**Manage/Maintenance of Decentralized/Distributed Wastewater Systems Tennessee**

Michael Hines, M.S., P.E.[1]

## Abstract

Management structures must be in place for every wastewater system. These structures must be adequate to ensure systems perform as designed throughout their useful lives. In 1980, USEPA published recommended guidance on five Models of management based on increased complexity and level of risk posed by those systems. The paper will discuss how those Models are applied to management entities in Tennessee. A brief overview of maintenance requirements is presented. In January/February 2024, Tennessee Department of Environment and Conservation conducted snapshot inspections of 350 advanced treatment/effluent drip dispersal systems to identify how these were performing. Results of those inspections are presented in the paper. The inspections suggest that utilizing instances of ponding as primary evidence of noncompliance is not supported.

## Background

Over the last several years, considerable confusion has arisen over the terms "decentralized" and "distributed" as applied to water/wastewater management. In July 2022, the Committee Leadership Council of the Water Environment Federation created the Distributed Water Infrastructure Task Force (DWIT). Although still in draft form, the DWIT report defines Distributed Water Infrastructure (DWI) as water infrastructure or systems serving single or multiple properties within one neighborhood or district that are managed by a professional management entity (Responsible Management Entity, RME).

Under the DWIT definition, DWI systems do not include traditional onsite wastewater systems based on a septic tank and soil absorption system nor systems owned by public utilities regulated by utility commissions. This exclusion is inconsistent with the origin of the distributed infrastructure term derived from the field of distributed computer capacity. It also is inconsistent with the reality that many government and nongovernment public utilities have adopted concepts, designs, and technologies of decentralized systems within their jurisdictions. It also ignores the reality that in Tennessee as in other states, the term "Public Utility" includes privately owned utility organizations which use almost exclusively technologies, designs, and governances termed DWI by the DWIT.

For purposes of this discussion, decentralized wastewater infrastructure is defined as any technology utilized to provide just in time service at or near the point of need utilizing readily available technology. DWI is defined as any wastewater system or system components requiring management and/or O&M enhanced beyond that required for conventional septic tank/drainfield systems. DWI differs from decentralized only in a higher level of management oversight required.

Design of land-based wastewater dispersal systems depends entirely on the ability of soil morphology to accept the applied flow without surfacing; move the flow away from the site; and

[1] Founding Principal, Southeast Environmental Engineering, LLC

remove organics, nutrients, harmful organisms, and other pollutants. Applicable loading rates vary with soil texture, structure, depth, and wastewater strength as well as local climatic conditions. Combining these parameters makes designing land based effluent dispersal systems an inexact science. Based on decades of experience with septic drain fields, regulators have imposed semi scientifically derived loading rates and relied on "no surfacing" as the principal test of performance. This mentality carried over into the regulation of design and operation of effluent drip dispersal systems.

Prior to the 1990's, wastewater services to rural developments in Tennessee were limited to conventional septic systems with land based effluent dispersal. Some commercial establishments were permitted by the Tennessee Department of Environment and Conservation (TDEC) to discharge to surface streams following secondary biological treatment. However, the number of systems permitted under the National Pollutant Elimination System (NPDES) regulations were very rare and subject to very stringent effluent limitations. Management of those systems, i.e. operation and maintenance, were the responsibility of the owners or contract O&M personnel.

**Management**

Properly designed, constructed, operated and maintained, decentralized technology is protective of public health and environment. The degree of regulatory and professional management required to achieve this protection can be directly related to the degree of risk resulting from failure or laxity in any of those parameters. In 2003, EPA released its *Voluntary National Guidelines for Management of Onsite and Clustered (Decentralized) Wastewater Treatment Systems*. While the Guidelines were developed specific to wastewater, they are readily modifiable.

