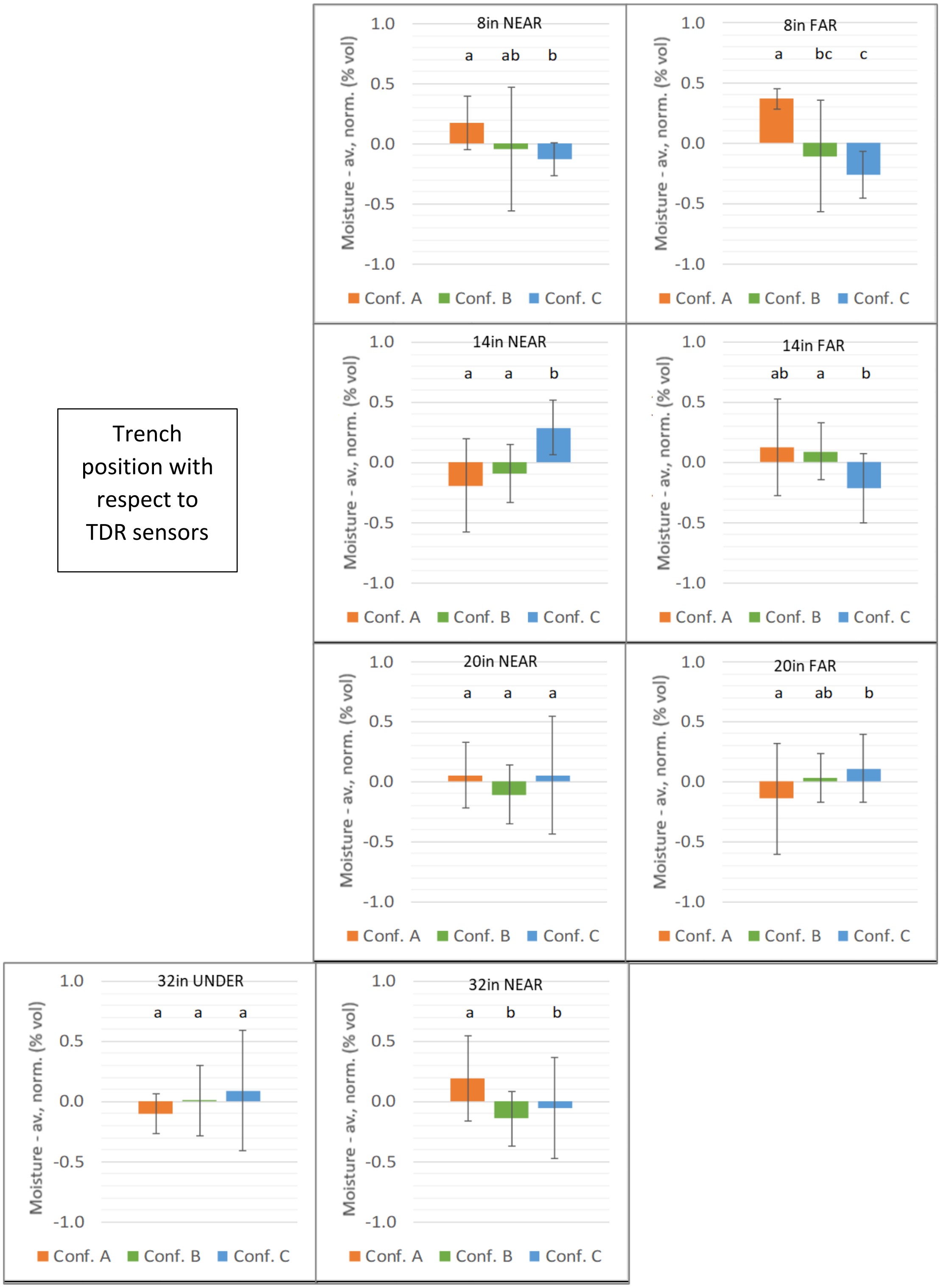

Figure 38. Average volumetric soil moisture at all sensors locations and all configurations. Each moisture value is obtained from the difference between a period (10-days of data) average and the period average among all configurations and blocks, then normalized for the period range among all configurations and blocks. Bars indicate standard deviation, and letters show if configurations are statistically significantly different among each other with the T-Test

Soil physical and chemical characteristics. Soil texture was measured again, this time in the lab, from samples collected on March 5, 2020 using a 3-1/4 inches hand auger bucket. 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, but closer to 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 39). Coarse fragment was found at the 0-6 inches depth in both profiles (1%), and at depths of 18-22 and 30-34 inches in Block 1 (1 and 2%, respectively). Although the two profiles look quite similar, Block 1 has consistently less sand and more silt and clay along the profile; especially in surface This difference in texture, together with the different elevation, could have contributed to the greater moisture found in Block 1. Cracks were observed on the surface in the drier months.

Samples collected at 6-9 and 18-22 inches of depth were used to conduct a clay detailed analysis, including X-ray diffraction (XRD) and Fourier transform infrared (FTIR). Overall, the XRD and ATR-FTIR data indicated that the four samples are similar in mineral composition: dominated by smectite, then kaolinite, illite, quartz, and feldspars. This is the common clay mineral composition in the Brazos area. In particular, the sharp peaks on the XRD patterns (Figure 40) are from quartz and feldspars (chiefly albite), and the broad peaks are from smectite. Small amount of kaolinite and illite can be seen here too. As the clay minerals yield weak but broad XRD peaks, we used square root on the Y-axis to show the weak peak. The FTIR patterns (Figure 41) were recorded with the ATR (Attenuated Total Reflection) accessories. The ATR-FITR is a quick IR analysis and is subject to sample preparation and sample heterogeneity as it only analyzes a few mg samples. ATR confirmed the presence of small amounts of kaolinite in the samples in addition to smectite and quartz.

All samples were used to determine the following chemical characteristics: Cation exchange capacity (Sodium acetate/ammonium acetate extraction) and water soluble salts from saturated paste (SAR, soluble cations, electrical conductivity). Results did not show any differences between the two sampling locations (Figure 42).

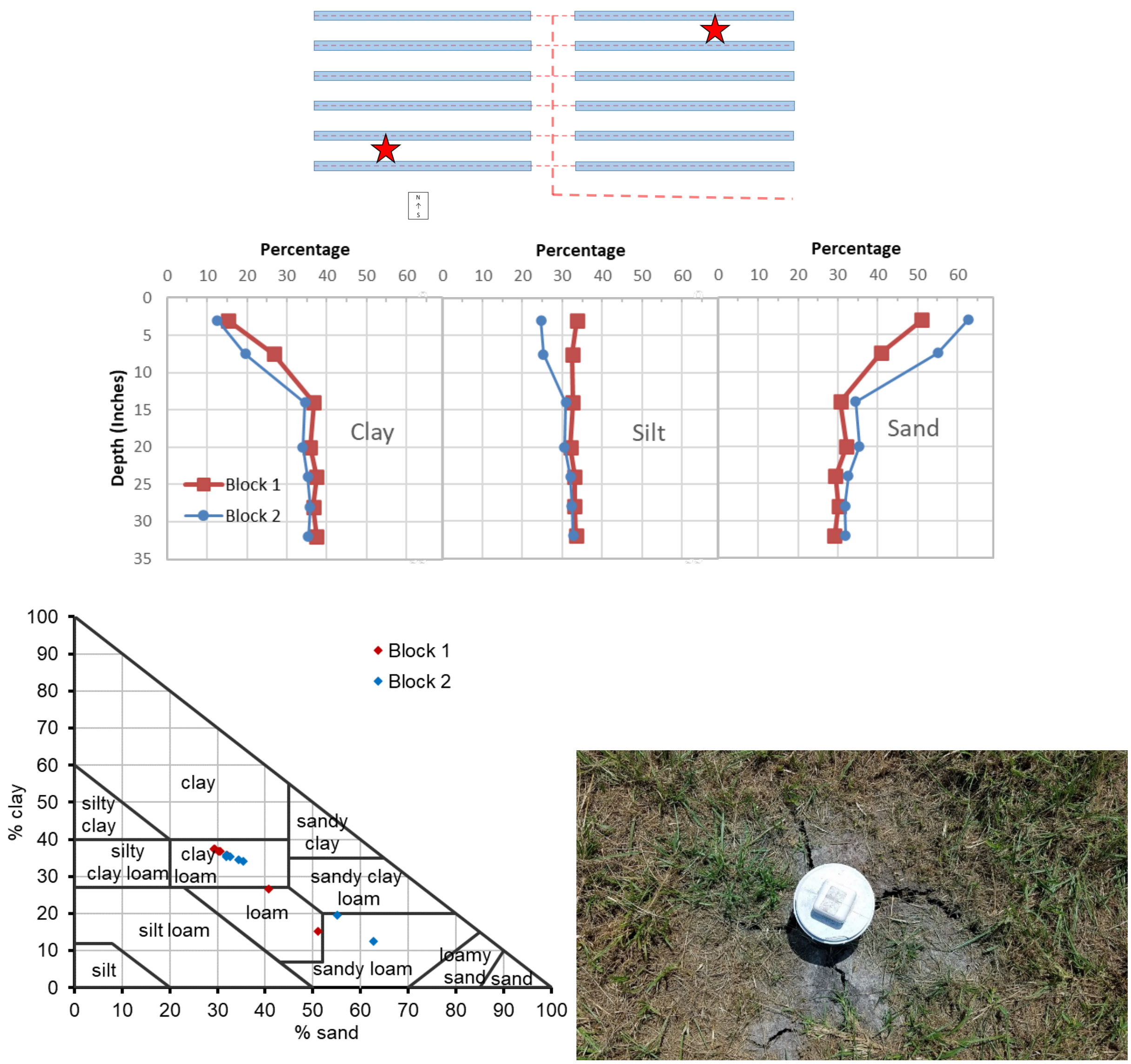

Figure 39. Top: Location of sampling (stars); Middle: Soil texture observed at the South-West side (Block 1) and the North-East side (Block 2) of the LPD drain field, near the corresponding TDR sensors, from samples collected with hand auger bucket on March 5, 2020; Bottom (left): Texture USDA classification of the two profiles; Bottom (right): Cracking of the topsoil in proximity of an inspection port

