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Ranking of Septic Tank and Drainfield Sites Using Travel Time to the Groundwater Table

Brenda S. Langkopf, James T. McCord

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RANKING OF SEPTIC TANK AND DRAINFIELD SITES USING TRAVEL TIME TO THE GROUNDWATER TABLE

Brenda S. Langkopf and James T. McCord
Environmental Risk Assessment and Risk Management Department
Sandia National Laboratories
Albuquerque, New Mexico 87185

Abstract

The Environmental Restoration Program at Sandia National Laboratories, New Mexico (SNL/NM) is tasked with performing assessments and cleanup of waste sites that belong to SNL. SNL's waste sites are divided into several activities. Septic Tanks and Drainfields (STD) is an activity that includes 23 different sites at SNL/NM. All these sites may have released hazardous wastes into the soil from drains or sewers of buildings. The STD sites must be assessed and, if necessary, remediated according to the Resource Conservation and Recovery Act (RCRA) Corrective Action process. A modeling study has been completed to help prioritize the sites for future field investigation based on the risk that each site may pose to human health and the environment. Two of the influences on the risk to human health and environment are addressed in this study—the fluid disposal volume and groundwater depth. These two parameters, as well as several others, were used as input into a computer model to calculate groundwater travel time to the water table. The computer model was based on Darcy's Law and a simple mass balance. To account for uncertainty in the input parameters, a Monte Carlo approach was used to determine the travel times; 1000 realizations were completed to determine the travel time for each site. The range assigned to each of the input parameters was sampled according to an assigned statistical distribution using the Latin Hypercube Method to arrive at input for the calculations. The groundwater travel times resulting from these calculations were used to rank the sites for future field investigation.

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NOMENCLATURE

DF	Drainfield
DF+SP	Drainfield plus seepage pit
KAFB	Kirtland Air Force Base
RCRA	Resource Conservation and Recovery Act
RFI	RCRA Facility Investigation
SNL/NM	Sandia National Laboratories, New Mexico
SP	Seepage Pit
STD	Septic Tanks and Drainfields
TUBA	Turning Bands Algorithm

Ranking of Septic Tank and Drainfield Sites Using Travel Time to the Groundwater Table

INTRODUCTION

The Environmental Restoration Program at Sandia National Laboratories, New Mexico (SNL/NM) is tasked with performing assessments and cleanup of inactive waste sites. This program formally started in 1984 when the U.S. Department of Energy began identifying potential hazardous waste sites. The programs in place today, including the analyses described here, have expanded these first efforts.

SNL/NM waste sites have been divided into several activities. The Septic Tanks and Drainfields (STD) activity includes 23 different sites located in remote areas at SNL/NM. Table 1 provides a brief description of these sites, and Figure 1 shows their locations. All these sites may have released hazardous wastes into the soil from drains or sewers of buildings. The waste, potentially, would have been released into either drainfields or seepage pits similar to domestic septic systems.

The STD sites must be assessed and, if necessary, remediated in accordance with the Resource Conservation and Recovery Act (RCRA) corrective action process. To meet this objective, each site will be investigated in sufficient detail to determine the potential risks to human and environmental health as a result of a possible contaminant release into the seepage pits and drainfields. Because we cannot investigate all the sites at once, we must set some sequential ordering scheme, or prioritization, for conducting the field work. Therefore, we have performed a quantitative analysis of the travel time to the groundwater table at the STD sites. The

results have been used to prioritize the sites for field work. Additionally, the information derived from the preliminary quantitative analysis will help to identify sites that are likely to require groundwater monitoring networks. This report addresses the development and application of the quantitative approach used to rank the sites for field work.

METHODOLOGY

The primary idea underlying the ranking approach is that we should first investigate the sites that pose the most risk to human health and the environment and work our way down to the lower risk sites. The problem is to quantify the risks and subsequently rank the sites based on this quantification.

The risk posed by each site depends on several criteria, including, but not limited to, (1) the principal contaminants, (2) the volume of contaminants and fluids disposed of, (3) the flow and transport characteristics of the contaminants through the site-specific geologic media, (4) the depth to groundwater, and (5) the proximity to receptors. Given the very limited site-specific data based on facility use derived from staff interviews and SNL/NM records, there is a great deal of uncertainty in our knowledge of the risk associated with the first three criteria. The knowledge of the groundwater hydrology is also limited and casts uncertainty on the last three criteria. This dictated that we develop a highly simplified and conservative approach toward preliminary risk quantification. It also suggested that

TABLE 1. Brief Description of STD Sites

Site #	Location Description	Initial Service Date
49	Bldg 9820, Photometrics/ Machine Shop	1958
101	Bldg 9926, Explosive Research Laboratory	1958
116	Bldg 9990, Electroexplosive Research Facility	1969
137	Bldg 6540/6542, Photometrics Building	1959
138	Bldg 6630, Climatic Test Facility	1959
139	Bldg 9964, Instrument Building for Shock Facility	1965
140	Bldg 9965, Remote Control Building for Shock Facility	1965
141	Bldg 9967, High Explosive Assembly Building	1968
142	Bldg 9970, Antenna Measurement Facility	1963
143	Bldg 9972, EMP Studies Facility A	1987
144	Bldg 9980, Solar Power Tower	1976
145	Bldgs 9981/9982, 5-MW Solar Control Building/ 5-MW Solar Assembly Building	1976 --
146	Bldg 9920, Explosive Test Facility	1958
147	Bldg 9925, Coyote Test Field Headquarters	1959
148	Bldg 9927, Explosive Test Facility	1962
149	Bldg 9930, Explosive & Test Lab Building	1961
150	Bldgs 9939, 9939A, Evaluation Explosive Facility Control Building	1967 & 1978 --
151	Bldg 9940, Explosive Test Facility	1962
152	Bldg 9950, Materials Test Facility	1964
153	Bldg 9956, Intermediate Velocity Gun Facility	1969
154	Bldg 9960, Explosive Preparation Facility	1965
160	Bldg 9832, Vehicle Assembly Building	1968
161	Bldg 6636, Non-destructive Test Facility	1971

risks derived from this approach should be considered relative and not absolute.

In this study, we have used groundwater travel time from the source to the groundwater table to rank the relative risks of the sites. Thus, this study addresses two of the five criteria listed above: depth to the groundwater table and chemically unreactive flow through the site-specific geologic media.

Approach

To provide a quantitative estimate of effective travel time through the vadose zone to the water table, we employed a simple mass balance approach and Darcy's Law. As shown in Figure 2, we used the following four basic parameters to estimate the effective travel time: an estimation of discharge rate to the septic system, Q ; the cross-sectional area of the geologic media wetted by the effluent, A ; the porosity of the wetted media, n ; and the depth to groundwater, D_{wt} . As a first pass, we assumed that the vadose zone was uniformly saturated by the septic discharge and that the media were able to transport the discharge at the assumed rate of release. To obtain the average linear velocity, or seepage velocity of the fluid, v_s , we divided the Darcy velocity, v_d , by the moisture content:

$$v_s = v_d/n = Q/A/n \quad (1)$$

The effective travel time through the vadose zone to the water table, t_{vadose} , would be:

$$t_{vadose} = D_{wt}/v_s = D_{wt}/(Q/A/n) \quad (2)$$

According to Darcy's Law, $v_d = K \cdot \text{gradient}$. If the media are uniformly wetted, with gravity as the only driving force, the gradient will approach unity, and the associated vertical Darcy velocity will approach the saturated hydraulic conductivity, K_s , of the medium. For any medium, the maximum hydraulic conductivity will be the saturated hydraulic conductivity, K_s ; the hydraulic conductivity decreases as the moisture content decreases and tension head increases (Figure 3). Thus, in our second pass at the calculations, two velocities were compared: one calculated using Q and the other, K_s , sampled from a range of SNL/NM saturated hydraulic conductivities. The smaller of these two values was used as the seepage velocity.

