EVALUATION OF HYDRAULIC LOADING CRITERIA FOR THE "PERC-RITE"® SUBSURFACE DRIP IRRIGATION SYSTEMS

Prepared for
WASTE WATER SYSTEMS, INC.
Lilburn, Georgia

Prepared by
AYRES ASSOCIATES
Madison, Wisconsin

July 1994

Richard J. Otis, P.E.
Vice President
Environmental Management

Rick A. Apfel, CPSS
Project Manager

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BACKGROUND

Waste Water Systems, Inc. of Lilburn, Georgia, manufactures the "Perc-Rite"® subsurface drip irrigation equipment designed to treat and dispose of septic tank effluent in soils onsite. The equipment consists of a pump, 115 micron Arkal disc filters, Netafim RAM® dripperline, currently marketed under the name of BioLine®, automatic valves and associated piping, and a programmable controller to operate and monitor the system. The pump is activated by a level controller in a wet well following the pretreatment system, typically a septic tank, to periodically dose the subsurface drip irrigation field on demand or a timed cycle. It pumps the septic tank effluent through the disc filters and into a supply manifold feeding the subsurface dripperline. The pump maintains pressure in the dripperline while the filtered septic tank effluent is forced out pressure compensating drip emitters spaced every two feet of dripperline. The Netafim RAM® emitters are designed to discharge at a constant rate of 0.6 gallons per hour over a range of in-line pressures above ten pounds per square inch. The pump maintains an in-line pressure of 40-60 pounds per square inch during the dosing cycle.

The programmable controller automatically operates the system. If multiple irrigation zones are used, the controller will direct the filtered effluent to a particular zone in a prescribed pattern. At periodic intervals, the controller activates flushing operations. The disc filters are backwashed and the dripperline flushed automatically by opening and closing appropriate valves. This is done to remove any solids which may reduce the operating efficiency of the system. The flush water is returned to the septic tank. The controller also records the total volume of wastewater discharged to the irrigation system.

This method of wastewater treatment and disposal is relatively new. Developed out of agricultural irrigation technology, it is an effective method of applying controlled volumes of wastewater over large areas to prevent hydraulic or treatment failures of the infiltration system. With proper sizing, both treatment and disposal can be enhanced over conventional onsite systems because overloading of the infiltrative surface of the soil is prevented. Also, it can provide an effective means to reuse wastewater through turf irrigation.

PURPOSE OF STUDY

Criteria for proper sizing of subsurface drip irrigation systems have not been well established. Experience and operating data are limited. Current criteria have been borrowed from agricultural irrigation practices which use area loadings rather than infiltrative surface loadings. This is inappropriate for wastewater because of the biological clogging that occurs at the infiltrative surface of the soil due to the waste organics and nutrients the wastewater contains. Extrapolation of sizing criteria from conventional onsite wastewater treatment systems is, on the other hand, difficult because of the significant differences in construction of subsurface drip irrigation systems. Conventional system construction exposes large infiltrative surfaces in trenches by the use of porous media, typically gravel, or "chambers", or open bottom structures, buried below the soil surface. In addition to maintaining exposure of the infiltrative surfaces to the applied wastewater, the media or chambers used in conventional systems provide void volume for wastewater storage during peak flows. Subsurface drip irrigation systems, on the other hand, use dripperline laid in narrow trenches directly without a gravel envelope. The infiltrative surface exposed to each emitter in the dripperline is limited and little void volume for wastewater storage is provided. Therefore, sizing criteria for drip irrigation systems is uncertain.

Without greater certainty regarding appropriate sizing criteria for drip irrigation of wastewater, the North Carolina Department of Environment, Health and Natural Resources (DEHNR) will approve the "Perc-Rite"® system as an "innovative" system acceptable for use in accordance with 15A NCAC 18A.1969, only if the wastewater receives secondary treatment prior to the "Perc-Rite"® system. DEHNR requires the higher level of pretreatment because of concerns the department has over the uncertainty of the sizing criteria. The higher level of pretreatment is required by the department to reduce the organic content in the wastewater to lower the risk of hydraulic failures of the infiltration zones from bioclogging of the soil around the dripperline. Waste Water Systems, Inc. objects to this requirement because successful experience with operating systems in other states receiving septic tank effluent suggests that secondary pretreatment provides little, if any, benefit to the hydraulic performance of the system and adds unnecessary costs to the system.

As a result of the ruling by North Carolina DEHNR, Waste Water Systems, Inc. retained Ayres Associates to assess the performance of several "Perc-Rite"® systems which treat and dispose of septic tank effluent. The objective of the assessment was to provide estimated infiltration surface hydraulic loading rates of successfully operating "Perc-Rite"® systems receiving septic tank effluent which could be used as preliminary sizing guidelines by DEHNR to eliminate the need for secondary pretreatment.

STUDY APPROACH

Because of the limited scope and duration of the study, the estimation of hydraulic loading rates of the "Perc-Rite"® drip irrigation system was based on observation and qualitative evaluations of operating systems in Georgia. The study included the following tasks:

Presentation of the Study Approach to the North Carolina DEHNR

The project objective and proposed tasks and methods were sent to the DEHNR for their comment and concurrence. This was done to provide DEHNR an opportunity to critique the approach and suggest any modifications the department felt necessary.

Identification and Selection of "Perc-Rite"® Systems for Evaluation

Waste Water Systems, Inc. provided a list of "Perc-Rite"® systems installed in Georgia from which systems were selected for field observations. Systems were selected based on system age, characteristics of the soils in which they were installed, average daily wastewater flows, and the willingness of the owner to allow excavations of the irrigation system for inspection.