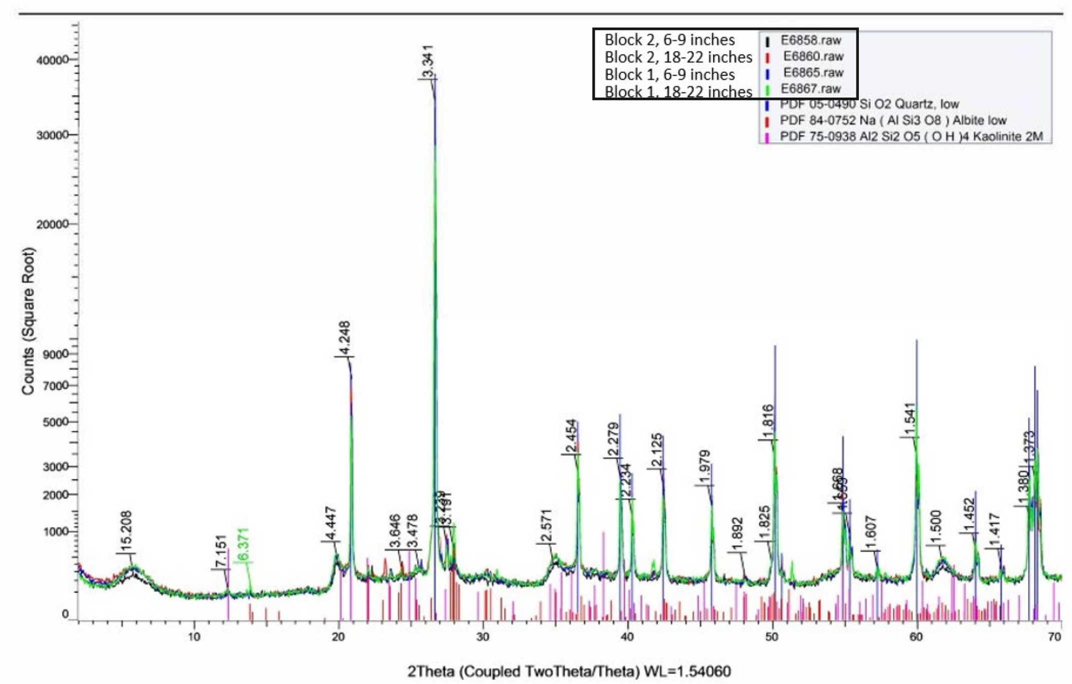

Figure 40. Clay detailed analysis (X-ray diffraction, XRD), from samples collected at 6-9 and 18-22 inches of depth with hand auger bucket on March 5, 2020

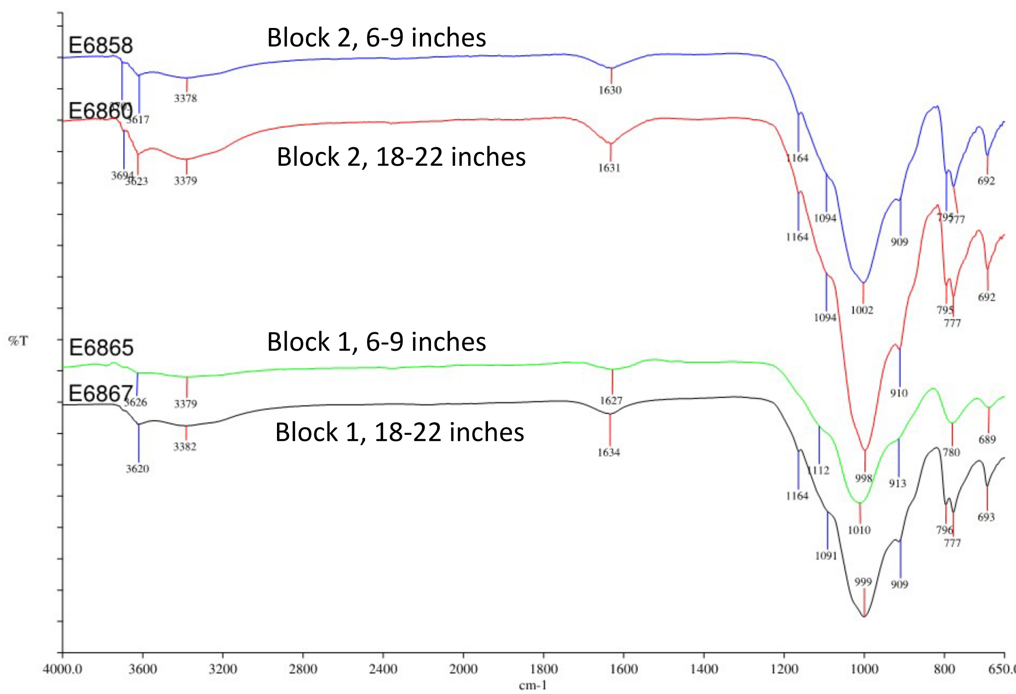

Figure 41. Clay detailed analysis (Fourier transform infrared, FTIR) from samples collected at 6-9 and 18-22 inches of depth with hand auger bucket on March 5, 2020

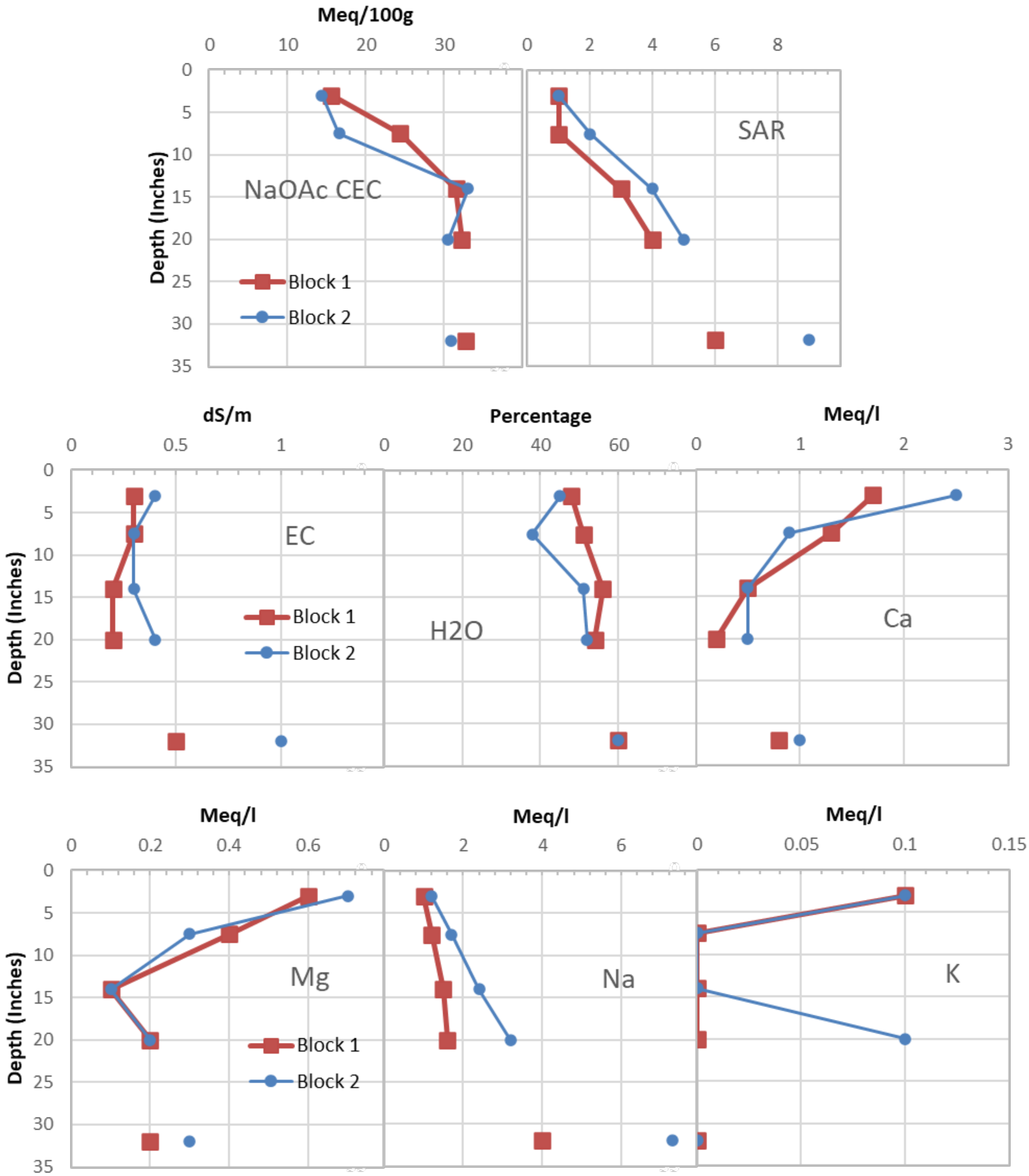

Figure 42. Cation exchange capacity and water soluble salts from saturated paste from samples collected with hand auger bucket on March 5, 2020. Top: Sodium acetate/ammonium acetate extraction, SAR; Middle: electrical conductivity, water content, Ca; Bottom: Mg, Na, K

CONCLUSIONS AND RECCOMENDATIONS

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, during, and at the end of the project. 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: survey was distributed not only at face-to-face events but also in electronic form and online; and field experiment lasted six months characterized by varying climatic conditions (extremely cold and extremely hot; very wet and very dry conditions, both in the spring and in the summer).