Appendix A lists the computer program used in the first pass, and Appendix B lists the program used in the second pass.

Application to Seepage Pit and Drainfield Sites

Because of the uncertainty in the input parameters, a Monte Carlo approach was used to estimate the travel times; 1000 realizations were completed to determine the travel time for each set of site parameters. The approach described in the document, *A FORTRAN 77 Program and User's Guide for the Generation of Latin Hypercube and Random Samples for Use with Computer Models* (Iman and Shortencarier, 1984), was used to arrive at the data used for input in these realizations. The remainder of this section identifies the input data used in the travel time calculations, and the bounds and sample distribution of the input data that were input into the Latin hypercube program to arrive at the data sets for the 1000 realizations.

FIGURE 2. Schematic of Flow to the Groundwater Table

FIGURE 3. Tension Head Versus Volumetric Moisture Content and Hydraulic Conductivity (K) Versus Tension Head

Although there are 23 septic tank and drainfield sites, 35 sets of calculations were run.¹ The additional sets of calculations were mainly used to account for uncertainties in the input parameter ranges. The following input parameters were varied in each of these calculation sets: Q , A , n , K_s , and usually D_{wt} . In sampling the parameters, it was assumed that none of the parameters were correlated. Because the ranges and sample distributions assumed for n and K_s were the same for all sites, these input parameters will be discussed first.

The values for n were assumed to be uniformly distributed between the values of 0.2 and 0.5. The following information puts this information in perspective. Porosities from repacked samples collected near Technical Area III (near many of the STD sites) at SNL varied from 0.23 to 0.38 (Daniel B. Stephens & Associates, Inc., 1990 a,b; McTigue and Stein, 1990). Freeze and Cherry (1979) indicate that silt has porosities ranging from 0.35 to 0.50, sand has porosities ranging from 0.25 to 0.50, and gravel has porosities ranging from 0.25 to 0.40. The unsaturated zone underlying most of the sites is generally described as being "*unconsolidated and semi-consolidated sands, gravel, silts, and clays*" (SNL, 1994). The effective porosity subject to flowing water is probably somewhat less than the total porosity values described above. Thus, the range of porosity values used to calculate absolute travel times to the water table may have resulted in shorter travel times. However, because the calculations are mostly to be used as a relative measure of travel time, we thought that the range of values used was reasonable.

The values for K_s were estimated to be lognormally distributed, with 1.16×10^{-2} ft/day (4×10^{-6} cm/s) being the .001 quantile value and 10.77 ft/day (4×10^{-3} cm/s) being the .999 quantile value. These quantile values were based on the measured saturated hydraulic conductivity of repacked soils at the Chemical Waste Landfill and other SNL locations (Daniel B. Stephens & Associates, Inc., 1990a,b; McTigue and Stein, 1990). Statistical analysis of all the data from these sources confirmed that the data were lognormally distributed. Figure 4 shows the results of the Lilliefors statistical test for normalcy (the lognormal of the saturated hydraulic conductivity is plotted).

The values for the remainder of the parameters (Q , A , and D_{wt}) were specific to a particular seepage pit/ drainfield site. However, the values for Q and A were both actually the product of two values, one of which was usually not site specific. Q was usually the product of the number of people using the site and the assumed water usage rate per person. Generally, the water usage rate was not site specific and was assumed to be uniformly distributed between 10 and 100 gal/day. The upper end value of 100 gal/day would allow 10 five-gal toilet flushes and a 50-gal shower per day. Otis et al. (1980) indicate that the average daily wastewater flow from a typical residential dwelling is 45 gal/day, and the maximum is typically no larger than 75 gal/day. These same authors indicate that the typical wastewater flow from an industrial building (excluding industry and cafeteria) ranges from 7.9 to 17.2 gal/day. Thus, the rates we have chosen are rather conservative and

¹Site 146 was not included in the calculations because there were no available estimates for the discharge rate to the septic system. This site is expected to have one of the lowest discharge rates of all the STD sites.

FIGURE 4. Results of Lilliefors Statistical Test for Normalcy (Iman and Conover, 1983) with 95% Confidence Bounds Displayed

include employee usage plus some industrial usage.

Table 2 lists the values that were used for each site for the number of people and the water usage rate. In some cases, the number of people listed in the table includes full-time and occasional people. This description is usually associated with sites that had a constant base level of people, the full-time people, and an influx of people, the occasional people, when there was testing at the site. At these sites, it was assumed that 80% of the time, the number of people at the site was at the base level and the remainder of the time the number of people at the site varied uniformly from the base level to the sum of the base level and influx of people. Figure 5 is an example of the sample distribution used when there were full-time and occasional people at the same site. At sites where only full-time people

are specified (see Table 2), a uniform sample was taken over the possible range of full-time people. Figure 6 graphically displays the minimum, maximum, and the arithmetic mean of the water usage rate (the product of the number of people and the water usage rate per person) for all the calculations. The water usage rates are ordered by site geometry. Only two drain-field sites (sites 145 and 147) had significantly higher water usage rates than the seepage pit sites. The site numbers on the x-axis include a designation of DF for drain-field, DF + SP for drainfield and seepage pit, and SP for seepage pit.

Four sites were assigned water usage rates that differed from the norm of 10 to 100 gal/day/person: sites 49, 139, 160, and 154. Site 49 did not have toilet facilities and bottled water was used for drinking. Nonpotable water was trucked in and

TABLE 2. Description of Site-Specific Input Parameters

Site Number	Number of People	Water Usage Rate (gal/day/person)	Depth to Water Table (ft)	Geometry Description
49	1 full time, occasionally up to 10	10	50	Open drain - modeled as seepage pit 2 ft dia
101	12 full time	10 to 100	400 to 500	2 seepage pits, ea 5 ft dia x 5 ft deep
116	1 full time, occasionally up to 6	10 to 100	52	4 seepage pits, ea 5 ft dia x 9 ft deep
137	6 to 8 full time	10 to 100	400 to 500	1080 ft drainfield
138	12 full time	10 to 100	400 to 500	240 ft drainfield
139a	1 full time	10	50 to 150	3 ft dia x 3 ft deep dry well, modeled as seepage pit
139b	1 full time	10	300 to 400	3 ft dia x 3 ft deep dry well, modeled as seepage pit
140a	1 full time, occasionally up to 5	10 to 100	50 to 150	6 ft dia x 6 1/2 ft deep seepage pit
140b	1 full time, occasionally up to 5	10 to 100	300 to 400	6 ft dia x 6 1/2 ft deep seepage pit
141a*	1 full time	10 to 100	50 to 150	5 ft dia x 15.7 ft deep seepage pit
141c*	1 full time	10 to 100	300 to 400	5 ft dia x 15.7 ft deep seepage pit
142a	3 full time	10 to 100	50 to 150	4 ft dia x 5 ft deep seepage pit
142b	3 full time	10 to 100	100 to 200	4 ft dia x 5 ft deep seepage pit
143a	5 full time	10 to 100	50 to 150	300 ft drainfield
143b	5 full time	10 to 100	100 to 200	300 ft drainfield
144a	0 to 5 full time	10 to 100	50 to 150	300 ft drainfield
144b	0 to 5 full time	10 to 100	200 to 300	300 ft drainfield
145a	30 to 50 full time	10 to 100	50 to 150	75 ft drainfield
145b	30 to 50 full time	10 to 100	200 to 300	75 ft drainfield
147a	10 full time, occasionally up to 30	10 to 100	50 to 150	130 ft drainfield
147b	10 full time, occasionally up to 30	10 to 100	50 to 150	450 drainfield
148	2 full time, occasionally up to 5	10 to 100	400 to 500	4 ft dia x 10 ft deep seepage pit**
149a	4 full time, occasionally up to 8	10 to 100	300 to 400	4 ft dia x 4 ft deep seepage pit
149b	4 full time, occasionally up to 8	10 to 100	50 to 150	4 ft dia x 4 ft deep seepage pit
150a	2 full time, occasionally up to 4	10 to 100	150 to 200	2 seepage pits, ea 9 ft dia x 9 ft deep
150b	2 full time, occasionally up to 4	10 to 100	50 to 150	2 seepage pits, ea 9 ft dia x 9 ft deep
151	4 full time	10 to 100	300 to 400	6.5 ft dia x 7.3 ft deep seepage pit
152	9 full time	10 to 100	400 to 500	40 ft drainfield & 5 ft dia x 5 ft deep seepage pit
153a	15 full time	10 to 100	400 to 500	200 ft drainfield & 5 ft dia x 5 ft deep seepage pit
153b	15 full time	10 to 100	400 to 500	5 ft dia x 5 ft deep seepage pit
154a	4 full time	10 to 100	50 to 150	5 ft dia x 5 ft deep seepage pit
154b	4 full time	10 to 100	200 to 300	5 ft dia x 5 ft deep seepage pit
154c	0 to 1 full time	300	200 to 300	2 seepage pits, ea 5 ft dia x 20 ft deep
160	1 full time	10 to 50	50	4 ft dia x 15.7 ft deep seepage pit
161	1 occasional (modeled w/ 0 to 1 full time)	10 to 100	400 to 500	620 ft drainfield