Wastewater Characterization

Wastewater samples were collected from each system to determine the efficiency of the disc filter system, the strength of the applied wastewater, and to compare its strength to typical domestic septic tank effluent. Samples were taken of the septic tank effluent from within the wet well upstream of the "Perc-Rite"® pump and filter assembly. Grab samples of the effluent were taken below the water surface at the same elevation as the suction intake of the pump. Grab samples of the filtered effluent were taken from sampling ports in the force main immediately downstream of the disc filters. The samples were submitted to Law & Company, an analytical laboratory located in Tucker, Georgia for total suspended solids (TSS) and 5-day biochemical oxygen demand (BOD_5) analyses. The results were compared to typical literature values for domestic septic tank effluent.

Observation of Infiltrative Surfaces

Excavations of the dripperline in each system were made at selected points by a small backhoe. The purpose of the excavations was to observe the soil conditions around the dripperline and to estimate area wetted by each emitter prior to the wastewater infiltrating the soil. At least two excavations at arbitrary locations were made at each site to expose five to eight feet of dripperline. The backhoe was used to locate the dripperline and remove most of the overburden above the line. A hand trowel was used to carefully expose the dripperline and the surrounding soils. The soil conditions specifically observed was the presence of a biomat, moisture content, soil color, root growth and void space around the dripperline. The dripperline was cut and carefully removed to observe conditions below the line. The segment of dripperline which was removed was cut open to examine the interior of the line and the emitters. The emitters were opened also to observe the condition of the labyrinth and orifice. After all observations were made, solid wall tubing was spliced onto the existing dripperline and the trench backfilled.

Characterization of Soils

Soil profiles were exposed and described at each site by an Ayres Associates Certified Professional Soil Scientist. Because of the size of the backhoe employed, a complete soil profile could not be exposed. Profile descriptions were limited from the surface to just below the dripperline. USDA nomenclature was used.

Evaluation of System Design Criteria

Based on the findings, estimates of average operating hydraulic and organic loadings in each system were made. These loadings were used to establish preliminary sizing criteria for "Perc-Rite"® subsurface drip irrigation systems. Other recommendations relating to design and construction were also made.

STUDY FINDINGS

DEHNR Comments on Study Approach

The work plan for the study was sent to DEHNR for their review. A response was received on January 19, 1994, indicating acceptance of the objective with the plan, but offering only that the approval status of "Perc-Rite"® would be "reconsidered" if the study were successful in meeting the stated objective. Comments were also offered for additional data gathering which the department would find desirable. A return letter was prepared to respond to the comments offered. The correspondence appears in Appendix A.

Site Descriptions

Five systems were selected from the list of systems provided by Waste Water Systems, Inc. These systems represented a variety of soil types and average daily flows that had been in operation the longest (Table 1). For each of the systems selected, Waste Water Systems, Inc. provided soils reports, design drawings, and monitoring data where available. Information provided for each system by Waste Water Systems, Inc. is provided in Appendix B.

Jackson County High School: Jackson County High School currently has 942 students and 85 faculty and staff for a total daily population of 1027 people. The average daily wastewater flow was computed by dividing the number of gallons recorded by the system totalizer by the number of days since the last reading. At the time of the study the average daily flow was 17,800 gpd or 17.3 gpd/capita. This computation assumes a seven rather than a five day school week. The majority of flow occurs between 9:00 a.m. and 3 p.m. on week days. Therefore, larger flows are expected on weekdays and much smaller flows on weekends. During the summer, the average daily flow is approximately 4,000 gpd.

The wastewater treatment and disposal facility was first operational in August 1991. The system uses septic tanks for wastewater pretreatment and three drip irrigation zones. The zones are planted in turf grass. Two of the zones contain 14,000 liner feet (lf) of dripperline.

TABLE 1: DESCRIPTION OF SYSTEMS SELECTED FOR ASSESSMENT

SYSTEM NAME	DESIGN FLOW	SOIL TYPE	DATE INSTALLED
JACKSON COUNTY HIGH SCHOOL	20,000 GPD	HAIWASSE CLAY LOAM	AUGUST, 1990
GORDON COUNTY MIDDLE SCHOOL	12,000 GPD	FULLERTON SILT LOAM AND FILL	JULY, 1992
SOUTH FORSYTH SCHOOLS	30,000 GPD	PACOLET SANDY CLAY LOAM AND FILL	NOVEMBER, 1992
GUESS RESIDENCE	480 GPD	SANDY CLAY LOAM	AUGUST, 1991
ABC DAYCARE CENTER	700 GPD	SANDY CLAY LOAM	JUNE, 1989

The third contains 4,000 lf. The two larger zones are located on a steeply sloping cut bank of a hillside. The dripperline is installed approximately 3 ft below grade. The smaller zone is located on a slightly sloping area which was also in a cut area. The dripperline is installed at approximately 18 in below grade. The automatic dripperline flushing feature is not included in this system. Flushing the lines is performed manually twice a year. The septic tanks are pumped every two years. They were last pumped in July 1993.

During normal operation, only two of the zones are used. The third is rested for approximately 30 days before being rotated into service. This is done manually. Dosing of the zones occurs on demand when septic tank effluent in the wet well reaches the pump on switch. Dose volumes are 425 to 1,500 gallons each. The length of dose is controlled by a timer to ensure that each zone receives a dose volume proportionate to its size.

Gordon County Middle School: Gordon County Middle School had 660 students and faculty at the time of the study. The average daily wastewater flow was determined similarly to Jackson County High School. During the current school year it averaged 10,200 gpd or 15.5 gpd/capita. This average was determined similarly to the Jackson County High School.

Therefore, actual daily flows are expected to be higher during the school week and much smaller on weekends. During the summer, the average daily flow is 3,000 gpd.

The wastewater treatment and disposal facility was first operational in July 1992. It uses septic tanks for pretreatment and two subsurface drip irrigation zones. They are located on a relatively flat area with about 5 to 6 ft fall across the site. The area is partially grassed. One zone contains approximately 10,200 lf of dripperline. This zone is located almost entirely in natural soils. The other zone contains approximately 7,500 lf of dripperline. Nearly half the zone is located in a filled area. The dripperlines are installed 20 to 25 in below grade. The lines are flushed automatically about every three months. The septic tanks have not been pumped during the two years since the system became operational.