The Guidelines described recommended management structures for such systems as a function of the degree of risk posed by these systems in their various environments. Five Management Model levels are described for decentralized systems posing the least to the highest level of public or environmental risk:

Management Model 1 – Homeowner Awareness
Management Model 2 - Maintenance Contracts
Management Model 3 - Operating Permits
Management Model 4 - Responsible Management Entity (RME) Operation and Maintenance
Management Model 5 - RME Ownership

Models 1 through 3 are appropriate for mechanically and biologically simple systems located in environments where system failure does not pose an inordinate risk to public or environmental health. Preferably, the Model 4 RME would hold and share responsibility with the system owner for compliance with a renewable permit specifying the operation and maintenance of the system. Large or biologically/mechanically complex wastewater systems or those located in very sensitive environments **demand** that a Model 5 RME legally own and be liable for operation/maintenance and effluent quality.

Prior to the late 1990s, Tennessee, rural residential subdivision developments were required to connect to permitted municipal systems or have septic systems at individual residences. Marginal

soil conditions limited the lot density of many of these subdivisions. A few residential subdivisions were approved with collection sewers, treatment, and effluent dispersal systems owned and operated/maintained by Homeowner Associations (HOAs). These HOAs were not authorized under state statutes to own wastewater facilities and subsequent failure of their wastewater management systems resulted in abandonment by the HOA leaving TDEC without regulatory authority over the system owners. TDEC stopped issuing wastewater system permits to HOAs as a result.

Individual properties served by septic/land application systems required only a construction permit from TDEC or a county approved by TDEC to administer the septic systems program. These systems were managed under Models 1-3. Individual properties served by mechanical (activated sludge) systems were required to have TDEC construction permits and NPDES discharge permits. Most of these systems were owned by the business or property owner who generally contracted with a Tennessee Licensed Wastewater System Operator for O&M. Most of those operators were moonlighting governmental facility operators.

In the mid 1990s, a few wastewater engineers and contractors began experimenting with recirculating sand filters (RSFs) followed by effluent drip dispersal to treat domestic wastewater flows. TDEC septic system regulators would not approve these systems as they did not meet the TDEC design rules for septic drain fields. Ultimately, the NPDES staff within TDEC was granted authority to issue non-discharge State Operating Permits (SOPs) to such systems if the drip lines were no deeper that 7.5 inches below grade.[2]

While undesirable, these clustered systems could be owned by HOAs. TDEC required that HOAs provide performance bonds to ensure sufficient funding for about one-year of operation and maintenance should the HOA or its contractor fail to perform. The HOAs collected some form of fees from the property owners to pay for contracted services.

However, Tennessee statutes already required that any entity providing utility services for a fee was, by definition, a public utility. Fortunately, Tennessee also had a public service commission entity, the Tennessee Regulatory Agency, (TRA) now the Tennessee Public Utility Commission, (TPUC), that regulated privately owned (non-governmental) water, natural gas, phone, and electric utilities as Public Utilities. It was a relatively small step to add privately owned wastewater utilities to that list, although the requirements that such entities had to satisfy were lengthy and expensive. As a result, TDEC gained authority to issue wastewater system permits, either NPDES or non-discharge SOP to non-governmental public utility entities.

The creation of regulated privately owned public utilities allowed for the subsequent approval of hundreds of multi-property developments served by central wastewater collection, treatment, and effluent dispersal/reuse within the boundary of the development. As each system was owned by a public utility (governmental or private), all these management entities met the EPA Management Model 5 criteria. Additionally, TDEC required that the utility maintain operators licensed by TDEC in classifications consistent with the level of complexity of the utility's treatment systems.

[2] Memo to staff from Deputy Commissioner Wayne Sharber

The first subdivision wastewater management system approved in Tennessee for an SOP and granted a Certificate of Convenience and Necessity by the TRA was placed into operation in the late 1990s. Within the first several years, a handful (now totaling 13) of privately owned public wastewater utilities were created. Most of these ultimately owned a few subdivisions or small wastewater systems serving commercial customers. Over time, a few government utilities began to own and operate medium to large DWI wastewater systems.