*The results from 141b are not included as part of this report.

** Although the seepage pit for site 148 is only 4 feet deep, the seepage pit itself starts 6 feet below ground level.

FIGURE 5. Example Sample Distribution for Number of People when There Are Full-Time and Occasional People (site 148 is given as the example)

FIGURE 6. Minimum, Maximum, and Arithmetic Mean of Water Usage Rate for All Calculations Completed (ordered by geometry and mean water usage rate)

stored in a 1000-gal water supply tank. Although it is unknown how often the water supply tank was replenished, it was assumed that the water usage rate for this site was 10 gal/day/person. Site 139 had no sinks or toilet facilities in the building and no water supply. Again, the water usage rate for this site was assumed to be 10 gal/day/person. Site 160 had no toilets, and the building is not connected to any permanent water supply. The site had a central wash-down trough and a sink for hand washing; water for washing was transported by truck to a holding tank. This description led us to believe that more water was used here than at sites 49 and 139. Therefore, the water usage rate for this site was chosen to range between 10 to 50 gal/day/person. Documentation for site 154 indicated that up to 300 gal/day of water may have been contaminated in hosing down machines and the building floor. The discharge area for this water was separate from that for the sewage system. For this reason, we added a third calculation in which the water usage varied uniformly between zero and 300 gal/day. Two other sets of calculations were completed for site 154. These calculations were based solely upon the number of people in the building and a water usage rate of 10 to 100 gal/day/person.

Site 161 was handled differently from other sites that had occasional employees because there were no full-time employees and only an occasional employee. To avoid the computational problems associated with zero employees, the number of people at this site was sampled uniformly over the range 0 to 1. This variation in approach means that the actual travel times for site 161 should probably be slightly greater than those calculated.

The bounds chosen for the water usage rate may be a little high because the calculations use a seven-day water usage rate rather than a five-day workweek water usage rate. This

information is poorly characterized for these sites. It is not known how the number of people actually varied over time, and no one has characterized the water usage rates at these sites.

In determining the area, A , the engineered horizontal drainage area was considered along with another parameter called the spread constant, S_c . For all the sites, the spread constant was assumed to vary uniformly between 1 and 3 feet. The spread constant accounts for lateral spreading of infiltrating water beyond the bounds of the engineered drainage area. The spread constant was added to the diameter of the seepage pits and drywells and was added to the constant 2-ft width of the drainfield trenches. Figure 7 illustrates how the spread constant expands the original geometry of a seepage pit. The spread constants were based on recent research by McCord (1991) related to anisotropy for unsaturated flow. This research suggests that the lateral spreading can be quite large; thus, the spread constant may be significantly larger than one.

The dimensions of the engineered features used in the calculations are summarized in Table 2. In three cases (sites 147, 153, and 154), an additional set of calculations was completed for each site because of variations in the engineered geometry. Site 147 had two drainfields associated with it. One set of calculations was completed with the original drainfield that serviced the building, a drainfield of 130 linear feet. Because this drainfield was later abandoned, a second calculation was completed with its replacement, a drainfield of 450 linear feet. For site 153, the geometry changed from only a seepage pit in 1969 to a drainfield and seepage pit in 1978. For site 154, there were two separate drainage systems. Two seepage pits existed for "industrial" use and

$$V_s = V_d/n = Q/A/n = Q/(\frac{d+S_c}{2})^2 \pi/n$$

$$t_{\text{vadose}} = D_{wt}/V_s$$

FIGURE 7. Seepage Pit Diagram and Equation for Travel Time to the Water Table

a separate single seepage pit for sanitary wastes.

The information about the engineered geometry of the sites is the best characterized of the input data; however, the spread factor could be different from that used in the calculations. We expect that this uncertainty will not be as large an influence on the travel time as some of the uncertainties in the other input parameters.

The last input parameter is the depth to the water table. It was assumed to be uniformly distributed. In many cases, two sets of calculations were run for each site because of uncertainties regarding the depth to the water table. The depth values used in the calculations are also summarized in Table 2. One set of calculations used the range that was included in the original description of each site in the RCRA Facility Investigation (RFI) for the Septic Tanks and Drainfields activity (SNL, 1993). The depth range in

the second set of calculations is based on a map of the potentiometric surface of the SNL/KAFB area included in the report for the Site-Wide Hydrogeologic Characterization Project for the 1992 calendar year (Crowson et al., 1993). STD sites in this category include sites 139 through 145, 149, 150, and 154. For the sites that had drainfields, the effluent was assumed to travel from the surface to the groundwater table. Because of the significant depth of the seepage pits, the effluent was assumed to start its path to the water table from the bottom of the seepage pit. The seepage pit geometry is illustrated in Figure 7. Figure 8 graphically presents the minimum, maximum, and arithmetic mean of the depth to the water table. It is ordered by system geometry. This figure indicates that both seepage pits and drainfields include a wide range of depths.

FIGURE 8. Minimum, Maximum, and Arithmetic Mean of Depth to the Water Table for All Calculations Completed (ordered by geometry and depth to the water table)

RESULTS

Tables 3 and 4 list the minimum, maximum, and arithmetic mean for the travel times from the first and second pass of the travel time calculations. As discussed above, the first pass assumes that water moves to the water table at the rate that it is discharged through the seepage pit or drainfield area. The results of this pass are shown in Figures 9, 11 and 13. In the second pass, the seepage velocity was potentially limited by the saturated hydraulic conductivity value that was sampled. (Although the hydraulic conductivity was only limited by the saturated hydraulic conductivity if the calculated discharge exceeded the saturated hydraulic conductivity, in the remaining figures and future discussion about the calculations potentially limited by saturated hydraulic conductivity, the adverb "potentially" is dropped, and the calculations are referred to

as "limited" by saturated hydraulic conductivity.) The second-pass results are shown in Figures 10, 12 and 14. Figures 9 and 10 are ordered by the site number, Figures 11 and 12 are ordered by the mean travel time, and Figures 13 and 14 are ordered by geometry and mean travel time. In Figure 12, where the velocities are limited by the saturated hydraulic conductivity, most of the mean travel times are between 1.0 and 10.0 year.

