ASSESSMENT OF UNCERTAINTIES OF ESTIMATED SOLUTE TRANSPORT TO GROUND WATER

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To my kind and giving grandma,

who helped raising me, took me under

her wings and taught me the principles,

with her brilliantly humorous wisdom.

PREFACE

Confucius once said: "life begins at the age of thirty". I came from the other side of the Pacific Ocean with $20 in my pocket and wild ambition in my heart at age of twenty six. Today, five years later, at age thirty one, I have finally finished this dissertation. Although one year older than Confucius suggested, it marks the end of one age and the beginning of another. If the environmental issue is one of the greatest concerns of mankind today, I feel much blessed to have the highest degree in Environmental Science. I hope that, 30 or 40 years down the road, this education will enable me to answer one or two questions among the millions.

Very little, if any, of this work would have been possible without the commitment made in good faith, trust and encouragement of a very special group of people. I am referring to people who have helped me in two different ways, personally, and professionally.

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CHAPTER I

INTRODUCTION

Problem Statement

Ground water is a valuable natural resource. It is estimated that twenty-five percent of fresh water supply for all purposes combined in the United States comes from ground water (Tripp et al., 1979). This percentage of total water use is particularly high in the western states. The demand for clean, ground water has been increasing steadily over the years (Mercer and Faust, 1980). Contamination of ground water from human activities is a growing public concern. The degradation in ground water quality depends on the materials the water comes in contact with including both the unsaturated and saturated zones. Because ground water is vulnerable to contamination, there has been considerable recent legislation governing the production, transportation, use, and disposal of industrial and agricultural chemicals potentially harmful to the environment (Wilkinson, 1989).

Environmental concerns related to agricultural production have generated considerable research dealing with the issue of nonpoint source pollution. These concerns are increasingly focused on the impact of agricultural chemicals on water quality. The problem is alarmingly extensive. There are about 600 pesticide chemicals in common use formulating over 45,000 individual products. It is estimated that seventy-seven percent of pesticide used in the USA are used in agriculture (OSDA, 1987). Years of pesticide use have resulted in contamination of ground water in many parts of the country (Cohen, 1986). The problem has been recognized relatively recently and the extent of pesticide contamination is yet to be determined.

Nonpoint source pollution from agricultural chemicals is essentially a hydrologic problem. To evaluate the extent of pesticide transport to ground water requires a sound understanding of solute transport processes in the unsaturated zone. A number of simulation models dealing with the chemical transport process have been developed and applied (Nofziger and Hornsby, 1986; Carsel et al., 1984; Wagenet and Hutson; 1987). These models vary in complexity, intended use, and method used to predict water flow and solute transport in the unsaturated zone. All of them share a common characteristic. They generate fixed numbers or curves as their output. Understandably, these results are only estimates of the responses of the hydrologic system based on a single set of model parameters. Natural processes are almost always inherently variable. Traditional point estimates might produce misleading interpretations (Shaffer, 1988). It is desirable to consider the probabilistic aspects of the problem and place confidence intervals on the pesticide transport predictions.

Modeling pesticide transport in the unsaturated zone is often frustrating when one starts to select data for the model. In most cases there are just not enough adequate databases to fulfill even rudimentary data requirements of a solute transport model. The application of current transport models is seriously limited by availability and quality of data which impacts the success of modeling efforts. Many of the current databases (such as Soil Conservation Service Form Five Data Sheet) were never intended to serve the need of solute transport modeling nor to be used in pesticide management decisions. Improved databases are badly needed. Data collection is an expensive and time-consuming endeavor requiring careful planning and scientific guidance. Studies of the solute transport process, especially the impact of modeling parameters on the estimated fate of solute transport, will provide the scientific guidance for a data sampling program. Such studies will also help one to rationally allocate limited resources in collecting data on those model parameters that are most influential to the simulation of transport processes and probably most variable under natural conditions.

Study Objectives

The purpose of this study was to assess the sensitivity of estimated pesticide transport through the unsaturated zone to transport model parameters and to establish confidence limits on point estimates of pesticide transport. The specific objectives for reaching these goals are:

1) Investigate the sensitivity in estimated pesticide transport caused by the variability of individual model parameters.

2) Investigate the overall uncertainty in estimated pesticide transport caused by the variability of all the model parameters combined.

3) Determine the impact of the natural variability in precipitation on estimated pesticide transport.

4) Develop guidelines for soil sampling programs in terms of the required degree of certainty in estimated pesticide transport.

Scope of Study

Assessing the variability of estimated pesticide transport is essentially a sensitivity study on each of the model parameters. The CMLS (Chemical Movement in Layered Soils) model (Nofziger and Hornsby, 1986) was selected for this study. The model was modified to run in a batch mode. The model outputs are travel time to different depths and depth of penetration at different times. The model parameters investigated were bulk density, organic carbon content, field capacity, permanent wilting point, chemical partition coefficient, and degradation half-life. The rainfall record in Caddo County, Oklahoma was used to define the parameters of a stochastic rainfall model. The rainfall model was used to generate rainfall records for use in the Monte Carlo sensitivity study.

The interrelationship of the model parameters was first studied. Some of the model parameters do not independently enter the model and thus could be investigated by varying another parameter. The range on some parameters was limited by physical relationships to other parameters. Several possible values were assigned to each parameter. The number of selections were balanced between good representation of reality and the time required to complete the Monte Carlo simulation. The results from the simulation were used to calculate dimensionless sensitivity coefficients for each model parameter in terms of estimated pesticide travel time to a specific depth. Guidelines for soil sampling programs in terms of the required degree of certainty in pesticide transport estimates were developed based on the results from the sensitivity study.

The impact of natural variability of precipitation on solute transport was also studied by similar Monte Carlo simulations. Soil properties were summarized through a pool of measured soil profiles across soil series and held constant during the simulation. The results offered insight into the expected degree of confidence in model prediction. Efforts were made to address the probabilistic aspects of the problem and place confidence intervals on the pesticide transport predictions.

CHAPTER II

LITERATURE REVIEW

Sensitivity Analysis

Hydrologic processes are inherently variable in both space and time. There is no complete theoretical operational model in hydrology which encompasses all of the underlying physics involved in the hydrologic processes. To some extent, all hydrologic models contain empirical relationships (Haan, 1989). Investigating hydrologic processes through models requires a good understanding of the uncertainties involved in the model prediction. The errors associated with model prediction may come from errors in observations, natural variability in input parameters, errors in model parameters, and other sources. Only the errors from input parameters were investigated in this study. One way of quantifying the impact of these errors on the model prediction is to study each variable and understand its role in the model. This often requires a sensitivity analysis.

Different terms are used to described studies of uncertainty in input parameters and making inference about the uncertainty in model output. The term uncertainty (or error) analysis is often used when the impact of natural variability on model prediction is the main subject. The term sensitivity analysis is used when one refers to studies of uncertainty not limited by the natural variability. Nevertheless, both terms share common features. This section discusses sensitivity analysis. Later sections deal with uncertainty analysis techniques.

The theoretical basis of sensitivity is outlined by Tomovic (1962), Vemuri et al. (1969), and McCuen (1973). The general mathematical form of sensitivity can be expressed by applying a Taylor series expansion of the explicit function:

$$Y = f(p_1,\ p_2,\ ....\ p_n) \tag{2.1}$$

The change in Y resulting from change in p_i can be approximated as follows:

$$f(p_i+\Delta p_i,\ p_{j,j\neq i}) = Y + \frac{\partial Y}{\partial p_i}\Delta p_i + (1/2!)\frac{\partial^2 Y}{\partial {p_i}^2}\Delta p_i^2 + ... \tag{2.2}$$

If the nonlinear terms are negligible compared to the linear terms, Equation 2.2 is reduced to:

$$f(p_i+\Delta p_i,\ p_{j,j\neq i}) = Y + \frac{\partial Y}{\partial p_i}\Delta p_i \tag{2.3}$$

The change in Y can be expressed as:

$$\Delta Y = f(p_i+\Delta p_i,\ p_{j,j\neq i}) - Y = \frac{\partial Y}{\partial p_i}\Delta p_i \tag{2.4}$$

Equation 2.4 is called the linearized sensitivity equation. This equation can be extended when more than one parameter is allowed to vary simultaneously. The general definition of sensitivity (S) is given by (McCuen, 1973):

$$S = \frac{\partial Y}{\partial p_i} = [f(p_i+\Delta p_i,\ p_{j,j\neq i}) - f(p_1,\ p_2,\ ....\ p_n)]/\Delta p_i \tag{2.5}$$

Equation 2.5 suggests two ways of conducting sensitivity analyses. One basic approach of both uncertainty and sensitivity analysis is to introduce small perturbations in the various processes and parameters of the model and to study their relative effects on the output variable of interest. This may not be an efficient method, because it requires intensive computation. A straight forward approach is to mathematically differentiate the relationship (the hydrologic model) to derive equations for the rate of change of the dependent variable with respect to each independent variable. This method may be more direct but requires the model be mathematically tractable (Saxton, 1975).

From Equation 2.5, two ways of expressing sensitivity become obvious. One may be called dimensional sensitivity (S_d) where

$$S_d = \frac{\partial Y}{\partial p_i} \qquad (2.6)$$

The advantage of Equation 2.6 is that it gives a direct indication of the fraction change in model output. Another one may be called dimensionless sensitivity (S_l) or relative sensitivity, designed to compare the relative magnitude of sensitivity among many model parameters.

$$S_l = \frac{\partial Y}{\partial p_i} \bullet \frac{p_i}{Y} \qquad (2.7)$$

The application of sensitivity analysis to hydrologic problems has been examined by several researchers. Most sensitivity studies were conducted using complex hydrologic models. The analyses were accomplished by Monte Carlo simulation and expressed in the form of dimensional sensitivity (Gardner et al. 1980; Jury et al. 1984; Oravitz and Friedman, 1986; Bathurst, 1986; and Jarvis and Leeds-Harrison 1987). A sensitivity analysis by direct differentiation is given by Butt and McElwee (1985) in their evaluation of aquifer parameter sensitivity from variable rate pumping tests. Sensitivity expressed in dimensionless form was also used to test a numerical model of evapotranspiration (Camillo and Gurney, 1984), to study the parameters in an infiltration model (Pingoud, 1984), to determine the parameter sensitivity of ANSWERS model (Thomas and Beasley, 1986), and to investigate the ability of a surface watershed model to estimate ground water recharge (Chiew and McMahon, 1990).

First Order and Second Order Uncertainty Analysis

If one knows the mean and variance of model parameters under natural conditions, estimates of the mean and variance for the dependent variable (model output) as a function of the mean and variance of each independent variate (model parameter) may be obtained if the model is mathematically continuous and differentiable.

The term first order analysis refers to the analysis of the mean and variance-covariance of a random function based on its first order Taylor series expansion. Second order analysis refers to analysis of the mean based on a second order Taylor series expansion but the concurrent analysis of the variance-covariance is still restricted to use of the first order series expansion. Therefore, the mean derived by first and second order analysis may be different, the variance-covariance matrix is not (Dettinger and Wilson, 1981).

Both sensitivity and the first order analysis start with a Tayor Series approximation. First order analysis of the moments of a random function is designed to estimate its probabilistic properties. Consider a univariate random function y=f(x) with x as random variable. A Taylor series expansion leads to:

$$Y = f(\mu_X) + f^{(1)}(x - \mu_X) + f^{(2)}(x - \mu_X)^2/2 + f^{(3)}(x - \mu_X)^3/6 + \ldots\ldots \tag{2.8}$$

where $f^{(k)}$ is the kth derivative of Y with respect to x, evaluated at μ_X. Retaining only the first order terms, the mean or expected value of Y is approximated by

$$E(Y) = \mu_Y \approx E[f(\mu_X)+f^{(1)}(x-\mu_X)] = E[f(\mu_X)] + f^{(1)}E(x-\mu_X) = E[f(\mu_X)]$$

since $E(x-\mu_X) = E(x)-\mu_X = \mu_X-\mu_X = 0$

$$\mu_Y \approx f(\mu_X) \tag{2.9}$$

For a random function Y=f(**x**) where **x** is a column of random variables. First order analysis gives the approximation

$$Y = f(\mathbf{x}) \approx f(\mathbf{M_X}) + (\mathbf{x} - \mathbf{M_X})\mathbf{b}^T \tag{2.10}$$

where $\mathbf{M_X}$ is a vector of means, and $\mathbf{b}^T$ is the transpose of a vector of partial derivatives (Loague and Green, 1988). The ith element of **b**, again evaluated at the mean, is given by

$$b_i = \frac{\partial f(\mathbf{x})}{\partial x_i} \tag{2.11}$$

Assuming one keeps the second order term in Equation 2.8, the second order analysis approximation of Y=f(x) yields:

$$Y = f(\mu_X) + f^{(1)}(x - \mu_X) + 1/2f^{(2)}(x - \mu_X)^2$$

The second order approximation of the mean is given by

$$E(Y) = \mu_Y \approx f(\mu_X) + f^{(1)}E(x-\mu_X) + 1/2f^2E[x-\mu_X]^2$$
$$= f(\mu_X) + 1/2f^{(2)}\sigma_X^2 \qquad (2.12)$$

Obviously Equation 2.12 is more accurate than Equation 2.9 since it is the expected value of Y conditioned on the mean and variance of x.

The second moment of Y=f(x) can be approximated similarly. In the univariate case, the second moment is defined to be variance. First order analysis gives the approximation

$$\sigma_Y^2 \approx E[(f(\mu_X) + f^{(1)}(x - \mu_X) - \mu_Y)^2]$$
$$= E[(f(\mu_X) + f^{(1)}(x - \mu_X) - f(\mu_X))^2]$$
$$= E[f^{(1)}(x - \mu_X)]^2$$
$$= [f^{(1)}]^2\sigma_X^2 \qquad (2.13)$$

or in multivariate case, first order analysis gives

$$\sigma_Y^2 \approx \mathbf{b}^T C_X \mathbf{b} \qquad (2.14)$$

where C_X is the covariance matrix of the functionally dependent variables x_i. Consequently, the uncertainty contributed by an ith variable (S_i) can be approximated by

$$S_i \approx \left| \frac{\partial f(x)}{\partial x_i} \right| S_{x_i} \qquad (2.15)$$

where S_{x_i} is the standard deviation of the variable x_i. It is noted that Equation 2.15 is very similar to Equation 2.4. The total uncertainty (S_Y) contributed by all the variables combined is

$$S_Y \approx [\sum_{i=1}^{n} S_i^2]^{1/2}$$

Where n is the number of random variables in the function Y=f(**x**).

Benjamin and Cornell (1970) demonstrated that first order analysis will produce less than 1% error if the coefficient of variation of the random variable x is less than 10%. Cornell (1972) suggested the for coefficient of variation $\leq$ 0.2, the analysis method is applicable to moderately nonlinear systems.

First and second order analysis methods based on Taylor series expansions have been employed in hydrologic research by several people. Cornell (1972) presented applications of the approach to a wide variety of simple hydrologic and water resources problems and suggested much wider applications. Dettinger and Wilson (1981) presented a number of simple analytical examples specific to ground water flow applications. A finite element model of flow in a confined aquifer was analyzed by Sagar (1978) using the approach with a simple one-dimensional flow example. More recently, Jaffe and Parker (1984) used the method to determine the output distribution of a first order decay model. Loague et al. (1990) used the method to characterize the uncertainty in estimates of pesticide mobility index resulting from uncertainties in various input data.

Stochastic or PDF Analysis

The stochastic method is often referred to as the Monte Carlo method. The name stems from the fact that many pseudo random observations have to be generated from the assumed parent probability density function (PDF). The Monte Carlo method is probably the most powerful and commonly used technique for uncertainty analysis of a complex system (Carsel et al., 1988). The technique requires knowledge of the statistical distribution (PDF) of each independent variable together with its mean, variance, and correlation with other independent variables. The subsequent simulations are based on the unbiased selection of values of the independent variables from their respective statistical distributions. The process ends when enough output has been obtained to yield a clear statistical description of the dependent variable.

Booth (1989) generalized the Monte Carlo method into four steps. (i) Specification of a parametric statistical model (PDF) for the joint distribution of the input vector, **x**, for a random y chosen within the given classification. The PDF may come from the analysis of real observations of the input vector, **x**, or from similar studies conducted in the past. (ii) Estimation of the parameters of the specified PDF using either observed input vectors, x_1, x_2, ...x_n, at a sample of n sites within the given classification or the resulting parameters estimated in similar studies. (iii) Generate many pseudo input vectors from the PDF in (i) with the parameters in (ii). (iv) Run the model for each pseudo input vector to obtain a probability distribution for the output variable y.

Monte Carlo method may provide a different view of the system from that derived by first order analysis (Warwick & Gale, 1986). Although both methods yield similar estimates of average values (Burges and Lettenmaier, 1975), variance estimates can be quite different. Scavia et al. (1981) pointed out the first order analysis estimates variability about typical components of the modeled population while the Monte Carlo method gives variance estimates of the population mean. In other words, the Monte Carlo results describe expected variability in the system.

Moreover, the Monte Carlo method allows determination of the probability density function associated with an output variable (Warwidk and Gale, 1986). This in turn provides significant insight into total system behavior.

The Monte Carlo method has been widely employed in many disciplines in addition to hydrology. Shaffer (1988) used the Monte Carlo method to estimate the confidence bands for a soil-crop simulation model. Carsel et al. (1988a,b) used a similar procedure to generate PRZM model parameters for both the unsaturated and saturated zones in making regional assessments of pesticide residue loading to ground water. Persaud et al. (1985) obtained 200 pairs of multivariate lognormal values of the dispersion coefficient and pore-fluid velocity by a Monte Carlo data generation technique to solve the one dimensional partial differential equation describing noninteracting solute transport in ground water.

The Monte Carlo technique can also be used to study the sensitivity of model prediction corresponding to the uncertainties of a particular model parameter. Alcamo and Bartnicki (1987) used the method to determine the sensitivity of a sulfur-air transport model to its parameters under a prescribed 20% coefficient of variation. The technique is also useful in estimating model parameters. Ibbitt (1972) devised a conceptual model to generate synthetic error-free runoff data from precipitation and potential evaporation records. Random errors were then introduced into all three data records. By automatically and objectively fitting the model to different combinations of error-free and error-contaminated records, the effects of the errors on the fitting were obtained. Borah and Haan (1989) studied the uncertainties associated with parameter estimation by introducing prescribed errors into each value of the precipitation and synthetic runoff records of the USGS Precipitation Runoff Modeling Systems.

Nonparametric Uncertainty Analysis

The theory of nonparametric uncertainty analysis is relatively new. It was developed in late 1970s with the advent of high-speed digital computers. The method is computation intensive, but the payoff for such intensive computation is freedom from two limiting factors that have dominated statistical theory since its beginning. One of the limiting factors is the assumption that the data conform to a certain type of distribution. The other is the need to focus on statistical measures whose theoretical properties can be analyzed mathematically (Efron, 1982; Diaconis and Efron, 1983). The most frequently used method in estimating model uncertainty is called bootstrap.

The principles of bootstrap can be illustrated by an example. Suppose one has $\{x_1, x_2, \ldots\ldots, x_n\}$ independent observations from some distribution u. Each x_i can be written as

$$x_i = \mu + \epsilon_i \qquad i=1,2,3,\ldots\ldots,n$$

where μ is the sample mean and ϵ_i is the deviation of ith sample from μ. Sample statistics can be obtained as a function of μ and $\{\epsilon_1, \epsilon_2, \ldots\ldots, \epsilon_n\}$. The bootstrap distribution, denoted by T, can be written as $T = T(\mu, \epsilon_1, \epsilon_2, \ldots\ldots, \epsilon_n)$. The bootstrap estimate of a statistic is written as

$$T* = T(\mu, \epsilon_1*, \epsilon_2*, \ldots\ldots, \epsilon_n*) \qquad (2.16)$$

where $\epsilon_1*, \epsilon_2*, \ldots\ldots, \epsilon_n*$ are obtained by following Monte Carlo resampling procedures (Efron and Gong, 1983) listed below:

(i) construct Ψ, the empirical distribution function, which is equal to 1/n on each observed data point x_i.

(ii) draw a bootstrap sample $\{x^*{}_1, x^*{}_2, \ldots\ldots, x^*{}_n\}$ by independent random sampling from Ψ. In other words, make n random drawings with replacement from $\{x_1, x_2, \ldots\ldots, x_n\}$.

(iii) repeat step (ii) a large number of times. Then compute T* in Equation 2.16 for the independent bootstrap replications. In the case of the standard error of the mean, bootstrap gives

$$S.E.(T) = [1/n^2 \sum_{i=1}^{n} (x_i-\mu)^2]^{1/2} \qquad (2.18)$$

A fundamental assumption of bootstrap resampling is that the existing data are true representation of the population under study. Only in that case can one assure that rare events are reinvoked only rarely. The bootstrap technique has not found extensive application in hydrology. Hornsby et al. (1989) employed the bootstrap resampling methods in creating a large number of pseudo soil profiles which were then used to determine the probability of pesticide loading to ground water above the health advisory level in Florida. Heidam (1987) carried out pseudo-repetitions of experiment on air pollution by bootstrapping of the original data. Willmott et al. (1985) exploited the possibility of bootstrap application in a number of geophysics studies.

Comparison of the Three Uncertainty Analysis Methods

The advantage of first order analysis is that it is simple to use and does not require intensive Monte Carlo simulation. However, it can only be applied to some simple models which are continuous with respect to both model parameters and time. In addition, the approximation of first order analysis deteriorates if the coefficient of variation of model parameters is greater than 10-20%. Such variation is not unusual for many hydrology variables. For example in solute transport problems permeability and dispersion coefficients can vary by several orders of magnitudes. The use of first order analysis is obviously limited.

PDF analysis is capable of dealing with complex models in most circumstances. It is the most widely applied approach and is getting more popular with the increasing computing power. The drawback of the method is that it assumes complete representation of the population distribution by the available samples. Thus the sample size has to be large enough to give a reasonable estimate. The time required to do intensive Monte Carlo computations is certainly longer than that with first order analysis, but this consideration is diminishing with the ever improving computing technology.

Bootstrap statistics also require intensive computation - as much, if not more than, PDF analysis. It offers some unique advantage over PDF analysis. No assumption on population distribution is needed to make the method work. Confidence intervals can be readily established even if the theoretical distributional characteristics have not been derived. Since bootstrap is based upon the reshuffling of original observations, the immediate limitation of the methods can be found in the situation where not enough sample observations are available to start with.

Sampling Theory

Soil sampling is required to determine an average value of some soil property for a region. Because of the heterogeneity of soil properties, multiple soil samples are frequently required to reasonably define the property. The number of soil samples required to achieve a degree of certainty can be determined on the basis of valid statistical principles. Cline (1944) summarized these statistical principles of sampling for soil scientists and gave the classical formulae for estimating the number of soil samples to achieve a desirable estimation variance as

$$n = [t_{(1-\alpha/2,n-1)} \cdot S_X/(x-\mu)]^2 \qquad (2.18)$$

where

n is number of samples required for x.

μ is true population mean of x.

$x-\mu$ is tolerable deviation of x from μ.

$t_{(1-\alpha/2,n-1)}$ is value of Student t distribution at $1-\alpha$ confidence level.

S_X is standard deviation of x.

Equation 2.18 assumes random sampling from a normally distributed population. Equation 2.18 has its shortcomings. It is commonly known that soil properties are usually spatially dependent. Closely spaced soil samples tend to be similar, whereas widely spaced soil samples are not. An observation made at one location carries some information about its neighborhood. When a region is randomly sampled as dictated by Equation 2.18, some samples may be inevitably close together. These close samples duplicate information to some extent. Therefore, McBratney and Webster (1983) pointed out that systematic sampling can almost always improve the precision attained by random sampling. Berry (1962) and Webster (1977) have demonstrated the advantages of sampling on grids rather than simply at random with up to 10-fold gains in precision when estimating the proportions of particular classes of soil.

Another advance in sampling theory is related to the development of regionalized variables proposed by Matheron (1963). A regionalized variable is a numerical space function which varies in space and/or in time with apparent continuity but which varies in a manner that cannot generally be described by an ordinary workable function (Matheron, 1963). The theory enables spatial dependence in a property to be estimated quantitatively from data under reasonable assumptions and then to be used to estimate means with minimum variance (McBratney and Webster, 1983). The regionalized variable theory is used extensively in kriging, an interpolation and/or extrapolation technique. It has been applied to local estimation in soil mapping (Burgess and Webster, 1980a,b) and for designing sampling schemes (Burgess et al. 1981). Application of the theory requires knowledge of the semivariance of the variable of interest as a measure of the degree of spatial dependence between samples measured a specific distance apart (Journel and Huijbregts, 1978).

CHAPTER III

SOLUTE TRANSPORT PROCESSES AND SOLUTE TRANSPORT MODEL

Governing Equations

The governing equation describing unsaturated water movement through porous mediums is given by Richards equation (Richards, 1931). Its one-dimensional form can be written as:

$$\frac{\partial \theta}{\partial t} = \frac{\partial}{\partial z} \left(K(h)\frac{\partial \psi}{\partial z}\right) \quad (3.1)$$

where

$K(h)$ is the soil hydraulic conductivity (L/T) as a function of h, soil water matric potential (L).

ψ (=h+z) is the total soil water potential (L).

z is the vertical distance (L).

θ is volumetric soil water content (L^3/L^3).

Richards equation is derived by combining Darcy's law and the law of conservation of mass. Darcy's law was originally derived for saturated flow. It was extended by Buckingham to unsaturated flow. During the process of derivation, the soil matrix and liquid are assumed incompressible to further simplify the final equation. The most important assumption is probably that the air phase plays a negligible role in unsaturated flow processes and hence that a single equation can be used to describe unsaturated and saturated flow (Nielsen et al., 1986).

Equation 3.1 is highly nonlinear. It is usually solved by numerical methods. Solving the equation requires knowledge of the soil moisture characteristic curve ($\theta(h)$) and the relationship of unsaturated soil water conductivity (K) vs. volumetric soil water content (θ) or soil matrix potential (h). Both of these relationships are rarely available in common soil databases and time-consuming to determine by laboratory experiments. There are many other complicating factors. For instance, the soil moisture characteristics curve is subject to the influence of hysteresis effects. Soil hydraulic properties are also influenced by temperature and soil salinity.

Under transient flow conditions, water content changes with time. Therefore Equation 3.1 needs to be solved simultaneously at each time step with the solute transport equation. There are many mechanisms that affect solute transport processes in porous mediums. Among them the most important one is the convective transport process (or mass flow). The other processes include dispersion, adsorption, degradation, plant uptake and many others. The general solute transport equation for nonvolatile chemicals can be written as:

$$R \frac{\partial C}{\partial t} = D \frac{\partial^2 C}{\partial z^2} - V \frac{\partial C}{\partial z} - RkC \tag{3.2}$$

where

C is solute concentration (M/L^3) in soil water.

D is hydrodynamic dispersion coefficient (L^2/T), incorporating both molecular diffusion and mechanical dispersion.

V is interstitial water velocity (L/T), defined as the ratio of the water flux (q) to the volumetric water content (θ).

R is retardation factor ($R = 1 + \frac{BD \cdot K_d}{\theta}$).

BD is soil bulk density (M/L^3).

K_d is partition coefficient of the chemical (L^3/M).

k represents the pooled rate coefficient for chemical degradation (or decay) via all pathways and in all phases (Rao et al. 1988).

Equation 3.2 is commonly referred as the convective-dispersive equation for solute flow. On the right hand side of Equation 3.2, the first term accounts for effect of dispersion, the second for mass flow, and the last for degradation (or decay) losses. The real physical-chemical solute transport processes are much more complicated than those described in Equation 3.2. Many underlying assumptions were made in deriving the Equation 3.2.

Diffusion and Dispersion

Diffusion and dispersion tend to spread out the instantaneous pulse of solute flow. In the absence of diffusion and dispersion effects, the solute flow approximates piston flow. The relative importance of diffusion vs. dispersion depends mainly on water velocity.

For relatively mobile solute species, mechanical dispersion tends to dominate. On the other hand, if water movement is slow, molecular diffusion may be the dominant mechanism controlling the hydrodynamic dispersion coefficient (D).

The processes are usually assumed additive and simulated by Fick's first law. Rao et al. (1988) expressed the processes in following summation:

$$D = [D_e + D_m + D_s] \tag{3.3}$$

where

D is the hydrodynamic dispersion coefficient (L^2/T).

D_e is the molecular diffusion coefficient (L^2/T).

D_m is the "mechanical" dispersion coefficient (L^2/T).

D_s is the "sink" diffusion coefficient (L^2/T).

The last term D_s in Equation 3.3 describes solute diffusion between pore domains having different velocities (Rao et al., 1988). The sink effect due to solute diffusion into and out of the intra-aggregate regions becomes more dominant in aggregated soils (van Genuchten, 1985).

Adsorption

Solute in soil water can be adsorbed onto the formation solid matrix material. If the process is diffusion onto the solid matrix, the process exhibits a time-dependent nature. If it is just a surface effect, the process is rapid and considered near equilibrium (Srinivasan and Mercer, 1988). The commonly used reversible equilibrium sorption models only address the later phenomenon. It should be pointed out that Equation 3.2 is derived by assuming a linear equilibrium isotherm, simplified from the nonlinear Freundlich isotherm.

$$S = K\, C^{1/n} \tag{3.4}$$

where

S - adsorbed concentration (M/M).

K - Freundlich constant. When 1/n is set to unity, the resulting equation is linear isotherm, i.e. $K = K_d$.