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*" indicated orifice clogging and maintenance as the main issues experienced. A total of 6,248 systems were represented in the received answers, where each answer was multiplied by the number of systems designed/installed/maintained/inspected/owned, and a system is counted for each problem indicated (some individuals indicated more than one problem).
Field experiment was successfully implemented, and all observations conducted as planned. Although compared configurations performed quite similarly, some significant differences were found. Significant differences were also found within the area due to different elevation and soil characteristics. 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.

Water level inside the trenches quickly responded to rain and wastewater loading events. And overflowed occasionally after heavy storms. Trenches had water most of the time, even after several dry weeks, and level was above the gravel (or top chamber) only for few days after rain events. Trenches under configuration with holes up and leaching chamber showed the lowest levels and were empty on few occasions, A statistically significant difference of water level was found among the three configurations: with respect to the average, water level was at +0.8, +2.1, and -3 inches, respectively in design with holes facing down (design A), holes facing up protected by orifice shield (design B), and holes facing up with leaching chamber (design C). When comparing water level change (absolute value of increase/decrease) in the trench during rain events, it was found that there was a statistically significant difference among design B (lower level change) and the other two configurations (greater level change).

Pressure in the laterals increased among quarters (+ 0.57 in after the first quarter, and + 0.64 in after the second quarter), but no statistically significant differences was found among configurations. Sediment was observed in the second and third test, which could explain part of the increased pressure. Sediment was denser in trenches located toward the North side of the drain field, the farthest from the effluent source.

Total Suspended Solids (TSS) and 5-day Biochemical Oxygen Demand (BOD5) in the Pump tank effluent were quite low, with BOD5 ranging between 20 and 260 mg/L, and TSS between 9 and 26 mg/L. This could be explained by a good performance of effluent filters located in both septic and pump tank in between the two compartments.

Soil moisture content tested with the gravimetric method before the drain field installation showed that the West portion of the field (Block 1, 14.2%) was slightly wetter than the East portion. This is consistent with the differences found in most observations between these two portions of the drain field, independently from the tested design. Soil moisture monitored hourly with a Time Domain Reflectometer (TDR), showed similar profiles in all tested locations. In most cases moisture decrease at the begin of the summer started in shallow sensors far from the trench. In September 2021, moisture at 32 inches of depth under the trenches decreased only in configuration C, which corresponds to these trenches getting dry; and moisture at 32 inches of depth near the trenches decreased only in Block 2. A lower moisture was found in design C with respect to the other two configurations at 8 (both distances) and 14 (far from the trench) inches of depth. This is consistent with water level, which resulted lower in this configuration. Soil texture was quite similar in the two profiles analyzed in the drain field (West and East portion). However, the West portion had consistently less sand and more silt and clay, especially in surface. Soil chemical characteristics (cation exchange capacity and water-soluble salts from saturated paste) did not show any differences between the two sampling locations.

Based on the results obtained from the activity reported, the **project questions** can be answered as follow: 1) What are the operational problems faced by the users and operators with the current LPD design in Texas? **ANSWER:** Based on the survey that was conducted, the main issues are related to orifice plugging and maintenance. 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? **ANSWER**: Although a longer experiment is needed to properly answer this question, results showed that in the experiment conditions holes facing up did not present evident issues compared to holes facing down. In our analysis, design with holes facing up protected by orifice shield (design B) had significantly higher water level in the trenches, followed by design with holes facing down (design A) and design with holes facing up with leaching chamber (design C). The analysis indicated also that level change at rainfall events (increase/decrease) was significantly lower in design B compared to the other two configurations. Pressures in the laterals did increase significantly within the project period, but no significant differences were found among configurations. Longer testing is likely needed to have any indications on this regard. Our analysis showed also that a lower moisture was found in design C with respect to the other two configurations at 8 (both distances) and 14 (far from the trench) inches of depth. This is consistent with water level, which resulted lower in this configuration. Overall, there is indication that, with respect to the control, design B could have an advantage in reducing the water level change during raining events (increase/decrease), and design C could have an advantage in keeping low the level in the trenches. 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? **ANSWER**: Based on the field experiment results, it appears that the smallest differences in site conditions (e.g., elevation, texture) had significant effect on most results, which indicates that soil evaluation has a key role in the at design phases and should be emphasized. As no major issues were identified with the alternative designs with holes facing up, such configurations should be considered for further testing and possible inclusion in the rules.

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APPENDIXES

APPENDIX A - Survey form for OSSF license holders, regulators, and homeowners to determine the type and magnitude of problems faced in Texas with LPD systems, and reported surveys (printed and online)

Texas A&M AgriLife Extension

Survey to get your feedback for improving low-pressure dosing (LPD) design in terms of effluent distribution uniformity, and ability to maintain the system

Please complete the following questions to the best of your ability.

About you

Indicate if you are a:

☐ Owner ☐ Designer ☐ Installer ☐ Maintenance Provider ☐ Regulator

Estimate number of LPD systems designed/installed/maintained/inspected: _____

Observed problems

- ☐ No problems
- ☐ Orifice plugging
- ☐ Not uniform distribution
- ☐ Maintenance
- ☐ Other ______________________________

Please describe the type and frequency of problem/s: ______________________________

____

Suggestions

Indicate your suggestions for improving LPD design:

____

____

____

____

Survey form (page 1)

Additional comments

FAQs

How will this information be used? Texas A&M AgriLife Extension is a public entity, therefore data collected is classified as public information. Data collected from surveys may be published in a report intended for research and educational purposes.

Why should I answer these questions? TCEQ have provided Texas A&M AgriLife Extension grant money[1] to conduct research to investigate whether the design of LPD systems can be improved in terms of effluent distribution over time, and ability to maintain the distribution system[2].

For more information contact:

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[1] TCEQ Solicitation 582-19-9377, RT-2.3.3
[2] North Carolina State Sea Grant College Publication UNC-S82-03 is currently used to aid in low-pressure dosing field design

Survey form (page 2)

TEXAS A&M AGRILIFE EXTENSION

Survey to get your feedback for improving low-pressure dosing (LPD) design in terms of effluent distribution uniformity, and ability to maintain the system

Please complete the following questions to the best of your ability.

About you

Indicate if you are a:

☐ Owner ☒ Designer ☐ Installer ☐ Maintenance Provider ☒ Regulator

Estimate number of LPD systems designed/installed/maintained/inspected: >100 ~~<500~~ <250

Observed problems

- ☐ No problems
- ☒ Orifice plugging
- ☐ Not uniform distribution
- ☒ Maintenance
- ☒ Other OLDER LPD IN TEXAS ALLOW 5' WIDE CREDIT ON <6" WIDE DITCHES. DESIGNER WERE USING PARTS OF TX REGS & NORTH CAROLINA STUDY.
- ☒ HIGH WATER USE IN RESIDENT/COMMERCIAL.

Please describe the type and frequency of problem/s: PLUGGING ORIFICE, LACK OF MAINTENANCE, FIELDS TRENCHES DESIGNED TO SMALL. (i.e. <6" TRENCH WIDTH & <6" GRAVEL DEPTH.

Suggestions

Indicate your suggestions for improving LPD design:

TEACH A CLASS FOR DESIGNERS AND D.R.'S TO ATTEND, ON HOW TO DESIGN & APPROVE DESIGNS.

SUGGESTIONS ON CORRECT METHODS TO UNPLUG A CLOGGED DOSING LINE. BEST PRACTICES!

Additional comments

MORE RESEARCH ON MOUND LPD'S TO USE IN AREAS WHERE OWNER DOES NOT WANT AN ATU.
HAVE A FEW LOCATED IN GILLESPIE COUNTY AND, AM NOT AWARE OF FAILURES. (I HAVE NOT LOOK AT THEM FOR YEARS OR KNOW IF THE SYSTEMS HAVE HAD ANY MAINTENANCE OVER THE YEARS)

FAQs

How will this information be used? Texas A&M AgriLife Extension is a public entity, therefore data collected is classified as public information. Data collected from surveys may be published in a report intended for research and educational purposes.

Why should I answer these questions? TCEQ have provided Texas A&M AgriLife Extension grant money[1] to conduct research to investigate whether the design of LPD systems can be improved in terms of effluent distribution over time, and ability to maintain the distribution system[2].