Today, Tennessee Wastewater Systems, Inc. (TWSI) is the largest privately owned public wastewater utility in Tennessee with 120 subdivision facilities serving 5,300 customers. Government utilities include the Wilson Water & Wastewater Authority (WWWA) with 40 subdivisions and 3,600 platted lots, the Consolidated Utility District of Rutherford County (CUDR) with 103 subdivisions and 8,000 lots, and Watts Barr Utility District (WBUD) which owns seven wastewater plants and two separate STEP collection systems serving a total of 537 residences and four schools/businesses. Since 1990, these four utility entities alone have constructed more than 270 non-discharging, SOP permitted wastewater systems serving more than 17,000 customers.

In many areas, soils do not support land application of septic effluent with loading rates sufficient to support densities to make development profitable. The equipment industry has introduced small, proprietary biological treatment units purported to treat domestic wastewater to a sufficiently high quality as to allow for discharge into the environment. Use of these Advanced Treatment Systems (ATSs) is growing for individual residential lots with marginal soils.

TDEC began permitting use of ATS units in 2013 under its subsurface sewage system disposal rules. Use of the systems was limited to single family residential or commercial structures with flows less than 1,000 gpd. Approval required that the ATS unit be followed by a subsurface drip dispersal system and that a contract with a TDEC approved service provider be maintained in perpetuity. These provisions have resulted in costs to property owners several multiples greater than the costs for similarly sized conventional septic systems. As a result, use of ATS/drip systems has been economically limited to high value lots otherwise unbuildable. Additionally, there is essentially very limited inspection or enforcement of TDEC approved service providers.

Prior to the 1980s, package activated sludge plants were promoted and used for commercial installations outside of municipal sewer jurisdictions. Many were installed to serve commercial buildings, apartment complexes, a few subdivisions, and other concentrated sources of domestic wastewater. Virtually all were permitted under the Tennessee NPDES program. Unfortunately, these package plants did not receive adequate levels of operation and maintenance. They routinely experienced equipment failure, MLSS burping, and general deteriorating ability to meet permit limits. As a result, TDEC adopted rules that prohibited package activated sludge plants for wastewater flows of less than 30,000 gallons per day and restricted their use in systems with flows between 30,000 and 100,000 gallons per day.[3] Due to pressure from developers and design engineers, enforcement of these rules was recently terminated.

From the 1980s forward, DWI systems became increasingly popular in Tennessee. At the same time Tennessee changed many of its regulatory programs to accommodate the DWI concepts,

[3] TDEC Rule 400-40-02-.03 (3) 9/17/2013

including system permitting rules. As a result of the state's regulatory changes, virtually all DWI systems utilize STEP/STEG collection with fixed film biological treatment followed by effluent drip dispersal. RSF units, AdvanTex®, and Bioclere® are the most common treatment systems with some high strength facilities served by specialized units. Virtually all are permitted as non-discharging SOP systems. Less than a half dozen DWI systems are permitted under the NPDES program.

Management Structures

Depending upon the mechanism of their creation, Model 5 RMEs in Tennessee are regulated under various state environmental and public utility statutes. Municipal utility departments are units of the municipal government funded through normal municipal budget processes. Capital projects are funded by bonds, loans, grants, etc. obtained by and administered through the municipality. Debt financing of municipal capital projects is common. User fees collected are required by TCA §7-34-115 to be utilized solely for the benefit of the customers. Other non-municipal RMEs such as utility districts, sanitary districts, and water and wastewater authorities created by counties, multiple counties or other units of local government are governed by appointed boards and with normal O&M operations funded by customer user fees. These types of districts also fund capital projects similarly to municipal utility departments.

Privately owned public utilities are those owned by persons, corporations, partnerships or other non-governmental legal entities. In Tennessee, they are regulated by the Tennessee Public Utility Commission (TPUC) as to financial stability, rates, accounting structure, and chartered service territory. Private utilities enjoy a protected monopoly status to provide service within their territory. Significantly, potential customers design and construct new or additional wastewater facilities to specifications of the utilities and then turn ownership over to the utilities upon completion to own and operate in perpetuity. All asset development costs are borne by the developers. All future operation and maintenance costs including equipment replacement costs are borne by the utilities. This model is vital in keeping user fees reasonable.