The chemical partition coefficient K_d for non-polar organic compounds can be estimated from soil organic matter content because soil organic matter has been shown to be a primary site for adsorption. Schwarzenbach and Westfall (1981) and Helling (1971) have shown that the adsorption of organic material is highly correlated with soil organic carbon content. They developed some relationships between K_d and its octanol/water partition coefficient and organic carbon content.

$$K_d = K_{oc} \bullet OC = a \bullet (K_{ow})^b \bullet OC \tag{3.5}$$

where

K_{oc} is distribution coefficient of solute on soil organic carbon (L^3/M).

K_{ow} is distribution coefficient of solute between octanol and water (L^3/M).

OC is soil organic carbon content (M/M).

a and b are parameters determined by experiment.

Other factors not addressed by the equilibrium isotherm include clay content and the presence of other competing solute species. Adsorption will increase with increasing clay content of the soil due to increasing surface area and cation exchange capacity (O'Connor and Connolly, 1980).

Degradation

Solute loss to both microbiological and chemical transformation processes is collectively termed degradation. Degradation is a complex phenomenon because the process can be purely chemical and/or biological. In the plant root zone, degradation due to microbiological activities is faster than that due to chemical breakdown. However, there is little biological activities below the root zone (Wagenet, 1986). Degradation is therefore accomplished at a much slower rate in the deeper unsaturated zone, as well as in the ground water.

The degradation process is often described by simple first-order kinetics, i.e.

$$\frac{dC}{dt} = KC \tag{3.6}$$

where

K is the first order decay rate constant (1/T).

Integrating Equation 3.6 results in:

$$C(t) = C_0 e^{-Kt} \tag{3.7}$$

where

$C(t)$ is the chemical concentration (M/L^3) at time t.

C_0 is the initial chemical concentration (M/L^3) at time t_0.

An improvement on simulating biodegradation can be achieved by considering both aerobic and anaerobic degradation. In that case a separate oxygen transport equation similar to Equation 3.2 is needed in addition to the convective-dispersive equations (Srinivasan and Mercer, 1988). In reality the degradation rate will depend on temperature as well as the particular phases in which the solute resides (Helling and Gish, 1986). Under isothermal conditions, Walker (1974) found that the overall rate of degradation is controlled by volumetric water content. The reason is that water content affects aeration condition and the proportion of solute undergoing degradation. In addition, the soil pH will also affect the rate of degradation for some of the solute species (Hance, 1979).

Plant Uptake

Very few models consider the loss of solute due to plant uptake because of the difficulties of conducting experiments without disturbing the plant system (Hance, 1988). The process is more complex than one's intuitive view of the function of the root system. For instance, Sagar et al. (1982) have found that not all solute species enter roots at a rate proportional to water uptake.

It is believed that most soluble compounds seem to enter and be transported in the plant system passively. Therefore it is possible to view the plant uptake process as a series of partition steps between soil water and plant root system, and continued between transpiration stream and the various plant tissues (Hance, 1988). Nevertheless, the plant uptake process is often neglected in the belief that its magnitude of influence, beyond the sink effect on soil water due to evapotranspiration, is relatively small in comparison to the previously discussed processes.

Boundary Conditions

Solving Equations 3.1 and 3.2 simultaneously requires not only intensive computation, but also comprehensive initial and boundary conditions. Three kinds of boundary conditions are frequently found in the literature. A concentration dependent boundary condition is given by the Dirichlet condition:

$$\begin{aligned} C &= C_0 e^{-\lambda t} && t \le t_0 \\ &= 0 && \text{otherwise} \end{aligned} \tag{3.8}$$

where

C_0 is boundary concentration (M/L^3).

λ is a coefficient for optional exponential degradation of C_0 ($1/T$). When $\lambda = 0$, it simulates a constant concentration boundary condition.

Another boundary condition called Neumann type is also common when there is a mass flux across the boundary until a specified time:

$$-D\frac{\partial C}{\partial z} = qe^{-\lambda t} \qquad t \leq t_o$$

$$= 0 \qquad \text{otherwise} \qquad (3.9)$$

where

q is a measure of mass flux at the boundary ($ML^{-1}T^{-1}$).

The more general type of boundary condition is the Cauchy type, when the flux across the boundary is both dispersion and mass flow driven. It is usually given as:

$$-D\frac{\partial C}{\partial z} + VC = ge^{-\lambda t} \qquad t \leq t_o$$

$$= 0 \qquad \text{otherwise} \qquad (3.10)$$

where

g is a measure of mass flux across the boundary ($ML^{-1}T^{-1}$).

V is interstitial water velocity (L/T) as defined in Equation 3.2.

It is not difficult to realize that the application of these fundamental water flow and solute transport equations in field condition requires many model input parameters that are rarely available in most databases. The task of supplying boundary conditions alone is often excessive for most field-scale problems. Therefore, there is a need to develop simple models that are not only comprehensive enough to encompass the major processes influencing solute transport in soil, but also simple enough to make predictions without special data requirements.

Piston Flow Theory and Field-Scale Solute Transport Model

The convective-dispersive transport equation (Equation 3.2) can be greatly simplified if one neglects dispersive process and adopts piston flow theory. The piston flow theory, as the name implies, assumes the infiltrating water completely displaces all of the initial water resident in the soil profile. In other words, the incoming water and the resident water act as immiscible fluids during the displacement process. This assumption holds reasonably for non-structured soils (Rao et al. 1988), especially for sandy soils. The theory was used in formulating ACTMO model (Frere et al., 1975). By considering degradation processes, Rao et al. (1976) proposed the following field-scale solute transport model:

$$Z_i = Z_{i-1} + \left(\frac{I_i - I_d}{FC \cdot R}\right) \qquad I_d < I_i \tag{3.11}$$

$$Z_i = Z_{i-1} \qquad I_d \geq I_i$$

where

Z_i and Z_{i-1} are the depths (L) at which the solute front is located after the ith and (i-1)th events.

I_i is amount (L) of water infiltrating into soil for the ith event.

I_d is amount (L) of soil water deficiency resulting from evapotranspiration.

FC is volumetric field capacity (usually taken to be the θ at -0.1 bar).

R is retardation factor defined as $R = 1 + \frac{BD \bullet K_d}{FC}$, which equals the retardation factor defined in Equation 3.2 when θ = FC.

This model mimics the discrete, episodic nature of solute transport in response to individual rainfall or irrigation events. Thus, whenever the infiltrating water exceeds the soil water deficiency as a result of evapotranspiration, the surplus infiltrating water will carry the solute to a distance determined by field capacity and retardation factor. Since the concentration distribution within the solute front (pulse) under the above assumptions is of infinitesimal width, Z_i corresponds to the center of mass of the solute pulse.

One of the assumptions becomes immediate: the infiltrating water is redistributed to the field capacity instantaneously during the increment of computation. This assumption is more appropriate for coarse textured soil than for fine textured ones (Nofziger and Hornsby, 1986).

Carsel et al. (1984) have developed a model called PRZM for predicting pesticide movement in crop root zone. The model uses piston flow theory in its soil water submodel. The model has been used by EPA in determining pesticide registration. Smith et al. (1984) formulated a simplified version of convective-dispersive solute transport equation by using the piston flow theory. They also accounted for the dispersive process by a constant average dispersion coefficient. The model was tested favorably in simulating bromide concentration in soil in field plots.

More recently, Nofziger and Hornsby (1986) have developed an interactive agricultural chemical management model based on the above concept of solute transport. The model, called CMLS, was used in this study to simulate the pesticide transport in many hypothetical soil profiles.

CMLS Model and Its Data Requirements

The CMLS (Chemical Movement in Layered Soils) model was developed at the University of Florida and continuously upgraded at Oklahoma State University. The most popular version of the model is an interactive model which computes the depth of pesticide penetration and the relative amount of pesticide applied reaching a given depth. The model also provides a user friendly interface with graphic outputs. A comprehensive database of chemodynamic properties of many pesticides is included in the model to ease part of the data requirements. The model has been tested favorably and used in many parts of the country (Hornsby et al. 1988; Mulla et al. 1989).

The concept of piston flow and solute transport as described in Equation 3.11 was implemented in CMLS model. CMLS first performs daily water budgeting, which will decide if there is effective infiltration that drives the chemical downward. The model assumes that water entering soil redistributes instantaneously to field capacity. The depth of solute front, Δd_s, in a uniform soil (or within a layer of a layered soil) is determined by

$$\Delta d_s = q/(R \bullet FC) \tag{3.12}$$

where q is the amount of water passing the depth d_s. The model uses linear, reversible, equilibrium isotherm in describing adsorption process, resulting a retardation factor given by

$$R = 1 + \frac{BD \bullet K_d}{FC} \tag{3.13}$$

The model traces the chemical vertical migration in and beyond the agricultural root zone in a layer by layer manner. A recent implementation allows the soil profile to be divided into 25 layers. For each soil layer, CMLS requires the depth of the layer, soil bulk density (BD), field capacity (FC), permanent wilting point (WP), organic carbon content (OC), organic carbon partition coefficient (K_{OC}), and degradation half-life ($t_{1/2}$).

The version used in this study is a modified batch version suitable for continuous Monte Carlo simulations. Many improvements were made during the process of this study in making the model more versatile. An infiltration routine was added to partition precipitation or irrigation into surface runoff and infiltration. The routine is based on SCS curve number method. Also implemented was a rainfall simulator that was modified from the WGEN model reported by Richardson and Wright (1984). The current implementation facilitates up to 40 years of continuously simulated rainfall series based on some parameters obtained by analyzing the observed local precipitation record. The output from CMLS was also modified to include the travel time to a specified depth and the depth of penetration at a specified time.

CHAPTER IV

SENSITIVITY ANALYSIS

Sensitivity analysis is the key part of this study in determining the impact of individual CMLS parameter on the estimated pesticide transport. The Monte Carlo simulation with CMLS was carried out using many pseudo soil profiles and chemodynamic properties. The properties of observed soil profiles were first studied. The observed parameter ranges and variation guided the selection of generated parameter ranges. The actual number of Monte Carlo simulations was a balance between a fair representation of the problem and the time required to solve the problem. The general procedures of this study are presented in this chapter.

Description of Soil Data

All of the soil data used in this study are from Oklahoma soils. The study used only those soil profiles with measured soil properties corresponding to the requirements of the CMLS model. Most of the measured soil profile data came from the USDA Soil Testing Laboratory based in Lincoln, Nebraska. The rest of the measured soil profile data were from the internal database of the Erosion Productivity Impact Calculator (EPIC) model. The

TABLE 1

PROPERTIES OF OBSERVED SOIL DATA

	Bulk density	Permanent wilting point	Field capacity	Organic carbon
	BD(g/cm^3)	PWP(%)	FC(%)	OC(%)
N OF CASES	391	391	391	391
MINIMUM	1.29	1.0	4.2	0.02
MAXIMUM	1.98	31.6	41.2	3.59
RANGE	0.69	30.6	37.0	3.57
MEAN	1.57	12.8	22.7	0.56
VARIANCE	0.018	35.08	47.20	0.249
STANDARD DEV	0.133	5.92	6.87	0.499
SKEWNESS(G1)	0.492	0.25	-0.28	1.914
KURTOSIS(G2)	0.109	-0.45	-0.14	5.097
C.V.	0.085	0.46	0.30	0.891

PEARSON CORRELATION MATRIX

	BD	PWP	FC	OC
BD	1.000			
PWP	-0.012	1.000		
FC	-0.170	0.902	1.000	
OC	-0.371	0.050	0.127	1.000

soil profiles with only one measured layer or less than one meter depth were not considered in this study. There were 52 soil profiles in total which were used. Table 1 gives the sample statistics on the four CMLS parameters across soil types and layers.

Among these 52 soil profiles, 17 profiles have measured soil properties up to two meters depth. The four CMLS required soil properties were plotted for these 17 soil profiles and included in Appendix A. These plots were made to seek feasible models to represent the change of these CMLS parameters with depth.

Organic Carbon Content

Organic carbon content (OC) is one of the most difficult parameters to model in this entire dataset. Organic carbon content usually decreases with depth at an exponential rate. It also varies tremendously from soil to soil. A simple exponential decay function was used to mimic this change:

$$OC = OC_a \cdot EXP(-OC_b \cdot DEPTH) \quad (4.1)$$

where

OC - organic carbon content (%).

DEPTH - depth in soil (meter).

OC_a and OC_b - parameters.

The key task is to determine the parameters OC_a and OC_b in Equation 4.1. Equation 4.1 was fitted by a nonlinear regression routine to each of the profiles plotted in Appendix A. The fitted curves are plotted as curves and the observed data are represented by symbols. The range of parameter OC_a was found between 0.5 and 2.0. The range of parameter OC_b was between 0.5 and 3.5. The range of parameter OC_a used in the sensitivity study was chosen to be 0.1 to 2.0. The range of parameter OC_b was chosen to be 1.0 to 4.0.

Available Water Capacity

Available water capacity is the difference between field capacity (FC) and permanent wilting point. Field capacity and permanent wilting point usually vary slightly with depth. The more important characteristic is that they tend to vary together, as shown by the plots in Appendix A. Their correlation is confirmed in the sample statistics in Table 1.

Although field capacity and permanent wilting point enter the CMLS model as separate parameters, their close correlation needs to be preserved in the Monte Carlo simulation. The preservation of this correlation is needed to ensure the pseudo soil profiles are realistic. A linear regression was fitted between field capacity (%) and permanent wilting point (%).

$$WP = -4.892 + 0.778\ FC \tag{4.2}$$

The regression line is statistically significant (r^2=0.9). The 95% confidence interval for the regression line was computed as ±5.02 at the mean.

The range of field capacity used in the study was from 5% to 45%. The range of permanent wilting point was from 1% to 31% based on the actual observed ranges of variation reported in Table 1. Equation 4.2 was used to compute the predicted permanent wilting point. The predicted value was then compared with the pre-selected value. Whenever the pre-selected permanent wilting point fell outside the 95% confidence interval, that pre-selected permanent wilting point was considered unacceptable as far as the correlation is concerned.

Other CMLS Parameters

The only soil property not discussed so far is soil bulk density (BD). It is the least variable parameter in the CMLS model. Such small variation was demonstrated by the small coefficient of variation in comparison to others (Table 1). It also does not vary much with depth, as revealed from the plots in Appendix A. Equation 3.11 illustrated how bulk density functions in the CMLS model:

$$R = 1 + \frac{BD \bullet K_d}{FC}$$

Because of the product relationship between chemical partition coefficient and bulk density, only one parameter needs to be varied as far as the sensitivity study is concerned. Bulk density is much less variable than K_{oc}. A logical choice is to keep bulk density constant while varying K_{oc}.

The bulk density was held at 1.4 g/cm^3 in this study. Assuming a 2.65g/cm^3 soil particle density, soil porosity can be calculated from the bulk density:

$$\text{Porosity} = 1 - (BD/2.65) = 1 - (1.4/2.65) = 0.47$$

Because field capacity should always be less than porosity, this 47% porosity value put an additional constraint on the selection of field capacity.

The chemodynamic properties used in the CMLS model are organic carbon partition coefficient (K_{OC}) and degradation half-life ($t_{1/2}$). These two parameters can vary greatly from chemical to chemical. Travel time to a specific depth is used to compute the sensitivity. A wide range of K_{OC} (from 0 mg/g OC to 2000 mg/g OC) is considered in the study.

Range of CMLS Parameters

The range of the CMLS parameters are listed in Table 2. The values given in Table 2 are the actual parameters values used in the Monte Carlo simulation. Mathematically, there are 5600 possible combinations. Enforcing the correlation between field capacity and permanent wilting point (Equation 4.2) reduced this number to 1269. 100 simulations were made on each pseudo profile to account for the variation in precipitation. Therefore the total number of the Monte Carlo simulation was 126,900 in this study. All pseudo soil profiles have five layers and are one meter in depth. All CMLS parameters were held constant across layers except organic carbon content. The correlation between field capacity and permanent wilting point is 0.963 for the generated CMLS parameters.

TABLE 2

VALUES OF THE CMLS PARAMETERS

PARAMETER	UNIT	VALUE SELECTED
K_{oc}	mg/g OC	0, 2, 10, 20, 50, 100, 500, 1000, 2000
BD	g/cm^3	1.4
OC_a		0.1, 0.2, 0.5, 1.0, 2.0
OC_b		1.0, 2.0, 3.0, 4.0
FC	%	5.0, 15.0, 25.0, 35.0, 45.0
WP	%	1.0, 6.0, 11.0, 16.0, 21.0, 26.0, 31.0

CHAPTER V

RESULTS OF SENSITIVITY ANALYSIS

The CMLS output of sensitivity analysis is included in Appendix B. The mean of travel time (days) to one meter depth was calculated for each of the 1269 pseudo soil profiles. Equation 2.7 was modified to cope with the discrete data points.

$$S_1 = \frac{\Delta Y}{\Delta p_i} \bullet \frac{p_i}{Y} \qquad (5.1)$$

This modified version of the relative sensitivity equation was then used to compute the relative sensitivity in terms of the mean travel time. Equation 5.1 can be rearranged to following form

$$\frac{\Delta Y}{Y} = S_1 \bullet \frac{\Delta p_i}{p_i}$$

which indicates that one percent change in p_i produces a S_1 percent change in Y. Results show that the relative sensitivity with respect to one parameter is a function of the values of other parameters. Whenever the term sensitivity of a parameter is mentioned in this chapter, it is understood that all other parameters are held at some constant level. This characteristic of the sensitivity measures results from the interrelationships of the CMLS parameters.

Equations 3.12 and 3.13 are frequently referred to in the following sections in interpreting the results of the sensitivity analysis. They are rewritten here for convenience:

$$\Delta d_s = q/(R \bullet FC) \tag{5.2}$$

$$\begin{aligned} R &= 1 + (BD \bullet K_d)/FC \\ &= 1 + (BD \bullet K_{oc} \bullet OC)/FC \\ &= 1 + [BD \bullet K_{oc} \bullet OC_a \bullet EXP(-OC_b \bullet depth)]/FC \end{aligned} \tag{5.3}$$

Sensitivity of Travel Time to K_{oc}

K_{oc} participates in the computation of solute transport through soils by influencing the retardation factor (R). Its influence on the retardation factor becomes clear when Equation 5.3 is differentiated with respect to K_{oc} and multiplied by K_{oc}/R:

$$\begin{aligned} S_{K_{oc}} &= \frac{\partial R}{\partial K_{oc}} \bullet \frac{K_{oc}}{R} \\ &= [BD \bullet OC_a \bullet EXP(-OC_b \bullet depth)]/FC \bullet \frac{K_{oc}}{R} \end{aligned} \tag{5.4}$$

The resulting equation is an expression of relative sensitivity of R to K_{oc}. A large numerator or smaller the denominator corresponds to a large relative sensitivity of R with respect to K_{oc}. Results from Monte Carlo simulations suggest that the relative sensitivity of retardation factor is comparable to that of chemical travel time because travel time is directly related to retardance. Since chemical travel time is determined numerically and is not directly differentiable, differentiating the retardation factor offers a way to visualize the impact of the value of each CMLS parameter on the sensitivity of chemical travel time in a qualitative sense. This, however, does not eliminate the need for Monte Carlo simulations because only the simulations produce the estimate of the magnitude of the relative sensitivity of chemical travel time.

Figures 1 through 5 are plots of relative sensitivity of chemical travel time to K_{oc}. The curve parameter in each plot is field capacity. Parameter OC_a for organic carbon content was incremented from 0.1 in Figure 1 to 2.0 in Figure 5. All other parameters were held constant. These parameters are BD=1.4 g/cm^3, OC_b=1, PWP=11% or 26%. The data used to make these sensitvity plots, and the rest of the sensitivity plots, are listed in Appendix C.

Regardless the levels of other parameters, the relative sensitivity of travel time to K_{oc} increases with increasing K_{oc}. This is apparent from Equation 5.4 and is true for all the curves in all the plots. The relative sensitivity to K_{oc} is also relative to other parameters, especially the ones identified in Equation 5.4. Parameter OC_a for organic carbon content was increased from Figure 1 to Figure 5. This resulted in a gradual increase in relative sensitivity of travel time to K_{oc} from Figure 1 to Figure 5 as well. The same effect from parameter OC_a is also demonstrated by Figure 6 where relative sensitivity of travel time to K_{oc} for different values of OC_a is shown. Other parameters in Figure 6 are held at BD=1.4 g/cm^3, FC=25%, PWP=16%, and OC_b=1 respectively.

It can be seen that curves are gradually cut off at large K_{oc} values as OC_a increases from Figure 1 to Figure 5. This happens when retardation factor is large (as K_{oc} and/or OC get large). For those

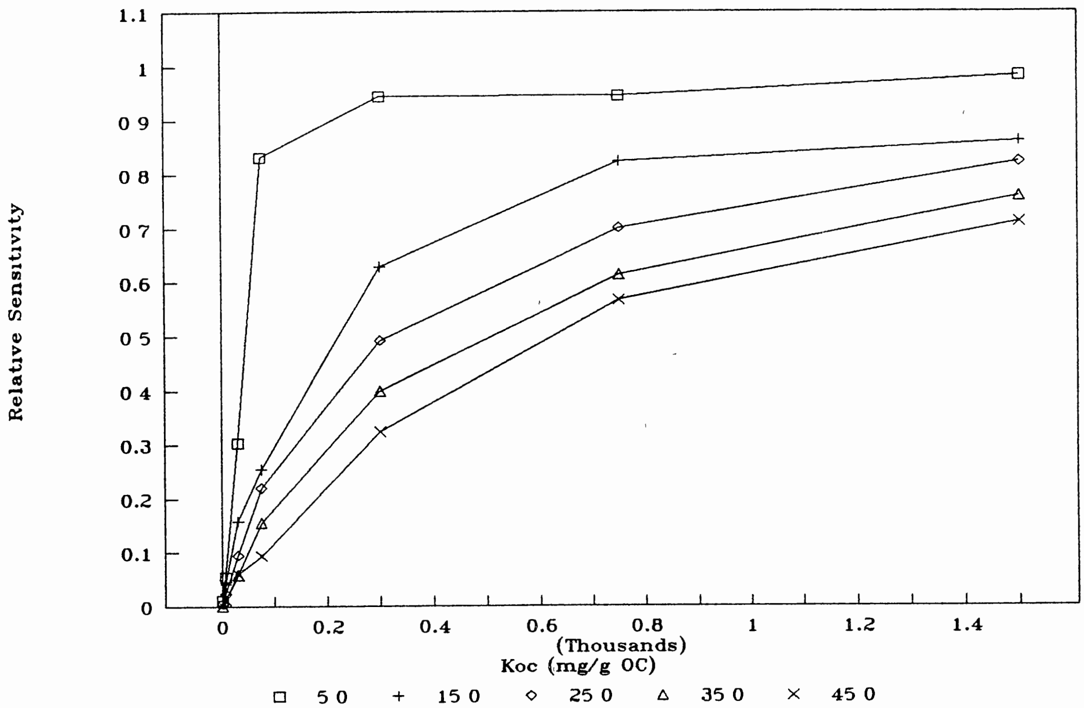

Figure 1. Relative Sensitivity of Travel Time to K_{oc} at Different Field Capacity (OC_a=0.1)

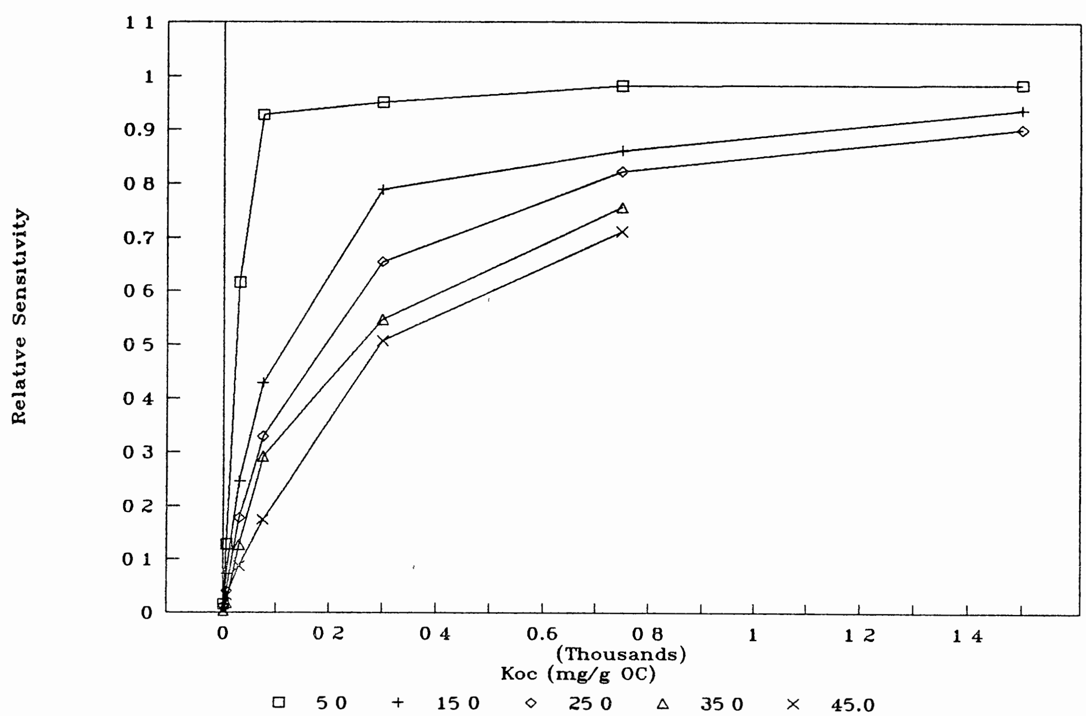

Figure 2. Relative Sensitivity of Travel Time to K_{oc} at Different Field Capacity (OC_a=0.2)

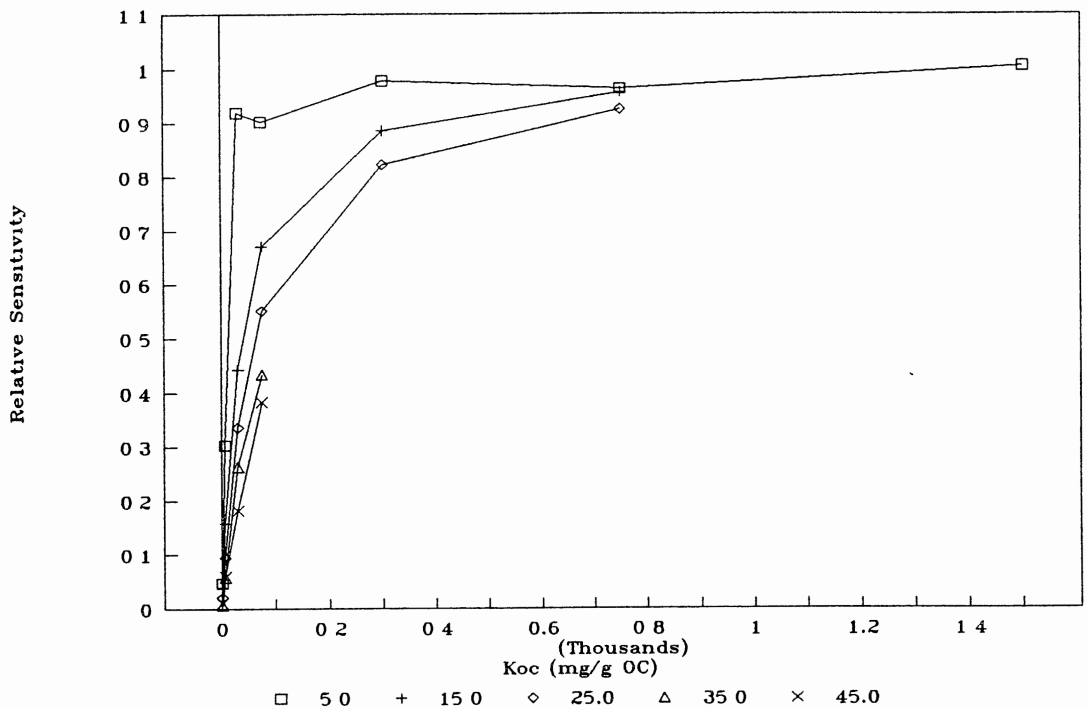

Figure 3. Relative Sensitivity of Travel Time to K_{OC} at Different Field Capacity (OC_a=0.5)