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TEXAS A&M AGRILIFE EXTENSION

Survey to get your feedback for improving low-pressure dosing (LPD) design in terms of effluent distribution uniformity, and ability to maintain the system

Please complete the following questions to the best of your ability.

About you

Indicate if you are a:

☐ Owner ☒ Designer ☐ Installer ☐ Maintenance Provider ☐ Regulator

Estimate number of LPD systems designed/installed/maintained/inspected: 50+

Observed problems

- ☐ No problems
- ☒ Orifice plugging
- ☒ Not uniform distribution
- ☐ Maintenance
- ☐ Other EQUALIZING HEAD PRESSURE ON MULTIPLE LINES

Please describe the type and frequency of problem/s: BREAKOUT, FORMATION OF "CHIMNEY," ORIFICE PLUGGING; REQUIRES FREQUENT BACKFLUSH TO CLEAR LINES

Suggestions

Indicate your suggestions for improving LPD design:

REQUIRE EFFLUENT LINE BE ENCASED IN LARGER (3-4") PERFORATED CASING; ORIFICES TO BE TURNED UP -

THIS IS IN 1995(?) NC ~~[illegible]~~ MANUAL

WE NEED TO USE MOST RECENT NC OR OTHER GUIDELINES

INSTALLER IN NE TEXAS WILL NOT INSTALL LPD'S.

Additional comments

MANUAL LABOR REQUIRED MAKES COST EXCESSIVE.

FAQs

How will this information be used? Texas A&M AgriLife Extension is a public entity, therefore data collected is classified as public information. Data collected from surveys may be published in a report intended for research and educational purposes.

Why should I answer these questions? TCEQ have provided Texas A&M AgriLife Extension grant money[1] to conduct research to investigate whether the design of LPD systems can be improved in terms of effluent distribution over time, and ability to maintain the distribution system[2].

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[1] TCEQ Solicitation 582-19-9377, RT-2.3.3

[2] North Carolina State Sea Grant College Publication UNC-S82-03 is currently used to aid in low-pressure dosing field design

TEXAS A&M AGRILIFE EXTENSION

Survey to get your feedback for improving low-pressure dosing (LPD) design in terms of effluent distribution uniformity, and ability to maintain the system

Please complete the following questions to the best of your ability.

About you

Indicate if you are a:

☐ Owner ☑ Designer ☑ Installer ☑ Maintenance Provider ☐ Regulator

Estimate number of LPD systems designed/installed/maintained/inspected: 10

Observed problems

- ☐ No problems
- ☑ Orifice plugging
- ☑ Not uniform distribution
- ☑ Maintenance
- ☐ Other ______

Please describe the type and frequency of problem/s: The main problem we have noticed is the absence of regular/required maintenance. We find lines full of solids, and we see drainfields failing due to saturation overall and improper distribution.

Suggestions

Indicate your suggestions for improving LPD design:

① Required maintenance ~~maybe~~
② Return flush line to 1st solids tank.
③ Timed dose

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Please complete the following questions to the best of your ability.

About you

Indicate if you are a:

☐ Owner ☐ Designer ☒ Installer ☒ Maintenance Provider ☐ Regulator

Estimate number of LPD systems designed/installed/maintained/inspected: _____

Observed problems

- ☐ No problems
- ☐ Orifice plugging
- ☒ Not uniform distribution
- ☒ Maintenance
- ☐ Other ____________

Please describe the type and frequency of problem/s: Typically Pump replacements every 2 to 5 years. Most don't reset the psi upon pump replacement or flush the lines

Suggestions

Indicate your suggestions for improving LPD design:

____

____

____

____

____

____

____

TEXAS A&M AGRILIFE EXTENSION

Survey to get your feedback for improving low-pressure dosing (LPD) design in terms of effluent distribution uniformity, and ability to maintain the system

Please complete the following questions to the best of your ability.

About you

Indicate if you are a:

☐ Owner ☐ Designer ☐ Installer ☑ Maintenance Provider ☐ Regulator

Estimate number of LPD systems designed/installed/maintained/inspected: 15-20

Observed problems

☐ No problems
☐ Orifice plugging
☐ Not uniform distribution
☑ Maintenance
☐ Other ____________________

Please describe the type and frequency of problem/s: failed pumps, failed floats, Pumped out systems,

Suggestions

Indicate your suggestions for improving LPD design:

More maintenance friendly.

TEXAS A&M AGRILIFE EXTENSION

Survey to get your feedback for improving low-pressure dosing (LPD) design in terms of effluent distribution uniformity, and ability to maintain the system

Please complete the following questions to the best of your ability.

About you

Indicate if you are a:

☐ Owner ☑ Designer ☐ Installer ☐ Maintenance Provider ☑ Regulator

Estimate number of LPD systems designed/installed/maintained/inspected: 10%

Observed problems

☐ No problems
☑ Orifice plugging
☐ Not uniform distribution
☑ Maintenance
☑ Other BASIC DESIGN GUIDELINES & TROUBLESHOOTING

Please describe the type and frequency of problem/s: ______

Suggestions

Indicate your suggestions for improving LPD design:

- HARD/DIGITAL DESIGN MANUEL
- AUTOMATIC EXCEL DESIGN SPREADSHEET AVAILABLE TO DESIGNERS, INSTALLERS & REGULAR FOR CONSISTANT FORMAT
- PARTS LIST - COMMON & ALTERNATIVE

TEXAS A&M AGRILIFE EXTENSION

Survey to get your feedback for improving low-pressure dosing (LPD) design in terms of effluent distribution uniformity, and ability to maintain the system

Please complete the following questions to the best of your ability.

About you

Indicate if you are a:

☑ Owner ☑ Designer ☑ Installer ☑ Maintenance Provider ☐ Regulator

Estimate number of LPD systems designed/installed/maintained/inspected: 0

Observed problems

- ☑ No problems
- ☐ Orifice plugging
- ☐ Not uniform distribution
- ☐ Maintenance
- ☐ Other ______

Please describe the type and frequency of problem/s: NA

Suggestions

Indicate your suggestions for improving LPD design:

In my area, we typically do not utilize LPD.

TEXAS A&M AGRILIFE EXTENSION

Survey to get your feedback for improving low-pressure dosing (LPD) design in terms of effluent distribution uniformity, and ability to maintain the system

Please complete the following questions to the best of your ability.

About you

Indicate if you are a:

☐ Owner ☑ Designer ☐ Installer ☐ Maintenance Provider ☑ Regulator

Estimate number of LPD systems designed/installed/maintained/inspected: 0

Observed problems

- ☐ No problems
- ☐ Orifice plugging
- ☐ Not uniform distribution
- ☐ Maintenance
- ☐ Other ______

Please describe the type and frequency of problem/s: ______

Suggestions

Indicate your suggestions for improving LPD design:

TEXAS A&M AGRILIFE EXTENSION

Survey to get your feedback for improving low-pressure dosing (LPD) design in terms of effluent distribution uniformity, and ability to maintain the system

Please complete the following questions to the best of your ability.

About you

Indicate if you are a:

☐ Owner ☐ Designer ☐ Installer ☐ Maintenance Provider ☑ Regulator

Estimate number of LPD systems designed/installed/maintained/inspected: 50+

Observed problems

- ☐ No problems
- ☐ Orifice plugging
- ☐ Not uniform distribution
- ☑ Maintenance
- ☐ Other

Please describe the type and frequency of problem/s: main issue observed is infrequent tank pumping and neglected filter maintenance. poor/improper installation

Suggestions

Indicate your suggestions for improving LPD design:

based on my experience, most LPD issues arise from homeowner mis-use. Also, installers will not take the time to ensure level trench bottoms, only rock/pipe level. They will then place any "extra" media in and on top of disposal area, bringing the storage area too close to the surface.

By encouragement of the installer to properly direct rain

Additional comments

fall off of the disposal area, system life can be extended.

Removal of the class II backfill requirement would in my opinion, be an improvement. This requirement creates a prime environment for the "upward" movement of wastewater. Basically encourages surfacing.

FAQs

How will this information be used? Texas A&M AgriLife Extension is a public entity, therefore data collected is classified as public information. Data collected from surveys may be published in a report intended for research and educational purposes.

Why should I answer these questions? TCEQ have provided Texas A&M AgriLife Extension grant money[1] to conduct research to investigate whether the design of LPD systems can be improved in terms of effluent distribution over time, and ability to maintain the distribution system[2].

For more information contact:

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[1] TCEQ Solicitation 582-19-9377, RT-2.3.3
[2] North Carolina State Sea Grant College Publication UNC-S82-03 is currently used to aid in low-pressure dosing field design

TEXAS A&M AGRILIFE EXTENSION

Survey to get your feedback for improving low-pressure dosing (LPD) design in terms of effluent distribution uniformity, and ability to maintain the system

Please complete the following questions to the best of your ability.