In the other case where the maximum flux was not limited by the saturated hydraulic conductivity (Figure 11), about half the travel times range between 0.1 and 1.0 year. Limiting the velocities by the saturated hydraulic conductivities smoothed the differences in the mean travel times for the sites but increased the range of the minimum to maximum values for a given site. This is

TABLE 3. Travel Time to the Groundwater Table when Velocity IS NOT Limited by Saturated Hydraulic Conductivity

Site Number	Minimum Travel Time (Yr)	Maximum Travel Time (Yr)	Mean Travel Time (Yr)
49	0.02	0.94	0.39
101	0.09	2.81	0.53
116	0.14	4.13	0.95
137	13.22	383.03	66.35
138	1.29	38.92	6.55
139a	0.27	3.96	1.38
139b	1.69	10.98	4.95
140a	0.04	5.60	0.77
140b	0.19	15.28	2.79
141a	0.07	4.34	0.61
141b	0.02	2.10	0.30
141c	0.45	14.23	2.35
142a	0.02	1.07	0.16
142b	0.04	1.47	0.25
143a	0.58	27.10	4.36
143b	1.03	43.78	6.66
144a	0.67	2,581.72	32.72
144b	2.03	34,505.60	105.93
145a	0.02	1.04	0.14
145b	0.06	2.18	0.35
147a	0.04	5.61	0.88
147b	0.14	19.41	3.04
148	0.11	6.30	1.06
149a	0.06	2.31	0.42
149b	0.01	0.81	0.12
150a	0.38	14.45	2.70
150b	0.14	12.57	1.49
151	0.17	6.53	0.91
152	0.32	11.19	1.83
153a	0.89	26.93	4.52
153b	0.04	1.28	0.21
154a	0.02	1.05	0.17
154b	0.09	2.31	0.43
154c	0.22	414.91	3.29
160	0.06	1.21	0.28
161	47.09	644,936.00	2,553.63

TABLE 4. Range of Calculated Travel Times to the Groundwater Table when Velocity IS Limited by Saturated Hydraulic Conductivity

Site Number	Minimum Travel Time (Yr)	Maximum Travel Time (Yr)	Mean Travel Time (Yr)
49	0.02	2.99	0.47
101	0.18	43.68	2.30
116	0.06	6.96	1.09
137	8.71	356.53	51.46
138	1.31	44.13	7.02
139a	0.28	12.06	1.47
139b	1.81	26.63	5.23
140a	0.05	12.13	0.94
140b	0.24	20.89	3.38
141a	0.06	8.04	0.78
141c	0.46	28.44	2.96
142a	0.02	10.34	0.51
142b	0.04	12.40	0.78
143a	0.59	31.34	4.41
143b	1.06	43.77	6.63
144a	0.70	3,567.43	28.05
144b	2.74	231,480.00	307.41
145a	0.02	13.47	0.51
145b	0.09	15.76	1.28
147a	0.08	7.59	1.03
147b	0.26	26.29	3.04
148	0.19	26.19	2.47
149a	0.10	29.94	1.78
149b	0.02	7.30	0.48
150a	0.43	16.33	2.86
150b	0.18	10.95	1.56
151	0.18	30.93	1.99
152	0.38	37.67	2.96
153a	0.90	27.32	4.93
153b	0.10	19.08	1.75
154a	0.02	7.25	0.50
154b	0.08	26.95	1.32
154c	0.22	414.91	3.79
160	0.07	2.05	0.33
161	48.29	138,675.00	1,368.41

FIGURE 9. Minimum, Maximum, and Arithmetic Mean of the Travel Time for Septic Tank and Drainfield Sites when the Velocity Is NOT Limited by the Saturated Hydraulic Conductivity (ordered by site number)

FIGURE 10. Minimum, Maximum, and Arithmetic Mean of the Travel Time for Septic Tank and Drainfield Site when Velocity IS Limited by Saturated Hydraulic Conductivity (ordered by site number)

FIGURE 11. Minimum, Maximum, and Arithmetic Mean of the Travel Time for Septic Tank and Drainfield Site when Velocity Is NOT Limited by Saturated Hydraulic Conductivity (ordered by mean travel time)

FIGURE 12. Minimum, Maximum, and Arithmetic Mean of the Travel Time for Septic Tank and Drainfield Site when Velocity IS Limited by Saturated Hydraulic Conductivity (ordered by mean travel time)

FIGURE 13. Minimum, Maximum, and Arithmetic Mean of the Travel Time for Septic Tank and Drainfield Sites when Velocity Is NOT Limited by Saturated Hydraulic Conductivity (ordered by geometry and mean travel time)

FIGURE 14. Minimum, Maximum, and Arithmetic Mean of the Travel Time for the Septic Tank and Drainfields Site when Velocity IS Limited by Saturated Hydraulic Conductivity (ordered by geometry and mean travel time)

the last that will be discussed of the pass in which the travel times were not limited by the saturated hydraulic conductivity. The results from the pass in which travel times were limited by the saturated hydraulic conductivity are considered to be more realistic and were selected to determine the priority ranking of the sites. These results will be the focus of the remainder of this section.

To use the travel time results to rank the sites, the multiple sets of calculations for a given site had to be combined. The arithmetic means of all the calculations for a given site were averaged; the minimum of the minimal values and the maximum of the maximal values of all the calculations for a given site were preserved. As in the previous travel time plots, the resulting combined information is displayed in three figures, one ordered by mean travel time (Figure 15), one by geometry (Figure 16), and one by site number (Figure 17). The x-axis of each of these plots also indicates the priority established for each site on the basis of travel time. The priority was determined in the following manner. The minimum values were assigned a number from 1 to 4. Each number corresponded to a major subdivision on a logarithmic scale (i.e., a 1 corresponded to a minimum value in the range of 0.01 to 0.10, a 2 corresponded to a minimum value in the range of 0.10 to 1.00, etc.). The maximum values were assigned a number in a similar manner. A 1 corresponded to a maximum value in the range of 1.00 to 10.00, a 2 to a maximum value in the range of 10.00 to 100.00, etc. Because there was not as large a variation in the mean travel times, the numbers assigned to the mean values were based on one-half a major subdivision on a logarithmic scale (i.e., a 1 corresponded to values from 0.5 to 1.0, a 2 to values from 1.0 to 5.0, etc.). The values assigned to the mean travel time were multiplied by two and added to the

values assigned to the minimum and maximum values to determine the final ranking of the sites. This sum was then used to group the sites into five different priority groups. The priorities assigned to the sites are shown on the x-axis of Figures 15 through 17. For example, the designation 140-3, SP indicates that site 140 is a seepage site with a priority of 3. For the most part, the priorities assigned are in the order of increasing mean travel time. However, some of the priority 2, 3, and 4 sites do not follow this pattern.

The differences in travel time between the first and the fifth priorities are significant enough to indicate a potential for differences in risk to human health and the environment. However, the travel times (arithmetic mean, minimum, and maximum) for the remainder of the sites are so close in value that someone else could easily arrive at a different prioritization scheme if given the same data. For these sites, the present prioritization scheme only serves to divide the sites into more manageable subgroups. With more information or consideration of the health hazards of the contaminants of concern, the prioritization of these sites could easily change.