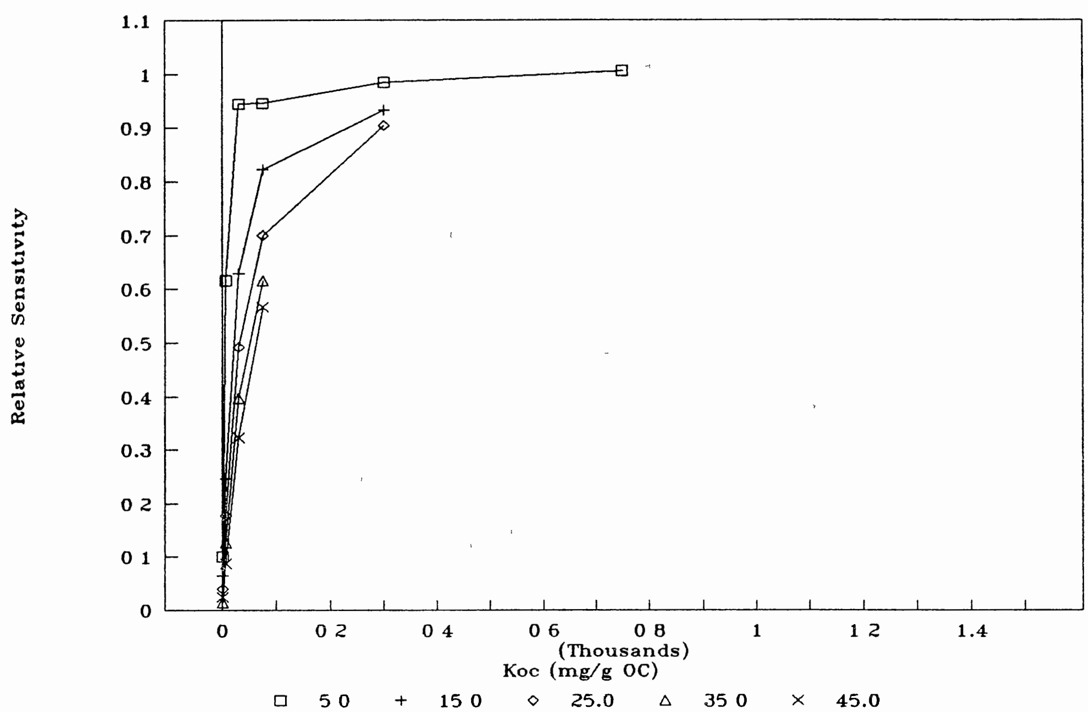

Figure 4. Relative Sensitivity of Travel Time to K_{OC} at Different Field Capacity (OC_a=1.0)

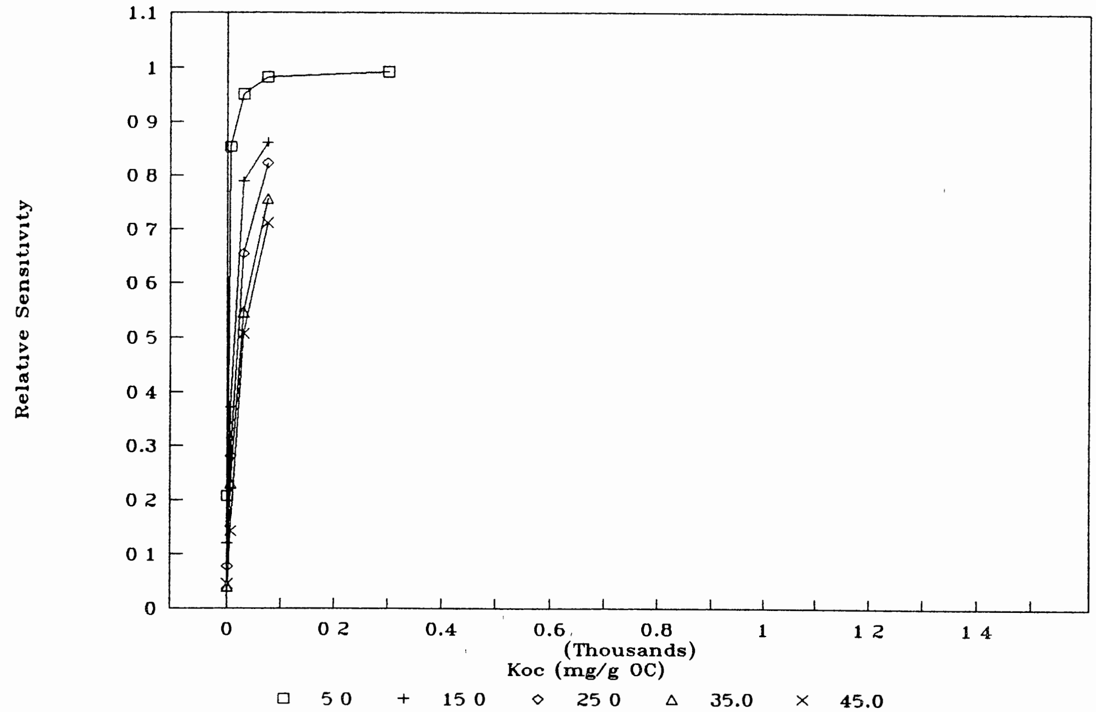

Figure 5. Relative Sensitivity of Travel Time to K_{OC} at Different Field Capacity (OC_a=2.0)

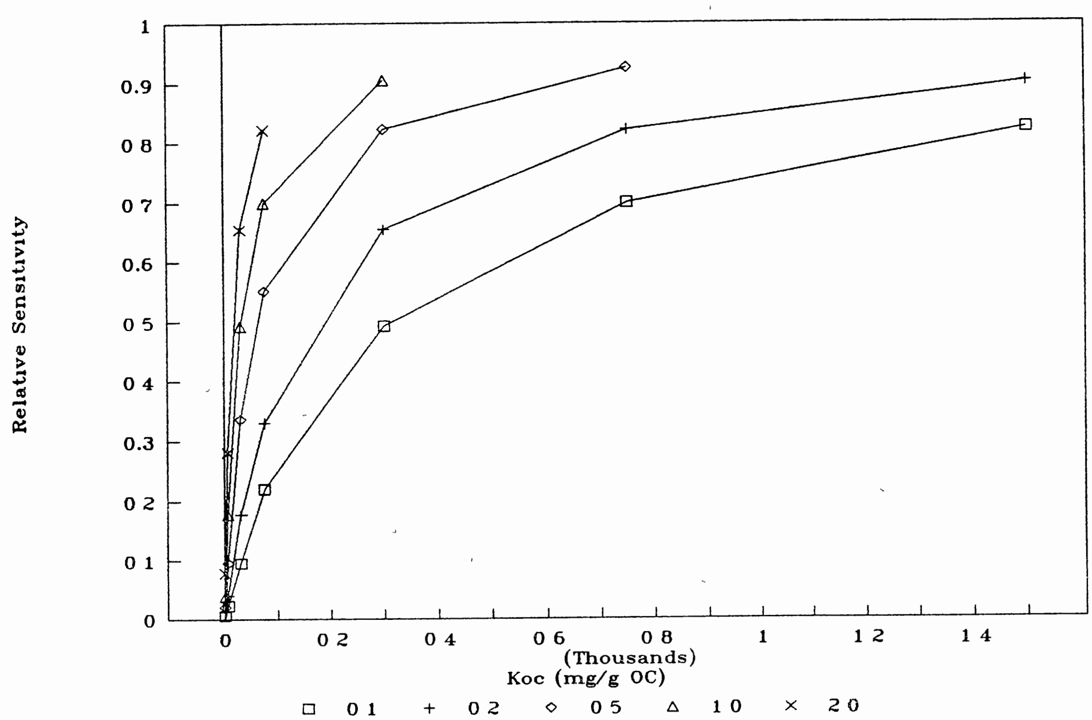

Figure 6. Relative Sensitivity of Travel Time to K_{OC} at Different OC_a

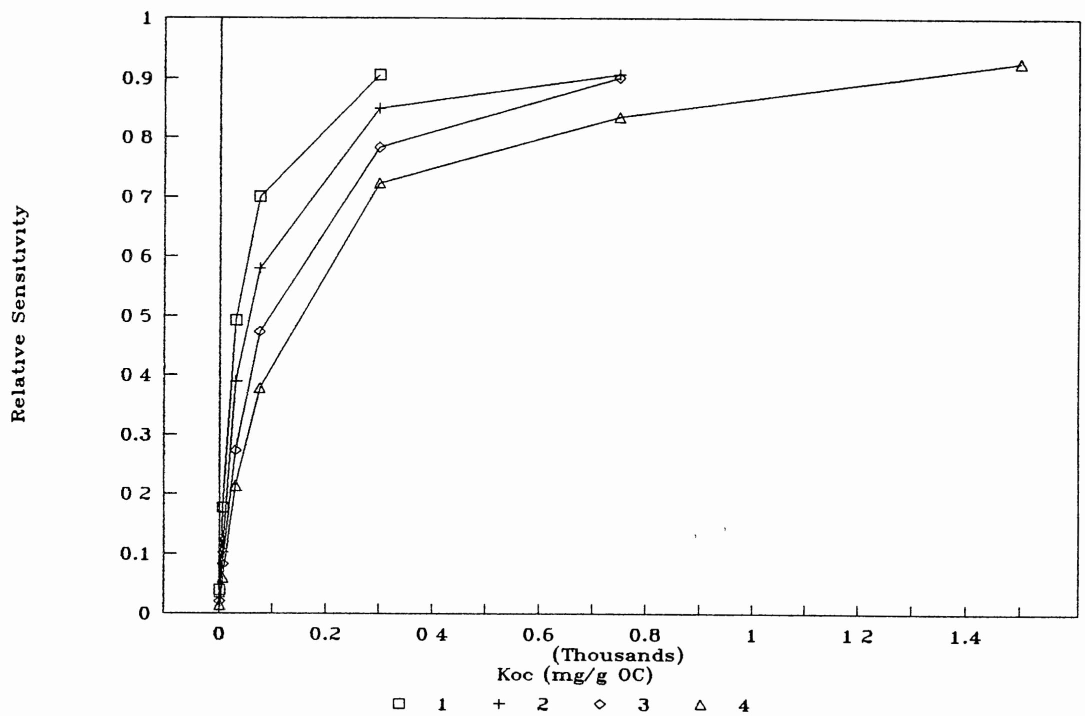

Figure 7. Relative Sensitivity of Travel Time to K_{oc} at Different OC_b

combinations of parameters the relative sensitivity values were not defined because of the pesticide never reached one meter depth within the maximum allowed simulation time of 40 years.

Figure 7 is a plot of relative sensitivity of travel time to K_{oc} for different values of OC_b. The other parameters held constant are same as those in Figure 6 except OC_a is taken at 1. Smaller OC_b means a slower dissipating rate of organic carbon with depth in the soil. This results in a higher organic carbon content at depth away from the soil surface and a higher relative sensitivity of travel time to K_{oc}. In addition, an increase in field capacity increases the denominator in Equation 5.4. This results in a decrease in relative sensitivity of travel time to K_{oc}. Again the results from the Monte Carlo simulations show that the relation in terms of retardation factor also holds for relative sensitivity in terms of travel time.

Overall, the relative sensitivity of travel time to K_{oc} increases quickly when K_{oc} increases from zero to about 100 mg/g OC. The rate of increase subsides at higher K_{oc} values. The actual rate of increase depends upon the value of other parameters. For this data set, the maximum relative sensitivity of travel time to K_{oc} seems to approach unity as evidenced in Figures 1 through 7. When relative sensitivity is unity, 1% change in K_{oc} corresponds to 1% change in travel time. In general a 1% change in parameter corresponds to a $100S_1$% change in response. Consider Figure 6 as an example. When OC_a is 0.2, a change of K_{oc} from 10 to 15 results in about 4% change in R. A change of K_{oc} from 500 to 505 results in only 1% change in R.

Irregular perturbations appear in some of the previously discussed plots (such as Figure 3). In most cases these irregular perturbations occurred when field capacity and permanent wilting point are 5% and 1%, respectively. These values are unusually small for agricultural soils. This tiny water holding capacity, compounded with low adsorption caused by low K_{oc} and organic carbon content, makes the soil very susceptible to the influence of the magnitude of the first few rainfall events. The resulting travel time to one meter depth is usually small. These factors made the fluctuation of the travel time to one meter highly dependent on a few simulated rainfall events. Fluctuations in travel time translate directly to fluctuation in relative sensitivity of travel time. In addition, travel time is not cumulated continuously but by discrete days. This may also introduce some numerical error.

Sensitivity of Travel Time to Bulk Density

Equation 5.3 indicates that bulk density should influence the sensitivity of the retardation factor in the same way as K_{oc}. It is mathematically straight forward to differentiate Equation 5.3 with respect to bulk density to get an analogous expression for the relative sensitivity of R to bulk density.

$$S_{BD} = \frac{\partial R}{\partial BD} \bullet \frac{BD}{R}$$

$$= [K_{oc} \bullet OC_a \bullet EXP(-OC_b \bullet depth)]/FC \bullet \frac{BD}{R} \qquad (5.5)$$

Since Equations 5.4 and 5.5 are identical, the influence of bulk density on chemical transport was simulated by selecting different K_{oc} values. Bulk density was held at a constant value of 1.4 g/cm^3 throughout the Monte Carlo simulation. The only difference in terms of influence on chemical transport between bulk density and K_{oc} lies in the difference in magnitude of the parameter values. As mentioned in chapter four, bulk density is the least variable CMLS parameter. Table 1 revealed that bulk density varies between 1.3 g/cm^3 and 2.0 g/cm^3 for this data set. This range of variation is well covered in the above discussion of relative sensitivity of travel time to K_{OC}.

An example calculation may cast more light on the issue. Consider the following set of parameter values: K_{OC} = 400 mg/g OC, BD = 1.4 g/cm^3, OC = 0.01, FC = 0.1, Equation 5.3 gives the retardation factor based on these parameters as

$$R = 1 + [1.4 \times 400 \times 0.01]/0.1 = 57$$

It is not difficult to see that this retardation factor can be kept constant by changing bulk density and K_{OC} in an opposite fashion. For instance, when bulk density is reduced to 1.3 g/cm^3, R will be same if K_{OC} is increased to about 431 mg/g OC. When bulk density is increased to 2.0 g/cm^3, R will be same if K_{OC} is 280 mg/g OC. Therefore the change in bulk density from 1.3 g/cm^3 to 2.0 g/cm^3 is equivalent to change in K_{OC} from 431 mg/g OC to 280 mg/g OC. In other words, Figure 1 through Figure 7 could also apply to the relative sensitivity of travel time to bulk density about the corresponding parameters. In the above case when K_{OC} was initially set at 400 mg/g OC, the relative sensitivity of travel time to bulk density is shown on the part of the curves where K_{OC} changes from 280 mg/g OC to 431 mg/g OC.

It is obvious that the comments made to the relative sensitivity of travel time to K_{OC} are equally true for bulk density. Namely, the relative sensitivity of travel time to bulk density increases as bulk density and OC_a increase, but decreases as field capacity and OC_b

increase. The magnitude of the relative sensitivity of travel time to bulk density depends upon the values of other parameters in the same manner as to K_{OC}.

Sensitivity of Travel Time to OC

Organic carbon content is a crucial parameter controlling the availability of adsorption sites. The significance of organic carbon content is due to its high variability under natural conditions. Unlike bulk density, organic carbon content can vary from virtually zero percent to several percent, depending upon soil type and the depth of interest. This natural variability was demonstrated by the highest coefficient of variation in Table 1. Equation 5.3 states that organic carbon content influences the chemical transport in a similar way as bulk density and K_{OC}. Had organic carbon content been represented by one parameter in the simulation, it would have been possible to express the sensitivity of travel time to organic carbon content by a relationship similar to Equations 5.4 and 5.5. In that case, the expression for relative sensitivity of retardation factor to organic carbon content would be

$$S_{OC} = \frac{\partial R}{\partial OC} \bullet \frac{OC}{R}$$

$$= [BD \bullet K_{OC}]/FC \bullet \frac{OC}{R} \qquad (5.6)$$

However, organic carbon content was modeled by an exponential decay function with two parameters (Equation 4.1). As a result, the relative sensitivity of travel time to organic carbon content was divided into the relative sensitivity to parameter OC_a and the relative sensitivity to parameter OC_b. The relative sensitivity of travel time to parameter OC_a in terms of retardance coefficient can be easily derived when Equation 5.3 is differentiated with respect to OC_a as

$$S_{OC_a} = \frac{\partial R}{\partial OC_a} \cdot \frac{OC_a}{R}$$

$$= [BD \bullet K_{oc} \bullet EXP(-OC_b \bullet depth)]/FC \cdot \frac{OC_a}{R} \tag{5.7}$$

It is clear from Equation 5.7 that the sensitivity of R to OC_a increases as bulk density and K_{oc} increase, but decreases as OC_b and field capacity increase. Figures 8 through 12 shows that the sensitivity of travel time follows these same relationships. Figures 8 through 11 are plots of relative sensitivity of travel time to parameter OC_a at different K_{oc} levels. Parameter OC_b for organic carbon content was incremented from 1.0 in Figure 8 to 4.0 in Figure 11. Other parameters are BD=1.4 g/cm^3, FC=25%, PWP=16%. It is clear from these plots that higher relative sensitivity of travel time to parameter OC_a results from higher values of OC_a, high values of K_{oc}, or low values of OC_b. Figure 12 demonstrates that the relative sensitivity of travel time to OC_a decreases as field capacity increases. The other parameters held constant in Figure 12 are BD=1.4 g/cm^3, OC_b=1, K_{oc}=100 mg/g OC, PWP≠ 11% or 26%.

The rate of change in relative sensitivity of travel time to OC_a seems to be more rapid at lower OC_a values than at higher values. The maximum magnitude of relative sensitivity of travel time to OC_a approaches unity under these particular simulation constraints.

The relative sensitivity of retardation factor to OC_b can be expressed as

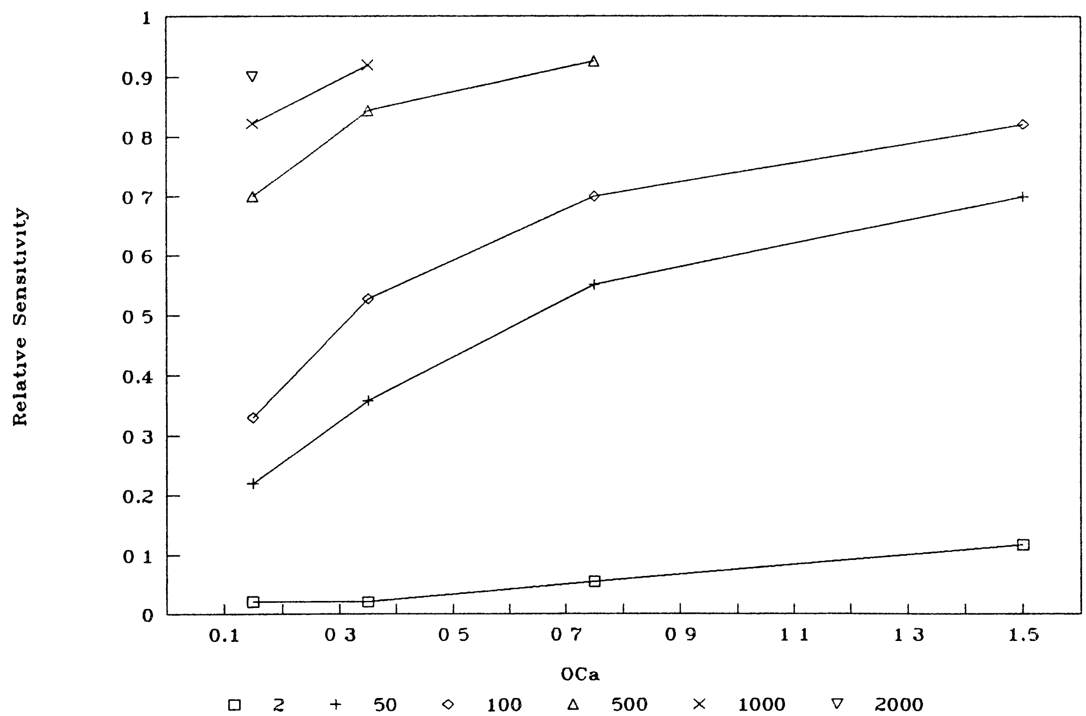

Figure 8. Relative Sensitivity of Travel Time to OC_a at Different K_{oc} (OC_b=1)

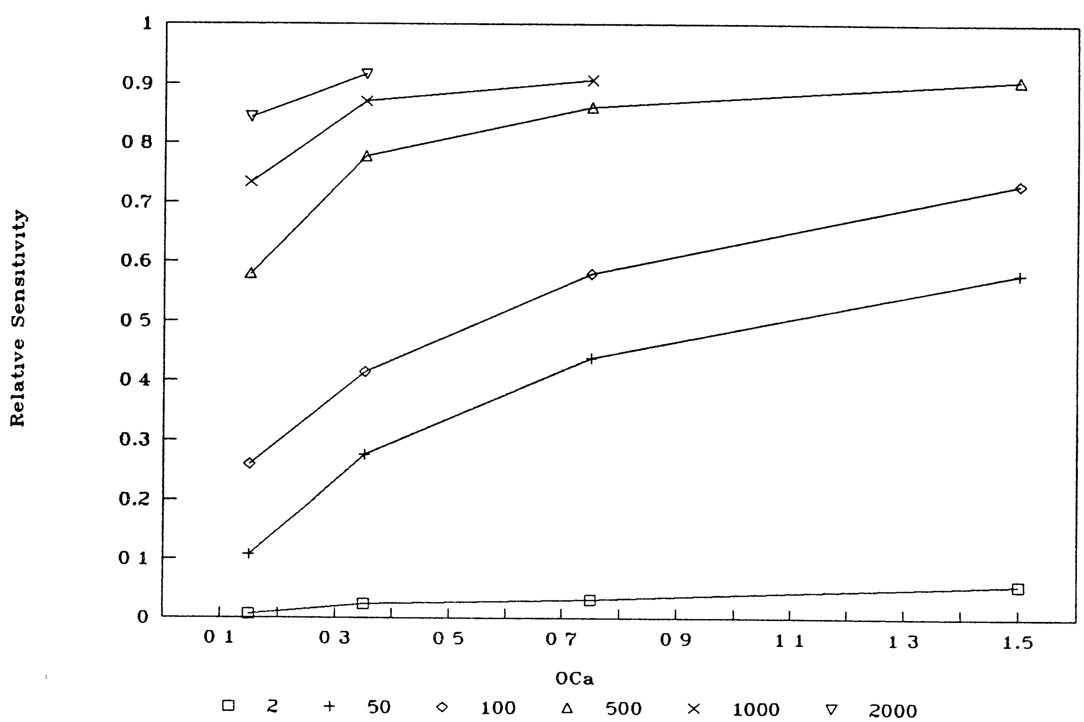

Figure 9. Relative Sensitivity of Travel Time to OC_a at Different K_{oc} (OC_b=2)

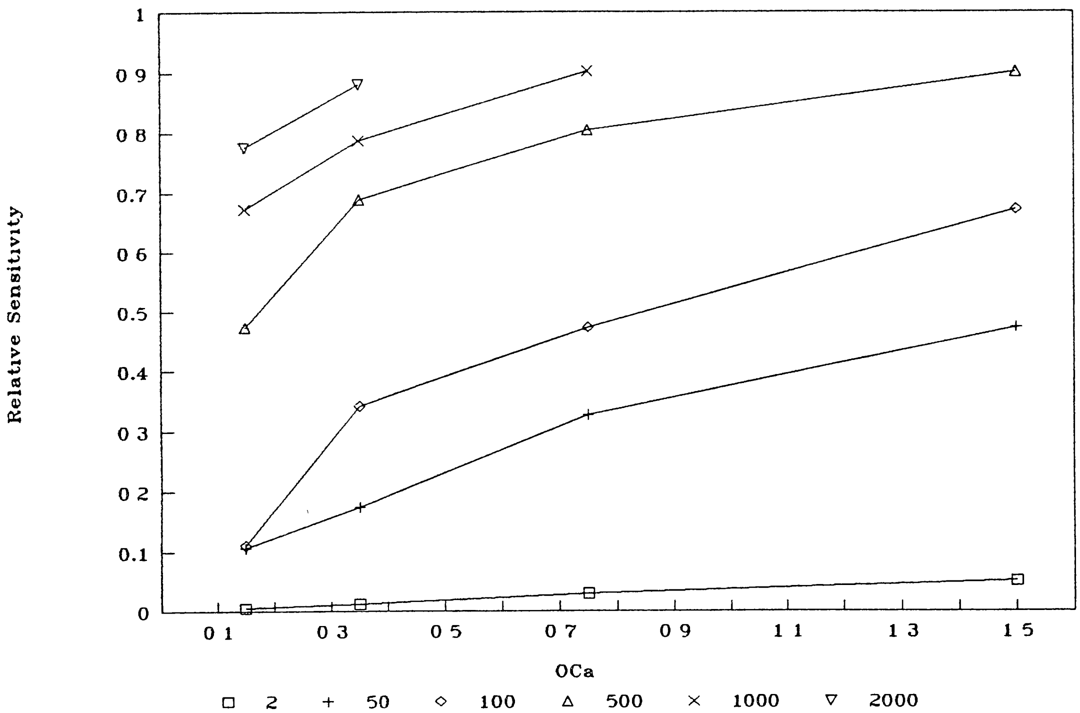

Figure 10. Relative Sensitivity of Travel Time to OC_a at Different K_{oc} (OC_b=3)

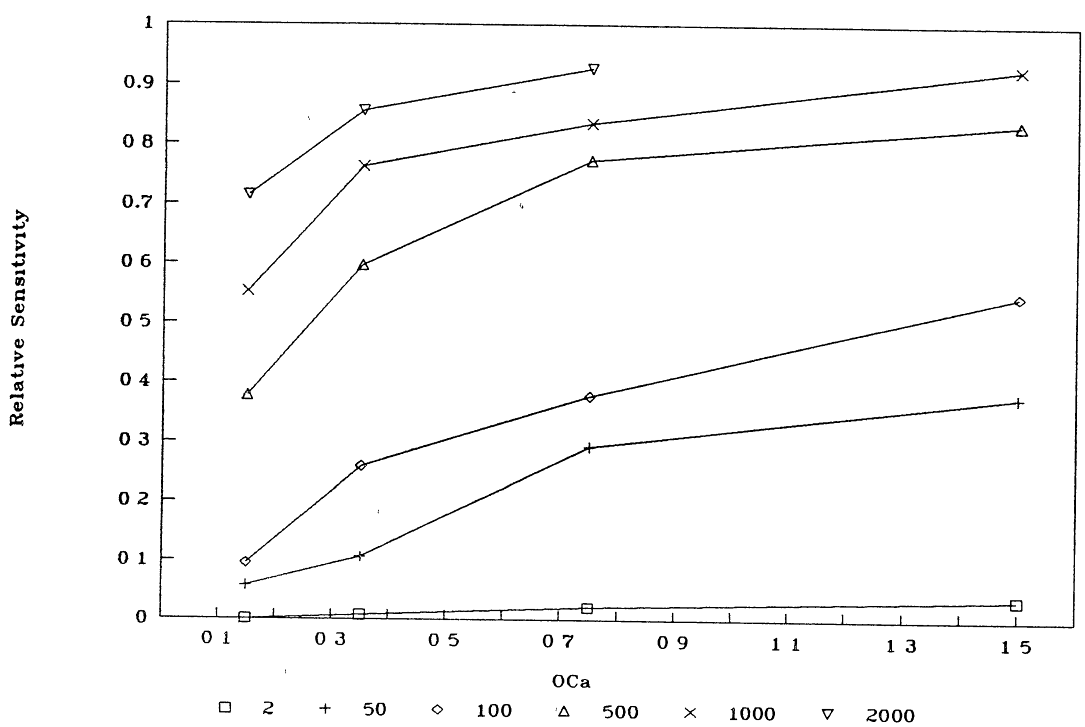

Figure 11. Relative Sensitivity of Travel Time to OC_a at Different K_{oc} (OC_b=4)

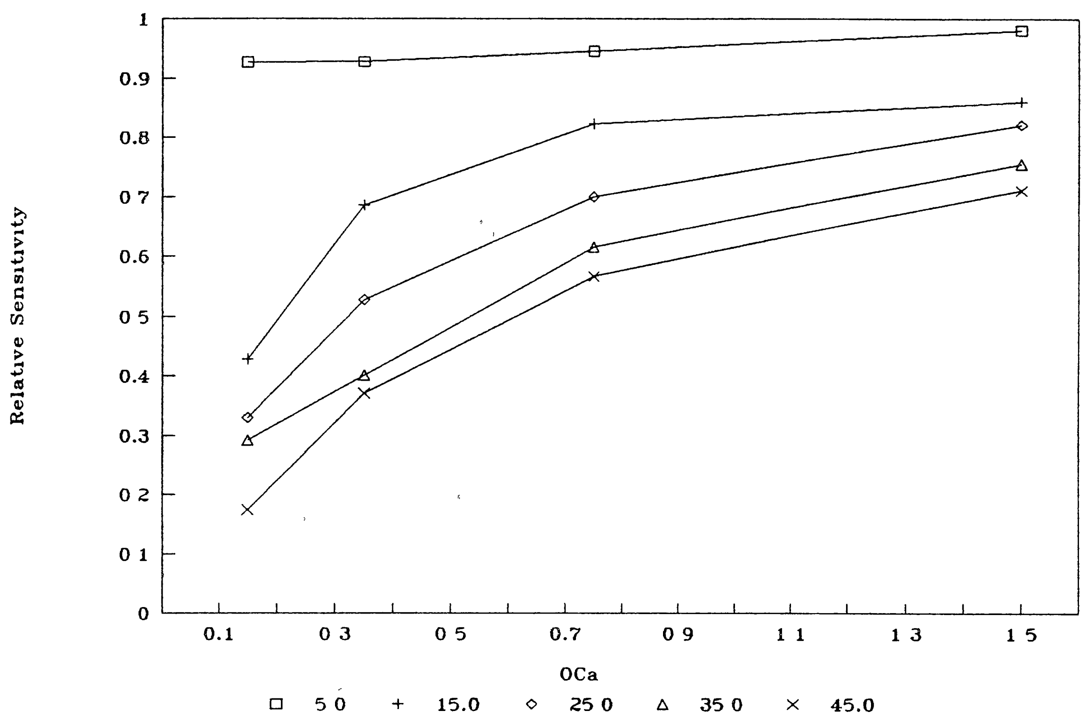

Figure 12. Relative Sensitivity of Travel Time to OC_a at Different Field Capacity

$$S_{OC_b} = \frac{\partial R}{\partial OC_b} \cdot \frac{OC_b}{R}$$

$$= -\ [BD \cdot K_{oc} \cdot OC_a \cdot depth \cdot EXP(-OC_b \cdot depth)]/FC \cdot \frac{OC_b}{R} \qquad (5.8)$$

Here the sensitivity value is negative, indicating that increasing OC_b decreases the retardance. In comparing relative sensitivity, the absolute value should be used since a relative sensitivity of +1 and -1 indicates the same level of change in response only in opposite directions. Equation 5.8 explicitly states that the relative sensitivity of retardance to OC_b is directly proportional to K_{oc}, bulk density, and OC_a, but inversely proportional to field capacity. Similar relationships were also confirmed for sensitivity of travel time by the Monte Carlo simulations. Figures 13 through 18 illustrate that the sensitivity increases with K_{oc} and OC_a, but decreases with field capacity. Parameter OC_a for organic carbon content was incremented from 0.1 in Figure 13 to 2.0 in Figure 17. OC_a in Figure 18 is 2.0. Other parameters are BD=1.4 g/cm^3, FC=25%, PWP=16%.