About you

Indicate if you are a:

☐ Owner ☑ Designer ☐ Installer ☐ Maintenance Provider ☐ Regulator

Estimate number of LPD systems designed/installed/maintained/inspected: ≥300

Observed problems

☐ No problems
☑ Orifice plugging
☐ Not uniform distribution
☑ Maintenance
☐ Other ____________

Please describe the type and frequency of problem/s: COMMON → HYDRAULIC OVERLOADING, IMPROPERLY EXPOSED COMMON → ELECTRICAL WIRING (ANTS), OVERSIZED ZONES / INSUFFICIENT # OF ZONES (ONLY 1 OR 2), FAILURE TO PUMP-OUT TANKS ← COMMON

Suggestions

Indicate your suggestions for improving LPD design:

3 OR MORE ZONES VIA KRAIN INDEXING VALVE, REQUIREMENTS TO ACCOUNT FOR FRICTION LOSS IN MANIFOLD BETWEEN TRENCHES, REQUIREMENTS:

- TRENCHES SHOULD BE FED DOWN THE MIDDLE (DO NOT PLUMB MANIFOLD ON THE ENDS)
- FEED THE HIGHEST TRENCH FIRST IN EACH ZONE.
- INSTALL CHECK VALVES ON SUPPLY LINES FOLLOWING INDEXING VALVE WHEN DRAINFIELD IS ABOVE/UPHILL FROM VALVE

TEXAS A&M AGRILIFE EXTENSION

Survey to get your feedback for improving low-pressure dosing (LPD) design in terms of effluent distribution uniformity, and ability to maintain the system

Please complete the following questions to the best of your ability.

About you

Indicate if you are a:

☐ Owner ☒ Designer ☐ Installer ☐ Maintenance Provider ☒ Regulator

Estimate number of LPD systems designed/installed/maintained/inspected: ~10

Observed problems

☐ No problems
☐ Orifice plugging
☐ Not uniform distribution
☒ Maintenance
☐ Other ____

Please describe the type and frequency of problem/s: Only problem I've encountered is an LPD with a faulty pump the homeowner refuses to replace.

Suggestions

Indicate your suggestions for improving LPD design:

TEXAS A&M AGRILIFE EXTENSION

Survey to get your feedback for improving low-pressure dosing (LPD) design in terms of effluent distribution uniformity, and ability to maintain the system

Please complete the following questions to the best of your ability.

About you

Indicate if you are a:

☐ Owner ☐ Designer ☑ Installer ☑ Maintenance Provider ☐ Regulator

Estimate number of LPD systems designed/installed/maintained/inspected: 10

Observed problems

- ☑ No problems
- ☐ Orifice plugging
- ☐ Not uniform distribution
- ☐ Maintenance
- ☐ Other ______

Please describe the type and frequency of problem/s: ______

Suggestions

Indicate your suggestions for improving LPD design:

Like the holes on bottom the best

TEXAS A&M AGRILIFE EXTENSION

Survey to get your feedback for improving low-pressure dosing (LPD) design in terms of effluent distribution uniformity, and ability to maintain the system

Please complete the following questions to the best of your ability.

About you

Indicate if you are a:

☐ Owner ☐ Designer ☑ Installer ☑ Maintenance Provider ☐ Regulator

Estimate number of LPD systems designed/installed/maintained/inspected: 12

Observed problems

☐ No problems
☐ Orifice plugging
☑ Not uniform distribution
☐ Maintenance
☐ Other

Please describe the type and frequency of problem/s: Pump Wear and System not Pumped Regular

Suggestions

Indicate your suggestions for improving LPD design:

a maintance contract would improve systems working. There is very little maintaince on these systems

TEXAS A&M AGRILIFE EXTENSION

Survey to get your feedback for improving low-pressure dosing (LPD) design in terms of effluent distribution uniformity, and ability to maintain the system

Please complete the following questions to the best of your ability.

About you

Indicate if you are a:

☐ Owner ☐ Designer ☐ Installer ☐ Maintenance Provider ☒ Regulator

Estimate number of LPD systems designed/installed/maintained/inspected: 0

Observed problems

- ☐ No problems
- ☐ Orifice plugging
- ☐ Not uniform distribution
- ☐ Maintenance
- ☒ Other not seen one in my jurisdiction

Please describe the type and frequency of problem/s: ______

Suggestions

Indicate your suggestions for improving LPD design:

TEXAS A&M AGRILIFE EXTENSION

Survey to get your feedback for improving low-pressure dosing (LPD) design in terms of effluent distribution uniformity, and ability to maintain the system

Please complete the following questions to the best of your ability.

About you

Indicate if you are a:

☐ Owner ☐ Designer ☒ Installer ☐ Maintenance Provider ☐ Regulator

Estimate number of LPD systems designed/installed/maintained/inspected: 0

Observed problems

- ☐ No problems
- ☐ Orifice plugging
- ☐ Not uniform distribution
- ☐ Maintenance
- ☒ Other Never Installed one or seen one

Please describe the type and frequency of problem/s: ______

Suggestions

Indicate your suggestions for improving LPD design:

I have never seen one

TEXAS A&M AGRILIFE EXTENSION

Survey to get your feedback for improving low-pressure dosing (LPD) design in terms of effluent distribution uniformity, and ability to maintain the system

Please complete the following questions to the best of your ability.

About you

Indicate if you are a:

☐ Owner ☐ Designer ☑ Installer ☑ Maintenance Provider ☐ Regulator

Estimate number of LPD systems designed/installed/maintained/inspected: 0

Observed problems

- ☐ No problems
- ☐ Orifice plugging
- ☐ Not uniform distribution
- ☐ Maintenance
- ☐ Other N/A

Please describe the type and frequency of problem/s: N/A

Suggestions

Indicate your suggestions for improving LPD design:

N/A

TEXAS A&M AGRILIFE EXTENSION

Survey to get your feedback for improving low-pressure dosing (LPD) design in terms of effluent distribution uniformity, and ability to maintain the system

Please complete the following questions to the best of your ability.

About you

Indicate if you are a:

☐ Owner ☒ Designer ☐ Installer ☐ Maintenance Provider ☐ Regulator

Estimate number of LPD systems designed/installed/maintained/inspected: 2000 – 3000

Observed problems

- ☐ No problems
- ☒ Orifice plugging
- ☐ Not uniform distribution
- ☐ Maintenance
- ☐ Other

Please describe the type and frequency of problem/s:
Home owner flooding; Horses on the field
Cigarette Butts
Finite life of about 15-20yrs
Fields blind

Suggestions

Indicate your suggestions for improving LPD design:
Maybe Oversize
Mound LPD are good

TEXAS A&M AGRILIFE EXTENSION

Survey to get your feedback for improving low-pressure dosing (LPD) design in terms of effluent distribution uniformity, and ability to maintain the system

Please complete the following questions to the best of your ability.

About you

Indicate if you are a:

☑ Owner ☐ Designer ☑ Installer ☑ Maintenance Provider ☐ Regulator

Estimate number of LPD systems designed/installed/maintained/inspected: 25

Observed problems

- ☑ No problems
- ☐ Orifice plugging
- ☐ Not uniform distribution
- ☐ Maintenance
- ☐ Other

Please describe the type and frequency of problem/s: none

Suggestions

Indicate your suggestions for improving LPD design:

Required Inspections to verify system is functioning as permitted. Annuall basis.

Mr. Bonaiti,
I am a regulator in Burnet County. We met a couple of years ago. I've probably inspected well over 1,000 systems utilizing LPD. The problems I run into are all related to pressure. Using a gate or ball valve to set head creates back pressure on the pump causing premature pump failure. A hose bib recirculating into the pump tank can be used to regulate pressure without causing back pressure. Also having the pressure too low can cause orifice plugging problems. Most installers open the valve wide open as soon as the inspector leaves. My experience is I would rather see 10' of head than 2'. Designers have become better in matching pumps to field sizes and head requirements eliminating the pressure valves. Holes up is a scary proposition. LPD in chambers seems to work alright as we have a few of these. My only concern is how the distribution lines are supported in the chambers. I have concerns with the durability of zip ties. All in all we have good success with LPD systems. We can usually manage 7-10 years on a pump in a system and most of my installers will "acid" the lines when they change a pump. It shocks a system but cleans the lines (we've dug several up). The main thing is educating homeowners to keep the grease out and periodic pumping. I always tell homeowners if you have to pump your system it's probably too late. Hope this helps!