The zones are dosed alternately on demand. Dose volumes are approximately 1,000 gal each. Dosing periods are about 20 minutes each. The dosing period has not changed since start-up indicating that emitter clogging has not occurred.

South Forsyth Schools: South Forsyth Schools is located in Forsyth County. It had 718 high school students, 688 middle school students and 150 faculty for a total of 1556 people during the study. Average daily wastewater flows were 24,600 gpd or 15.8 gpd/capita. As with Jackson County and Gordon County schools, the actual daily flows are expected to be higher on school days and much lower on weekends. The average daily flows during the summer are 10,000 gpd.

The wastewater treatment and disposal facility was first operational in November 1992. It uses septic tanks for pretreatment and four subsurface drip irrigation zones. The zones are located on a grassy nose slope with a slope ranging from 3 to 7 percent. Total drop over the site is approximately 8 ft. Each zone contains 25,000 lf of dripperline and are dosed individually. Dose volumes are 5,000 gal each. The dripperline is flushed automatically every month. The septic tanks are to be pumped every two years with the first pumping scheduled for July 1994.

Guess Residence: The Guess residence is a single family three bedroom home. It is occupied year around. Recorded average daily flows are 230 gal.

The wastewater treatment and disposal facility became operational in August 1991. It consists of a septic tank and single subsurface drip irrigation zone. The zone is located across two relatively flat areas in the lawn along the driveway which differ in elevation by approximately ten feet. It contains approximately 800 lf of dripperline. The zone is dosed on demand in 50 gal doses. The dripperline is flushed automatically every two months. The septic tank has not been pumped during the three years of operation.

ABC Daycare Center: The ABC Daycare Center is a year round child care facility. The recorded average daily wastewater flow is 460 gpd.

The wastewater treatment and disposal facility became operational in June 1989. It consists of a septic tank and a single subsurface drip irrigation zone. The zone is located on a grassed area with a slight slope. The zone contains approximately 1,820 lf of dripperline. The zone is dosed on demand with 150 gal doses. The dripperline is flushed manually twice per year. The septic tank was last pumped in 1993.

Wastewater Characterization

Characteristics of the wastewater determined from single grab samples at each site are presented in Table 2. Average daily flows were obtained from Waste Water Systems, Inc. Results of the grab samples of the unfiltered and filtered septic tank effluent from each system are presented and compared to typical septic tank effluent.

System Observations

Jackson County High School: Observations at this site were made on Monday, April 11, 1994. The two larger zones were in service at the time. Both were clearly visible on the hillslope by stripes of lush grass marking the location of the dripperlines. The location of smaller zone beyond the base of the slope was not well expressed at the surface (See Photo

TABLE 2: WASTEWATER CHARACTERISTICS

PARAMETER	JACKSON CO. H.S.	GORDON CO. M.S.	FORSYTH SCHOOLS	GUESS RESIDENCE	ABC DAYCARE	TYPICAL S.T.E.[1]
AVE FLOW summer[2] winter[3]	4,000 GPD 17,800 GPD	3,000 GPD 9,400 GPD	10,000 GPD 24,600 GPD	230 GPD 230 GPD	460 GPD 460 GPD	- -
BOD_5 UNFILTERED	180 MG/L	20 MG/L	50 MG/L	130 MG/L	280 MG/L	132-217 MG/L
BOD_5 FILTERED	160 MG/L	20 MG/L	40 MG/L	130 MG/L	140 MG/L	- -
TSS UNFILTERED	36 MG/L	200 MG/L	81 MG/L	55 MG/L	1,420 MG/L	49-161 MG/L
TSS FILTERED	47 MG/L	37 MG/L	52 MG/L	17 MG/L	60 MG/L	- -

[1] Range of literature values from States of Florida, Ohio, Oregon, and Wisconsin. Ayres Associates. 1993. Onsite sewage disposal system research in Florida - An evaluation of current OSDS practices in Florida.
[2] Flows during the summer from June to July
[3] Flows during the school year from August to May

JCHS 1, Appendix C). However, an area of distressed vegetation and very moist soils was observed at the lower end of this smaller zone. According to Waste Water Systems, Inc., loading to this zone must be limited or a breakout may occur at the lower end. The zone is loaded for only 30 days at a time or when the lower area shows signs of saturation.

Trenches were made to expose dripperlines in the lower zone. Trenches were not made in the upper zones because of the depth of burial of the dripperlines and the difficulty of excavating on the steep slope. Three trenches were dug at the center, upper and lower ends of the zone.

As the dripperline was exposed, the effluent pathway from the emitters could be seen. The dripperline had been placed in a 4-in wide trench with the emitters facing the trench invert. Blackened areas from an anaerobic biomat indicated where the wastewater would pond as it infiltrated the soil. It appeared that the majority of the effluent infiltrated the soil in a 4- by 6-in area around each emitter. The wastewater would flow in macropores created by the trenching operation (See Photo JCHS 2, Appendix C). Some flow occurred along the exterior of the dripperline, but it did not appear to be continuous. Where the biomat did occur, the soil behind the biomat displayed low chroma colors less than one-quarter inch thick (See Photo JCHS 3, Appendix C). There was no evidence that the wastewater ponded excessively during a dosing cycle.

At both the upper and lower ends of the zone, the dripperline trenches had been excavated in the saprolite. Reduced zones could be observed to conform to the original 4-in wide trench to the top of the saprolite. Heavy root growth was seen around the trench sidewall.