Comparison with Other Results

The travel times computed using Equation 1 are, for most of the sites, so short that a second, more rigorous study was undertaken for comparison purposes. We chose to model site 160 because of its short travel times, constant groundwater depth, and well-defined geometry. Goodrich (1994) calculated the travel time of a nonsorbing contaminant from the bottom of the seepage pit to the water table in two dimensions using VS2DT, a two-dimensional finite-difference code that solves Richard's equation for flow and the convection/dispersion

FIGURE 15. Ranking and the Minimum, Maximum, and Arithmetic Mean of the Travel Time for Seepage Pit and Drainfield Sites (ordered by mean travel time)

FIGURE 16. Ranking and the Minimum, Maximum, and Arithmetic Mean of the Travel Time for Seepage Pit and Drainfield Sites (ordered by geometry and mean travel time)

FIGURE 17. Ranking and the Minimum, Maximum, and Arithmetic Mean of the Travel Time for Seepage Pit and Drainfield Sites (ordered by the site number)

equation for transport (Healy, 1990). Two sets of calculations were completed, each using a different constant water usage rate. Thirty Monte Carlo calculations were performed within each set. The hydraulic properties were varied spatially for each calculation by using the TUrning Bands Algorithm (TUBA) (Zimmerman and Wilson, 1990); the spatial structure for the simulated property fields was modeled as imperfect layering as shown in Figure 18. Assumptions made in using the VS2DT model include the following:

- Van Genuchten's model (van Genuchten, 1980) of moisture content as a function of pressure head was assumed to be applicable; the van Genuchten parameter statistical distributions were inferred from SNL/NM site-specific data (Daniel B. Stephens & Associates, Inc., 1990a,b; McTigue and Stein, 1990).
- Dispersivities were assumed constant with the longitudinal dispersivity specified at 20 cm, and the transverse dispersivity specified at 2 cm.
- Darcy's Law was valid.
- There was no water loss from the system via evapotranspiration.
- The infiltration rate applied to the model was constant.

FIGURE 18. Example of the Two-Dimensional Spatial Variation in Hydraulic Conductivity Generated by TUBA

- The solute was conservative in that no retardation or decay was allowed.

The travel time results of the first model where the flux was limited by saturated hydraulic conductivity (the mass balance model) were compared with the VS2DT results. The results of this comparison are shown in Figures 19 and 20. Figure 19 shows the results at a water usage rate of approximately 10 gal/day. Thirty runs from the first model were chosen for comparison with the VS2DT results. The water usage rates from the simple model ranged from 10.020 to 11.182 gal/day. The travel time results from each method were first ordered from low to high and then paired for plotting. The results of this pairing are shown in Figure 19. In all cases, the VS2DT results were a factor of 1.7 to 4.5 times greater than the results from the simpler mass balance model.

Figure 20 shows the results at a water usage rate of approximately 50 gal/day. The same process as that described above was used to obtain the paired results displayed in Figure 20. The water usage rates from the simple model range from 48.820 to 49.998 gal/day. At this higher water usage rate, there appears to be slightly closer agreement between the two models, but the VS2DT results are still a factor of 2.0 to 3.9 times greater than the results from the simpler mass balance model.

SUMMARY AND CONCLUSIONS

Twenty-two of the twenty-three sites that are part of the STD activity are ranked on the basis of travel time from the septic structure to the water table. This ranking is a measure of the relative risk that each site may pose to human health and the environment.

FIGURE 19. Comparison of VS2DT and Mass Balance Travel Time Results for a Water Usage Rate of Approximately 10 Gal/Day

FIGURE 20. Comparison of VS2DT and Mass Balance Travel Time Results for a Water Usage Rate of Approximately 50 Gal/Day

It is possible to name other risk criteria that could have been used, including the principal contaminants, the volume of contaminants disposed of, flow and transport charac-

teristics of the contaminants through the site-specific geologic media, and proximity to the receptors. The limited site-specific data on facility use derived from staff interviews

about the contaminants to use the first three risk criteria, and the proximity to receptors, the last listed risk criterion, is nearly the same for all the sites considered. Thus, we decided to use the travel time from the septic structure to the water table to rank the sites.

The travel times used to rank the sites were calculated using a simple mass balance model with the calculated hydraulic conductivity (based on septic discharge and geometry) limited by a saturated hydraulic conductivity. The assumptions inherent in these calculations include piston flow, unit gradient, steady-state conditions, no retardation of contaminants, homogenous soil properties from the surface to the water table for a given realization, constant discharge from the septic system for a given realization, and porous media flow.

The 22 sites were divided into five priorities on the basis of the travel time from the

septic structure to the water table. The differences in travel time between the first and the fifth priority sites are significant enough to indicate the potential for differences in risk to human health and the environment. However, the travel times (the mean, minimum, and maximum) for the remainder of the sites are so close in value that someone else could easily arrive at a different prioritization scheme if given the same data.

Some of the travel time results from the simple mass balance model were compared with those calculated using VS2DT, a two-dimensional finite-difference code that solves Richard's equation for flow and the convection/dispersion equation for transport. The VS2DT travel times were a factor of 2 to 4 1/2 times slower than the travel times predicted with the simple mass balance model. Thus, the simple mass balance results are expected to be more conservative than those that might be predicted by VS2DT.

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APPENDIX A

PROGRAM LISTING FOR THE MASS BALANCE CALCULATIONS WHEN VELOCITY IS NOT LIMITED TO SATURATED HYDRAULIC CONDUCTIVITY


```

      Program Travel
C
C THIS PROGRAM CALCULATES THE GROUNDWATER TRAVEL TIME FROM THE SURFACE (OR FROM
C THE BOTTOM OF THE SEEPAGE PIT IF THE GEOMETRY OF CONCERN IS A SEEPAGE PIT) TO
C THE GROUNDWATER TABE. THE RATE OF TRAVEL IS DEPENDENT UPON THE CALCULATED RATE
C OF TRAVEL OF A SATURATED PLUG OF EFFLUENT. THE RATE OF TRAVEL IS BASED UPON A
C UNIT GRADIENT AND STEADY-STATE CONDITIONS. THERE IS NO RETARDATION OF THE
C EFFLUENT, NO EVAPORATION AND NO NATURAL RECHARGE. CONSTANT DISCHARGE FROM THE
C SEPTIC SYSTEM IS MODELED. THE SOIL PROPERTIES ARE HOMOGENEOUS FROM THE SURFACE
C TO THE WATER TABLE.
C
      dimension dia(5),dpth(5)
      data hcmmin, hcmax /0.3,200.0/
C
      string fnameT,fnameu,fname,sn
C
      FILE NAMES
C      fnameT = File of final numerical results (It includes the following
C               information in the following order: groundwater travel time (TT),
C               distance to the water table (t), groundwater velocity (v),
C               volumetric daily water usage rate of one person (h2o), and
C               number of people (pn).)
C      fnameu = File of interim results with a brief explanaiton of each result
C               (This is called "unplotted information.")
C      fname = File name of Latin hypercube input data
C
      A=0.0
      nopit=0
      norem=0
      nokmin=0
      nokmax=0
      depthl=0
C
      CALCULATED VALUES
C
      VF = volumetric flow in units of ft3/day
      v = calculated velocity in units of ft/day
      TT = Travel time to the water table in units of years
C
      INPUT CONSTANTS
C      Where
C      Idisp = integer field with values of 1 for seepage pit,
C             2 for drainfield or 3 for both seepage pit and drainfield
C      Dia = Diameter of seepage pit
C      Ft= Linear feet of drainfield
C      hcmmin= Minimum saturated hydraulic conductivity in ft/day
C      hcmax= Maximum saturated hydraulic conductivity in ft/day
C      sn=site number
C      irep=number of repeated calculation to be done
C      dpth(=septic tank depth
C      depthl=largest septic tank depth
C
      write(*,*) 'Enter 1 for seepage pit, 2 for drainfield and 3 for both '
      read *, Idisp
      go to (1,3,1)idisp
1    write (*,*) 'How many seepage pits are there? '
      read *,nopit
      do 100 j=1,nopit
      write(*,*)'Enter seepage pit diameter (in ft) '
      read (*,*) dia(j)
      write(*,*) 'Enter seepage pit depth (in ft) '
      read (*,*) dpth(j)
      if (dpth(j).gt.depthl)depthl=dpth(j)
100  continue
      if(idisp.eq.1)go to 3
3    write(*,*)'Enter linear footage of drainfield (in ft) '
      read (*,*) Ft
C
5    write(*,*) 'Enter the site number '
      read *, sn
      write(*,*) 'Enter the number of calculations to be done '
      read *, irep
C
      INPUT LATIN HYPERCUBE VARIABLES