Respectfully,
Herb Darling (DR)
Burnet County

ID (1)	Date (2020)	Indicate if you are a: Owner, Designer, Installer, Maintenance Provider, Regulator	Estimate number of LPD systems Designed/Installed/Maintained/Inspected	Observed problems: No problems, Orifice plugging, Non uniform distribution, Maintenance, Other	Other (describe)
21	6/16	Installer,Maintenance Provider	1	Not uniform distribution,Maintenance	
22	8/10	Regulator	50	Orifice plugging,Maintenance	
23	8/11	Regulator	0	No problems	
24	8/11	Regulator	10	Other	Homeowners Driving Over.
25	8/11	Regulator	10	No problems	
26	8/11	Regulator	10	Maintenance	
27	8/11	Regulator	1	No problems	
28	8/11	Installer,Regulator	50	Not uniform distribution	
29	8/11	Designer,Regulator	6	Other	Surfacing
30	8/11	Designer,Regulator	10	Orifice plugging,Not uniform distribution,Maintenance	
31	8/11	Regulator	15	Other	Pump failures
32	8/11	Regulator	6	No problems	
33	8/11	Regulator	10	Maintenance	
34	8/11	Regulator	0	Other	no comment
35	8/11	Regulator	25	Orifice plugging,Other	Sewage surfacing due to hydraulic overload.
36	8/11	Regulator	6	No problems	
37	8/12	Regulator	3	No problems	
38	8/12	Regulator	1,140	Other	Surfacing/Hydraulic overloading
39	8/13	Regulator	5	Orifice plugging,Not uniform distribution	
40	8/13	Regulator	50	No problems	
41	8/13	Designer,Regulator	6	No problems	
42	8/13	Regulator	more than 50	Orifice plugging,Maintenance	
43	8/18	Regulator	5	No problems	
44	10/5	Regulator	550	No problems	
45	10/27	Regulator	50+	Not uniform distribution,Other	Owners do have a clue what they own until it is a major problem

(1) Survey #43 was completed at 88/100, meaning one questions was skept; we still keep it as the main questions were answered (who you are, number of systems, observed problems)

ID	Please describe the type and frequency of problem/s
21	Areas of uneven distribution and effluent break out. Maintenance is difficult when many are installed without clean outs on the lateral pipe ends.
22	with only about 50 in the whole county, its hard for me to estimate frequency of problems but its not very often
23	no systems
24	Drip lines must be protected against traffic of homeowners .
26	* If designed correctly and then installed correctly, I have not seen many problems. * Some blow out on newly installed and mounds. * Original plump replaced with to large. * Dosing timer turned off or override and pump overflows field.
28	pressure across laterals unbalanced, one area saturated. seepage back to manifold if laterals run uphill plugging only when regular pumping is not performed
29	Usually see these systems have surfacing issues at the ends of runs. Also older systems tend to burn up pumps quickly.
30	Lines & Holes Plugging up. Having to back flush lines
31	Overall good systems
33	As an Authorized Agent I have not personally observed any problems. But in conversations with installers and designers maintenance and keep the orifices clear presents a problem
35	Rarely.
38	Minimum sizing requirements should be increased. Specifically drainfield minimum sizing should be increased. Increase minimum required gravel/porous material under disposal tubing
39	Of the ones that have been put in since I have been a DR most will have problem with even distribution and clogging of the lines. A few have been installed as an aerobic system with LPD distribution. This seems to work better and I encourage installers to use this method. One of the local designers who is a professional engineer requested that I add a requirement in our local orders that LPD disposal may only be used behind an aerobic plant.
42	Our county has >3,000 permitted LPDs in operation. From experience most LPD will start to malfunction when they have been in operation between 15-20 years. Most owners do not properly maintain.
45	Frequently the disposal area becomes oversaturated.

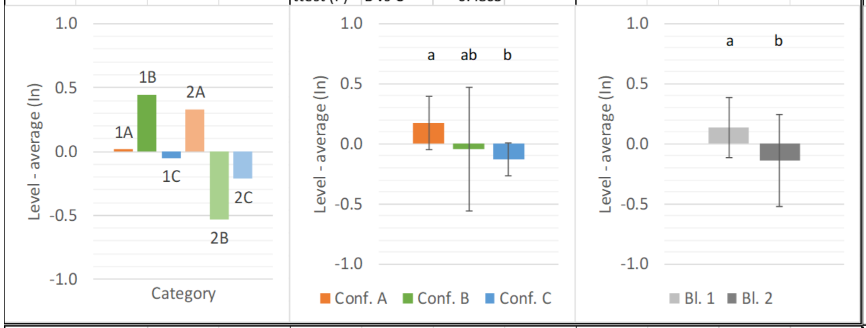
ID	Indicate your suggestions for improving LPD design	Additional comments	Contact
24	Display signs showing disposal area and do not tread. Etc.		
25		LPD's are used very infrequently in Galveston County. Mounded drip emitter system would be the go to system in this area along with surface application systems.	
26	Set pump sizes, Filters required. additional secondary treatment tanks required		
27			
28	possible looping of the ends to balance equal pressure over entire field drainfield divided into smaller rotating zones works well but many installers don't trust k-rain rotating valves to switch correctly over time as debris may clog switching valves	In our particular county (Fayette) LPD systems are very popular as an alternative to costly aerobic systems. there are a number of installers here that use this system and most work well for years until the drainfield fails. flushing lines usually buys a short extended period of time before field replacement.	
32	we have licensed six systems since 2002. we do not have a lot of history with LPD systems.		
35	Increase the drainfield sizing requirements		
37	I do not see enough LPD systems to have any input		
38			tpaty@collincountytx.gov
39	LPD disposal should only be used behind an aerobic plant		dbain@co.titus.tx.us
40			
41	There is a lot of guess work when first doing designs. I would like to see some standardized examples of systems so that new designers can have something to go off of to insure they are interpreting the rules correctly.		dapeck57@gmail.com
42	Have the legislature pass a law to require LPDs to be under a continuous maintenance contact and distribution lines to be annually flushed	We do not see these types of systems being installed much anymore due to the cost as installation is labor intensive	abadders@co.kerr.tx.us
44		Austin Water has not seen any problems with functioning LPD systems related to the field design. We have only seen issues with auxiliary components such as switching valves, riser caps, floats and control panels.	512-972-0186 Paul.Kaiser@Austintexas.gov
45	Increase disposal area requirements.	Increase industry knowledge related to soil science as it relates to wastewater, specifically: 1) capacity of each class of soil to treat and dispose wastewater; 2) details regarding water moving through soil; 3) details on impact of slope; 4) native soil profile v. disturbed/fill material (impact on water movement and treatment); 5) soil structure	(940) 349-2920

APPENDIX B - Statistical analysis of volumetric soil moisture readings at all sensors locations. Moisture is expressed as difference between the reading and the daily average of all configurations and blocks, and normalized for the daily range. Bars indicate standard deviation, and letters show if configurations are significantly different among each other with the T-Test

8in NEAR

	Conf. A	Conf. B	Conf. C
average	0.17	-0.04	-0.13
stdev	0.22	0.51	0.14
ttest (P)	A vs B	0.3119	
ttest (P)	A vs C	0.0125	*
ttest (P)	B vs C	0.4863	

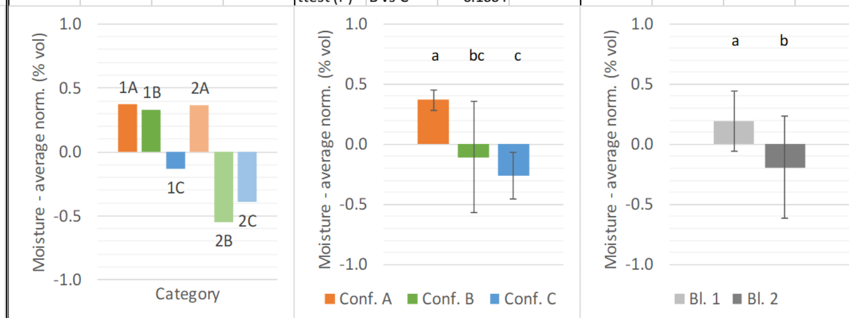
	Bl. 1	Bl. 2	
average	0.14	-0.14	
stdev	0.25	0.38	
ttest (P)	1 vs 2	0.0490	*



8in FAR

	Conf. A	Conf. B	Conf. C
average	0.37	-0.11	-0.26
stdev	0.08	0.46	0.19
ttest (P)	A vs B	0.0042	**
ttest (P)	A vs C	0.0000	***
ttest (P)	B vs C	0.1664	

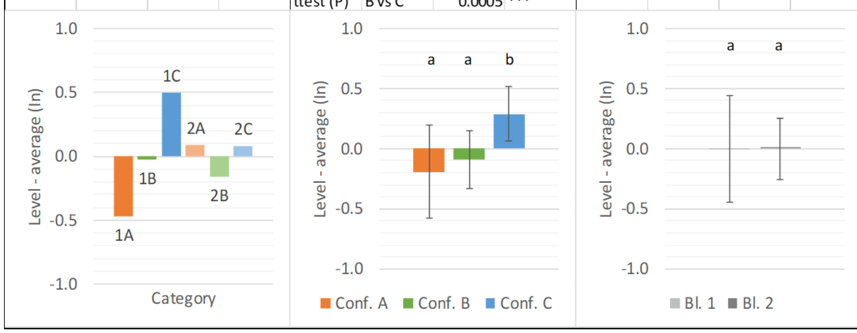
	Bl. 1	Bl. 2	
average	0.19	-0.19	
stdev	0.25	0.42	
ttest (P)	1 vs 2	0.0009	***



14in NEAR

	Conf. A	Conf. B	Conf. C
average	-0.19	-0.09	0.29
stdev	0.39	0.24	0.23
ttest (P)	A vs B	0.5192	
ttest (P)	A vs C	0.0154	*
ttest (P)	B vs C	0.0005	***

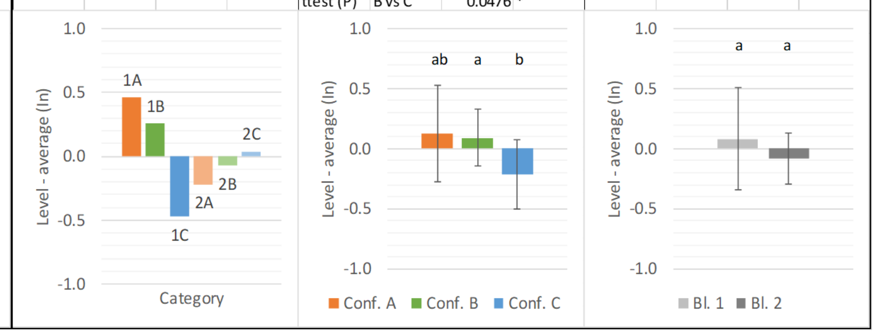
	Bl. 1	Bl. 2	
average	0.00	0.00	
stdev	0.44	0.25	
ttest (P)	1 vs 2	0.9789	