The Tennessee Department of Environment and Conservation (TDEC) is the agency responsible for regulating all environmental functions related to wastewater management (including stormwater) through its Division of Water Resources. Construction permits are required for installation of any wastewater system except for some serving agriculture or silviculture operations. This applies to conventional and advanced treatment systems serving individual homes as well as any system serving multiple properties or discharging to surface waters. Time limited operating permits are also required for any systems other than conventional septic systems.

For proposed discharges to surface waters, TDEC issues permits under its Tennessee NPDES program. Most TNPDES permits are for municipal wastewater systems on or near large water bodies or rivers. Most non-conventional septic wastewater systems in Tennessee consist of biological treatment followed by land application of treated effluent. These systems are subject to non-discharge State Operating Permits (SOPs). TNPDES permits impose extensive and frequent monitoring and operational requirements. Operator presence at the facility several days a week minimum is generally necessary. SOPs impose infrequent (quarterly, annual) monitoring

requirements for only a few parameters with operator inspections a minimum of twice a month or as otherwise approved.

**Business Characteristics of Responsible Management Entities (RMEs)**

DWI facilities in Tennessee are managed by three different EPA Management Level V RME forms. (1) Many municipalities have public utility departments that operate and maintain the water supplies and wastewater management systems of the municipality along with gas, solid waste, streets and road, internet, and other services. (2) Other governmental utility structures such as water and wastewater authorities, county or multicounty utility districts, sanitary districts, etc. perform similar roles. (3) privately owned, public utilities provide public utility water, wastewater, gas, phone, etc. services within chartered territories. Any system operating under an NPDES or SOP permit is required to be under the care of a state licensed operator. Any such system not governmentally owned is also required to be owned and operated by a Public Utility (by definition, privately owned).

Prior to 2023, most governmentally owned utility functions were, for business purposes, regulated by the Tennessee Utility Management Review Board and the Water & Wastewater Financing Board in TDEC. In April 2023, those functions were transferred to the Tennessee Board of utility Regulation in the office of the Tennessee Comptroller. The TPUC regulates privately owned public utilities as to business structure, rates, service territory, and customer relations. All environmental functions of all water and wastewater providers are regulated by TDEC.

Financial viability seems to be the only requirement to be approved as a Public Utility. The TPUC requires that all operating expenses including future system replacement be covered by the rates charged to customers. The TPUC sets rates such that this is assured. In return for which, the Public Utility is granted a monopoly to provide services within a guaranteed territory.

Although no engineering, environmental, or management competence is required to be approved as a Public Utility, experience shows that such competencies must exist within or be acquired by the Public Utility if it is to be successful. Experience also shows that creation of a new Public Utility requires a significant infusion of capital for up to several years as the customer base grows to the point that customer fees are sufficient to make the utility self-sustaining. Some Public Utilities operate as a division of a larger entity that utilizes its construction forces to build systems and generate sufficient income to operate systems during build-up.

Conventional septic wastewater systems serving individual properties are managed, if at all, by the homeowners. All are required to be installed under construction permits issued by TDEC or by a few county health departments enforcing state requirements. No operating permits are required for conventional systems and the only inspection programs that exist are those of some of the few contract counties. Single family residential lots served by individual package plants (advanced treatment units) with effluent drip dispersal must be inspected semiannually by private contractors licensed by the state as O&M personnel.

**Maintenance**

As discussed above, virtually all non-municipal wastewater systems in Tennessee are mechanical/biological treatment systems followed by effluent drip dispersal on land located at or near the properties served by the system. Conventional septic tank/drainfield systems are regulated by construction permits enforced by state and local complaint-based inspections. Operation and maintenance are provided by the homeowner. Non-conventional systems serving single residential properties obtain construction permits only but are required to be under supervision of contract personnel trained and certified by the supplying equipment manufacturer and licensed by TDEC.