Sections of the dripperline were removed for inspection. A small void could be seen in the soil below each emitter apparently from the force of the wastewater as it exited the emitter (See Photo JCHS 2, Appendix C). Many roots surrounded the void, but no roots could be seen in the emitter orifice. Inside the dripperline, bioslime was observed in the crown of the line. This appeared to be as a result of growth rather than deposition. The interior of the emitter contained some fine black solids, but the labyrinth and orifice were clear (See Photo JCHS 4, Appendix C).

The soil exposed by the trenching was loam. Saprolite was observed in areas of the 18-20 in deep trenches since much of the overburden had been stripped off when the site was developed for the school. The native soil conditions observed were as follows:

0-18"	2.5YR3/6 Loam; moderate, medium to coarse subangular blocky; friable, moist, moderate density; common, fine to medium mangans; common to many fine roots (Burmuda Grass); some zones of saprolite.

Gordon County Middle School: Observations at this site were made on Tuesday, April 12, 1994. Both of the zones were in service at the time. Locations of the dripperlines were clearly discernible by strips of lush grass (See Photo GCMS 1, Appendix C). Based on the surrounding topography and vegetation, it appeared that the eastern one-quarter of the two zones were constructed in areas where the natural soils had been cut while the center halves of both zones appeared to be constructed in relatively undisturbed native soils and the western quarters of both zones constructed in fill. The finished grade over the zones had a planar slope with an approximate five percent slope with a westerly aspect. Athletic fields were located to the east of the zones and at a higher elevation, a wooded area was to the north, and a pump house and school yard to the south. A river formed the western boundary of the site.

The eastern portions of the zones where the native soils had been cut were relatively devoid of grassy vegetation except immediately over the dripperlines. The western two-thirds of the system had heavy fescue grass growth which became more lush at the western boundary. A surface drainageway was present across the northeastern corner of the northern zone. This area also had a buried drain tile located beneath the dripperlines. The drain tile daylighted just north of the zone and was severely eroded at the outfall.

The zones did not appear to be of equal size. Physical measurements revealed that the southern zone contained approximately 10,200 lf while the northern zone contained approximately 7,500 lf of dripperline.

Just east of the drain tile outfall area, a breakout of wastewater was observed. This area was excavated to determine the cause. A dripperline was found to be damaged approximately 6 in from the manifold. The damaged segment was repaired and the excavation backfilled. No other areas of surface saturation or wastewater breakout were observed in either of the zones.

Dripperlines were exposed at four locations on the site, two in each zone. The first excavation was located centrally in the southern half of the southern zone. The dripperline was found 26 in below grade. It had been installed with a trenching machine. The soil above and to either side of the dripperline displayed bright native colors with moisture conditions similar to the surrounding soil immediately above the dripperline. The only indication of effluent application was reduced soil evidenced by low chroma colors in the footprint of the dripperline approximately 6 in along the dripperline either side of each emitter (See Photo GCMS 2, Appendix C). Careful removal of soil below the emitter location revealed the reduced soil condition occurred as a 1 in wide by 3 in deep crescent directly below the dripperline. No black biomat was observed at this location. Very small voids, approximately one-eighth inch in width and one-quarter inch in depth were observed below the emitters apparently due to the force of the wastewater as it left the emitters.

Fine roots were observed along the entire dripperline footprint to a depth of about 1 in below the line. Removal of the soil in the disturbed trench area showed that the dripperline was installed approximately 2 in above the bottom of a 4 to 5 in wide trench. Fine roots were observed to be massed along trench walls and bottom at the interface to the native soil. Fine roots also existed within the trench backfill but to a much lesser degree, estimated at less than 10 percent by volume.

A five foot section of dripperline was removed and the dripperline and emitters cut open for observations. The dripperline was clean but did have a thin black film on the inside. Two emitters were cut open and found to be very clean and functional. The second emitter, did have two very fine root hairs growing into the orifice but they had not entered the labyrinth nor did they appear to hamper function. Of all the sites investigated as part of this study, this was the only location where an emitter was observed to have roots in it.

The second excavation was located to the east and north of the first in an area relatively devoid of vegetation. Observed conditions surrounding the dripperline appeared to be similar to those found at the first excavation. However, rooting was noted to be significantly less than that observed at the first location.

The third excavation was located in the western half of the northern zone in an area of lush grass and at a lower position on the slope. The soil was observed to be a clay loam fill material. A variety of soil structure and mottled conditions were observed with no particular pattern. The soil was very moist above the dripperline and saturated around the pipe (it was later determined that the system had just dosed). A biomat about one-eighth inch thick was observed along the entire footprint of the dripperline. An area of reduced soil conditions occurred along the length of the exposed trench. The area extended about 2 in below the line and within a 2 in arc above the line (See Photo GCMS 3, Appendix C). A few pockets of fine gravel existed below the pipe. These pockets were saturated and appeared very black in color. Rooting was observed to be matted along trench walls but fewer roots were observed in the dripperline footprint and trench backfill. The line and emitter conditions were similar to those observed at the first excavation with the exception that no roots were observed in the emitter.

The fourth excavation was located centrally in the eastern quarter of the northern zone. This was an area where the contractor had originally attempted to knife the lines in with a vibratory plow rather than using a trenching machine. (Eventually this method was abandoned due to difficulties encountered with saprolite.) The disturbed soil area from the plow left a 6 in vertical envelope approximately 2 in at the widest with the dripperline located 2 in above the bottom of the envelope (See Photo GCMS 4, Appendix C). This envelope appeared as void space which was partially closed by loose soil materials. This envelope was saturated, black in color, and filled with a fine root mass. A tear drop shape of reduced soil conditions occurred 2 to 3 in around the lower two-thirds of the envelope. No voids could be observed due to rooting and general loose soil conditions within the plow envelope. These conditions were observed to occur along the length of the dripperline. Saprolite was common in this vicinity and effluent movement was observed along the rocky material where it was disturbed by the plowing operation.