14in FAR

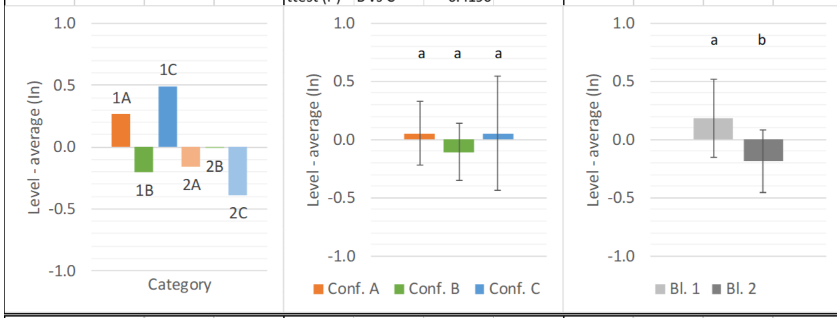
	Conf. A	Conf. B	Conf. C
average	0.12	0.09	-0.22
stdev	0.40	0.23	0.29
ttest (P)	A vs B	0.7466	
ttest (P)	A vs C	0.1058	
ttest (P)	B vs C	0.0476	*

	Bl. 1	Bl. 2	
average	0.08	-0.08	
stdev	0.43	0.22	
ttest (P)	1 vs 2	0.2347	

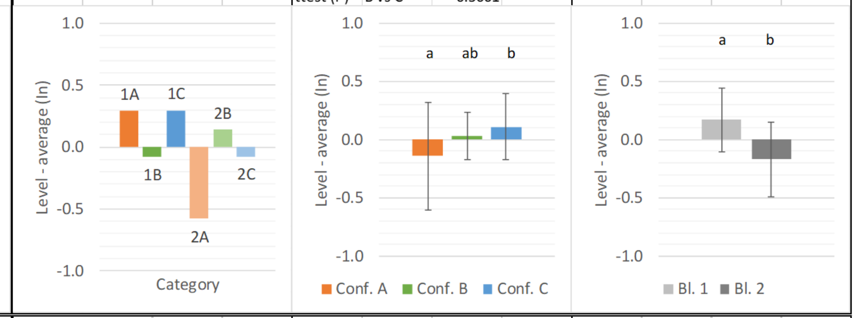


Statistical analysis of volumetric soil moisture readings at sensors located at 8 and 14 inches of depth. Moisture is expressed as difference between the reading and the daily average of all configurations and blocks, and normalized for the daily range. Bars indicate standard deviation, and letters show if configurations are significantly different among each other with the T-Test

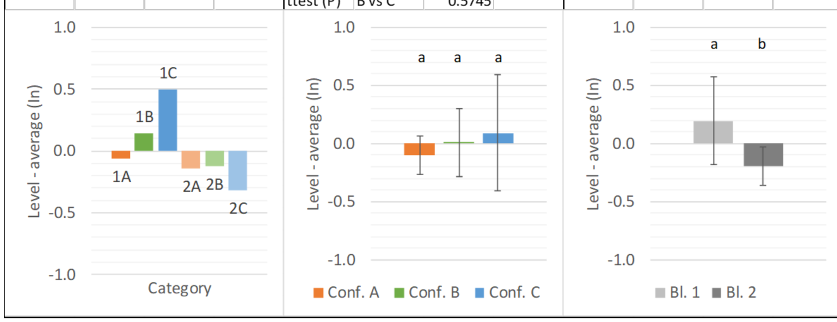
20in NEAR		Conf. A	Conf. B	Conf. C		Bl. 1	Bl. 2	
average		0.05	-0.11	0.05	average	0.19	-0.19	
stdev		0.27	0.24	0.49	stdev	0.33	0.27	
ttest (P)	A vs B	0.2052			ttest (P) 1 vs 2		0.0097	*
ttest (P)	A vs C	0.9938						
ttest (P)	B vs C	0.4196						



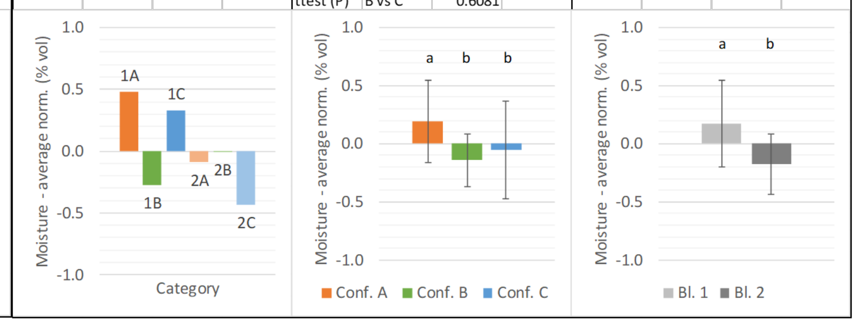
20in FAR		Conf. A	Conf. B	Conf. C		Bl. 1	Bl. 2	
average		-0.14	0.03	0.11	average	0.17	-0.17	
stdev		0.47	0.20	0.28	stdev	0.28	0.32	
ttest (P)	A vs B	0.3352			ttest (P) 1 vs 2		0.0137	*
ttest (P)	A vs C	0.0437 *						
ttest (P)	B vs C	0.5661						



32in UNDER		Conf. A	Conf. B	Conf. C		Bl. 1	Bl. 2	
average		-0.10	0.01	0.09	average	0.19	-0.19	
stdev		0.16	0.30	0.50	stdev	0.38	0.16	
ttest (P)	A vs B	0.3034			ttest (P) 1 vs 2		0.0017	*
ttest (P)	A vs C	0.2568						
ttest (P)	B vs C	0.5745						

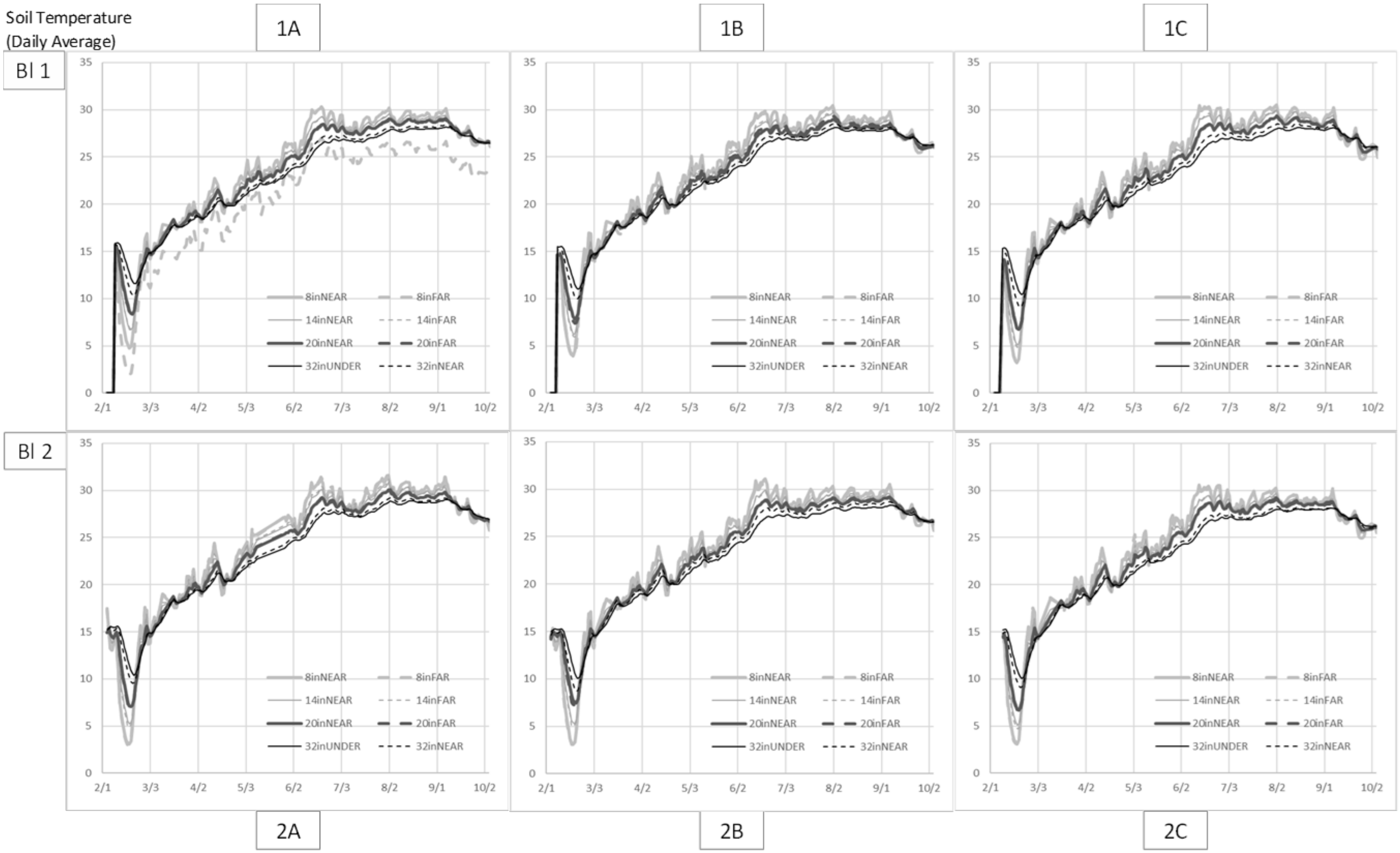


32in NEAR		Conf. A	Conf. B	Conf. C		Bl. 1	Bl. 2	
average		0.19	-0.14	-0.05	average	0.18	-0.18	
stdev		0.36	0.23	0.42	stdev	0.37	0.26	
ttest (P)	A vs B	0.0370 *			ttest (P) 1 vs 2		0.0129	*
ttest (P)	A vs C	0.0132 *						
ttest (P)	B vs C	0.6081						