Virtually all systems serving multiple properties or single properties with commercial or multi-residential customers are permitted in Tennessee by State Operating Permits (SOPs). By definition, these permits are non-discharge permits. The systems are required to be owned and operated by a public utility entity. SOP permits also require that the permittee's wastewater system must be supervised by Tennessee Licensed Collection and Wastewater System Operators. The two primary design considerations considered by TDEC are (1) anticipated daily flow, and (2) the loading rate of the soil profile.

All wastewater systems rely on competent operating and maintenance personnel to ensure uninterrupted treatment and effluent dispersal. For Tennessee systems, these individuals need to understand alternative collection sewers, STEP/STEG tanks, many forms of fixed film reactor-based treatment units, and drip dispersal systems. O&M of mechanical equipment such as pumps, filters, solenoid valves, and control panels are inherent in all these systems.

Tennessee has no specific design or O&M regulations. TDEC's drip dispersal program originally grew out of its septic tank regulatory program. The program is now within the Division of Water Resources, Land Management Branch. However, it is still managed by the septic tank unit staff. As a result, the regulatory focus of that staff continues to be prescriptive as to how the system is designed and how the soils are evaluated and loaded. The construction and SOP permits reflect that focus. Absent specific design rules, permits are withheld until the unique personal requirements of reviewing staff are satisfied.

SOP permits are written for each site with various conditions that, if not met, can subject the permittee to penalty actions. Most of these conditions are directed at O&M such as inspection of each zone a minimum of every 14 days, operator certification standards, vegetation maintenance, drip zone fencing, and maintaining warning signs at each entrance to a zone. However, the conditions most vexing to the engineering and utility communities are requirements related to wet spots or saturated soils in the drip field. Currently, all TDEC SOP permits for treatment/drip dispersal systems state that ponding in the drip field not associated with rainfall events is prohibited. There are no minimal accepted limits as to size of ponding area – any ponding observed regardless of size can be cause for violation and penalty action.

Additionally, the permits require that the entire hydraulic profile must be utilized. Again, there is no definition as to what is meant by this statement. In the past, TDEC has argued that drip line spacing greater than two feet would result in arial credit for only one foot either side of the drip tube. For several years, TDEC has argued that strict design and O&M regulations are needed to ensure adequate performance of treatment systems followed by land application of treated

effluents. At least two efforts were undertaken to adopt prescriptive regulations. Failure to involve the regulated communities other than allowing comment on the final regulation proposal resulted in sufficient complaints to the Tennessee General Assembly that the rule making efforts were thwarted.

Normal O&M at these SOP facilities consist of maintaining the treatment equipment in operating condition. This entails observing and recording pump run-times, operating pressures, condition of the attached growth media, and running simple operational tests such as pH, DO, and ammonia. Infrequent sampling for BOD, ammonia, nitrate in the effluent prior to drip is required in some cases. Drip zones are walked to check for ponding caused by leaking or broken valves, drip tubes, animal intrusion, downed trees or other infrastructure issues.

**TDEC Drip Study**

In late 2023, TDEC announced a massive inspection program to inspect every one of the 374 land application systems to determine their level of performance and identify design or O&M issues. In the writer's opinion, this was to demonstrate to the General Assembly that strict regulations, particularly design regulations, were warranted. All inspections were to be conducted by select TDEC staff making targeted observations during winter months with negligible evapotranspiration. The limiting condition across all systems would be the hydrology of the soil profile.

Inspections of most of the systems were completed in the second week of January 2024. However, a week of cold and rainy weather caused the staff to delay finishing inspections until the last week of January and the second week of February. (Several systems were inspected again in June and July 2024 without explanation.) 581 inspections were conducted of 420 distinct land application areas serving the 374 permitted installations. TDEC published a report of its inspection program entitled *Report on the Performance of Wastewater Systems Utilizing Drip Dispersal in Tennessee – June 7, 2024.* The agency also produced an internal spreadsheet of all the inspection activity.