```

```

c Where
c spf= spread factor(for linear drainfields the spread factor is
c added to a 2-ft trench width, and then this sum is multiplied by
c linear footage of drainfield; for a seepage pit the spreadfactor is
c an addition to the diamter of the seepage pit.)
c por=porosity
c pn=number of people
c h2o=volumetric daily water usage rate of one person
c d=distance to the water table (in the case of seepage pits, the depth
c of the deepest seepage pit (depth1) at the site is first subtracted)
c
c open(file=*,unit=10,status='old')
c inquire(unit=10,name=fname)
c write(*,*) 'The selected input file for Latin Hypercube variables is
c $ ',fname
c
c Write (*,*) 'Site number = ',sn,' ', ' repetitions = ',irep
c Writing to screen information for site with only seepage pits
c
c If (Idisp.eq.1)then
c do 200 jj=1,nopit
c write (*,*) 'The calculations are based upon a
c $ seepage pit of ', dia(jj), ' ft diameter '
200 continue
c endif
c
c Writing to screen information for sites with only drainfields
c
c If (Idisp.eq.2) write (*,*) 'The calculations are based upon a
c $ leachfield with ',ft, 'linear feet of drain'
c
c Writing to screen geometry information for sites with drainfields and one seepage
c pit.
c
c If (Idisp.eq.3.and.nopit.eq.1)
c $ write (*,*) 'The calculations are based upon a
c $ seepage pit of ', dia, ' ft diameter and a leachfield(s) with ',ft,
c $ 'linear feet of drain'
c
c
c Writing to screen geometry information for sites containing
c drainfields and more than one seepage pit
c
c If(idisp.eq.3.and.nopit.gt.1) then
c do 155 kk=1,nopit
c write (*,*) 'The calculations are based upon a
c $ seepage pit of ', dia(kk), ' ft diameter '
155 continue
c
c write(*,*) 'The calculations include seepage pits with the
c $ following depths: '
c do 255 nn=1,nopit
c write(*,*)dpth(nn),' ft'
255 continue
c write(*,*) 'The calculations also include a leachfield with ',ft,
c $ 'linear feet of drain '
c endif
c
c write (*,*) 'What is the file name for unplotted information?'
c read (*,*) fnameu
c open (1,file=fnameu)
c
c
c inquire(unit=1,name=fnameu)
c Type *, 'The file name for unplotted dat
c Write (1,*) 'Site number = ',sn,' repetitions= ',irep
c
c Writing to file information about site geometry for sites only containing
c seepage pits
c
c If (Idisp.eq.1)then
c do 300 kk=1,nopit
c write (1,*) 'The calculations are based upon a

```

```

    $ seepage pit of ', dia(kk), ' ft diameter '
300 continue
    endif
c
c Writing to file information about site geometry for sites containing only
c drainfields
c
    If (Idisp.eq.2) write (1,*) 'The calculations are based upon a
    $ leachfield with ',ft, 'linear feet of drain '
c
c Writing to file information about site geometry for sites containing
c drainfields and one seepage pit
c
    If (Idisp.eq.3.and.nopit.eq.1)then
        write (1,*) 'The calculations include a seepage pit of ',
        $ dia, ' ft diameter and a leachfield with ',
        $ft,'linear feet of drain '
    else
c
c Writing to file information about site geometry for sites containing
c drainfields and more than one seepage pit
c
        If(idisp.eq.3.and.nopit.gt.1) then
            do 350 kk=1,nopit
                write (1,*) 'The calculations are based upon a
                $ seepage pit of ', dia(kk), ' ft diameter '
350 continue
                write(1,*) 'The calculations include seepage pits with the
                $ following depths: '
                do 400 nn=1,nopit
                    write(1,*)dpth(nn),' ft'
400 continue
                write(1,*) 'The calculations also include a leachfield with ',ft,
                $'linear feet of drain '
                endif
            endif
c
            Write (*,*) 'What is the file name for recording only travel time
            $ data? '
            read (*,*) fnameT
            open (2,file=fnameT)
c
c
            do 110 n=1,irep
                a=0.0
                read(10,*) spf,por,pn,h2o,d
                write (*,*) 'spf,por,pn,h2o,d'
                write (*,*) spf,por,pn,h2o,d
                write (1,*) 'spf,por,pn,h2o,d'
                write (1,*) spf,por,pn,h2o,d
c
c Determine Area to be use in calculations
c
                go to (10,20,10)Idisp
10 do 500 ll=1,nopit
                    A=A+((dia(ll)+spf)/2)**2*3.14
c
c ***Skip printing out area results beyond the first 20 calculations
c
                    if(n.gt.20)go to 500
c
c ***
                    write(*,*) 'Temporary area is ',A,'ft2'
500 continue
                    If (Idisp.ne.3) go to 30
c
c The drainfield area is calculated as the linear footage of drain
c multiplied by the sum of the spreadfactor and the 2-ft wide
c gravel-filled trench.
c
20 A=(ft*(spf+2))+A
c
c *** Skip printing out area results beyond the first 20 calculations
c
                    if(n.gt.20) go to 30

```

```

        write (*,*) 'Final area is ',a,'ft2'
c***
c   Determine Volumetric Flow
c
c   30   Continue
c
c   The velocity calculated below is in ft cubed/day; the constant
c   converts the units from gal/day to ft cubed/day
c
        VF=pn*h2o*0.133680556
c *** Stop printing results of calculations beyond the first 20
c***
        if(n.gt.20)go to 1000
        write(*,*) 'Volumetric Flow is ',VF,'ft3/day'
c
c   Determine Velocity
c
c   The velocity is in units of ft/day

1000  v=vf/por/A
c *** Stop printing out results of calculations beyond the first 20
c***
        if(n.gt.20)go to 2000
        write (*,*) 'calc. vel = ',v,'ft/day',
$      kmin = ',ft/day',hcmin,' kmax = ',hcmax,'ft/day'
        write (1,*) 'calc. vel = ',v,'ft/day',
$      kmin = ',ft/day',hcmin,' kmax = ',hcmax,'ft/day'
2000  if (v.gt.hcmin)nokmin=nokmin+1
        if (v.gt.hcmax) then
            nokmax=nokmax+1
            v=hcmax
        endif
c
c   Determine Travel Time
c
c   The travel time is calculated in years
c
        tdepth=d-depth1
        TT=(tdepth)/v/365.
c*** Stop printing out results of calculations beyond the first 20
        if(n.gt.20) go to 110
        write (*,*) 'velocity used = ',v,'ft/day'
        write (1,*) 'velocity used = ',v,'ft/day'
c
c
c   Output calculated information and input information
c
        write (*,*) 'Spreadfactor was = ',spf,'ft'
        write (*,*) 'Porosity was = ',por
        Write (*,*) 'Number of people used in this calculation = ', pn
        Write (*,*) 'Volumetric water usage was = ',h2o,' gal/day'
        write (*,*) 'The distance from the surface to the water table is '
$      ,d,' ft'
        If(idisp.eq.1.or.idisp.eq.3) then
            write(*,*) 'The largest seepage pit was ',depth1,' ft deep'
            write (*,*) 'The distance to the water table used in this
$      calculation = ', tdepth,' ft'
        endif
        write (*,*) 'Travel time for this calculation was = ', tt,' years'
        write (1,*) 'The distance from the surface to the water table is '
$      ,d,' ft'
        If(idisp.eq.1.or.idisp.eq.3) then
            write (1,*) 'The largest seepage pit depth was ',depth1,'ft'
            Write (1,*) 'Distance to water table in this calc = ',tdepth,' ft'
        endif
        Write (1,*) 'Number of people used in this calculation = ', pn
        Write (1,*) 'Volumetric water usage was = ',h2o,' ft/day'
        Write (1,*)
110  Write (2,*) tt,d,v, h2o,pn
        Write (*,*) 'The velocity used was greater than the minimum
$      hydraulic conductivity ', nokmin, ' times,'
        Write (*,*) 'The velocity used was greater than the maximum
$      hydraulic conductivity ', nokmax, ' times. This value was used