The dripperline was installed with the emitters located on the side of the pipe rather than pointing down. This condition did not appear to hamper the operation or effluent dispersal. The dripperline and emitters had the black film but were otherwise clean and functional.

A soil boring was completed about 150 ft north of the zones in an undisturbed area. The native soil conditions observed were as follows:

0- 4"	5YR3/4 silt loam; moderate, fine, angular blocky; friable; moderate density; moist.
4-12"	7.5YR4/6 loam; moderate, medium, angular blocky; friable; moderate density; moist.
12-26"	2.5YR4/6 clay loam to clay; weak, moderate, angular blocky; firm; moist; with few, fine, mangans.
26-36"	2.5YR5/6 clay; weak, coarse, angular blocky; firm; moist; with common, medium, distinct high and low chroma mottles.

South Forsyth Schools: Observations at this site were made on Wednesday and Thursday, April 13 and 14, 1994. Three of the four zones were in service at the time. Zone 2 was off line in a "resting" mode. Zone 1 occupied a relatively flat filled area of higher elevation than the other three zones. The western half of Zone 1 was an area of lush grassy vegetation with common wet areas on the surface. Zones 2, 3 and 4 occupied native landscapes and had a relatively well established grass cover (See Photo SFS 1, Appendix C). The dripperline locations were well defined based on the lush grass strips. Zones 2 and 4 occupied planar slope positions while Zone 3 occupies the sides, nose and top of a long ridge. Slopes ranged from 0 to 8 percent over the site. Installation of the dripperlines had been accomplished through use of a vibratory plow.

Zone 2 appeared to be smaller in area than the other three zones. Rough field measurements were taken of the zone perimeters to attempt to determine the approximate size of the zones. Zones 1, 3 and 4 appeared to be 45,000 to 50,000 ft^2 in area which corresponds to approximately 25,000 lf of dripperline as designed. Zone 2, however, appeared to be approximately 35,000 ft^2 in area which corresponds to 17,500 lf of dripperline. Record drawings were not available to confirm the true size of the zones.

A site walkover revealed several weakly defined areas of effluent breakout in a subtle drainageway located on the sideslope on the southern side of Zone 3. An additional breakout was observed at the eastern end of Zone 3 in the vicinity of the manifold.

Dripperline excavations were completed at 6 locations; two in Zone 1, three in Zone 3 and one in Zone 4. No excavations were made in Zone 2 since it had been out of rotation for some time.

The first excavation was located in Zone 4 near the center of the northwestern quadrant in an upper sideslope position. Soil at this vicinity consisted of sandy clay loam over clay. The soils were well structured, brightly colored, moist, and contained saprolite fragments. The dripperline was laid approximately 15 in below grade. No discoloration or high moisture conditions were observed above the dripperline. A six foot segment of dripperline was removed to expose the dripperline footprint. The footprint was dark stained and contained a mat of fine roots throughout (See Photo SFS 2, Appendix C). A weakly discernible void approximately one-quarter inch in diameter and depth was observed below the emitter orifice apparently formed by the force of the wastewater as it exited the dripperline. Roots, estimated at 30 to 40 percent by volume, were present in the soil 2 to 3 in below the dripperline (See Photo SFS 3, Appendix C). The soil in this area was only slightly reduced in color with an occasional area of more distinct reduced colors associated with the saprolite fragments. The envelope resulting from the plow installation was barely discernible.

The second excavation was located in the northern half of Zone 3, in a swale at a lower elevation than the first excavation. Soil at this location consisted of a sandy loam over sandy clay loam which was weakly structured and contained remnants of coarse roots. The dripperline was located 18 in below grade. An area of reduced soil colors surrounded dripperline. It was observed to be approximately 4 in diameter and began one-half inch above the dripperline. When the line was removed from position, there was no black layer along pipe footprint, virtually no fine roots and no area of saturation. Some effluent movement appeared to occur along decaying root remnants but otherwise only the reduced soil conditions indicated effluent movement.

Inspection of the dripperline and emitter revealed no abnormalities. The line and emitters contained a black film deposit but were otherwise clean and operational (See Photo SFS 5, Appendix C).

The third excavation was located in the southeast quadrant of Zone 3 just below the ridgeline. Soils at this location were similar to those in the first excavation. The dripperline was located 13 in below grade and had the emitter orifices orientated upwards. A reduced zone of soil, approximately one-sixteenth to one-eighth inches in thickness, surrounded the dripperline along its exposed length. Fine roots were located only in the footprint of the pipe. No biomat or saturated conditions were observed. Since the orifices were on top of the pipe, any void space at the emitters was destroyed during the excavation to observe the dripperline.

The fourth excavation was located near the center of the eastern half of Zone 1. This zone was located in fill. The fill consisted of clay dominated material along with rock fragments and appeared to be as deep as 20 ft at the northern edge of the zone. The dripperline was located 17 in below grade. In general, black biomat areas filled the plow disturbed soil forming a vertical envelope which began 2 to 3 in above the pipe (See Photo SFS 6, Appendix C). The envelope was widest at the dripperline springline, approximately 2 to 3 in wide at this point. The envelope extended below the line about 2 to 3 in The soils outside the black zone exhibited reduced color a distance of 4 to 5 in in all directions around the pipe. Near saturated conditions were observed to occur approximately 3 in either side of an emitter location. Effluent dispersion appeared to be highly variable depending on soil structure, rock fragment orientation and degree of fill compaction. Because of saturated conditions at the emitter orifice, no void space below the emitter was discernible. Conditions inside the dripperline and emitters were similar to those observed in the second excavation.