Figures 13 through 17 demonstrate some irregular perturbations which demand further explanation. The main problem is that the relative sensitivity may increase or decrease with OC_b value. Figures 13 to 17 reveal that generally the relative sensitivity of travel time to OC_b decreases with OC_b when K_{oc} is low. This trend was gradually reversed when K_{oc} gets high. Equation 5.8 reveals that the impact of OC_b on the relative sensitivity of R is not as straight forward as other parameters. Consider a subset of Equation 5.8 whose parameters (OC_b and depth) affect relative sensitivity of R to OC_b

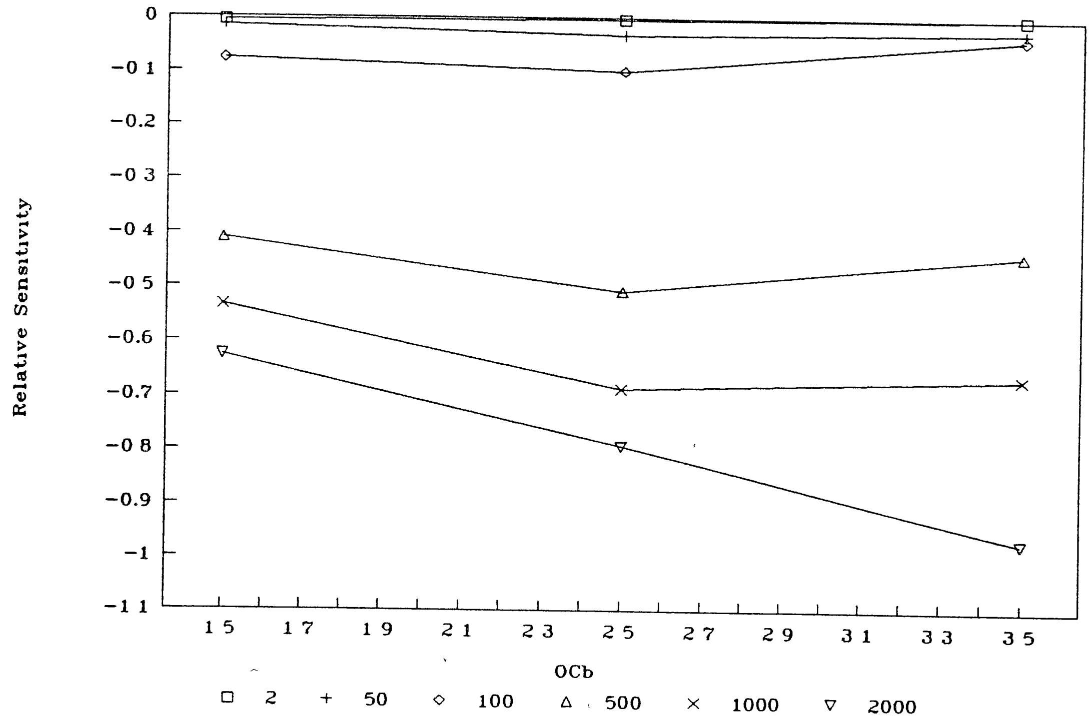

Figure 13. Relative Sensitivity of Travel Time to OC_b at Different K_{oc} (OC_a=0.1)

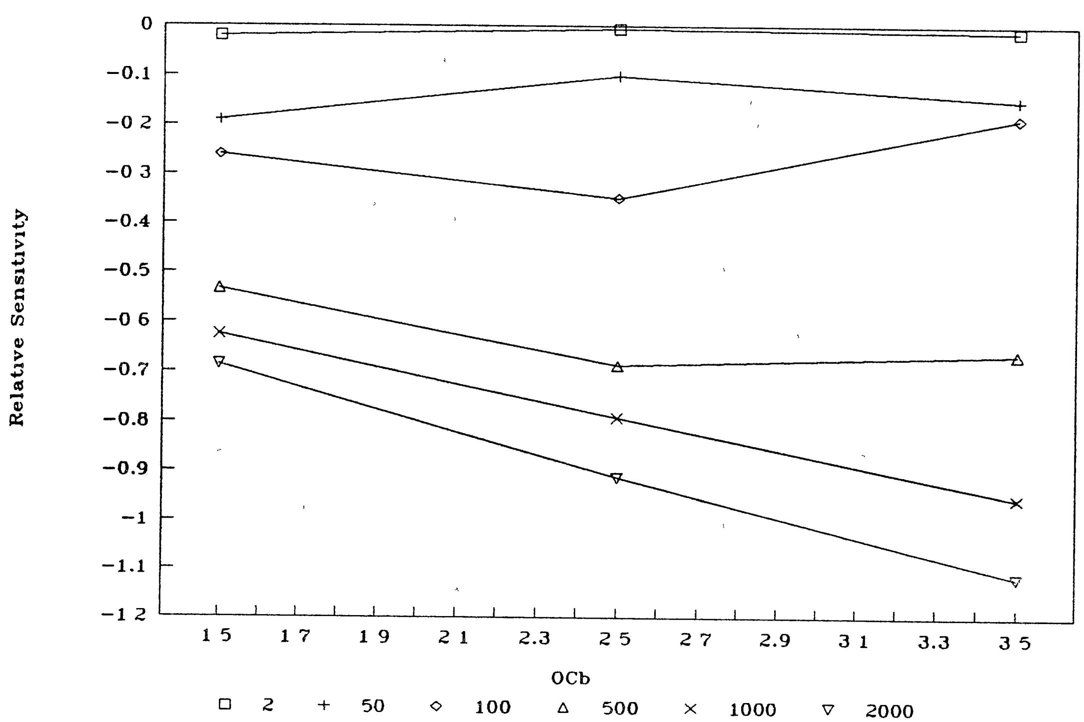

Figure 14. Relative Sensitivity of Travel Time to OC_b at Different K_{oc} (OC_a=0.2)

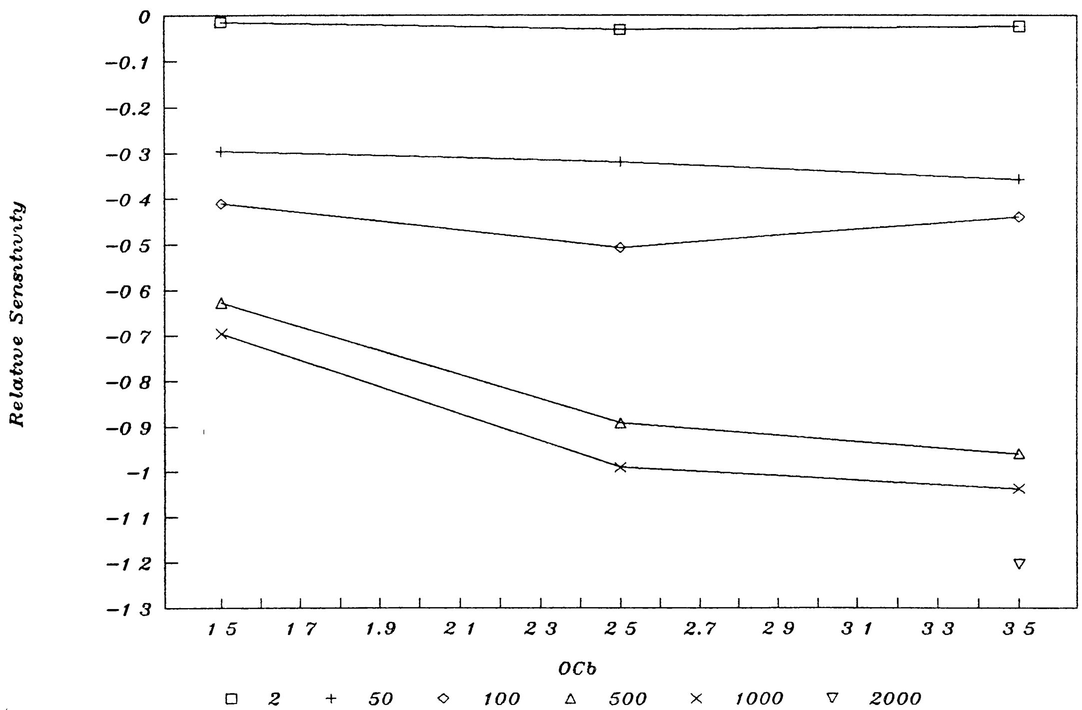

Figure 15. Relative Sensitivity of Travel Time to OC_b at Different K_{oc} (OC_a=0.5)

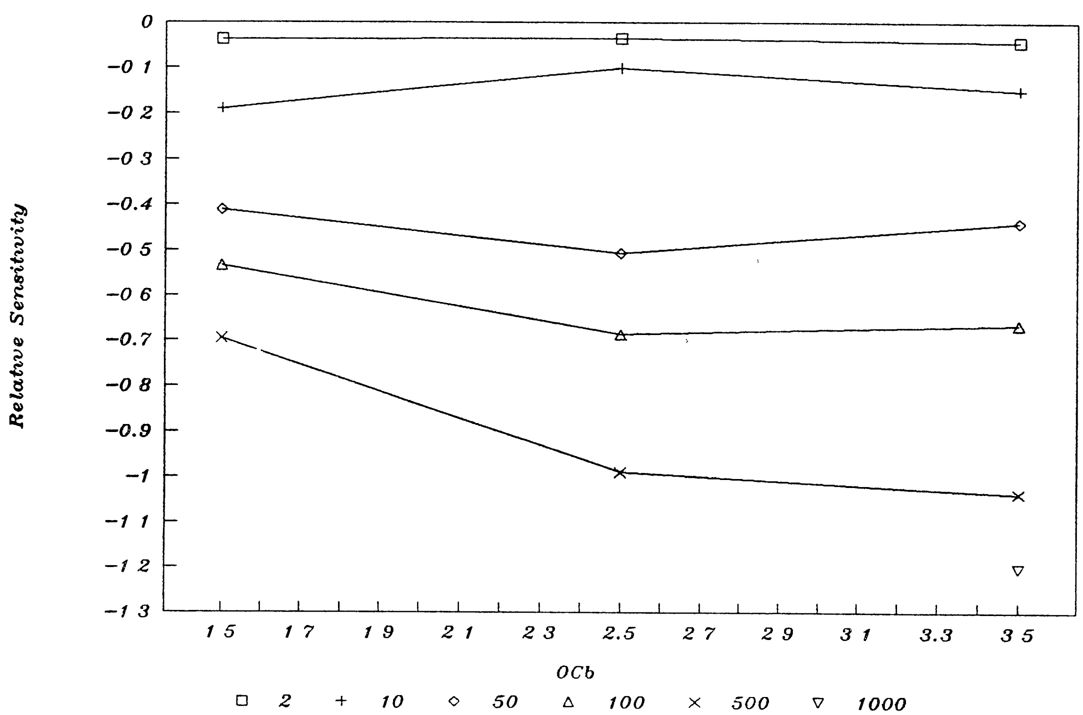

Figure 16. Relative Sensitivity of Travel Time to OC_b at Different K_{oc} (OC_a=1.0)

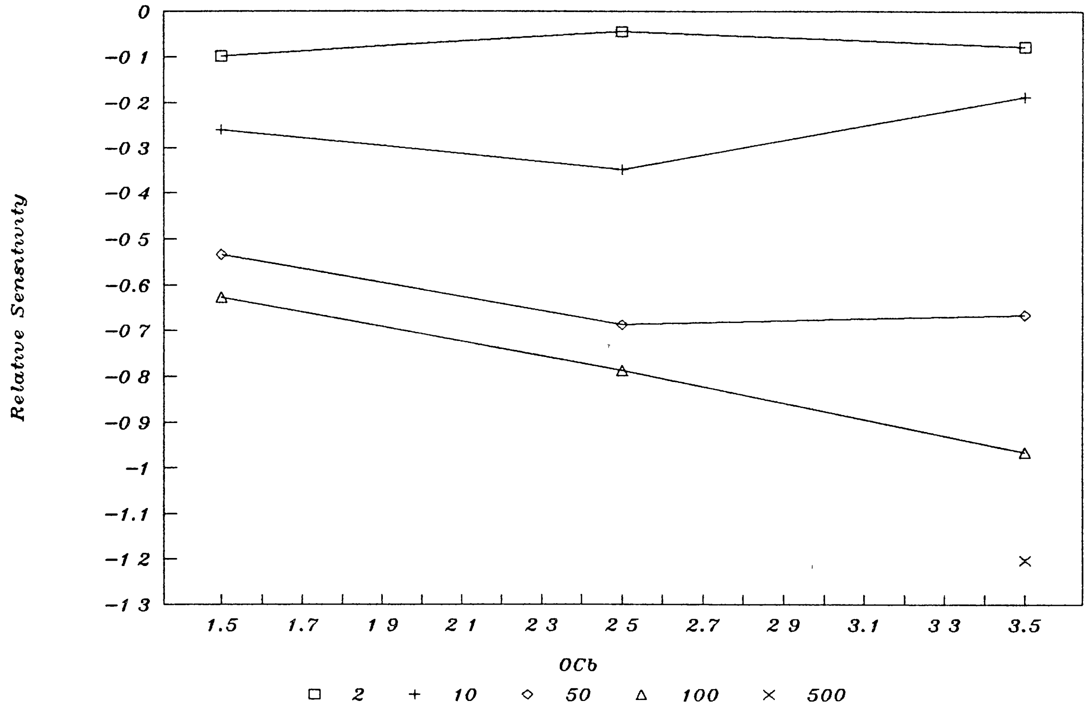

Figure 17. Relative Sensitivity of Travel Time to OC_b at Different K_{oc} (OC_a=2.0)

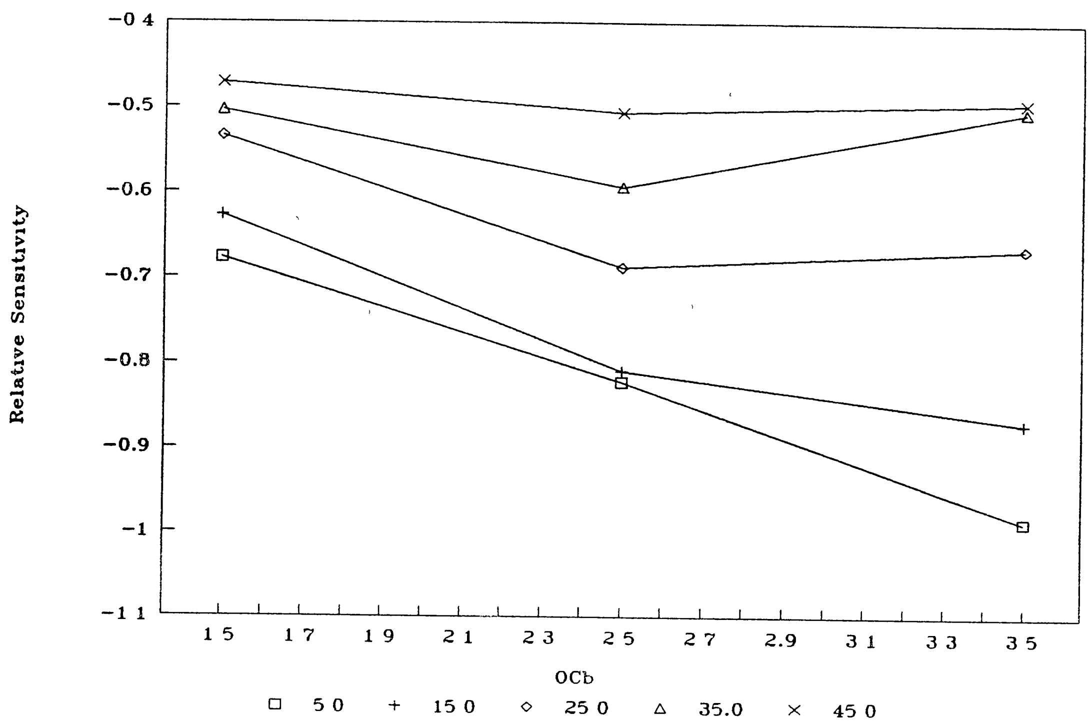

Figure 18. Relative Sensitivity of Travel Time to OC_b at Different Field Capacity

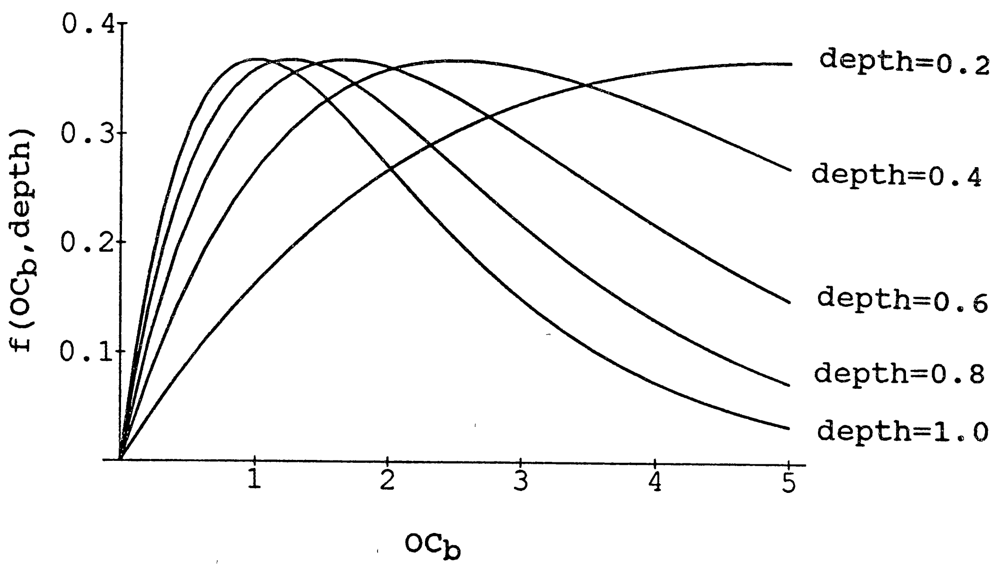

Figure 19. Equation 5.9 at Different Depth

$$f(OC_b, \text{depth}) = \text{depth} \cdot OC_b \cdot EXP(-\text{depth} \cdot OC_b) \quad (5.9)$$

This function is shown in Figure 19. OC_b was taken from zero to five and depth was fixed at 0.2, 0.4, 0.6, 0.8 and 1.0 M, respectively. It is apparent that the function always increases first, reaches a maximum, then decreases. The maximum value of the function shifts towards smaller OC_b as depth increases. The location of the function maximum can be found by differentiating Equation 5.9 with respect to OC_b and setting the result equal to zero. The resulting expression is

$$OC_b = 1/\text{depth} \quad (5.10)$$

For instance, when depth equals 0.8 m, the function reaches its maximum when OC_b is 1/0.8 = 1.25.

This is one of the causes of the irregular perturbations in Figures 13 through 18. First look at the scenario when K_{oc} is small. The retardance to chemical movement is also small. As the chemical moves deeper, it gets adsorbed in deeper soil layers. This prompts one to consider those curves in Figure 19 with larger values of depth. It is obvious that these curves reach their peaks at lower OC_b values and soon start to decrease. Consider the curve in Figure 19 when depth is 1.0m. It is shown that the function (Equation 5.9) reaches its maximum value when OC_b is 1. The function then decreases as OC_b increases from 1 to 5. Since the function (Equation 5.9) resembles the relative sensitivity of travel time to OC_b, the relative sensitivity to OC_b should also decrease in this case as OC_b increases from 1 to 5. In Figures 13 to 18 when relative sensitivity decreases as OC_b increases, K_{oc} is usually small. In that case it is likely that the peak of the relative sensitivity has been passed on those curves. What was shown in these curves are analogous to the subsiding part of the Figure 19. Therefore the influence (and thus the relative sensitivity) of OC_b decreased as OC_b increases.

Now consider those curves in Figure 19 when depth is small. Take depth 0.2m as an example, the maximum relative sensitivity value occurs when OC_b equals 5. If one looks only at the part of the function when OC_b increases from 1 to 5, the function (so is the relative sensitivity) increases as well. The reason being that the peak of the function is yet to be reached. Similarly when the relative sensitivity in Figures 13 to 18 increases as OC_b increases, K_{oc} is large. Consequently, the peak of the relative sensitivity is yet to be reached on those curves. What was shown in these curves are analogous to the rising part of the Figure 19. As a result, the relative sensitivity of travel time to OC_b increased as OC_b increases. It is understood that more data points in Figure 13 through 18 are probably needed to substantiate above arguments. Most curves in Figure 13 through Figure 18 are nevertheless in accordance with the trend described.

Sensitivity of Travel Time to FC, PWP and AWC

Field capacity influences the adsorption process (Equation 5.3) and the redistribution process (Equation 5.2) of infiltrating water. It is therefore necessary to consider both processes in evaluating its impact on chemical transport. Substituting Equation 5.3 into Equation 5.2 and differentiating with respect to field capacity yields an expression that aids in interpreting relative sensitivity of chemical travel time to field capacity (S_{FC})

$$\Delta d_s = q/[FC + BD \bullet K_{oc} \bullet OC_a \bullet EXP(-OC_b \bullet depth)] \quad (5.11)$$

$$S_{FC} = \frac{\partial \Delta d_s}{\partial FC} \bullet \frac{FC}{\Delta d_s}$$

$$= - q/[FC + BD \bullet K_{oc} \bullet OC_a \bullet EXP(-OC_b \bullet depth)]^2 \bullet \frac{FC}{\Delta d_s} \quad (5.12)$$

Assuming travel time is directly related to Δd_s, equation 5.12 enables a qualitative interpretation between the relative sensitivity of chemical travel time to field capacity and some CMLS parameters. The relative sensitivity of travel time to field capacity increases with increases in organic carbon parameter OC_b, but decreases with increases in K_{oc}, bulk density, and organic carbon parameter OC_a. Field capacity appears in the denominator in Equation 5.2 and Equation 5.3. The smaller the numerator, the more important (or sensitive) the denominator should be in a relative sense. Results of the Monte Carlo simulations confirm the above relationships. Figures 20 through 22 are plots of relative sensitivity of travel time to field capacity with different K_{oc} and OC_a values. Figure 23 is plot of relative sensitivity of travel time to field capacity with different OC_b values.

It is not straight forward to obtain an explicit interpretation between the relative sensitivity of travel time to field capacity and field capacity values from Equation 5.12 since FC appears in both the numerator and denominator. Figures 20 through 23 suggest a slight increase in relative sensitivity of travel time to field capacity as field capacity increases. It is difficult to find general support for this statement due to the scarcity of data points at the same available water capacity. Parameter OC_a for organic carbon content was

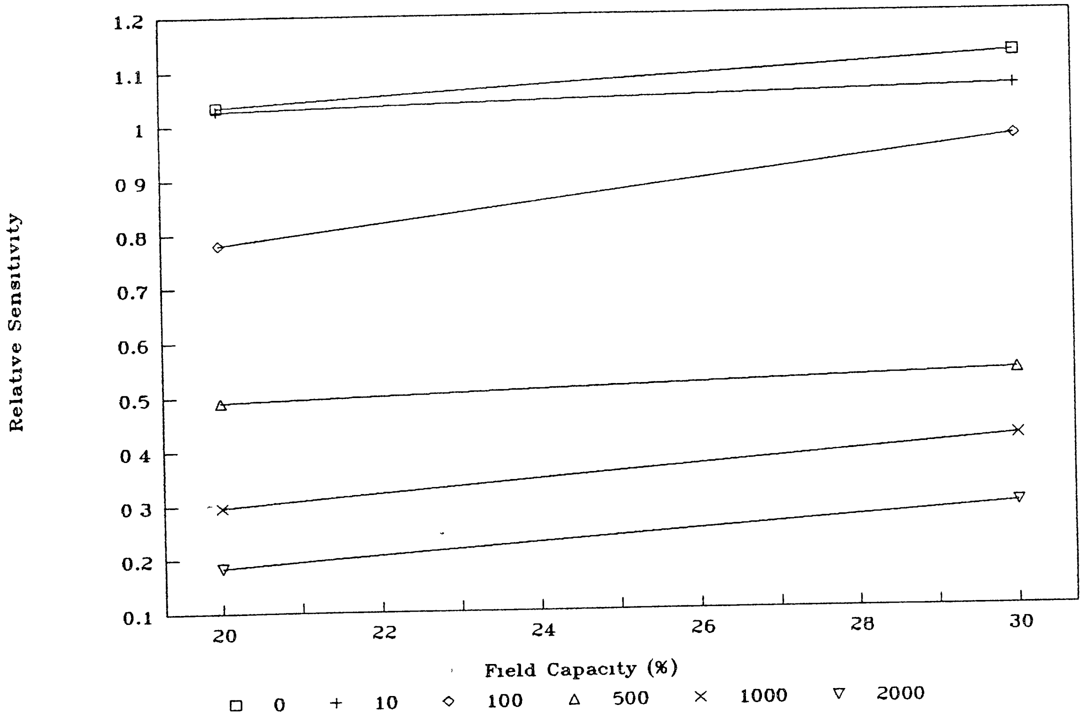

Figure 20. Relative Sensitivity of Travel Time to Field Capacity at Different K_{oc} (OC_a=0.1)

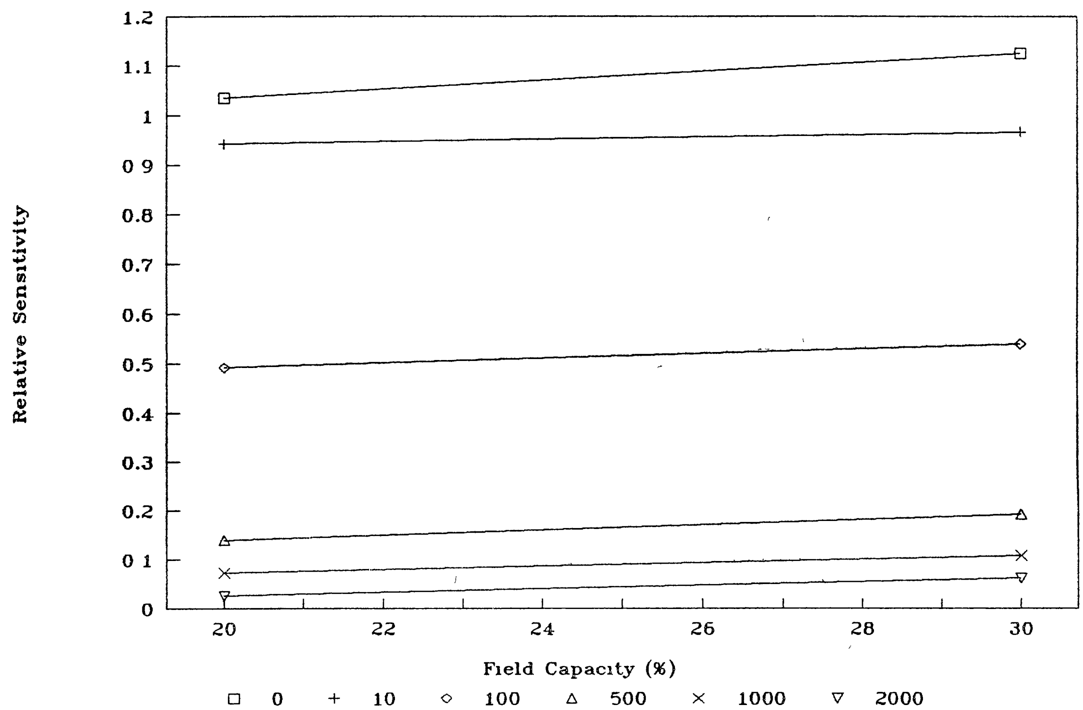

Figure 21. Relative Sensitivity of Travel Time to Field Capacity at Differen: K_{oc} (OC_a=0.5)