```

```
$ an equivalent number of times as the velocity in the travel
$ time calculations.'
    Write (1,*) 'The velocity used was greater than the minimum
$ hydraulic conductivity ', nokmin, ' times,'
    Write (1,*) 'The velocity used was greater than the maximum
$ hydraulic conductivity ', nokmin, ' times. This value was used
$ an equivalent number of times as the velocity in the travel
$ time calculations.'
close (10)
close (1)
close (2)
end
```


APPENDIX B

PROGRAM LISTING FOR THE MASS BALANCE CALCULATIONS WHEN VELOCITY IS LIMITED BY SATURATED HYDRAULIC CONDUCTIVITY


```

      Program Travlhc
C THIS PROGRAM CALCULATES THE GROUNDWATER TRAVEL TIME FROM THE SURFACE (OR FROM
C THE BOTTOM OF THE SEEPAGE PIT IF THE GEOMETRY OF CONCERN IS A SEEPAGE PIT) TO
C THE GROUNDWATER TABE. THE RATE OF TRAVEL IS DEPENDENT UPON EITHER A SATURATED
C HYDRAULIC CONDUCTIVITY DETERMINED FROM A LATIN HYPERCUBE SAMPLE FROM A LOGNORMAL
C DISTRIBUTION OR THE CALCULATED RATE OF TRAVEL OF A SATURATED PLUG OF EFFLUENT
C THE CALCULATED RATE OF TRAVEL IS BASED UPON A UNIT GRADIENT AND STEADY-STATE
C CONDITIONS. THERE IS NO RETARDATION OF THE EFFLUENT, NO EVAPORATION AND NO
C NATURAL RECHARGE. CONSTANT DISCHARGE FROM THE SEPTIC SYSTEM IS MODELED. THE
C SOIL PROPERTIES ARE HOMOGENEOUS FROM THE SURFACE TO THE WATER TABLE.
C
      dimension dia(5),dpth(5)
      data hcmn, hcmax /0.3,200.0/
C
      string fnameT, fnameu, fname, sn
C
      FILE NAMES
C fnameT = File of final numerical results (It includes the following
C          information in the following order: groundwater travel time (TT),
C          distance to the water table (t), groundwater velocity (v),
C          volumetric daily water usage rate of one person (h2o), and
C          number of people (pn).)
C fnameu = File of interim results with a brief explanaiton of each result
C          (This is called "unplotted information.")
C fname = File name of Latin hypercube input data
C
      A=0.0
      nopit=0
      norem=0
      nokmin=0
      nokmax=0
      depthl=0
      ihc=0
C
      CALCULATED VALUES
C
      VF = volumetric flow in units of ft3/day
      vcalc = calculated velocity in units of ft/day
      v = velocity used to calculate the travel time. This value was the minimum
C          of the calculated velocity and the Latin Hypercube sample of the the
C          saturated hydraulic conductivity. The units are ft/day.
C TT = Travel time to the water table in units of years
C
      INPUT CONSTANTS FOR A GIVE SITE
C Where
C Idisp = integer field with values of 1 for seepage pit,
C          2 for drainfield or 3 for a combination seepage pit and drainfield
C Dia = Diameter of seepage pit
C Ft= Linear feet of drainfield
C hcmn= Minimum saturated hydraulic conductivity in ft/day
C hcmax= Maximum saturated hydraulic conductivity in ft/day
C sn=site number
C irep=number of calculations to be done
C dpth(5)=septic tank depth
C depthl=largest septic tank depth
C nopit =number of seepage pits
C
      write(*,*) 'Enter 1 for seepage pit, 2 for drainfield and 3 for both '
      read *, Idisp
      go to (1,3,1)idisp
1    write (*,*) 'How many seepage pits are there? '
      read *,nopit
      do 100 j=1,nopit
      write(*,*) 'Enter seepage pit diameter (in ft) '
      read (*,*) dia(j)
      write(*,*) 'Enter seepage pit depth (in ft) '
      read (*,*) dpth(j)
      if (dpth(j).gt.depthl)depthl=dpth(j)
100  continue
      if(idisp.eq.1)go to 5
      3    write(*,*) 'Enter linear footage of drainfield (in ft) '
          read (*,*) Ft
      5    write(*,*) 'Enter the site number '