The fifth excavation was located near the center of the western half of Zone 1. The surface area had extremely heavy grass growth and many areas of standing water. The soil materials were fill similar to those found in the fourth excavation. The dripperline was located 20 in below grade. No discoloration of the soil was observed around the pipe, however, the soil was saturated. Within minutes of excavating, the trench had standing water to a depth of 1 in above dripperline elevation. After approximately 10 minutes, water began to seep from the excavation walls at 8 to 10 in above the pipe elevation (See Photo SFS 7, Appendix C). The remaining soil to the surface was very moist but did not seep. No further observations could be made at this location due to the volume of water in the excavation. It did not appear that the standing water at the surface was effluent from the system but rather storm water that was unable to drain.

The sixth excavation was located in the breakout area on the southern side of Zone 3. The dripperline was located 15 in below grade. Soil at this location consisted of sandy clay loam over clay. The clay at the elevation of the dripperline was weakly structured, very firm and had a low estimated permeability, although it did not appear to perch water under normal conditions. The area was thought to have been wooded prior to installation of the system due to the many root remnants which were present.

The applied wastewater appeared to move freely within the plow slot. Black biomat and reduced soil colors were observed in the plow slot approximately 9 in above the dripperline to approximately 2 in below the line with a maximum width of approximately 2 in near the dripperline springline. Two horizontal flow paths were observed at 6 and 10 in below grade on the downslope side of the plow slot (See Photo SFS 8, Appendix C). The shallowest flow path occurred at the textural change and the lower flow path at a fine gravel seam. Further trench excavation revealed that the horizontal extent of the gravel seam was limited. Roots from above were observed to virtually cease at the lower flow path except for coarser tree roots. No rooting was observed around or below the line. Reduced soil colors were observed only about one-quarter inch into the native soil except along root channels or macropores. A typical one-eighth to one-quarter inch void was observed below the emitter orifice. It appeared the effluent moved more freely upwards through the plow slot than into the soil. This condition may have occurred because of the lower elevation of the dripperline in this area relative to the remainder of the zone after the pump ceased operation. This difference in elevation may have allowed the lower area to receive drainage from the other dripperlines in the zone following each pumping cycle.

Finally, the breakout area at the eastern end of Zone 3 was investigated. After locating and excavating three dripperline/manifold connections, a forth dripperline was found which was not connected to the manifold. It had a crimped end from being cut by a backhoe or trencher. The dripperline was plugged and the excavation left open for the installing contractor to repair.

There were two distinct natural soils that were observed at the site. In the higher landscape positions, the following soil profile was observed:

0- 3"	2.5YR3/4 Sandy clay loam; moderate, fine, granular; friable; moist
3-18"	2.5YR3/6 Clay; moderate, medium, angular blocky; firm; moist
18-30"	2.5YR4/8 Clay; moderate, coarse, angular blocky; firm; moist

In the lower elevations, the following soil profile was observed:

0- 8"	10YR3/4 Sandy loam; weak, fine, granular; very friable; moist
8-17"	7.5YR4/6 Sandy clay loam; weak, moderate, angular blocky to near massive at bottom of horizon; friable to firm; very moist; low chroma mottling at 14-17"
17-30"	5YR4/6 Clay loam; weak, moderate, angular blocky; weak, fine, platy structure from 27 to 30"; very firm; very moist

Guess Residence: Observations at this location were made on Thursday, April 14, 1994. The drip irrigation zone reportedly contained 800 linear feet of dripperline spanning two separate terraces which differed in elevation by approximately 8 to 10 ft (See Photo GR 1, Appendix C). The lower terrace was on a native slope of 7 percent which had been cut and filled slightly. The upper terrace was just off the crest of a hill with a 2 to 3 percent slope. The surface of both areas was well established with sod and expressed no visible dripperline locations. No areas of soggy soil, lush vegetation or breakouts were observed in either area. The dripperlines had been installed using a trenching machine.

Two excavations were made at this site. The first was located near the center of the zone on the lower terrace. The dripperline was approximately 16 in below grade and about 4 in off the bottom of the trench. The trench limits were easily discernible. The bottom 9 in of the 5 in wide trench exhibited reduced soil colors and near saturation conditions (See Photo GR 2, Appendix C). The area surrounding the dripperline was very black. This area extended approximately one-half inch above the line and 1 to 2 in below. Penetration of the effluent into the native soil was expressed by reduced soil colors about one-quarter to one-half inch into the trench bottom and sidewalls (See Photo GR 3, Appendix C). Very little rooting, less than 5 percent by volume, occurred around or below the pipe. One-eighth to one-quarter inch void was observed below the emitter orifices due to the discharge of wastewater from the emitter. The interior of the dripperline and emitters contained the black slimy film, but were otherwise clean and functional.

The second excavation was located near the center of the zone in the upper terrace. The dripperline was 18 in below grade and approximately 4 in above the bottom of the trench. Soil about dripperline was moist to very moist but not near saturation. No black coloration in the soil or around the dripperline was observed even at the emitters (See Photo GR 4, Appendix C). A slight discoloration of the soil was observed which appeared to be the result of mixing of backfill with surface horizon with the lower horizon. Voids were observed below the emitters created by the force of the discharged wastewater. The voids were approximately three eighths inches in diameter and one-eighth to one-quarter inches deep. No rooting was observed in the trench backfill or dripperline footprint.

The description of a soil profile observed at this site was as follows:

0- 2"	Sandy loam fill
2- 4"	10YR2/2 Sandy loam; weak, fine, angular blocky; very friable; moist
4- 9"	7.5YR4/6 Sandy loam; moderate, medium to coarse, angular blocky; friable; moist
9-29"	2.5YR3/6 Sandy clay loam; moderate to strong, medium, angular blocky; friable; moist; with some areas of weak saprolite.

ABC Daycare Center: Observations at this site were made on Friday, April 15, 1994. The drip irrigation zone was placed around the inside corner of the southwest part of the lot (See Photo ABC 1, Appendix C). Field measurements indicated that approximately 1820 lf of dripperline was installed which is approximately 180 lf less than design. The zone was installed in native soil conditions with the inside corner installed in a cut area. The dripperlines were installed using a trenching machine. The surface over the system is a well established sod cover, however, dripperline locations were discernible by the slightly more lush grass growth. No areas of wet soil or effluent breakouts were observed during system walkover.