For readers with access to the report and the spreadsheet, it is important to note that while the report is supposedly based on the spreadsheet, there is no indication as to which inspection data was used in the report. The spreadsheet lists every inspection conducted during the stated time period plus some done during a June and July 2024 time period. Additionally, several systems and drip zones were inspected more than once. In both the report and spreadsheet, "system" denotes a particular wastewater system operating under its unique permit. "Area or treatment area" denotes a specific drip zone within the indicated system,

The land application systems inspected were scattered across Tennessee as shown in Figure 1 below and located in many different soil series and profiles. The heavy concentrations in middle Tennessee represent mostly subdivisions and commercial establishments. The east Tennessee concentration represents overnight rental cabin developments, subdivisions, and commercial establishments. They were permitted between 1995 and 2023.

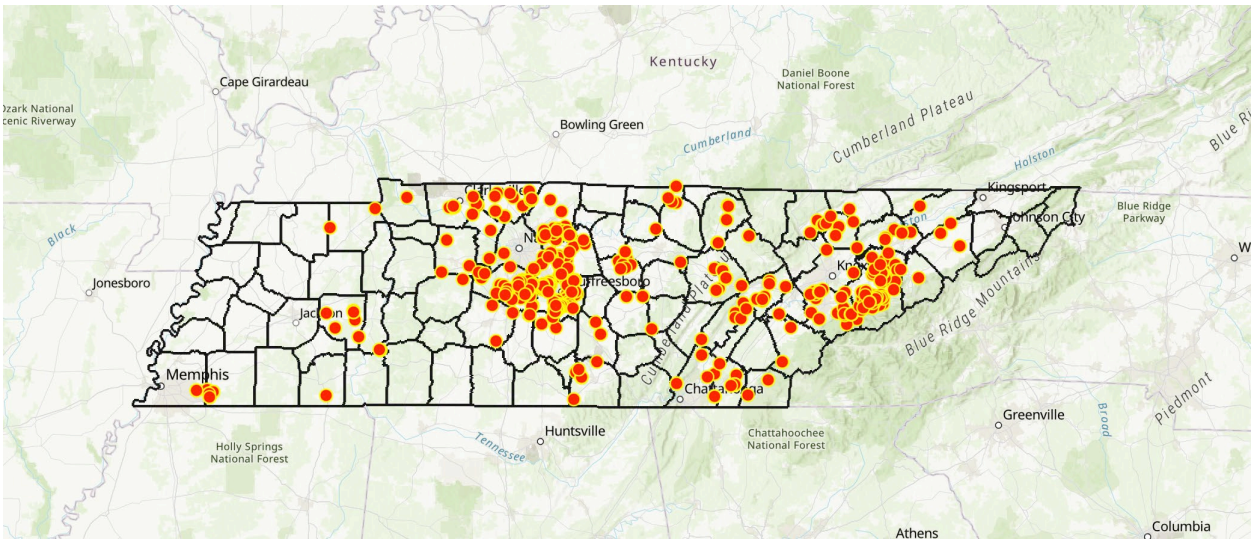

Figure 1. Distribution of Land Application Systems Utilizing Drip Dispersal in Tennessee (TDEC 2024)

TDEC's report states that of the 374 land application systems utilizing 420 land application areas (zones) inspected, 14 systems had not been installed or were never operated leaving a total of 360 systems in some state of operation. Of these, 41 systems were found to be discharging from the treatment system or from the infrastructure – in neither case was effluent reaching the drip distribution system (11.4% of the operational systems). Of the 319 systems utilizing 363 land application areas (zones), 205 drip zones operated by land application 177 systems were found to be malfunction free. In other words, 56.5% of the operational drip zones in Tennessee were functioning without issues, or more importantly, 43.5% of all drip zones in the state were malfunctioning. Additionally, 50.8% of the permitted facilities operating drip systems in the state were operating malfunctioning drip zones (including 41 bypassing the drip zones}.

The above information is a bit misleading as there are 102 separate owners of these systems. Further data analysis is needed to determine the percent and type of owners providing O&M sufficient to maintain well-functioning land application systems. Additionally, TDEC further identified 87 zones (24%) with only localized ponding and 14 zones so overgrown with vegetation that they could not be adequately observed – still they were counted as malfunctioning.