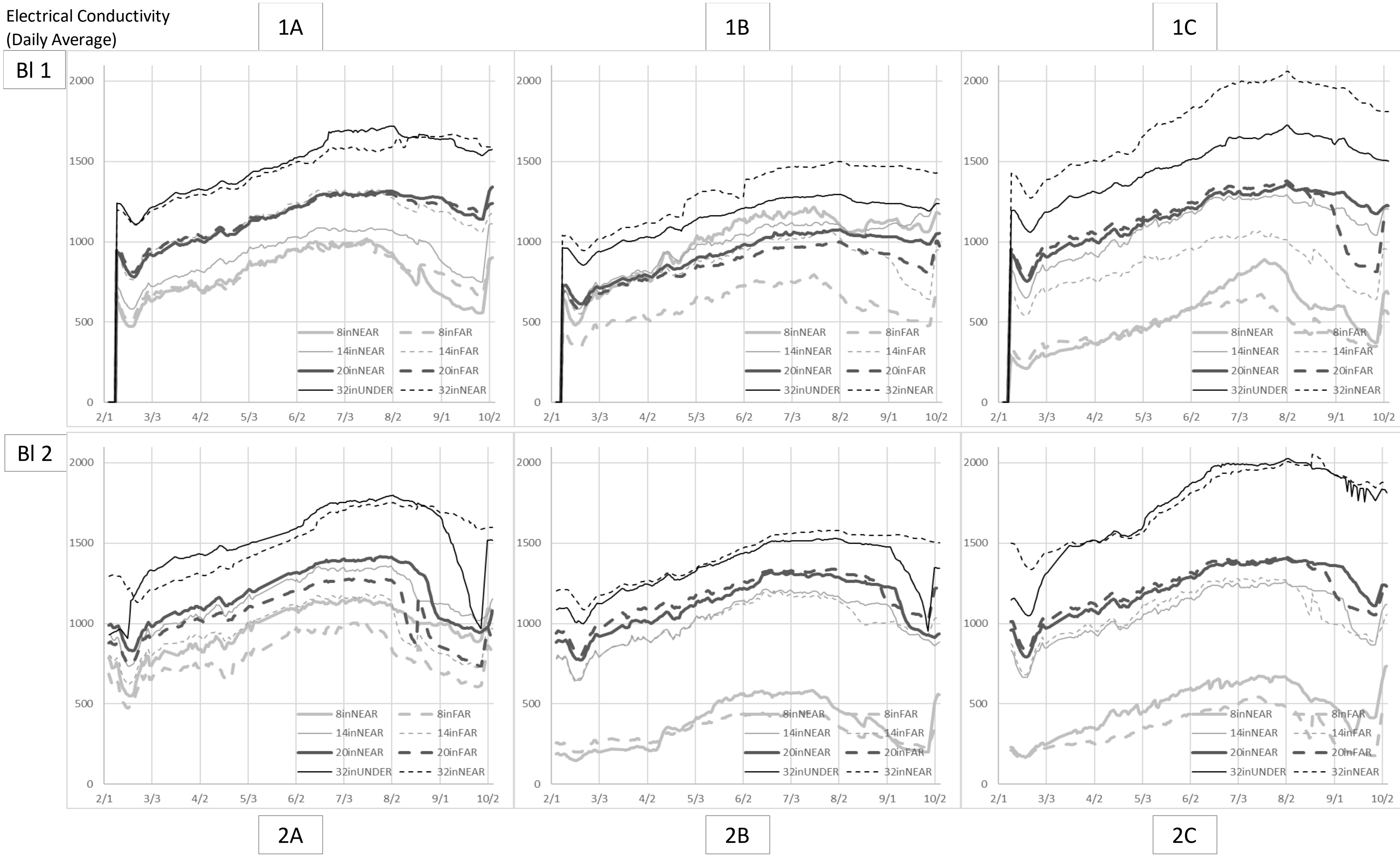


Statistical analysis of volumetric soil moisture readings at sensors located at 20 and 32 inches of depth. Moisture is expressed as difference between the reading and the daily average of all configurations and blocks, and normalized for the daily range. Bars indicate standard deviation, and letters show if configurations are significantly different among each other with the T-Test

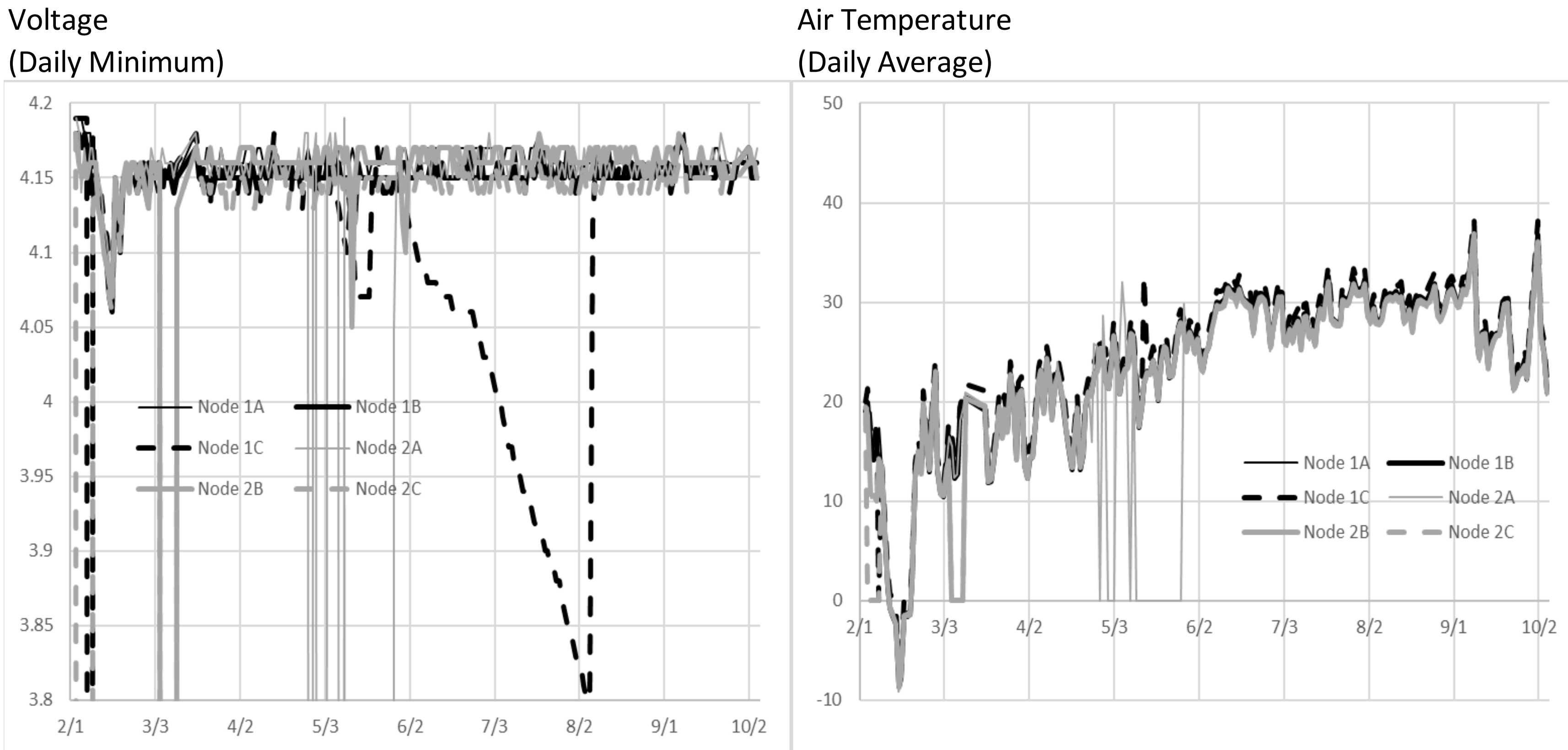
APPENDIX C - Additional recorded data by the TDR instrumentation, which include soil temperature and electrical conductivity from each sensor, and air temperature and solar voltage from each node



Soil temperature recorded by each TDR sensor



Electrical conductivity recorded by each TDR sensor



Solar voltage (left) and Air temperature (right) recorded by each node