Two excavations were made in the drip irrigation zone. The first excavation was located on the western leg of the system. The dripperline was observed to be 18 in below grade and approximately 4 in above the bottom of the trench. The dripperline was twisted at the excavation location with two holes on top of the line and the next two on the side the line. Very moist soil was observed at the emitter locations. A thin, (1/16 in) dark gray reduced zone was observed along dripperline (See Photo ABC 2, Appendix C). A thin root mat was observed around the dripperline only in the vicinity of the emitters. Reduced soil colors were observed approximately one-half to three-quarters inches below the line. Voids below the emitter orifices measured approximately three-eighth of an inch in diameter and were one-sixteenth to one-quarter inches deep and partially filled with fine roots.

The second excavation was installed in the cut area which was also the system low point. The amount of cut was estimated to be about 2 to 3 ft deep. The dripperline was located at 18 in below grade and approximately 3 in off the trench bottom (See Photo ABC 3, Appendix C). No soil discoloration or unusual moisture conditions were observed above the dripperline. Only dark gray coloration was observed in the dripperline foot print which extended 6 in along the line either side of the emitters (See Photo ABC 4, Appendix C). No voids were observed below emitter orifices.

Native soil conditions at the site were as follows:

0- 5"	2.5YR3/6 Sandy loam; weak, medium, angular blocky; 5 percent gravel; friable; low moisture
5-31"	2.5YR4/6 Sandy clay loam; weak to moderate, medium, angular blocky; firm, very moist; becoming drier and slightly lighter in texture with depth

Estimated System Loadings

Hydraulic and organic loadings of each of the systems were calculated and are presented in Table 3. Infiltrative surface loadings were calculated by dividing the average daily flow by the number of emitters and the estimated area of observed biomat around each emitter. Loadings per linear foot of dripperline were also calculated. Equivalent conventional system loadings are provided for comparison.

TABLE 3: ESTIMATED WASTEWATER LOADINGS

LOADING PARAMETER	JACKSON CO. H.S.	GORDON CO. M.S.	FORSYTH SCHOOLS	GUESS RESIDENCE	ABC DAYCARE
GPD/SQ FT[1]	4.31 - 6.70	2.72	1.68	1.47	1.12
GPD/L FT[2]	0.64 - 0.99	0.53	0.25	0.29	0.25
LBS BOD_5/SQ FT/D[3]	0.0058 - 0.0089	0.0005	0.0006	0.0016	0.0013
LBS BOD_5/L FT/D[4]	0.0008 - 0.0013	0.0001	0.0001	0.0003	0.0003
SOIL DESCRIPTION TEXTURE STRUCTURE	LOAM MED, MOD, SAB	CLAY LOAM WEAK, MED AB	CLAY MOD, MED AB	SANDY CLAY LOAM MOD, MED AB	SANDY CLAY LOAM MOD, MED AB
ESTIMATED SWIS LOADING[5]					
GPD/SQ FT	0.4	0.3	0.25	0.5	0.5
LBS BOD/SQ FT/D	0.0005	0.0004	0.0003	0.0006	0.0006

[1] Computed by dividing the average daily wastewater flow by the estimated active infiltrative surface area.
[2] Computed by dividing the average daily wastewater flow by the total number of linear feet of dripperline.
[3] Computed by multiplying the estimated hydraulic loading rate by the calculated pounds of BOD_5 in the applied wastewater.
[4] Computed by multiplying the estimated linear loading rate by the calculated pounds of BOD_5 in the applied wastewater.
[5] Conventional subsurface wastewater infiltration system (SWIS) loadings computed by using the estimated conventional loading rate for the observed soil characteristics and a typical domestic septic tank effluent (140 mg/L BOD_5).

Estimation of the active infiltration area in each system was difficult. Wastewater flow would occur in macropores in the soil which were common where the dripperline was installed in native soils with a trenching machine. In systems which were installed using a vibratory plow, a large vertical void or plane of weakness was left above the dripperline which seemed to be available to wastewater flow. Estimating the area of these potential surfaces was not possible since the area provided did not always seem needed by the system. In most excavations, the active infiltrative surface seemed to be the area around the perimeter of the dripperline.

There was uncertainty in estimating the actual wastewater application rates at each emitter also. The drip irrigation zones varied in size and dosing times and volumes were not measured. It was evident that where a zone was installed on a site with a significant slope, the lower areas of the zone received more wastewater. Where this was observed, it appeared that the wastewater would flow to the lower areas within the dripperline after each dose. There was no evidence of excessive flow toward the lower areas around the exteriors of the lines. These differences were not taken into account in computing the estimates of infiltrative surface loadings.

CONCLUSIONS

Wastewater Characteristics and Pretreatment

The BOD_5 and TSS concentrations of the septic tank effluent varied widely between the sites. The wastewater appeared to be within typical domestic septic tank effluent ranges at Jackson County High School and the Guess residence, but the BOD_5 concentrations at the Gordon County Middle School and the South Forsyth Schools were much weaker than domestic septic tank effluent. Both the BOD_5 and TSS concentrations at the ABC Daycare site were greater than typical domestic septic tank effluent. However, since only single grab samples were taken, the results may not be an accurate reflection of the true strength of the wastewater.

The Arkal disc filters included as an integral part of the "Perc-Rite"® system appeared to be effective in reducing high TSS concentrations of the septic tank effluent below typical domestic septic tank effluent values. The efficiency of the filters did not seem to be affected by the TSS concentration in the influent. Influent TSS concentrations ranged from 36 to 1,420 mg/L while effluent concentrations ranged from 17 to 60 mg/L. BOD_5 concentrations were little affected by the filtration step suggesting that most of the BOD_5 was in the dissolved form. The filters appeared to provide effective protection against high TSS loadings in the dripperline.