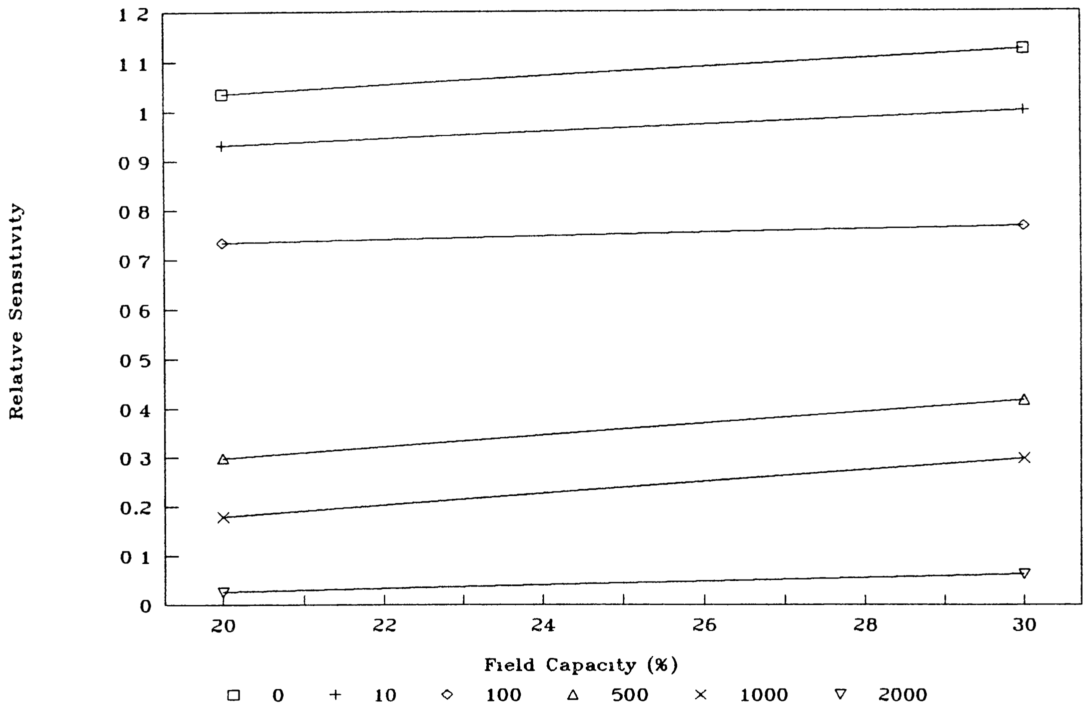

Figure 22. Relative Sensitivity of Travel Time to Field Capacity at Different K_{oc} (OC_a=2.0)

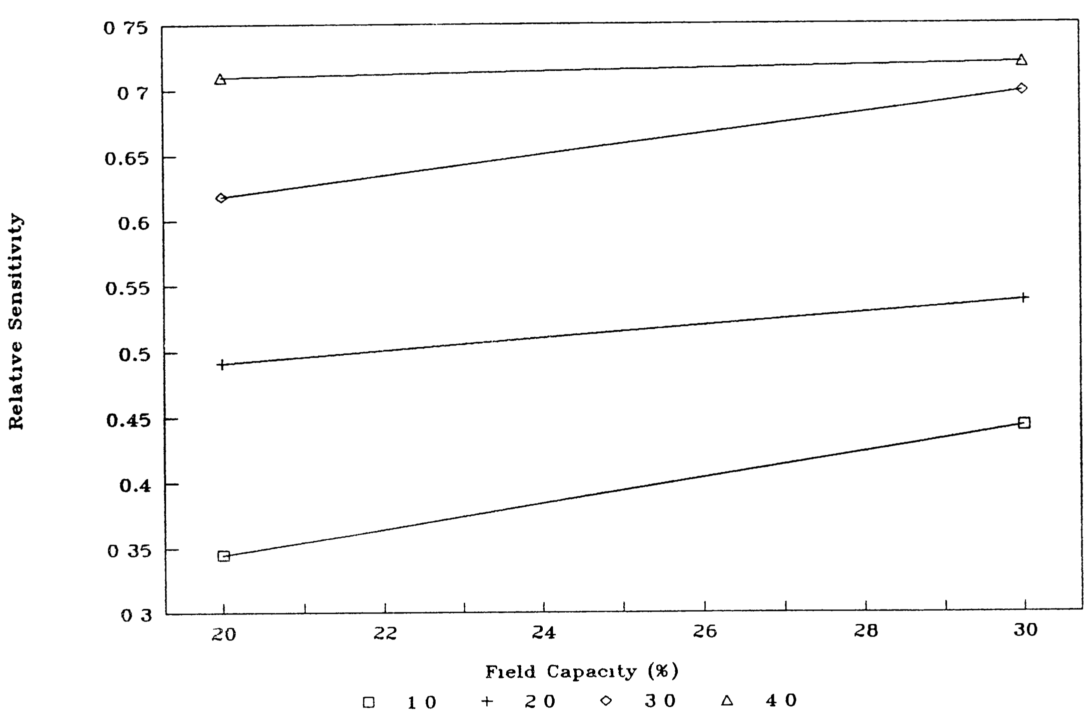

Figure 23. Relative Sensitivity of Travel Time to Field Capacity at Different OC_b

Another group of parameters is field capacity, permanent wilting point, and available water capacity, although the last one is not identified as an input to the CMLS model. They influence how much infiltrating water is available for chemical transport. This study showed that chemical travel time is less sensitive to these parameters. The plots of the relative sensitivity of travel time to field capacity are influenced more by the other parameter values (such as K_{OC}) than by the value of field capacity. The available water capacity gives the highest relative sensitivity value in this study. By definition, it is inherently impossible to fix field capacity and permanent wilting point at constant levels and vary available water capacity. Therefore, those relative sensitivity values to available water capacity can not be directly compared with those of other parameters.

It is also possible to consider those two groups of the CMLS parameters at the same time. One way of achieving this is to compute relative sensitivity of travel time directly from the retardation factor defined in Equation 5.3. Equation 5.3 includes all the previously discussed parameters except that field capacity appears elsewhere in Equation 5.2 as well. Figure 36 is such a plot with field capacity as curve parameter. It agrees with the previous discussion that relative sensitivity to retardation factor increases as the retardation factor increases. It is also not surprising to see that the relative sensitivity is not very sensitive to field capacity.

The interpretations on these parameter sensitivities are meaningful only when other parameter values are also considered. The results clearly show that any CMLS parameter has its more sensitive and less sensitive ranges, depending upon not only the parameter value, but

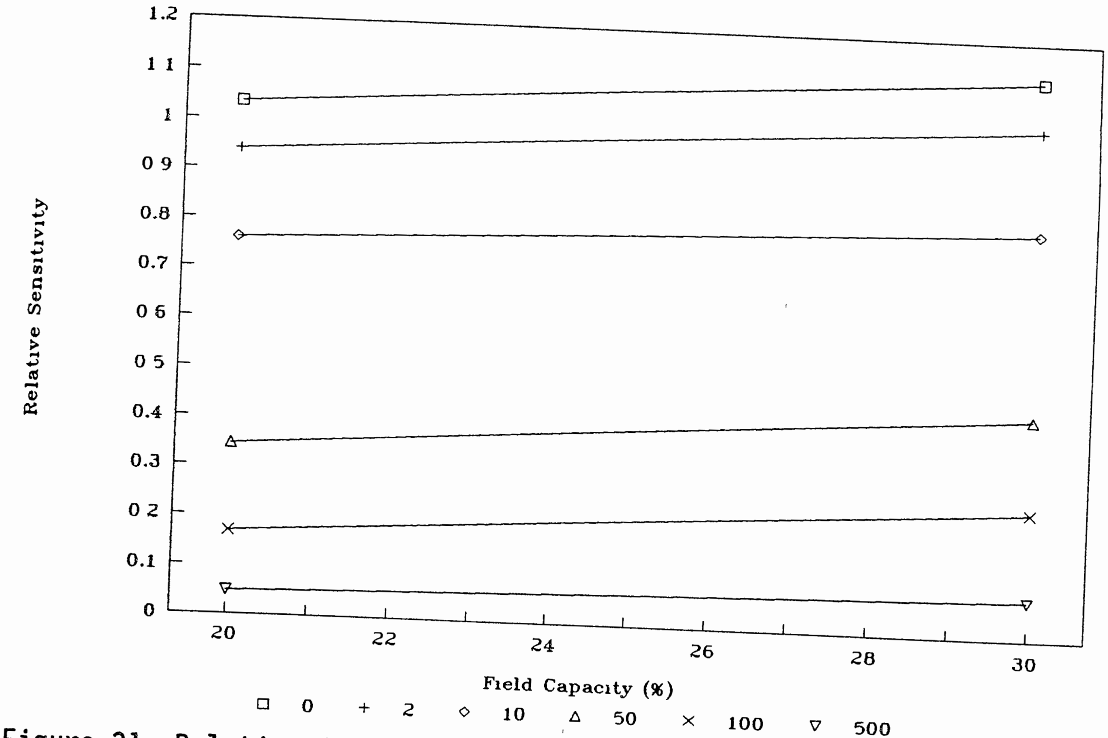

Figure 31. Relative Sensitivity of Travel Time to Field Capacity at Different K_{oc}

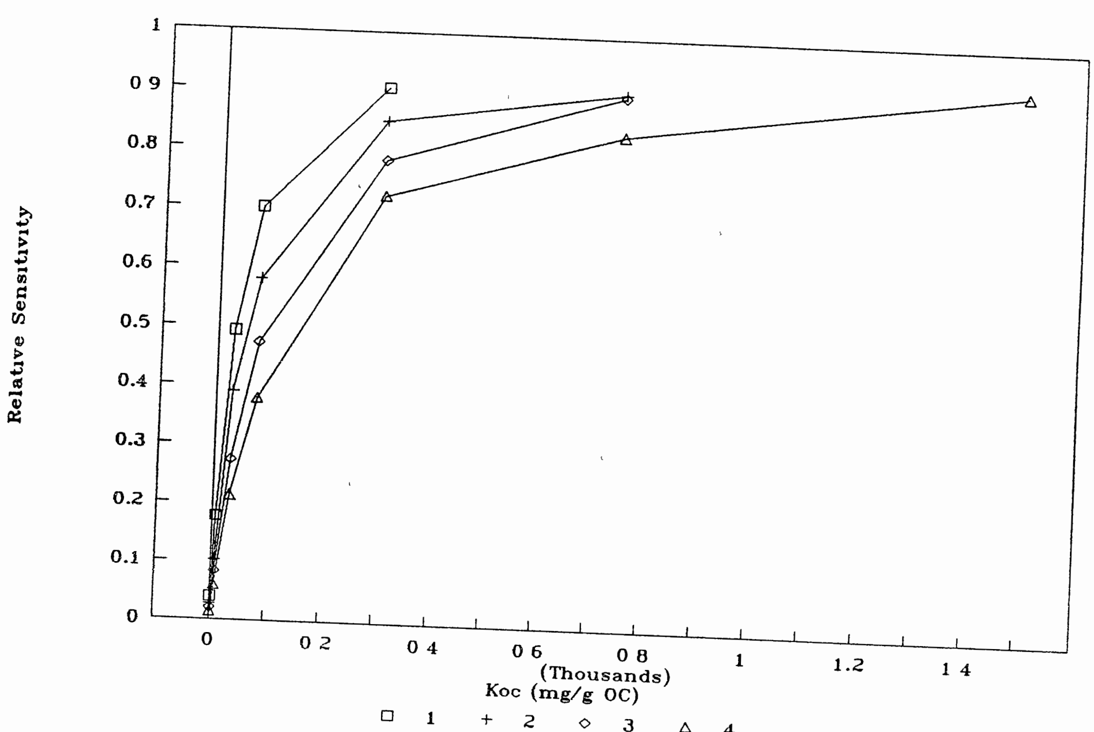

Figure 32. Relative Sensitivity of Travel Time to K_{oc} at Different OC_b

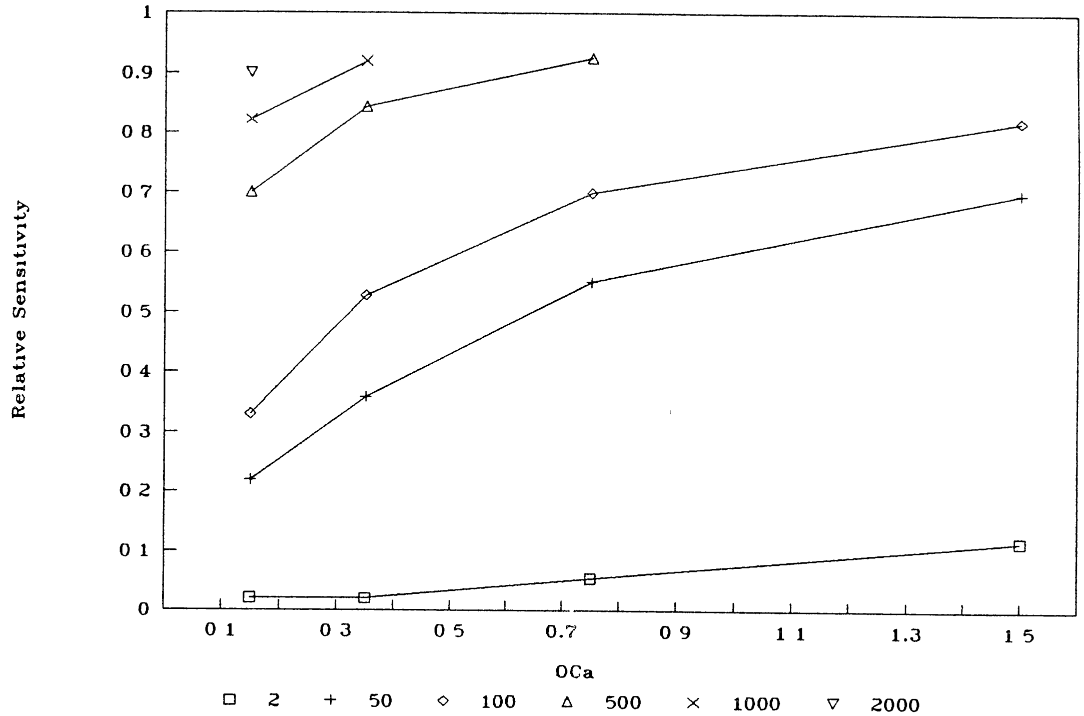

Figure 33. Relative Sensitivity of Travel Time to OC_a at Different K_{oc}

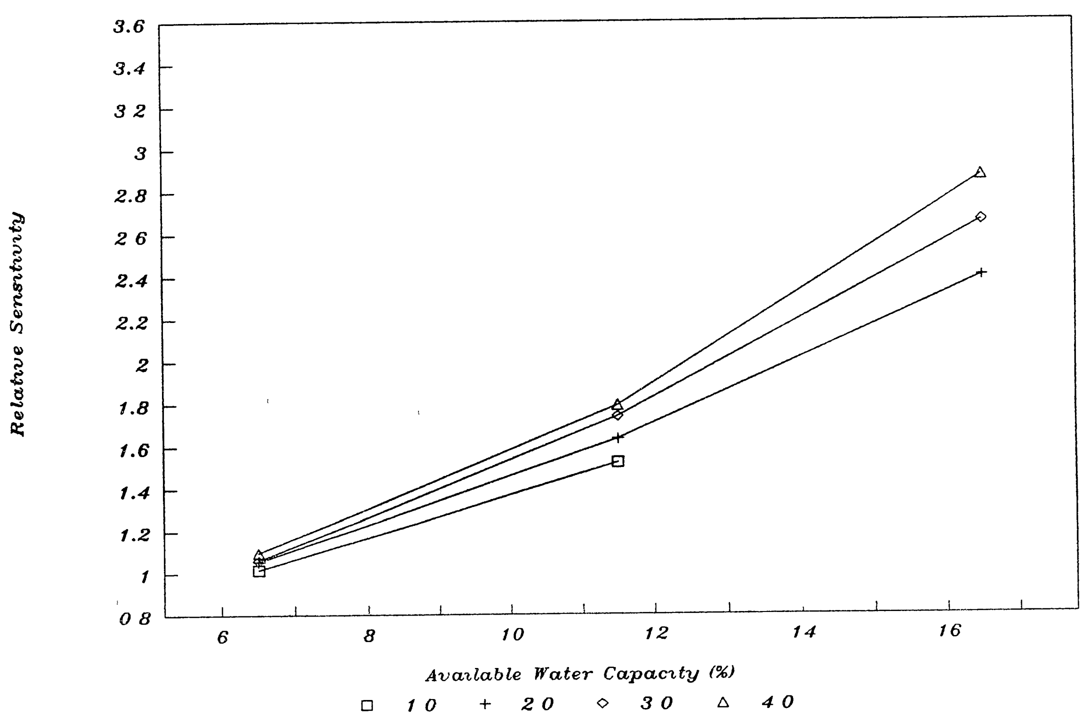

Figure 34. Relative Sensitivity of Travel Time to Available Water capacity at Different OC_b

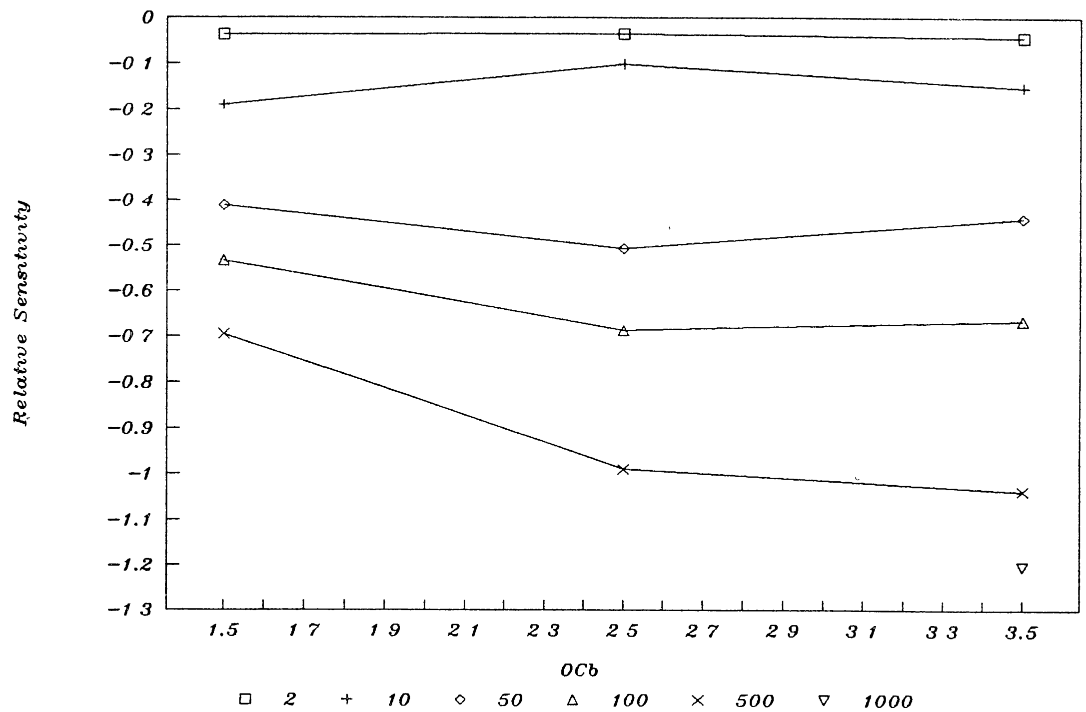

Figure 35. Relative Sensitivity of Travel Time to OC_b at Different K_{oc}

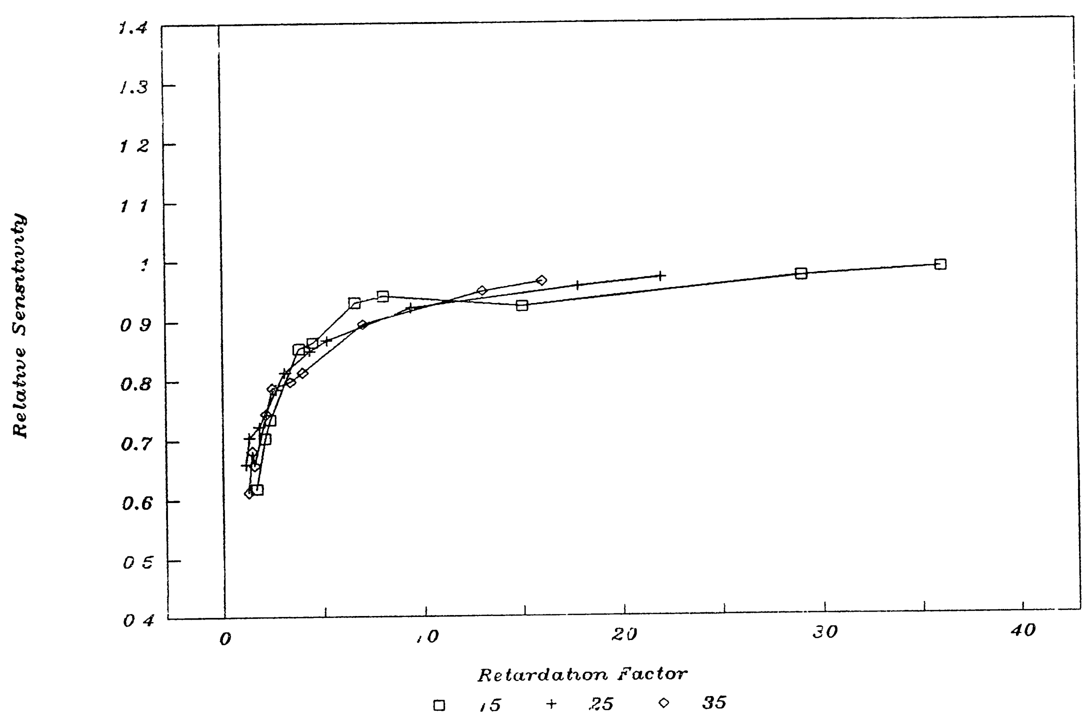

Figure 36. Relative Sensitivity of Travel Time to R at Different FC

also the other parameter values. Consider the following soil and chemical properties. BD=1.4 g/cm^3, FC=25%, WP=16%, OC_a=1.0, OC_b=1.0, K_{oc}=100mg/g OC. Figures 31 through 35 were generated incorporating these parameter values. It is then possible to read the relative sensitivity values directly off these plots. Figure 24 is also used to obtain the relative sensitivity to PWP. Extrapolation of Figure 35 is attempted to estimate the relative sensitivity to OC_b at 1.0. The resulting relative sensitivity value is similar to that for FC. Therefore, the comparison of relative sensitivity between FC and OC_b is inconclusive. The following rankings on all the CMLS parameters in terms of chemical travel time were made according to the relative sensitivity values from the plots.

$$OC_a = K_{oc} = BD > OC_b \approx FC > PWP$$

CHAPTER VI

UNCERTAINTY ANALYSIS

The stochastic or probability density function (PDF) approach described in chapter two was used to study the uncertainty in estimated chemical transport. Specifically, the uncertainty was caused by the natural variability in the CMLS parameters, the natural variability in precipitation, and the uncertainty due to the combination of the two sources of variability. These sources of uncertainty were studied individually. The general procedures and the results of these uncertainty analyses are presented in this chapter.

Data Generation Procedures for CMLS Parameter Uncertainty

The soil properties summarized in Table 1 are based on several soil types and soil layers. The resulting variability is inevitably large but is adequate to define the expected parameter range for sensitivity studies. On the other hand, uncertainty analysis using the PDF approach requires that the joint probability distribution of the input parameters be representative of the particular soil of interest. For a given soil, it further requires multiple soil samples to reasonably define a joint probability distribution of all the soil parameters. This information is not available for this study. Instead, the soil properties used were pooled from both observed topsoil properties and values suggested in the literature. The results presented here are qualitative and independent of any particular soil.

Table 3 gives the soil properties used in the uncertainty analysis. The means of the four CMLS soil parameters were computed based on all the topsoil layers of all the soil types. The soil types considered are same as those for Table 1. The coefficient of variation of these soil properties were selected from the report of Jury (1986) as representative for a single soil type. Figure 37 through Figure 40 are plots of the frequency distribution of the four CMLS parameters from the topsoil layers across soil types. It can be seen that most of the parameters can be reasonably represented by lognormal distribution. Strictly speaking, the frequency distribution of these soil properties are not known for any given soil. A joint lognormal distribution was assumed.

The parameter mean and standard deviation in Table 3 were then transformed to the mean and standard deviation of the logarithms of the data. The transformation equations were given by Chow (1954):

$$\mu_{ln} = 0.5 \ln[\mu^2/(C_v^2+1)] \tag{6.1}$$

$$S_{ln} = [\ln(C_v^2+1)]^{1/2} \tag{6.2}$$

where

μ and C_v are mean and coefficient of variation of the untransformed data, respectively.

μ_{ln} and S_{ln} are mean and standard deviation of the

TABLE 3

SOIL PROPERTIES USED FOR UNCERTAINTY ANALYSIS

	BD	PWP	FC	OC_a
OBSERVED MEAN OF TOPSOIL LAYER	1.489	10.080	21.487	1.204
C.V. (Jury, 1986)	0.07	0.30	0.20	0.30
ST. DEV. COMPUTED	0.104	3.024	4.297	0.361

CORRELATION MATRIX (BASED ON ORIGINAL DATA)

	BD	WP	FC	OC_a
BD	1.000			
WP	-0.065	1.000		
FC	-0.148	0.869	1.000	
OC_a	-0.290	0.352	0.294	1.000

LOG MEAN	0.39566	2.26746	3.04784	0.14256
LOG ST. DEV	0.06991	0.29356	0.19804	0.29356

CORRELATION MATRIX (BASED ON LOGARITHM TRANSFORMED DATA)

	BD	WP	FC	OC_a
BD	1.000			
WP	-0.183	1.000		
FC	-0.188	0.833	1.000	
OC_a	-0.321	0.539	0.390	1.000

COMPONENT LOADINGS (BASED ON LOGARITHM TRANSFORMED DATA)

	1	2	3	4
BD	-0.432	0.843	-0.318	0.021
WP	0.913	0.286	0.073	-0.282
FC	0.863	0.326	0.299	0.246
OC_a	0.738	-0.240	-0.626	0.074