Table 1. Data from *Report on the Performance of Wastewater Systems Utilizing Drip Dispersal in Tennessee – June 7, 2024*

| | Discrete Systems | Drip Zones | Description |
|---|---|---|---|
| | 14 (3.7% of permitted systems) | 14 (3.3% of permitted zones) | Not installed or non-operational |
| | 41 (11.4% of operating systems only) | 43 (10.6% of installed zones) | Discharge from treatment or infrastructure (not to drip) |
| Total | 55 | 57 | |

| | | | |
|---|---|---|---|
| | 177 (49.2% of operating systems only) | 205 (56.5% of operating zones) | No Malfunction |
| | 77 (21.2% of operating systems only | 87 (24.0% of operating zones) | Zones with localized malfunctions |
| | 53 (14.7% of operating systems only) | 57 (15.7% of operating zones) | Zones with extensive ponding or overland flow |
| | 12 (3.3% of operating systems only) | 14 (3.8% of operating zones) | Zones overgrown/not accessible |
| Total | 319 | 363 | |
| Grand Total | 374 | 420 | |

Data from the spreadsheet and report do not produce identical results as the user is not privy to how internal decisions were made as to categorizing data from the spreadsheet to the report. Data from the spreadsheet represents all inspections conducted, several of which were follow-up inspections of selected facilities. That data shows 188 inspections found systems (not zones) with hydraulically overloaded conditions (no clear discussion is presented as to how the hydraulic overload condition was measured). 109 inspections described systems as having long term ponding with 98 systems involving large areas. Effluent was found to be leaving 57 and reaching surface waters at 43 inspections.

Table 2. Inspection Data from Inspection Spreadsheet (TDEC July 2024)

| Owner | Hydraulic Overload | Soil Saturated | Ponding | Long Term Ponding | Large Area Ponded | Overland Flow | Effluent Left Site |
|---|---|---|---|---|---|---|---|
| Utility | 188 | 172 | 165 | 104 | 98 | 89 | 57 |
| Private | 24 | 25 | 22 | 16 | 11 | 16 | 6 |
| Totals | 212 | 197 | 187 | 120 | 109 | 106 | 63 |
| % of Inspected | 41.6% | 38.6% | 36.7% | 23.6% | 21.4% | 20.8% | 12.4% |

The above results are based on 510 discrete inspections of drip systems (not zones), some of which were repeat inspections. 41.6% of the inspections found systems in noncompliance because of hydraulically overloaded soils. However, fewer systems were found with saturated soils, succeedingly fewer still with ponding, long term ponding, large area ponding, and overland flow. Only 12.4% of the systems were operating drip zones discharging effluent off-site.

Tennessee determines administrative compliance of land application systems based on effluent samples, physical inspection frequency, ponding in drip zones, etc. However, under the Tennessee Water Quality Act, pollution of receiving waters is about the only truly legally enforceable violation. Most other findings are administrative in nature and subject to administrative enforcement actions, many of which have been unsuccessful because of the lack of properly promulgated regulations. Drawing meaningful conclusions regarding the performance of the

inspected systems from the report and spreadsheets is somewhat problematic due to the nature and depth of findings documented. Considering both documents, several possible conclusions stand out to the writer:

1. Influent flows and resulting arial loading rates were not measured but would be necessary to adequately evaluate performance of soil-based systems.
2. Most drip zones were operated without malfunction significant enough to result in treated effluent leaving the drip site.
3. Considerable improvement in both operation and maintenance would significantly lower the infrastructure malfunctions resulting in ponding on drip zones.
4. Government and private utility owned systems experience significantly higher malfunctions than systems owned by individuals, schools, businesses, etc.
5. The study demonstrated no design flaws related to soil loading or operating characteristics nor was the study designed to do so.
6. Ponding and/or overland flow were not sufficient indicators that offsite pollution would occur, although it would be expected that diluted effluent would leave the site during rainfall events sufficient to cause runoff.