There was no evidence of a need to provide pretreatment of the wastewater beyond septic tank treatment prior to the "Perc-Rite"® system. Hydraulic failures due to excessive soil clogging had not occurred in any of the systems evaluated. Dripperline or emitter clogging was not observed. Septic tank pretreatment followed by disc filtration was found to maintain performance of the systems as designed.

Wastewater Infiltration Rates

The operating loading rates estimated for the systems inspected exceed hydraulic and organic loading rates typically used in conventional subsurface wastewater infiltration system (SWIS) design. Except for Jackson County High School where the irrigation zone inspected was frequently rested, the estimated hydraulic loading rates ranged from 2.2 to 9.0 times typical hydraulic loading rates for conventional SWIS. (The estimated loadings at Jackson County

High School were 10 to 17 times that of conventional hydraulic loadings. Since the zone evaluated at Jackson County High School had not received constant loading, the results obtained in this study are considered to be atypical and are not considered further in the discussion of the results.) Organic loading rates (excluding Jackson County High School) ranged from 1.0 to 2.7 times typical SWIS organic loading rates. Despite substantially higher loading rates than typically used in conventional SWIS design, each of the systems evaluated appeared to be functioning well without hydraulic failure. The reason higher rates have been successful is suspected to be due to an improved aeration status of the soil surrounding the dripperline. Shallow narrow trenches with nearly uniform wastewater distribution along the length of the dripperline improve the natural aeration of the soil and limit the amount of oxygen demanding waste materials applied to the soil. As a result, prolonged anoxic or anaerobic conditions around the emitters may be effectively prevented. Well aerated soils encourage activity by various forms of soil fauna including worms and insects which create macropores in the soil and biomat. Anoxic or anaerobic soil conditions at the infiltrative surface limit this activity and promote soil clogging which ultimately lead to hydraulic failures. Observed soil colors around the dripperlines indicated that the extent of reduced conditions in the soil is very limited. With the improved aeration status of the soil over conventional SWIS, the drip irrigation system should support greater organic and hence greater hydraulic loadings. Observations at the five systems inspected appear to support this premise.

System Layout

Some of the systems evaluated had irrigation zones located on sloping sites. Because the dripperline was installed at a constant depth, the relative elevations of the dripperlines within the zones varied significantly. In such cases, it was observed that the dripperline trenches in the lower areas appeared to receive higher wastewater loadings than the upper areas. Since the Netafim RAM® emitters are pressure compensating, (emitter rates are constant at pressures greater than 10 psi), all emitters in a zone should discharge equal amounts of wastewater regardless of their relative elevation. However, it appears that as the pressure within the dripperline falls after a dosing cycle and the lines begin to empty, the wastewater remaining in the upper dripperlines drain through the piping to the lower lines. It is expected that this drainage is internal since there was no evidence of flow outside the dripperline.

Dripperline and Emitter Clogging

No evidence of dripperline or emitter clogging was observed in any of the systems evaluated. Bioslime was observed lining the inside of the dripperline, but no discrete solids which could obstruct the lines were observed. In systems where manual dripperline flushing was performed, the thickness of the bioslime layer was much greater. The interior of the emitters also had more fine solids, but in no case did function seem to be affected. Although many roots were found around the dripperlines and emitters, root penetration was observed only once. In that instance, the hairs had not entered the labyrinth nor did the emitter function appear to be affected.

Construction Methods

Trenching machines and vibratory plows were used to install the dripperlines of the systems evaluated. The trench formed by the trenching machine seemed to create more horizontal planar voids for wastewater movement. The vibratory plow created a vertical void above the dripperline where wastewater could move. Both methods appeared to be satisfactory. Emitter orientation did not appear to be critical in the performance or function of the systems.

Systems Installed in Fill

Where dripperlines were found to be installed in filled areas, the hydraulic performance of the system appeared to be affected. For example, at the South Forsyth Schools site, one zone had been installed in fill at a higher elevation than the other zones. This zone was saturated. The cause of the saturated conditions was thought to be due to the poor quality of the fill materials and the absence of soil structure to provide planar voids for water movement.

RECOMMENDATIONS

Wastewater Loading Rates

Because of the limited scope of this study, it was not possible to determine acceptable design septic tank effluent loadings for the "Perc-Rite"® drip irrigation system. However, in all systems evaluated, the estimated infiltration rates exceeded typical design loading rates for conventional SWIS by 2.2 to 6.8 times. Long-term, controlled studies are needed to establish appropriate hydraulic and organic loadings. In filled areas, the lack of soil structure may require that the hydraulic loadings be reduced from what is acceptable for natural soils. Quality fill, void of construction debris, large roots, cobbles or coarse rock fragments and similar in texture to the native soil, and careful placement may improve performance.

Assuming the active infiltration area is limited to the circumference of the dripperline, the infiltrative surface area per linear foot of dripperline would be 0.2 ft^2. Observations showed that the infiltrative area can be larger depending on the nature of the soils and the construction technique used, however. Therefore, 5 lf of dripperline will provide a mimium of 1 ft^2 of infiltrative surface area.

Piping Layout

Systems in which dripperlines in a single zone are installed at different elevations, care should be taken to prevent the drainage of the higher dripperlines to the lower dripperlines after the dosing cycle. Hydraulic and organic overloading of the infiltrative surfaces in the lower areas were evident in such cases, particularly in large systems. The drainage appeared to occur within the dripperlines rather than outside the dripperline within the dripperline trenches. Six to ten dripperlines should be coupled together off the supply manifold connected with a check valve to prevent flow back into the supply manifold and to other dripperlines. Similarly, the flush return manifold should also be constructed with check valves to prevent flow from one coupled group of dripperline to another. With such construction, lower areas should not receive excessive loadings.