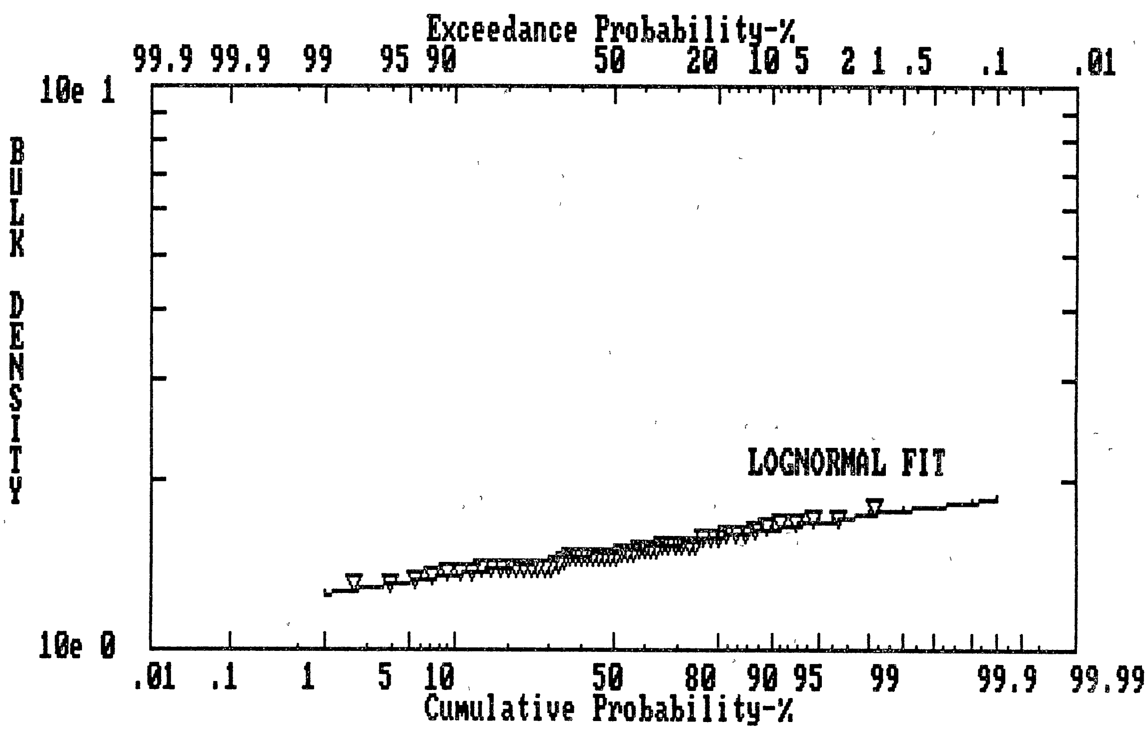

Figure 37. Distribution of Bulk Density of Topsoil Layers

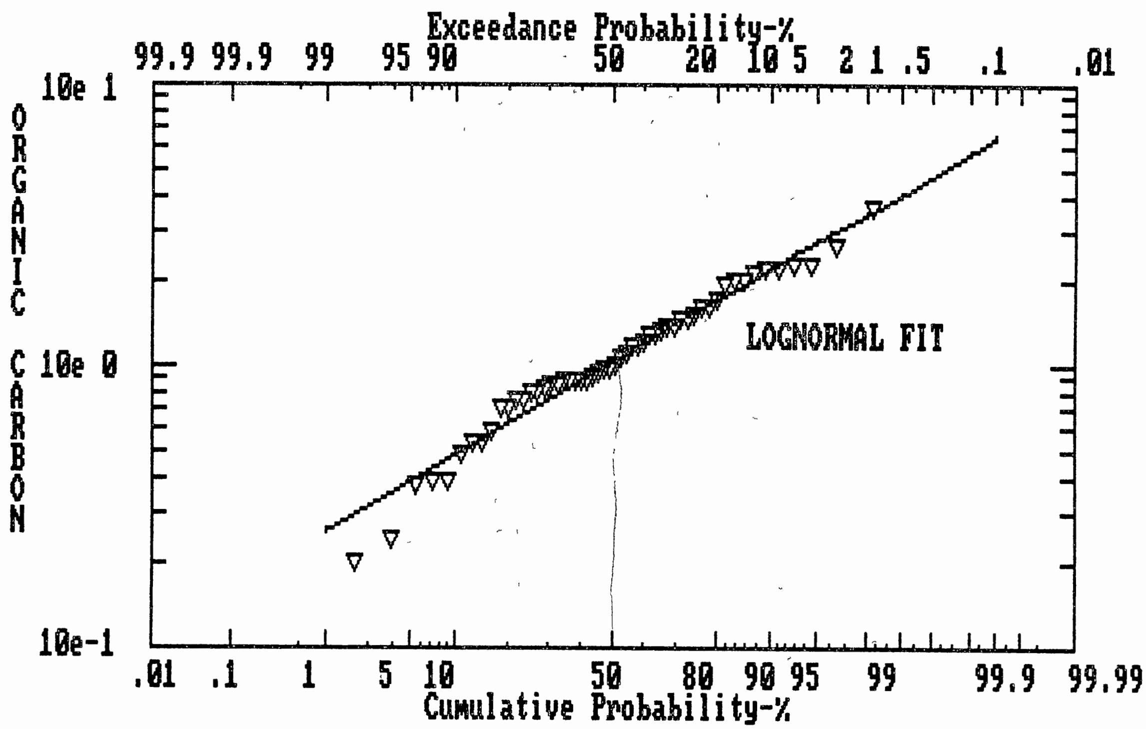

Figure 38. Distribution of Organic Carbon Content of Topsoil Layers

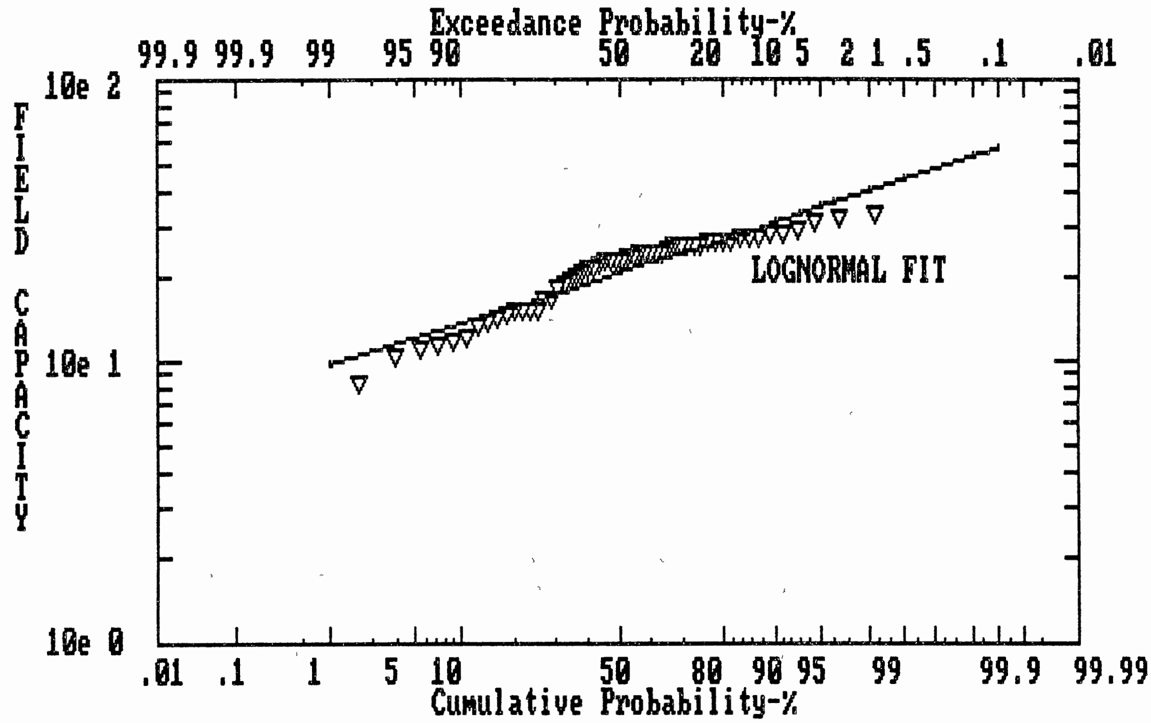

Figure 39. Distribution of Field Capacity of Topsoil Layers

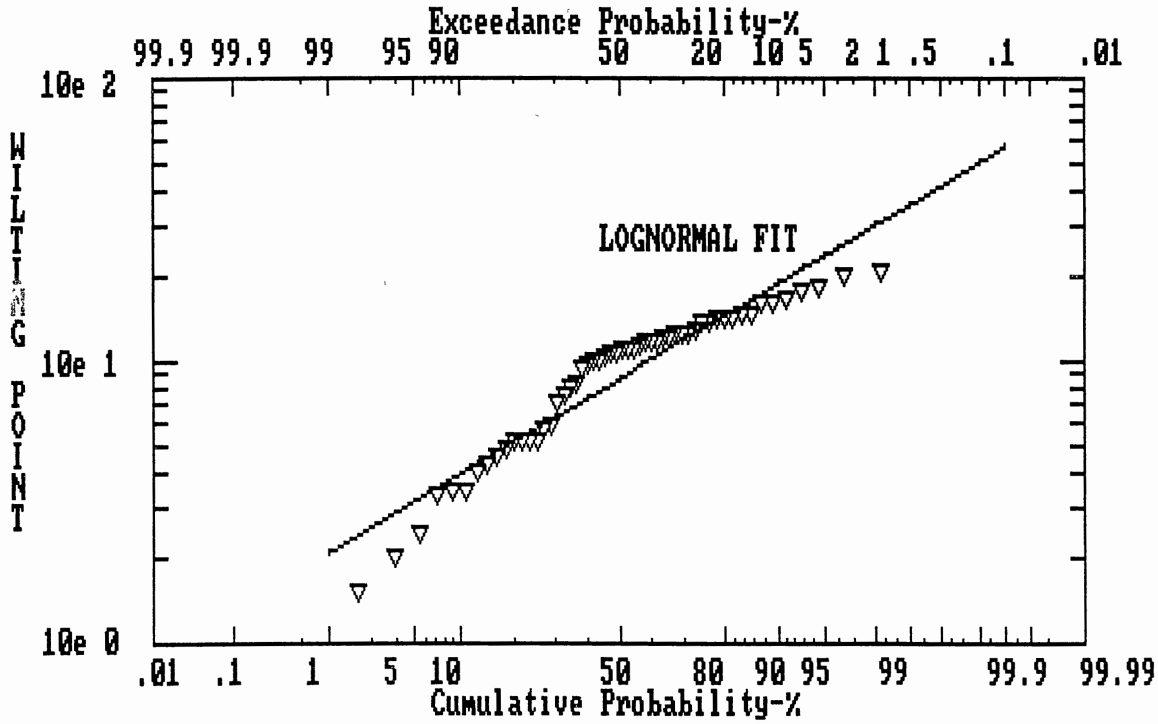

Figure 40. Distribution of Permanent Wilting Point of Topsoil Layers

logarithmically transformed data, respectively.

The first correlation matrix in Table 3 is computed based on the original data from the topsoil layers. It is used as a baseline comparison. The second correlation matrix in Table 3 is based upon the logarithmically transformed data. This correlation matrix was used to compute the principal components. These principal components were then used to generate a multivariate lognormal distribution. The procedure used to generate multivariate lognormal variables is given by Haan (1977). Appendix D is a listing of the computer program which implemented this procedure.

One thousand pseudo soil profiles were generated in this analysis. The procedures preserved both the mean and the correlation of the original data. The quality of the generated CMLS parameters are demonstrated in Table 4. The sample statistics and correlation matrices in Table 4 are very close to those in Table 3. All pseudo soil profiles in this analysis were assumed to be composed of five layers of equal thickness. Bulk density, field capacity, and permanent wilting point were assumed constant over depth. Equation 4.1, with OC_b taken as 1.0, was used to determine the organic carbon content at each artificial layer:

$$OC_i = OC_0 \bullet EXP(-i)$$

where

OC_i is the organic carbon content at each depth (i=0.1, 0.3, 0.5, 0.7, 0.9m)

TABLE 4

PROPERTIES OF GENERATED SOIL DATA

	BD	PWP	FC	OC_a
N OF CASES	1000	1000	1000	1000
MEAN	1.485	10.182	21.472	1.218
STANDARD DEV	0.106	3.109	4.311	0.374
C.V.	0.071	0.305	0.201	0.307

PEARSON CORRELATION MATRIX (BASED ON GENERATED DATA)

	BD	PWP	FC	OC_a
BD	1.000			
PWP	-0.190	1.000		
FC	-0.193	0.823	1.000	
OC_a	-0.296	0.566	0.407	1.000

PEARSON CORRELATION MATRIX (BASED ON LOG TRANSFORMED DATA)

	BD	PWP	FC	OC_a
BD	1.000			
PWP	-0.196	1.000		
FC	-0.191	0.829	1.000	
OC_a	-0.305	0.567	0.408	1.000

OC_0 is the generated organic carbon content of topsoil layer from the PDF approach.

Results of Uncertainty Analysis on CMLS Parameters

The CMLS model was run on those 1000 pseudo soil profiles. The rainfall record was the actual rainfall observed in Caddo County, Oklahoma, from 1948 to 1975. The chemical travel time (in days) to one meter depth was extracted from the output to compute the sample statistics listed in Table 5. The travel time to one meter varies greatly due to the soil parameter variability. It is interesting to note that the coefficient of variation for chemical travel time is actually smaller than the largest coefficient of variation for the CMLS parameters.

TABLE 5

PROPERTIES OF CHEMICAL TRAVEL TIME TO ONE METER
DUE TO SOIL PARAMETER UNCERTAINTY

	TRAVEL TIME (DAYS)
N OF CASES	952
MINIMUM	1906.000
MAXIMUM	9949.000
MEAN	4674.053
STANDARD DEV	1398.423
SKEWNESS(G1)	1.279
KURTOSIS(G2)	2.357
C.V.	0.299

There are 952 cases where chemical reached the one meter depth by the end of the observed rainfall record. In those missing cases, longer rainfall records are needed. Analyzing only the 952 cases may bias the results as the undefined travel times are essentially ignored. The following relationships are used to correct the cumulative probability distribution:

$$P_X(X) = \frac{952}{1000} \cdot P_X^{*}(X) \quad \text{if } X \leq 10220 \text{ days} \tag{6.3}$$

$$P_X(X) = \frac{952}{1000} + \frac{48}{1000} \cdot P_X^{**}(X) \quad \text{if } X > 10220 \text{ days} \tag{6.4}$$

where

$P_X(X)$ is the corrected cumulative probability distribution for X.

$P_X^{*}(X)$ is the cumulative probability distribution for $X \leq 10220$ days.

$P_X^{**}(X)$ is the cumulative probability distribution for $X > 10220$ days.

Equation 6.3 was used to adjust the cumulative probability distribution based on $X \leq 28$ years or 10220 days. Figure 41 is a plot of the frequency distribution of the chemical travel time to one meter based on the adjusted cumulative probability distribution. Values for $X > 10220$ days are not available. The plotting positions used to make Figure 41, and the following frequency distribution plots, are included in Appendix E. The values of the estimated chemical travel time in Figure 41 are widely spread out, implying a large uncertainty in the estimated values. Without making any assumption on the probability

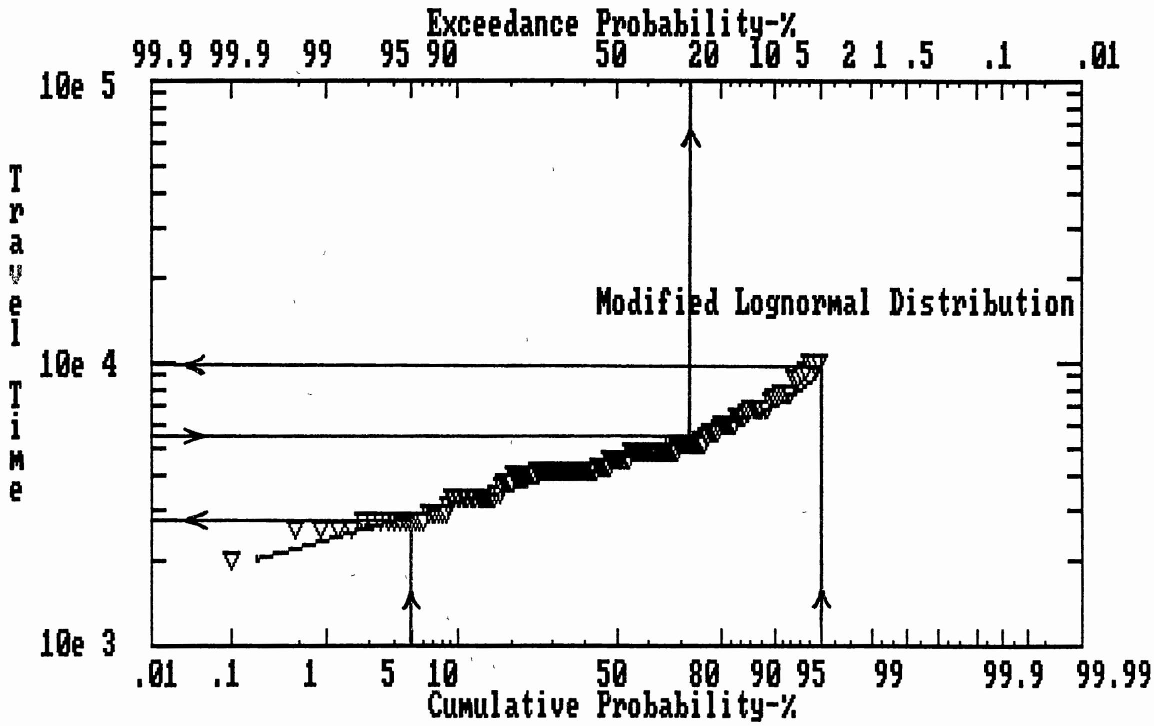

Figure 41. Distribution of Chemical Travel Time due to Soil Parameter Variability

distribution, one can empirically determine from the data for Figure 41 listed in Appendix E the probability of exceeding a given travel time and the confidence limits of a single estimate of travel time. In other words, if one relies on a single set of CMLS parameters and estimates the corresponding chemical travel time, the confidence limits (2713 days $< X <$ 9949 days) shown in Figure 41 would include this estimate 90% of the time. The clear message from this plot is that an estimate of chemical travel time based on a single set of CMLS parameters carries tremendous uncertainty. Bear in mind that the confidence limits in Figure 41 do not included the variability in natural rainfall.

Approximating the frequency distribution in Figure 41 with a known continuous distribution may simplify the representation of the uncertainty in travel time. In the case of the normal or lognormal distribution, only two parameters (mean and variance) are needed to describe the PDF. Another benefit of approximating the experimental frequency distribution is the convenience of extrapolation beyond the range of the data. For instance the 95% confidence limits of a single estimate of travel time requires extrapolating the data in the upper region of travel time in Figure 41. Such extrapolation is certainly not risk free. If the assumptions of the approximating distribution are violated, extrapolation may produce misleading results.

It appears that the distribution is better described by a lognormal distribution than by a normal distribution. Assuming a lognormal distribution for the chemical travel time, the magnitude of the chemical travel time can be calculated at any specific probability. Consider the probability of the travel time exceeding 15 years or 5475 days as an example.

Table 5 gives μ = 4674.053 days, C_v = 0.2991865. Apply Equations 6.1 and 6.2:

$$\mu_{ln} = 0.5 \ln[4674.053^2/(0.2991865^2+1)] \approx 8.407$$

$$S_{ln} = [\ln(0.2991865^2+1)]^{1/2} \approx 0.293$$

Apply the procedures described by Haan (1977),

$$Z = (\ln 5475 - 8.407)/0.293 \approx 0.686$$

and

$$P_X(X)^* = 0.7533$$

Apply Equation 6.3 to make the adjustment:

$$P_X(X) = \text{Prob}(Z < 0.686) = 0.952 \cdot 0.7533 \approx 0.7171$$

Therefore,

$$\begin{aligned}\text{Prob(travel time to one meter} > 5475 \text{ days)} &= 1 - \text{Prob}(Z < 0.686) \\ &= 1 - 0.7171 \\ &\approx 0.28\end{aligned}$$

In other words, 28% of the time, a single set of estimate for the CMLS parameters results in the chemical travel time to one meter exceeding 15 years.

Procedures of Uncertainty Analysis on Rainfall

Water is the driving force for chemical transport in soil. Rainfall and irrigation are the sources of this water. In the absence of irrigation, rainfall becomes the only source of this water. The impact of the yearly variability in rainfall on chemical transport is an additional variation superimposed upon the soil parameter variability previously discussed. The rainfall generation program mentioned in chapter three was used to produce continuous rainfall series. The parameters developed based on the observed rainfall records in Caddo County, Oklahoma, were used to drive the rainfall generation program. This rainfall generating process was repeated 1000 times on a single hypothetical soil profile. This hypothetical soil profile used the same parameter means reported in Table 3 in order to facilitate some comparison between the soil parameter uncertainty and the rainfall uncertainty. The hypothetical chemical has a K_{OC} of 100 mg/g OC and a degradation half-life of 40 days.

Results of Uncertainty Analysis on Rainfall

Table 6 lists some sample statistics on chemical travel time to one meter depth. The variability in chemical travel time is due to the variation in rainfall alone. The standard deviation and the coefficient of variation in Table 6 are comparable to the corresponding statistics in Table 5. This means the impact of soil parameter variability on the chemical transport is similar in magnitude to that of rainfall variability. This is at least true for the rainfall pattern in Caddo County, Oklahoma.

Figure 42 is a plot of frequency distribution of chemical travel time resulting from the uncertainty analysis on rainfall. It varies a great deal from year to year depending on the occurance of

TABLE 6

PROPERTIES OF CHEMICAL TRAVEL TIME TO ONE METER
DUE TO RAINFALL UNCERTAINTY

	TRAVEL TIME (DAYS)
N OF CASES	1000
MINIMUM	1830.000
MAXIMUM	7118.000
MEAN	4345.374
STANDARD DEV	1012.976
SKEWNESS(G1)	-0.009
KURTOSIS(G2)	-0.413
C.V.	0.233

wet years and dry years. The 90% confidence limits on a single estimated chemical travel time can be determined in a similar manner as demonstrated earlier for soil parameter variability. These confidence limits are approximately between 2930 days and 6230 days and are marked on Figure 42.

The confidence limits marked on Figure 42 indicate that an estimated chemical travel time is greatly influenced by the weather sequence. The confidence limits in Figure 42 are comparable to the ones in Figure 41. One should expect a comparable degree of uncertainty in estimated travel time if a single set of model parameters or a single sequence of rainfall is used. The uncertainty in the prediction is very large even when perfect knowledge of all the model parameters are on hand. A sequence of wet years shortens the travel time and a sequence of dry years lengthens it. Based on a single weather record, 90%

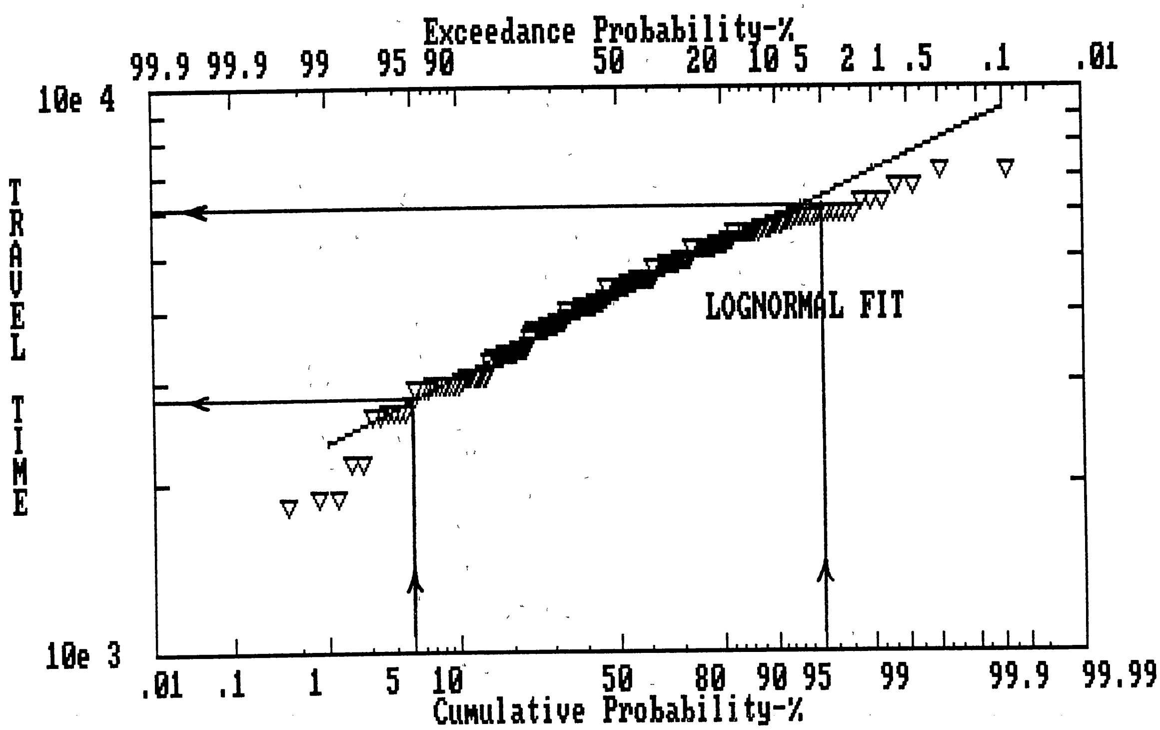

Figure 42. Distribution of Chemical Travel Time due to Rainfall Variability

of the time the confidence limits will include the travel time predicted based on this single, random weather sequence.

An analog can be drawn when one is actually able to measure (or monitor) chemical travel time in soil. The resulting chemical travel time based on one sequence of years of rainfall will differ from that based on a second sequence of years of rainfall. Even if the measurements (or detectability) is perfect, a positive detection of the chemical based on a single weather sequence does not necessarily indicate a positive detection after another weather sequence. The measurements are subject to the same confidence limits previously described.

The sample frequency distribution in Figure 42 can be approximated by a lognormal distribution. The uncertainty due to rainfall variability can be quantified in the same manner as the uncertainty due to soil parameter variability.

Example: μ = 4488.551 days, C_v = 0.2357454.

$$\mu_{ln} = 0.5 \ln[4488.551^2/(0.2357454^2+1)] \approx 8.382$$

$$S_{ln} = [\ln(0.2357454^2+1)]^{1/2} \approx 0.233$$

$$Z = (\ln 5475 - 8.382)/0.233 \approx 0.97$$

Therefore

$$\begin{aligned} \text{Prob(travel time to one meter} > 5475 \text{ days)} &= 1 - \text{Prob}(Z < 0.97) \\ &= 1 - 0.8340 \\ &\approx 0.17 \end{aligned}$$

Thus, in a large number of random weather sequences, 17% of the sequaences will result in a travel time in excess of 15 years.

Uncertainly Analysis of Parameter and Rainfall Variability

Under natural conditions, the uncertainty in chemical transport is influenced by both soil parameter variability and rainfall variability. To examine both sources of variability, the one thousand pseudo soil profiles created to study soil parameter variability were used to simulate chemical transport subject to the natural variability of rainfall created by the rainfall generating program described earlier. The hypothetical chemical remained the same.

Table 7 listed the sample statistics of the resulting chemical travel time to one meter. The standard deviation and the coefficient of variation in Table 7 are almost doubled in comparison to the corresponding statistics in either Table 5 or Table 6. This indicates the combined influences from soil parameter variability and rainfall variability magnify the uncertainty in comparison to either source of variability alone.

Figure 43 is the plot of frequency distribution of chemical travel time resulting from the combined uncertainty due to soil parameter variability and rainfall variability. The distribution can be approximated by a lognormal distribution.

Figure 43 depicts the uncertainty in the model estimate if one set of model parameters is used to estimate the chemical transport in soil under a single natural weather sequence. In other words, the figure

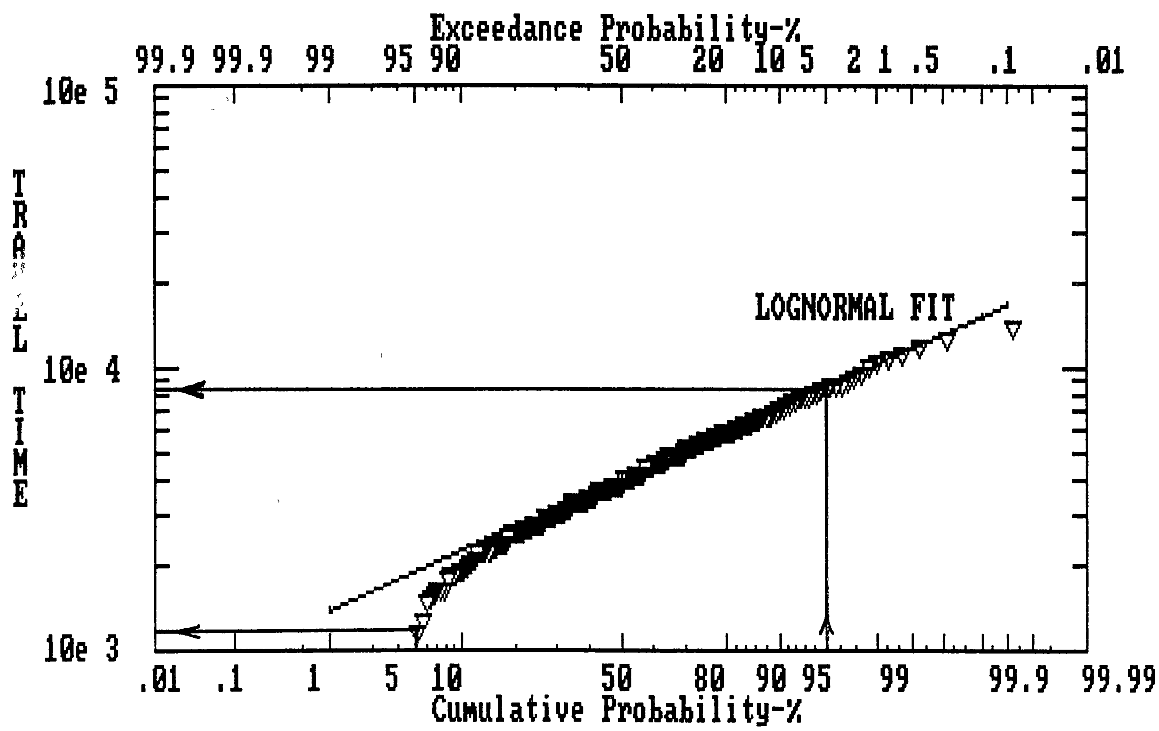

Figure 43. Distribution of Chemical Travel Time due to Overall Variability

TABLE 7

PROPERTIES OF CHEMICAL TRAVEL TIME TO ONE METER DUE TO BOTH SOIL PARAMETER AND RAINFALL UNCERTAINTY

	TRAVEL TIME (DAYS)
N OF CASES	1000
MINIMUM	874.000
MAXIMUM	13661.000
MEAN	4422.524
STANDARD DEV	2076.642
SKEWNESS(G1)	1.227
KURTOSIS(G2)	2.032
C.V.	0.470

combine the influence from the uncertainty due to rainfall and the uncertainty due to soil parameters. Under these constraints, the 90% confidence limits are between 1144 days and 8343 days. Thus, loosely interpreted, if a single randomly selected soil sample is subjected to a single randomly selected weather sequence, 90% of the time the travel time to one meter depth will lie between 1144 and 8343 days. The confidence limits are so wide that there can be more than fourfold difference between any two estimates obtained for the same scenario and yet have the two estimates fall inside the 90% confidence limits.

Many current models operating under similar premises are continuously being used to produce a solitary prediction on chemical transport without indicating the large uncertainty involved. The results of the uncertainty analysis suggest that solitary predictions, without stating the confidence limits, are not very meaningful, and may be totally misleading.

CHAPTER VII

IMPACTS ON SOIL SAMPLING

Parameter sensitivity analysis made it possible to determine the magnitude of variability in model response for a given magnitude of variability in model parameters. With the help of sampling theory, it is possible to determine the minimum number of soil samples required to define each CMLS parameter to provide a given accuracy in model response. This chapter describes the general procedures for applying the results from the sensitivity and the uncertainty analyses to the soil sampling problem. Only random samples are considered in this chapter.

Sampling Theory

If the PDF of x follows a normal distribution, the expression for the 100(1-α) confidence limits which contains the mean of the variable x is given by Haan (1977) as

$$L = \mu_X - t_{(1-\alpha/2,n-1)} \cdot S_X/n^{0.5} \tag{7.1}$$

$$U = \mu_X + t_{(1-\alpha/2,n-1)} \cdot S_X/n^{0.5} \tag{7.2}$$

where

L and U are lower and upper confidence limits of the mean respectively.

μ_x is the estimated mean of variable x.

$t_{1-\alpha/2,n-1}$ is the value of the Student t distribution. $1-\alpha$ is the confidence level.

S_x is the standard deviation of variable x.

n is number of samples on x.