```

```

      read *, sn
      write(*,*) 'Enter the number of calculations to be done
      read *, irep
c
c   INPUT LATIN HYPERCUBE VARIABLES
c   Where
c   spf= spread factor (for linear drainfields the spread factor is
c       added to a 2-ft trench width, and then this sum is multiplied by
c       linear footage of drainfield; for a seepage pit the spreadfactor is
c       an addition to the diameter of the seepage pit.)
c   por=porosity
c   pn=number of people
c   h2o=volumetric daily water usage rate of one person
c   d=distance to the water table (in the case of seepage pits, the depth
c       of the deepest seepage pit (depth1) at the site is first subtracted)
c   hc=saturated hydraulic conductivity determined from the
c       Latin hypercube assuming a lognormal distribution where the .001 quantile was
c       1.1622e-2 and the .999 quantile was 10.77 based upon 50?
c       field samples from the mixed waste landfill & another
c       unknown location on KAFB.
c
      open(file=*,unit=10,status='old')
      inquire(unit=10,name=fname)
      write(*,*) 'The selected input file for Latin Hypercube variables is
      $ ',fname

      Write (*,*) 'Site number = ',sn,' ', ' repetitions = ',irep
c
c   Writing to screen information for site with only seepage pits
c
      If (Idisp.eq.1)then
      do 200 jj=1,nopit
      write (*,*) 'The calculations are based upon a
      $ seepage pit of ', dia(jj), ' ft diameter '
200  continue
      endif
c
c   Writing to screen information for sites with only drainfields
c
      If (Idisp.eq.2) write (*,*) 'The calculations are based upon a
      $ drainfield with ',ft, 'linear feet of drain'
c
c   Writing to screen geometry information for sites with drainfields and one seepage
c   pit.
c
      If (Idisp.eq.3.and.nopit.eq.1)
      $ write (*,*) 'The calculations are based upon a
      $ seepage pit of ', dia, ' ft diameter and a drainfield(s) with ',ft,
      $ 'linear feet of drain'
c
c
c   Writing to screen geometry information for sites containing
c   drainfields and more than one seepage pit
c
      If(idisp.eq.3.and.nopit.gt.1) then
      do 155 kk=1,nopit
      write (*,*) 'The calculations are based upon a
      $ seepage pit of ', dia(kk), ' ft diameter '
155  continue

      write(*,*) 'The calculations include seepage pits with the
      $ following depths: '
      do 255 nn=1,nopit
      write(*,*) dpth(nn), ' ft'
255  continue
      write(*,*) 'The calculations also include a drainfield with ',ft,
      $ 'linear feet of drain '
      endif

      write (*,*) 'What is the file name for unplotted information?'
      read (*,*) fnameu
      open (1,file=fnameu)
c
c

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```

c    inquire(unit=1,name=fnameu)
c    Type *, 'The file name for unplotted dat
c    Write (1,*) 'Site number = ',sn,'      repetitions= ',irep
c
c    Writing to file information about site geometry for sites only containing
c    seepage pits
c
c    If (Idisp.eq.1)then
c    do 300 kk=1,nopit
c    write (1,*) 'The calculations are based upon a
c    $ seepage pit of ', dia(kk), ' ft diameter '
300    continue
c    endif
c
c    Writing to file information about site geometry for sites containing only
c    drainfields
c
c    If (Idisp.eq.2) write (1,*) 'The calculations are based upon a
c    $ drainfield with ',ft, 'linear feet of drain '
c
c    Writing to file information about site geometry for sites containing
c    drainfields and one seepage pit
c
c    If (Idisp.eq.3.and.nopit.eq.1)then
c    write (1,*) 'The calculations include a seepage pit of ',
c    $ dia, ' ft diameter and a drainfield with ',
c    $ft,'linear feet of drain '
c    else
c
c    Writing to file information about site geometry for sites containing
c    drainfields and more than one seepage pit
c
c    If(idisp.eq.3.and.nopit.gt.1) then
c    do 350 kk=1,nopit
c    write (1,*) 'The calculations are based upon a
c    $ seepage pit of ', dia(kk), ' ft diameter '
350    continue
c    write(1,*) 'The calculations include seepage pits with the
c    $ following depths: '
c    do 400 nn=1,nopit
c    write(1,*)dpth(nn),' ft'
400    continue
c    write(1,*) 'The calculations also include a drainfield with ',ft,
c    $ 'linear feet of drain '
c    endif
c    endif
c
c    Write (*,*) 'What is the file name for recording only travel time
c    $ data? '
c    read (*,*) fnameT
c    open (2,file=fnameT)
c
c
c    do 110 n=1,irep
c    a=0.0
c    read(10,*) spf,por,pn,h2o,d,hc
c    write (*,*) 'spf,por,pn,h2o,d,hc'
c    write (*,*) spf,por,pn,h2o,d,hc
c    write (1,*) 'spf,por,pn,h2o,d,hc'
c    write (1,*) spf,por,pn,h2o,d,hc
c
c    Determine Area to be use in calculations
c
c
c    go to (10,20,10)Idisp
10    do 500 ll=1,nopit
c    A=A+((dia(ll)+spf)/2)**2*3.14
c
c    ***Skip printing out area results beyond the first 20 calculations
c
c    if(n.gt.20)go to 500
c    ***
c    write(*,*) 'Temporary area is ',A,'ft2'
500    continue
c    If (Idisp.ne.3) go to 30

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c
c      The drainfield area is calculated as the linear footage of drain
c      multiplied by the sum of the spreadfactor and the 2-ft wide
c      gravel-filled trench.
c
c      20      A=(ft*(spf+2))+A
c *** Skip printing out area results beyond the first 20 calculations
c
c      if(n.gt.20) go to 30
c      write (*,*) 'Final area is ',a,'ft2'
c***
c      Determine Volumetric Flow
c
c      30      Continue
c
c      The velocity calculated below is in ft cubed/day; the constant
c      converts the units from gal/day to ft cubed/day
c
c      VF=pn*h2o*0.133680556
c****
c**** Stop printing results of calculations beyond the first 20
c****
c      if(n.gt.20)go to 1000
c      write(*,*) 'Volumetric Flow is ',VF,'ft3/day'
c
c      Determine Velocity
c
c      The velocity is in units of ft/day
c
c      1000    v=vf/por/A
c      vcalc=v
c *** Stop printing out results of calculations beyond the first 20
c****
c      if(n.gt.20)go to 2000
c      write (*,*) 'calc. vel = ',v,'ft/day',
c      $' kmin = ', 'ft/day',hclmin,' kmax = ',hclmax,'ft/day'
c      write (1,*) 'calc. vel = ',v,'ft/day',
c      $' kmin = ', 'ft/day',hclmin,' kmax = ',hclmax,'ft/day'
c      write (*,*) 'hc = ', hc
c      hcpor=hc/por
c      write (*,*) 'hcpor = ', hcpor
c      2000    if (v.gt.hclmin/por)nokmin=nokmin+1
c              if (v.gt.hclmax/por) then
c                  nokmax=nokmax+1
c              endif
c
c      if(v.gt.hc/por) then
c          v=hc/por
c          ihc=ihc+1
c      endif
c
c      Determine Travel Time
c
c      The travel time is calculated in years
c
c      tdepth=d-depth1
c      TT=(tdepth)/v/365.
c*** Stop printing out results of calculations beyond the first 20
c      if(n.gt.20) go to 110
c      write (*,*) 'velocity used = ',v,'ft/day'
c      write (*,*) 'calculated velocity = ',vcalc,'ft/day'
c      write (*,*) 'Latin Hypercube sat. conductivity = ',hc,'ft/day'
c      write (1,*) 'velocity used = ',v,'ft/day'
c      write (1,*) 'calculated velocity = ',vcalc,'ft/day'
c      write (1,*) 'Latin Hypercube sat. conductivity = ',hc,'ft/day'
c
c
c      Output calculated information and input information
c
c      write (*,*) 'Spreadfactor was = ',spf,'ft'
c      write (*,*) 'Porosity was = ',por
c      write (*,*) 'Number of people used in this calculation = ', pn

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Write (*,*) 'Volumetric water usage was = ',h2o,' gal/day'
write (*,*) 'The distance from the surface to the water table is '
$,d,' ft'
If(idisp.eq.1.or.idisp.eq.3) then
write(*,*)'The largest seepage pit was ',depth1,' ft deep'
write (*,*) 'The distance to the water table used in this
$ calculation = ', tdepth,' ft'
endif
write (*,*) 'Travel time for this calculation was = ', tt,' years'
write (1,*) 'The distance from the surface to the water table is '
$,d,' ft'
If(idisp.eq.1.or.idisp.eq.3) then
write (1,*) 'The largest seepage pit depth was ',depth1,'ft'
Write (1,*) 'Distance to water table in this calc = ',tdepth,' ft'
endif
Write (1,*) 'Number of people used in this calculation = ', pn
Write (1,*) 'Volumetric water usage was = ',h2o,' ft/day'
Write (1,*)
110 Write (2,*) tt,d,v, h2o,pn
Write (*,*) 'The velocity used was greater than the minimum
$ hydraulic conductivity ', nokmin, ' times,'
Write (*,*) 'The calculated velocity was greater than the maximum
$ hydraulic conductivity ', nokmax, ' times.'
Write (*,*) 'The velocity used was less than the calculated
$ hydraulic conductivity ', ihc, ' times. This value was used
$ an equivalent number of times as the velocity in the travel
$ time calculations.'
Write (1,*) 'The velocity used was greater than the minimum
$ hydraulic conductivity ', nokmin, ' times,'
Write (1,*) 'The velocity calculated was greater than the maximum
$ hydraulic conductivity ', nokmin, ' times.'
Write (1,*) 'The velocity used was less than the calculated
$ hydraulic conductivity ', ihc, ' times. This value was used
$ an equivalent number of times as the velocity in the travel
$ time calculations.'
close (10)
close (1)
close (2)
end

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