If the PDF of x follows lognormal distribution, the logarithmically transformed x should follow normal distribution. Equations 7.1 and 7.2 can still be used after following modification:

$$L = EXP[\mu_{ln} - t_{(1-\alpha/2,n-1)} \cdot S_{ln}/n^{0.5}] \qquad (7.3)$$

$$U = EXP[\mu_{ln} + t_{(1-\alpha/2,n-1)} \cdot S_{ln}/n^{0.5}] \qquad (7.4)$$

where

μ_{ln} and S_{ln} are mean and standard deviation of the logarithmically transformed variable x respectively. They can be determined by Equations 6.1 and 6.2.

If one is willing to tolerate a deviation, Δx, from the estimated mean of the variable x, the lower and upper confidence limits in Equation 7.3 and 7.4 for the mean of x would be

$$\mu_x - \Delta x = EXP[\mu_{ln} - t_{(1-\alpha/2,n-1)} \cdot S_{ln}/n^{0.5}] \qquad (7.5)$$

$$\mu_x + \Delta x = EXP[\mu_{ln} + t_{(1-\alpha/2,n-1)} \cdot S_{ln}/n^{0.5}] \qquad (7.6)$$

Subtracting Equation 7.5 from Equation 7.6 results in

$$2\Delta x = EXP[\mu_{ln}+t_{(1-\alpha/2,n-1)}\cdot S_{ln}/n^{0.5}] - EXP[\mu_{ln}-t_{(1-\alpha/2,n-1)}\cdot S_{ln}/n^{0.5}] \quad (7.7)$$

Equation 7.7 implicitly determines the minimum number of samples required to ensure that at the specified confidence level the estimated mean does not go beyond $\mu_x \pm \Delta x$. Application of Equation 7.6 assumes a lognormal distribution. Equation 7.7 is difficult to solve explicitly because of the dependence of t on n. A trial and error method may be used. This is done by assuming n, determining t, solving for the right hand side (RHS) of Equation 7.7, and comparing the result with the left hand side (LHS) of Equation 7.7. If two sides do not match, use another n to get the value of t and repeat the procedure. The iteration stops when there is a satisfactory match between the both sides of the equation. It should be noted that RHS value increases as n decreases.

Application of Sensitivity Analysis

The results in Chapter VI have illustrated the source and magnitude of uncertainty in the estimated chemical transport. Improvement on the estimate of chemical transport requires that the uncertainty in the model response be controlled. Since uncertainty due to rainfall variability is hard to control, a viable way to control the uncertainty in model response is to actually control the uncertainty in model parameter. The results of sensitivity analysis establish a link between the uncertainty in model response and the uncertainty in model parameters.

Recall the definition of relative sensitivity in Chapter V:

$$S_l = \frac{\Delta Y}{\Delta p_i} \bullet \frac{p_i}{Y} \tag{7.8}$$

Equation 7.8 provides the relative sensitivity of the model response (i.e. chemical transport) to one specific CMLS parameter, provided that other CMLS parameters are fixed at some constant levels. This relation of relative sensitivity can be directly used to map the uncertainty in model response to the uncertainty in model parameter. This can be done by using the sensitivity plots in Chapter V. One can get the relative sensitivity once the parameter value p_i is known. Rearrange Equation 7.8

$$\Delta p_i = \frac{\Delta Y}{S_l} \bullet \frac{p_i}{Y} \tag{7.9}$$

Equation 7.9 expresses the allowable uncertainty in model parameter from an acceptable uncertainty in model response. Specifically, if one chooses to tolerate deviation, ΔY, from model response Y, Equation 7.9 will determine the parameter deviation, Δp_i, from p_i corresponding to the deviation, ΔY.

Once the allowable uncertainty in the model parameter is known, one can apply sampling theory to determine the sample size required to achieve the given degree of certainty. Δp_i in Equation 7.9 is equivalent to Δx in Equation 7.6. Therefore, Equation 7.6 can be used to produce the minimum number of soil samples required for the parameter. The knowledge about the natural variability of the parameter is also required for the computation.

It was pointed out in Chapter V that the sensitivity of any parameter is not a fixed number, but varies with its parameter value and other parameters. This point can hardly be overemphasized because the number of soil samples required will vary with these conditions as well. In other words, the number of soil samples required for any parameter is relative to other parameters. Another important point is that the sample size determined by Equation 7.9 applies to one source of uncertainty in the estimated chemical transport only, i.e. a single soil parameter variability. The uncertainty due to rainfall variability can be quantified as demonstrated in Chapter VI, but its magnitude is beyond modelers' control.

Examples of Determining Sample Size

For the convenience of illustration, the following sample size calculations assume a hypothetical set of soil and chemical properties. These assumed properties are listed in Table 8. The soil properties are assumed to follow a multivariate lognormal distribution. The relative sensitivity of a parameter is determined at the value given by the table. When relative sensitivity to one parameter is computed, other parameters are also fixed at the values given by the table.

Field Capacity

The sample size for field capacity can be obtained from any sensitivity plot as long as sensitivity to field capacity is plotted. Consider the curve of OC_a=1.0 in Figure 23. Other constant parameters are the same as those in Table 8. When field capacity is 25%, linear interpolation of the data used to plot Figure 23 (Appendix C) gives S_1 = 0.39395 and Y = 1600.105 days. Suppose ΔY is set at 100 days, Applying Equation 7.9 results in

TABLE 8

SOIL AND CHEMICAL PROPERTIES USED
TO DETERMINE SAMPLE SIZE

	BD g/cm^3	PWP %	FC %	OC_a	OC_b	K_{oc} mg/g OC
μ_x	1.4	16.0	25.0	1.0	1.0	50
C_v	0.07	0.3	0.2	0.3		
S_x	0.098	4.8	5.0	0.3		

CORRELATION MATRIX (SAME AS TABLE 3)

	BD	PWP	FC	OC_a
BD	1.000			
PWP	-0.065	1.000		
FC	-0.148	0.869	1.000	
OC_a	-0.290	0.352	0.294	1.000
μ_{ln}	0.334	2.729	3.199	-0.043
S_{ln}	0.070	0.294	0.198	0.294

CORRELATION MATRIX (BASED ON LOGARITHM TRANSFORMED DATA)

	BD	PWP	FC	OC_a
BD	1.000			
PWP	-0.183	1.000		
FC	-0.188	0.833	1.000	
OC_a	-0.321	0.539	0.390	1.000

COMPONENT LOADINGS (BASED ON LOGARITHM TRANSFORMED DATA)

	1	2	3	4
BD	-0.432	0.843	-0.318	0.021
PWP	0.913	0.286	0.073	-0.282
FC	0.863	0.326	0.299	0.246
OC_a	0.738	-0.240	-0.626	0.074

$$\Delta p_i = \frac{\Delta Y}{S_1} \bullet \frac{p_i}{Y}$$

$$= \frac{100}{0.39395} \bullet \frac{25}{1600}$$

$$\approx 3.966$$

Table 8 also gives μ_{ln} = 3.199 and S_{ln} = 0.198. Set the confidence level at $1-\alpha = 0.95$. An initial estimate for n is taken as 10 ($t_{(0.975,9)}$=2.26). Substituting these values into Equation 7.7 results in

$$LHS = 2\Delta x = 2 \bullet 3.199 \approx 6.4$$

$$RHS = EXP[\mu_{ln}+t_{(1-\alpha/2,n-1)} \bullet S_{ln}/n^{0.5}] - EXP[\mu_{ln}-t_{(1-\alpha/2,n-1)} \bullet S_{ln}/n^{0.5}]$$

$$= EXP[3.199 + 2.26 \bullet 0.198/10^{0.5}] - EXP[3.199 - 2.26 \bullet 0.198/10^{0.5}]$$

$$\approx 6.95$$

Set n= 11, apply Equation 7.7 again

$$LHS = 2\Delta x = 2 \bullet 3.199 \approx 6.4$$

$$RHS = EXP[\mu_{ln}+t_{(1-\alpha/2,n-1)} \bullet S_{ln}/n^{0.5}] - EXP[\mu_{ln}-t_{(1-\alpha/2,n-1)} \bullet S_{ln}/n^{0.5}]$$

$$= EXP[3.199 + 2.23 \bullet 0.198/11^{0.5}] - EXP[3.199 - 2.23 \bullet 0.198/11^{0.5}]$$

$$\approx 6.54$$

Set n=12,

$$LHS = 2\Delta x = 2 \bullet 3.199 \approx 6.4$$

$$RHS = EXP[\mu_{ln}+t_{(1-\alpha/2,n-1)} \bullet S_{ln}/n^{0.5}] -$$

$$\text{EXP}[\mu_{ln}-t_{(1-\alpha/2,n-1)}\cdot S_{ln}/n^{0.5}]$$
$$= \text{EXP}[3.199 + 2.20\cdot 0.198/12^{0.5}] -$$
$$\text{EXP}[3.199 - 2.20\cdot 0.198/12^{0.5}]$$
$$\approx 6.18$$

Since the LHS is close to the RHS when n=11, 11 random soil samples on field capacity are needed in order to be 95% confident that $\Delta Y \leq 100$ days if all other soil parameters are known constants and rainfall variability is not considered. It should be emphasized again that the number of soil samples determined is dependent on the parameter values assumed. This procedure can be repeated for other model parameters.

Organic Carbon Content and Bulk Density

Soil organic carbon content is modeled by the exponential decay function described in Chapter IV.

$$OC = OC_a \bullet \text{EXP}(-OC_b \bullet \text{DEPTH}) \qquad (7.10)$$

It was concluded from the sensitivity analysis that the chemical travel time is more sensitive to OC_a than to OC_b. OC_a corresponds to the organic carbon content in topsoil layer. The following example deals with OC_a only. Use Figure 8 as an example. When OC_a=1.0, linear interpolation of the data used to plot Figure 8 (Appendix C) gives S_l = 0.6007, Y = 1596.48 days. Take ΔY = 100 days again in this example, Equation 7.9 gives

$$\Delta p_i = \frac{\Delta Y}{S_l} \bullet \frac{p_i}{Y}$$

$$= \frac{100}{0.6007} \bullet \frac{1.0}{1596}$$

$$\approx 0.104$$

Table 8 gives μ_{ln} = -0.043 and S_{ln} = 0.294. Set the confidence level at α = 0.05. Since organic carbon has the highest variability, a high initial estimate for n is taken as 51. Substituting these values into Equation 7.7 results in

$$LHS = 2\Delta x = 2 \bullet 0.104 \approx 0.20$$

$$RHS = EXP[\mu_{ln}+t_{(1-\alpha/2,n-1)} \bullet S_{ln}/n^{0.5}] - EXP[\mu_{ln}-t_{(1-\alpha/2,n-1)} \bullet S_{ln}/n^{0.5}]$$

$$= EXP[-0.043 + 2.01 \bullet 0.294/51^{0.5}] - EXP[-0.043 - 2.01 \bullet 0.294/51^{0.5}]$$

$$\approx 0.16$$

Set n=31, apply Equation 7.7 again

$$RHS \approx 0.21$$

Therefore about 31 random soil samples are needed to determine organic carbon content at the surface soil layer if the estimated chemical travel time is allowed to deviate ±100 days from the estimated mean value if all other soil parameters are known constants and rainfall variability is not considered. The high number of soil samples required reflects the high relative sensitivity and the natural variability of organic carbon content.

The results of sensitivity analysis have indicated that OC_a, BD, and K_{oc} have identical relative sensitivity of chemical travel time. Therefore, without further computation, we know that Δp_i = 0.104. Table

8 gives μ_{ln} = 0.334 and S_{ln} = 0.070. After the same computations as demonstrated earlier, the minimum number of random soil samples required for bulk density is determined at five. Similarly, it can be shown that the minimum number of random soil samples required for permanent wilting point is also around five.

Table 9 presents a summary of sample size required and the sensitivity plots used in the computations. It should be emphasized that the sample size in Table 9 is the number of random soil samples. The mean of these random soil samples is computed and only that mean enters the CMLS model for estimation of chemical transport. Determination of sample size also assumes that all other soil parameters are known constants and rainfall variability is not considered. The sample size in Table 9 is instructive to understand how much soil parameter variability is passed through the CMLS model and transformed into uncertainty in the estimated chemical transport. However, the properties of other soil parameters are not known in reality. Determination of sample size needs to consider the joint multivariate distribution.

Application of Uncertainty Analysis

The soil properties in Table 8 were used in generating 1000 sets CMLS soil parameters based on the multivariate lognormal distribution. The same PDF approach as discussed in Chapter VI is used in generating these parameter sets. The CMLS model was run on those 1000 sets of generated soil parameters. The rainfall record was the actual rainfall observed in Caddo County, Oklahoma, from 1948 to 1975. The chemical

TABLE 9

DETERMINATION OF NUMBER OF RANDOM SOIL SAMPLES

	BD (g/cm^3)	PWP (%)	FC (%)	OC_a (%)
p_i	1.4	16.0	25.0	1.0
Sensitivity Plot	Fig.4	Fig.24	Fig.23	Fig.8
Interpolated Y	2240	1600	1600	1596
S_1	0.601	0.250	0.394	0.601
ΔY	100	100	100	100
Δp_i computed	0.104	4.002	3.966	0.104
Sample Size	5	5	11	31

travel time (in days) to one meter depth was extracted from the output to compute the sample statistics listed in Table 10.

Assume that chemical travel time follows a lognormal distribution (as it did in Chapter VI). Equation 7.7 can be used to determine the number of CMLS parameter sets required if the estimated chemical travel time is allowed to deviate X% from the estimated mean travel time. Consider a deviate of 100 days from the estimated mean travel time. Substituting C_V=0.446 and μ_X=1573.453 into Equations 6.1 and 6.2 gives $\mu_{ln} \approx 7.406$ and $S_{ln} \approx 0.181$. Set the confidence level at $1-\alpha = 0.95$. The initial estimate for n is set as 31.

TABLE 10

PROPERTIES OF CHEMICAL TRAVEL TIME TO ONE METER
DUE TO SOIL PARAMETER UNCERTAINTY

	TRAVEL TIME (DAYS)
N OF CASES	1000
MINIMUM	413.000
MAXIMUM	4914.000
MEAN	1573.453
STANDARD DEV	701.107
SKEWNESS(G1)	0.613
KURTOSIS(G2)	0.096
C.V.	0.446

Substituting these values into Equation 7.7 results in

$$LHS = 2\Delta x = 2 \bullet 100 = 200$$

$$RHS = EXP[\mu_{ln}+t_{(1-\alpha/2,n-1)}\bullet S_{ln}/n^{0.5}] - EXP[\mu_{ln}-t_{(1-\alpha/2,n-1)}\bullet S_{ln}/n^{0.5}]$$

$$= EXP[7.406 + 2.04\bullet 0.181/31^{0.5}] - EXP[7.406 - 2.04\bullet 0.181/31^{0.5}]$$

$$\approx 218$$

Set n=36, apply Equation 7.7 again

$$RHS \approx 202$$

Set n=37, RHS $\approx$ 199

Therefore about 37 sets of random CMLS soil samples are needed in order to be 95% confident that the estimated chemical travel time does not deviate more than 10% from the mean travel time. The sample size in this case is different from the previous sample size for individual soil parameter. The sample size in this case assumes that 16 sets of CMLS soil parameters enter CMLS model individually, resulting 16 different values of chemical travel time. The confidence intervals so computed, at 95% time, will include the mean of these travel time. The sample size so determined assumes soil samples being randomly taken from the joint multivariate distribution. It is interesting to note that the sample sizes resulting from both approaches are in a comparable magnitude.

CHAPTER VIII

SUMMARY AND CONCLUSIONS

Summary

Solute transport in soil is a complex phenomenon governed by many different physical, chemical and biological processes. Mathematical models are often used to simulate part of these processes. The solute transport model used in this study was CMLS. CMLS is designed primarily to simulate the downward movement of a chemical through the soil vadose zone.

Sensitivity analysis is usually used to determine expected change in model response due to changes in model parameter values. The sensitivity of chemical travel time to CMLS parameters was studied in detail in this research. Efforts were made to quantify the impact of uncertainty in CMLS parameters on uncertainty in chemical transport. Unit free relative sensitivity charts were used to compare the relative importance of these CMLS parameters. The results of the sensitivity analyses were instructive in understanding the underlying interrelationships in the model and in formulating a soil sampling plan.

Sampling theory makes it possible to determine the minimum number of samples required to achieve a given degree of certainty in the mean of the sampled variable. The results of the sensitivity analysis helped to transform the degree of certainty required in model response to the degree of certainty required in model parameters. Thus the number of soil samples is controlled by both soil parameter variability and the relative sensitivity of chemical transport to the parameter of interest.

This research is designed to demonstrate a methodology with general applicability. Because of the scarcity of the measured soil data and the number of models available to simulate chemical transport, the study did not strive to provide a quantitative answer to a particular question, but rather to develop an approach. The resulting procedures can be used to study other solute transport models. A key component of this research was to determine the impact of uncertainty in model parameters on uncertainty of model response and the impact of both of these uncertainties on sample size requirements. A model with a different structure will produce different sensitivity plots and thus a different soil sample size requirement. The approach used should help one understand the model and the uncertainty in model response. The research is, however, not intended to test the validity of the solute transport model.

Another key component of the research is uncertainty analysis. Uncertainty analysis is used to determine the impact of the joint uncertainty in model parameters on uncertainty of model response. In other words, it is similar to sensitivity analysis but it considers simultaneous variability in all model parameters. Variability in the CMLS parameters and precipitation are always transformed into variability in estimated chemical transport. Uncertainty in the estimated chemical transport is required to address the probabilistic aspects of the model predictions. The uncertainty analysis was carried out in three phases. The first phase was devoted to the uncertainty resulting from the natural variability of all the CMLS parameters combined. The second phase was concentrated on the uncertainty due to the natural variability of rainfall alone. The last phase of the uncertainty analyses was designed to investigate the impacts of combined parameter and rainfall variability. The results of these uncertainty analyses made it possible to place confidence limits on the estimated chemical transport.

The results of uncertainty analysis also indicated that the estimated chemical travel time is greatly influenced by the weather sequence. Even when the perfect knowledge on all the model parameters are on hand, the resulting confidence limits on the estimated chemical transport are still very wide if only one weather record is used to make the prediction. The same finding is also true when one is actually able to measure the chemical transport in soil. The results suggest a very wide confidence limits despite perfect measurements. To improve the estimate, such measurements have to be prolonged over many many years to encompass different possible weather sequences. Such prolonged measurement may not be economically feasible under most circumstances.

Conclusions

Based upon the results of this research the following conclusions can be drawn:

1. Koc, BD, and OC influence the adsorption process in the CMLS model in a mathematically equivalent fashion. The relative sensitivity of chemical transport to these parameters is identical to each other.

The impact on chemical transport is governed by the parameter variability. In other words, the most variable parameter under natural condition produces the most variability in the estimated chemical transport.

2. In general, the estimated chemical travel time appears to be more sensitive to the CMLS parameters controlling the adsorption process than the CMLS parameters controlling the process of redistributing infiltrating water.

3. Any CMLS parameter has its more sensitive and less sensitive range. The magnitude of parameter sensitivity is only meaningful when all other parameters are also considered.

4. Consider the following soil and chemical properties. BD=1.4 g/cm^3, FC=25%, WP=16%, OC_a=1.0, OC_b=1.0, K_{oc}=100mg/g OC. CMLS parameters can be ranked in terms of their influences on the relative sensitivity of chemical travel time as

$$OC_a = K_{oc} = BD > OC_b \approx FC > PWP$$

5. The magnitude of uncertainty in the estimated chemical transport resulting from parameter variability is comparable to that resulting from rainfall variability. Increasing soil sample size will reach the point of diminishing return in improving estimated chemical transport because of the natural rainfall variability. The combined parameter and rainfall variabilities do appear to magnify the overall uncertainty in the estimated chemical transport.

6. The results of sensitivity and uncertainty analyses, in conjunction with the sampling theory, can be used to determine the

minimum number of random soil samples required to achieve a given degree of certainty in the estimated chemical transport.

Recommendations for Future Research

The following topics are suggested for future investigation.

1. The soil properties used to devise this research can be determined by soil sampling within given soil types. The result of such soil sampling will make the results of a similar research soil specific. It will also be useful in defining a better relationship to model the change of organic carbon content with depth. No relationship is expected to be universally applicable from soil to soil.

2. The values of CMLS parameters selected for the sensitivity analysis (Table 2) can be consolidated with more data points within the same data range. More data points in the sensitivity analysis mean more plotting points in the sensitivity plots. More points on the plots mean greater flexibility in determining the minimum number of soil samples required for each CMLS parameter. Therefore, such consolidation will improve the accuracy of sensitivity analysis and the determination of soil sample size.

3. Available water capacity is the difference between field capacity and permanent wilting point. The values of field capacity and permanent wilting point are also correlated. For sensitivity analysis these two parameters should be selected in such a way that not only their correlation is preserved, but also their difference, or available water capacity, is preserved at some constant level. Such improved

selection will produce results that can be used to further investigate the impact of field capacity and available water capacity on the relative sensitivity of chemical transport.

4. This research can be improved if field capacity, permanent wilting point, and bulk density are considered as functions of depth with some impirical model or stochastic method. Multiple soil samples of same soil type are usually required to guide the determination of such impirical model.

5. Systematic soil sampling can help to define the semi-variogram of the CMLS parameters, which may reduce the estimated number of soil samples computed for random sampling.

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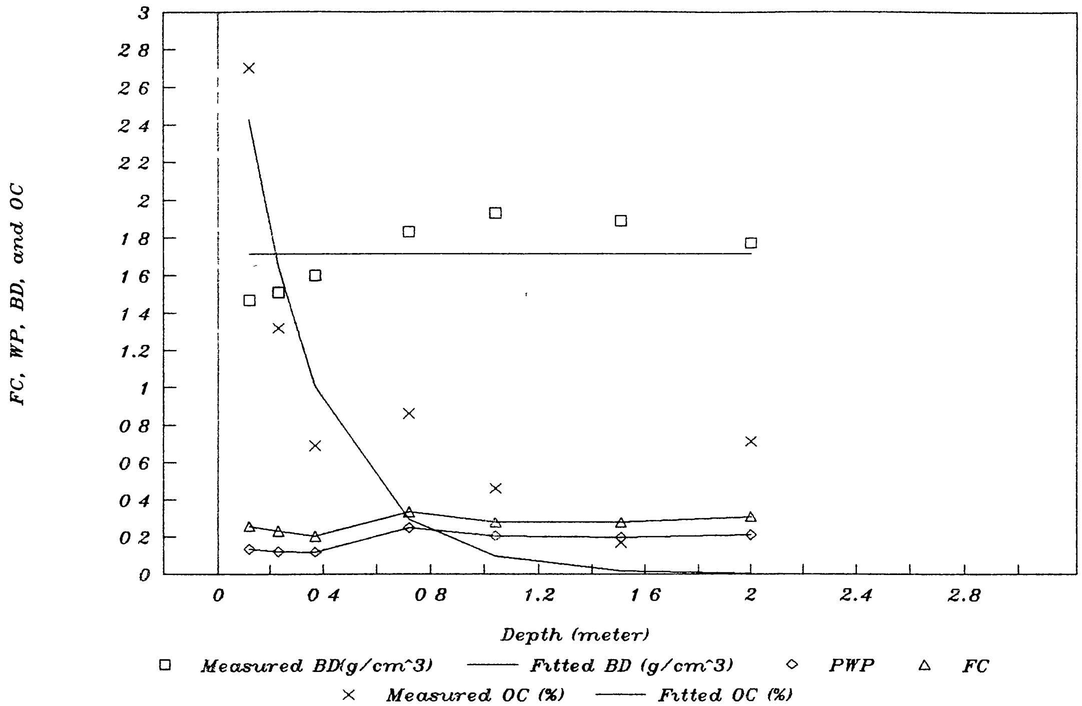
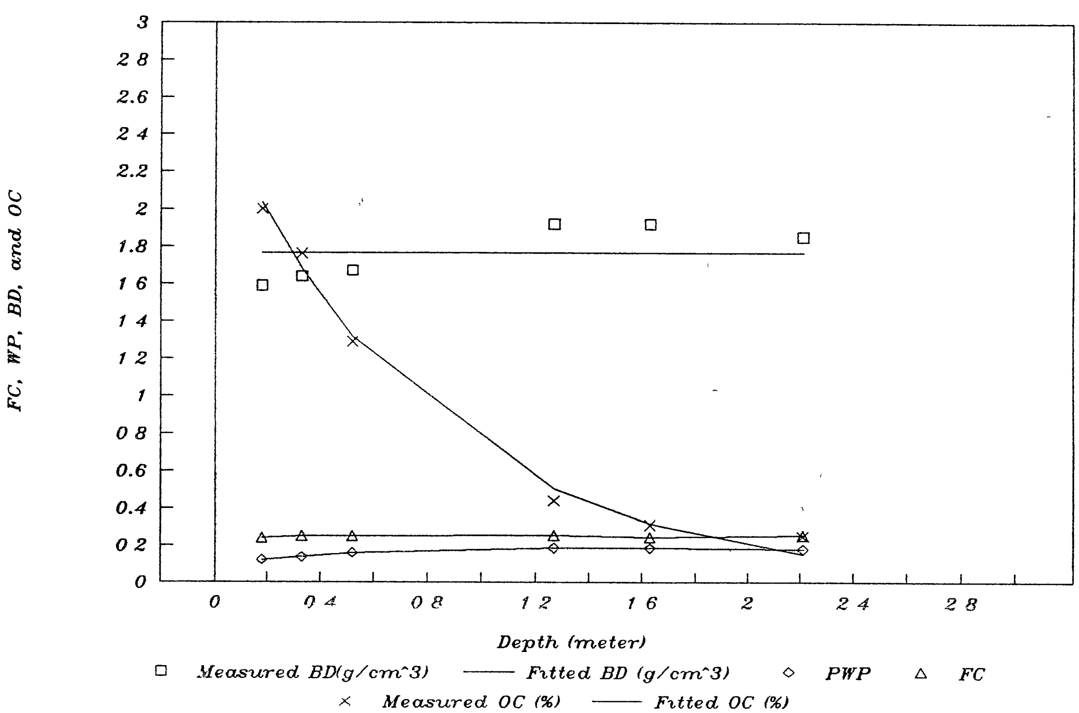
APPENDIXES

APPENDIX A

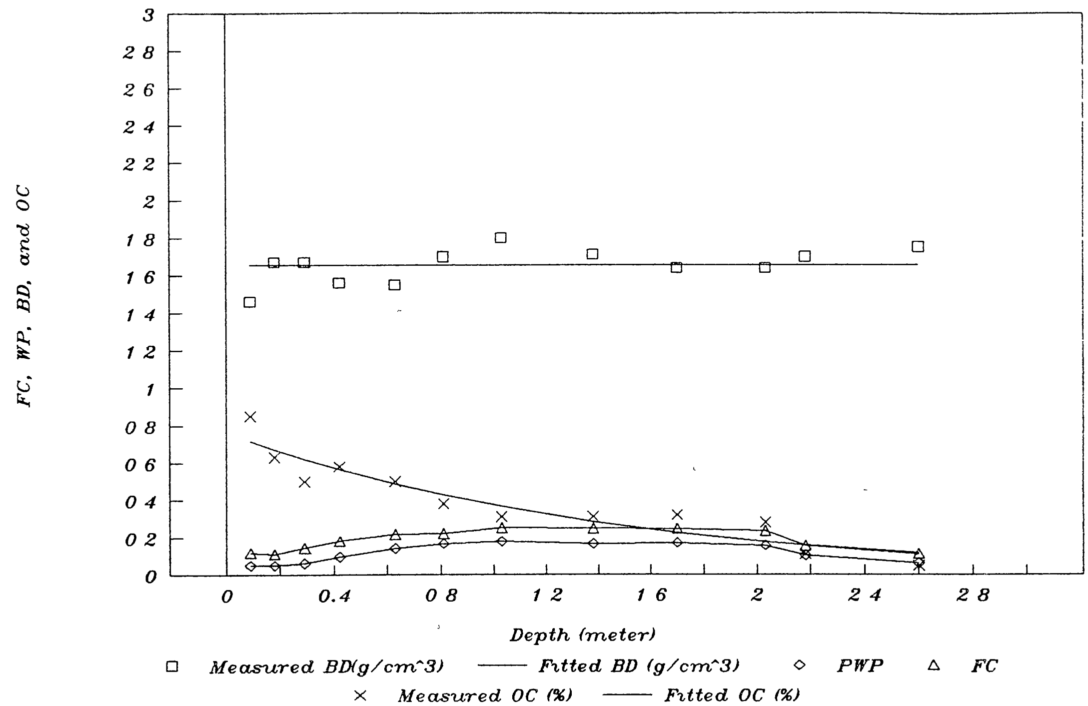
PLOTS OF MEASURED CMLS SOIL PROPERTIES



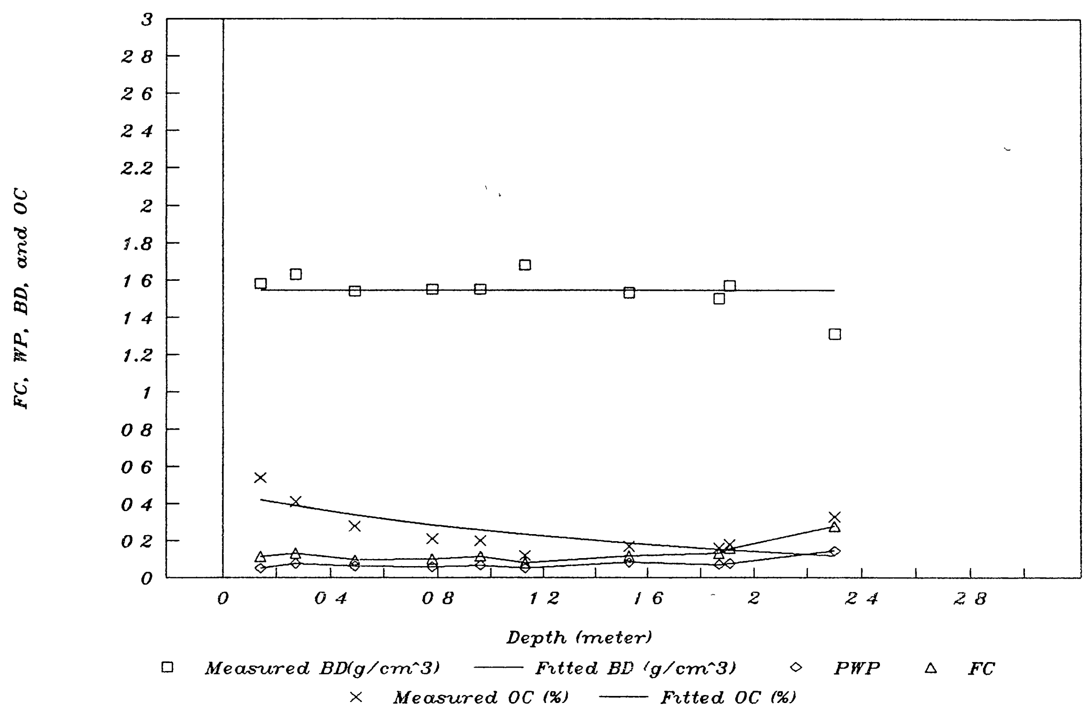
Soil Properties of Parsons Series



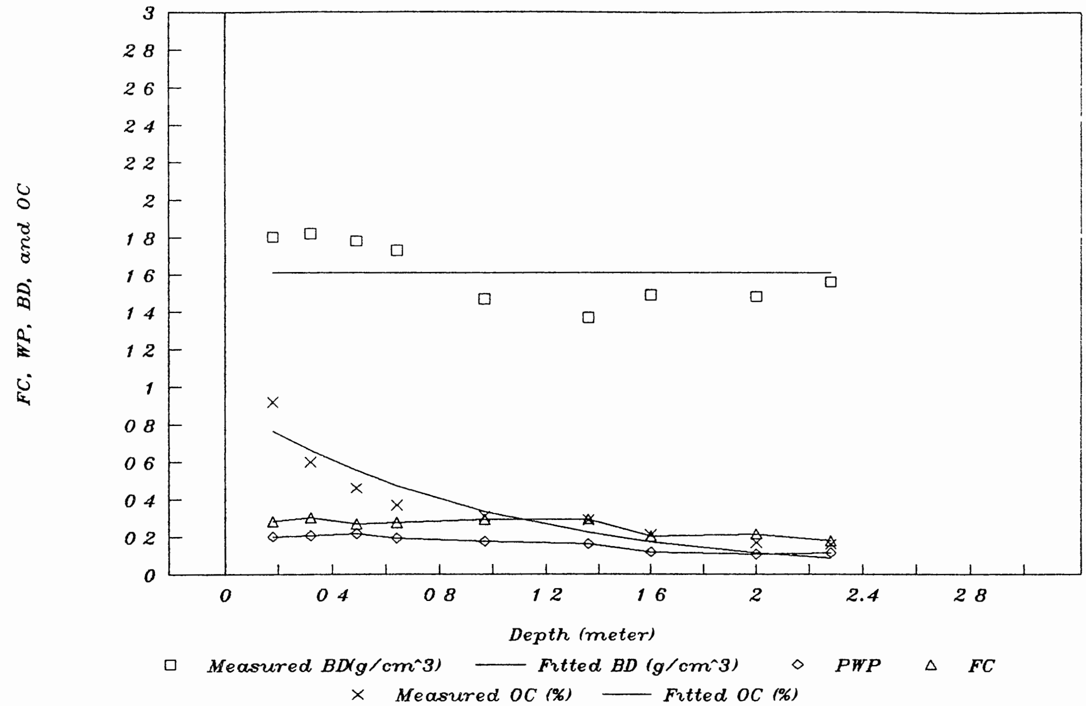
Soil Properties of Summit Series



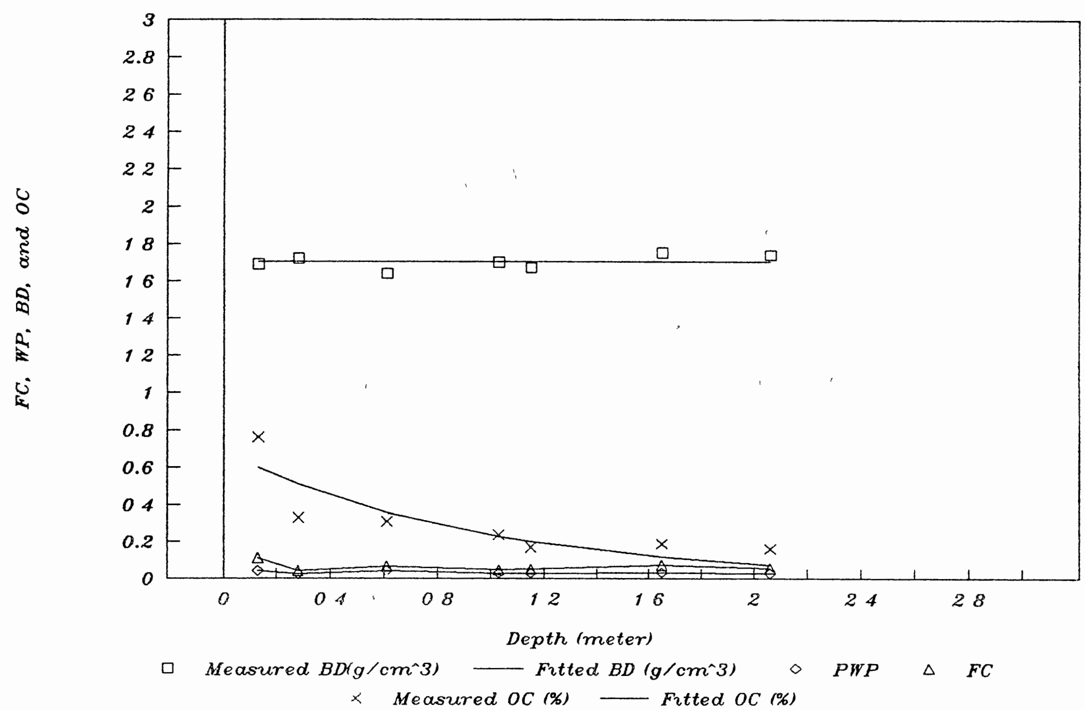
Soil Properties of Dalhart Series (1)



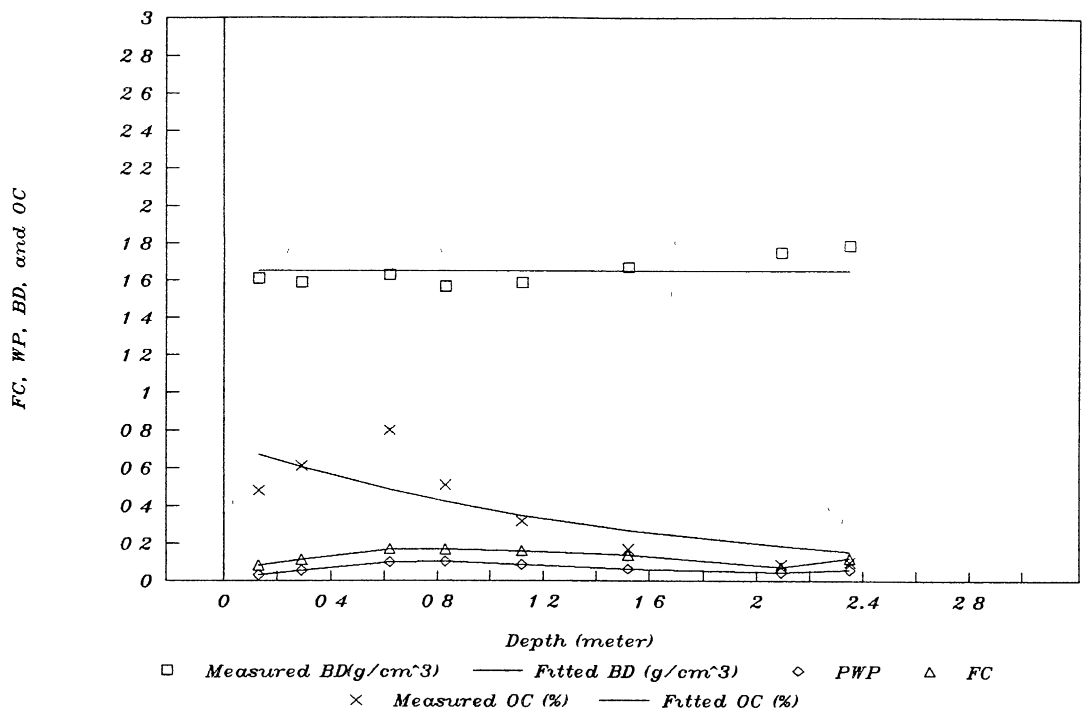
Soil Properties of Dalhart Series (2)



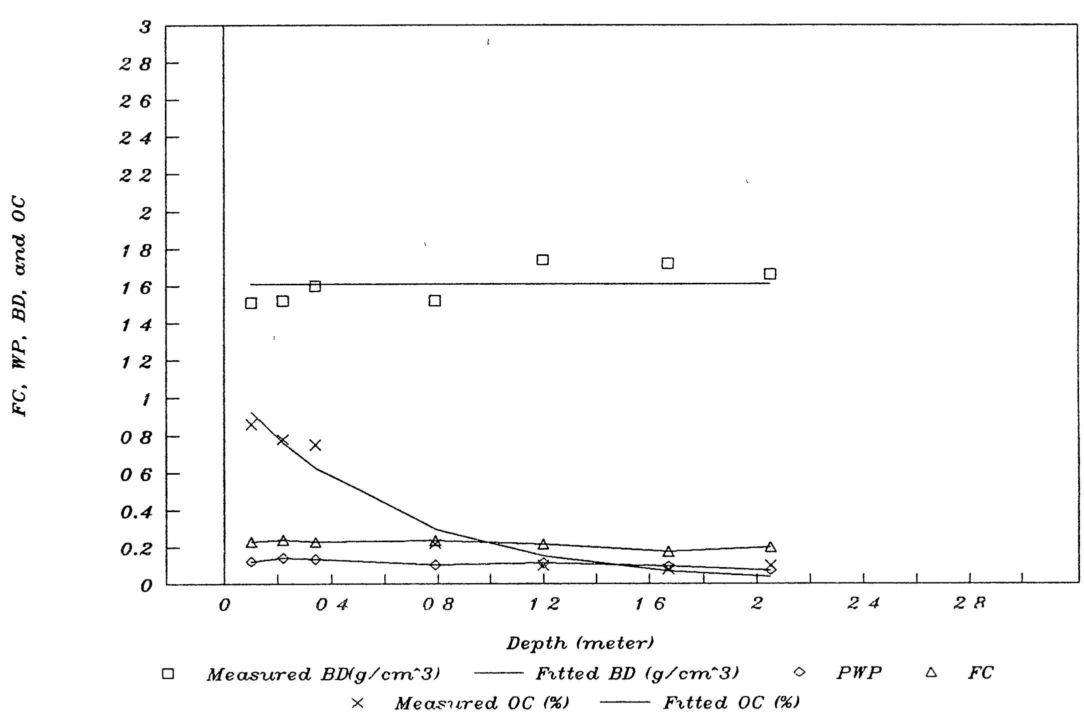
Soil Properties of Richfield Series (1)



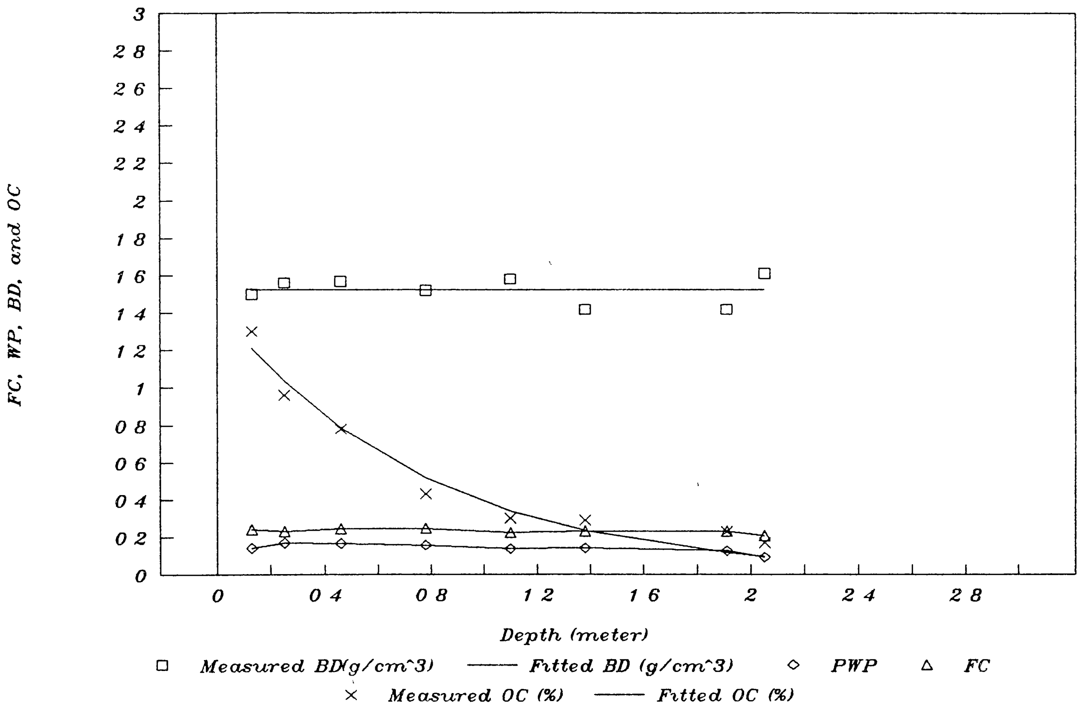
Soil Properties of Vona-like Series



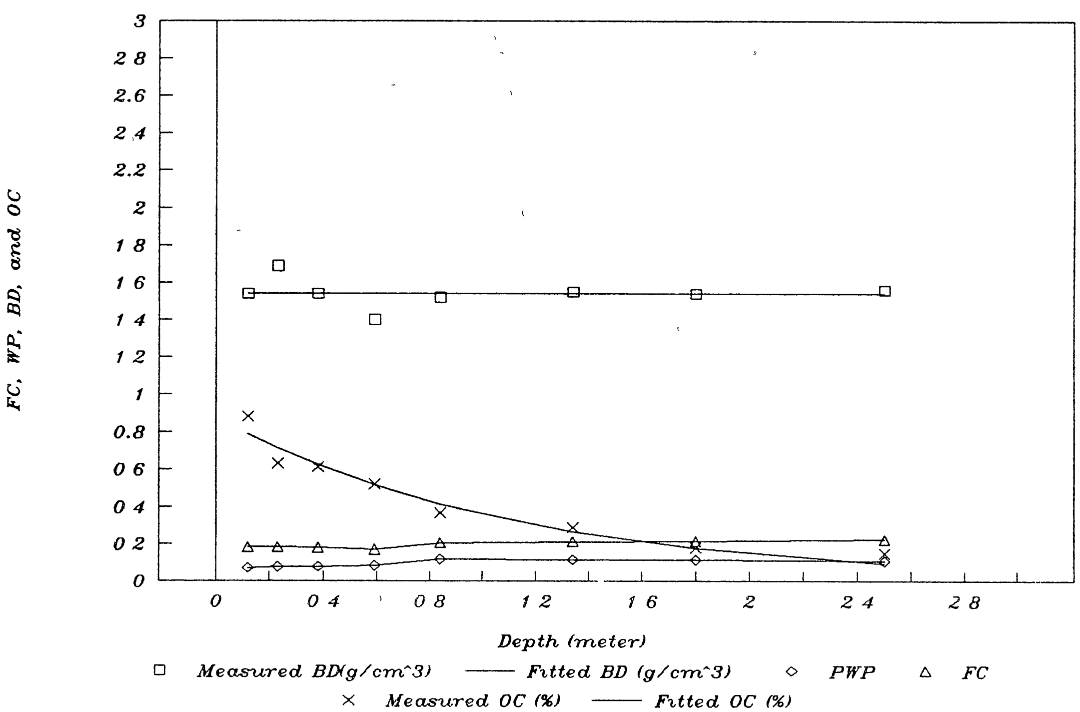
Soil Properties of Dalhart Series (3)



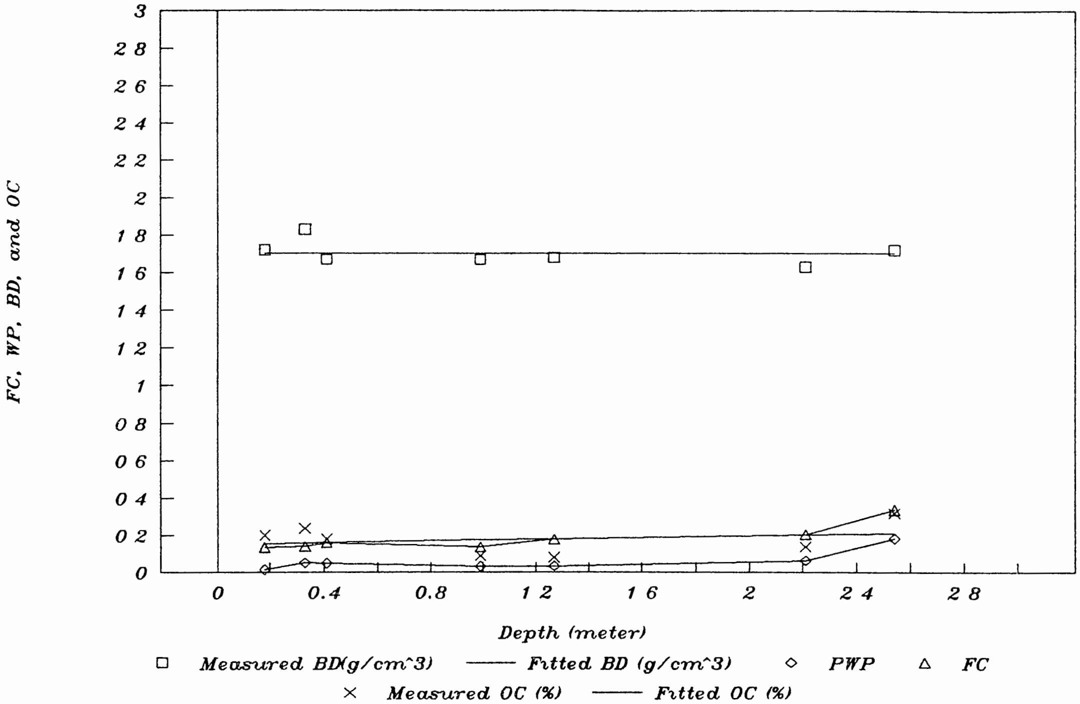
Soil Properties of Portales-like Series



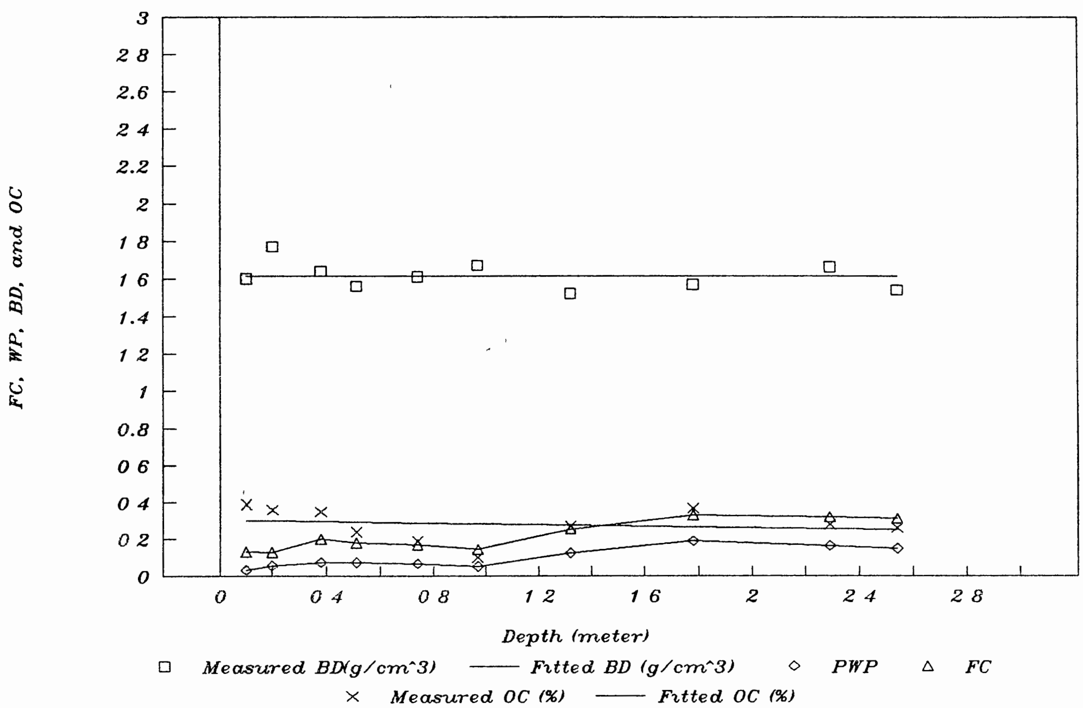
Soil Properties of Ulysses Series (1)



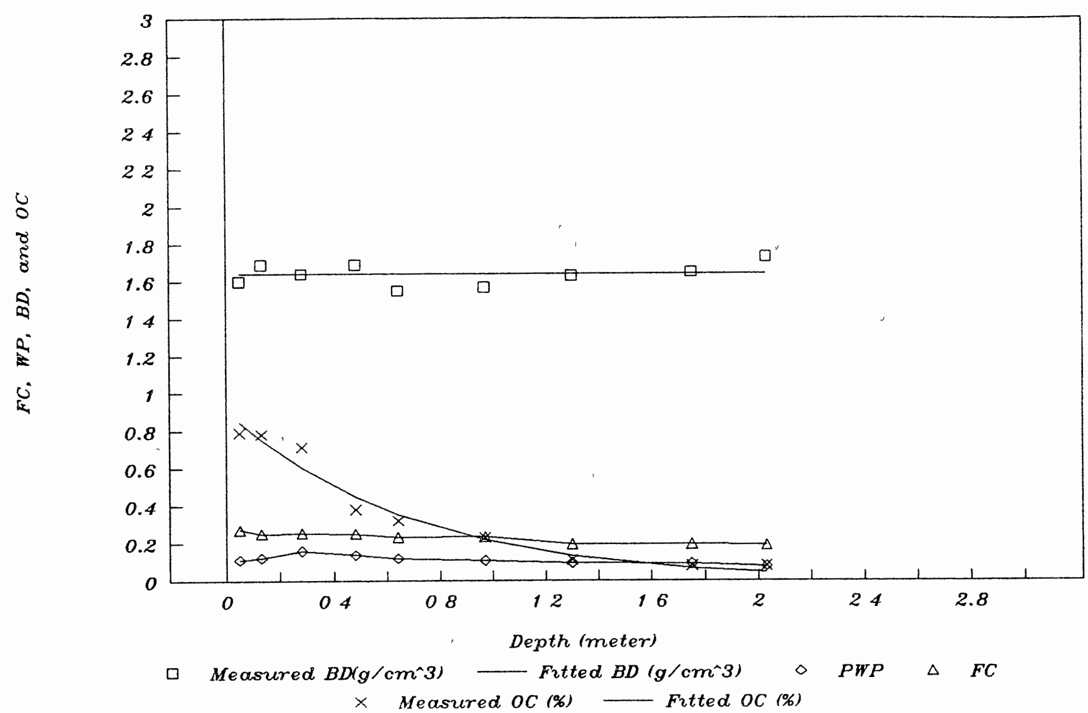
Soil Properties of Carey Series



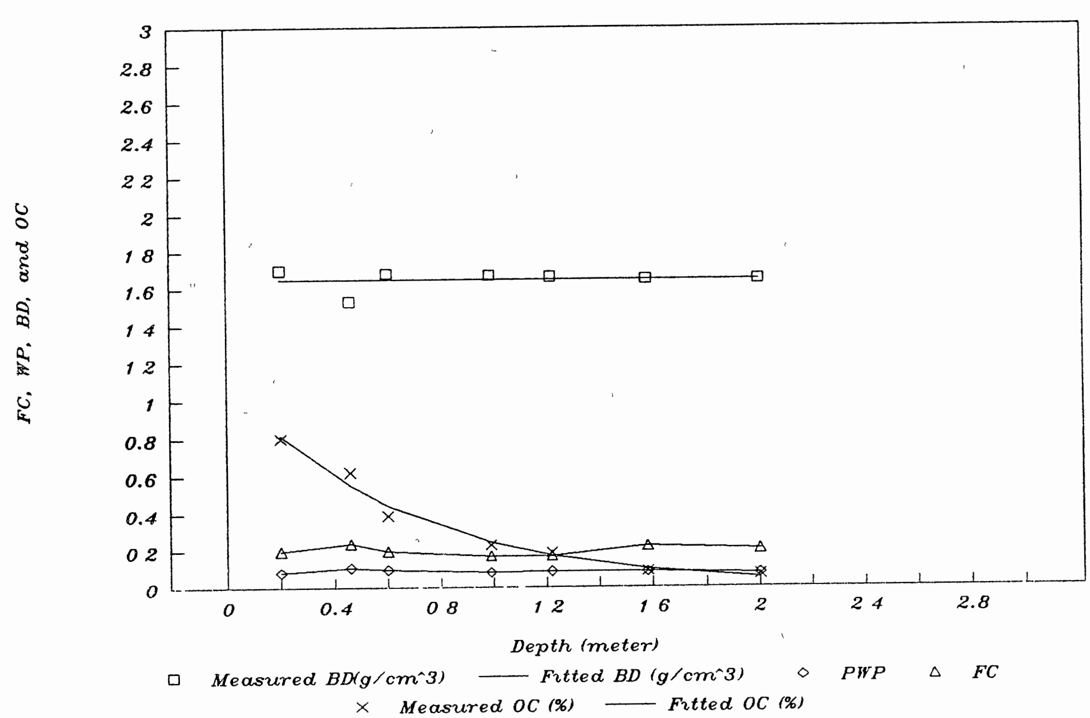
Soil Properties of Pratt Series



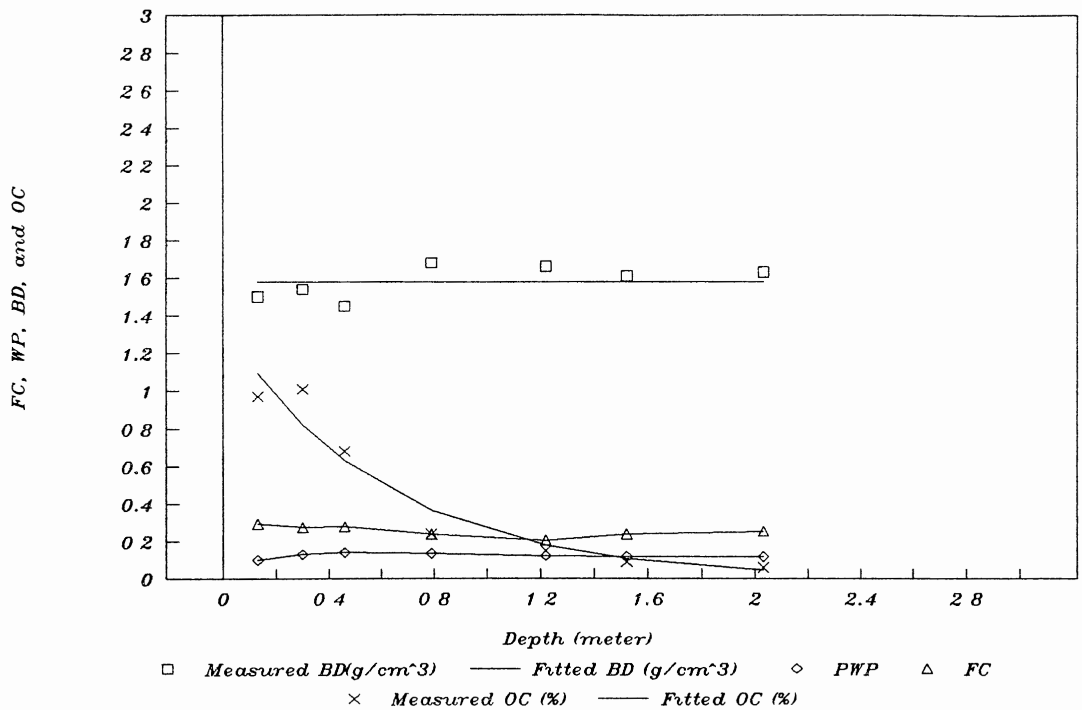
Soil Properties of Dalhart Series (4)



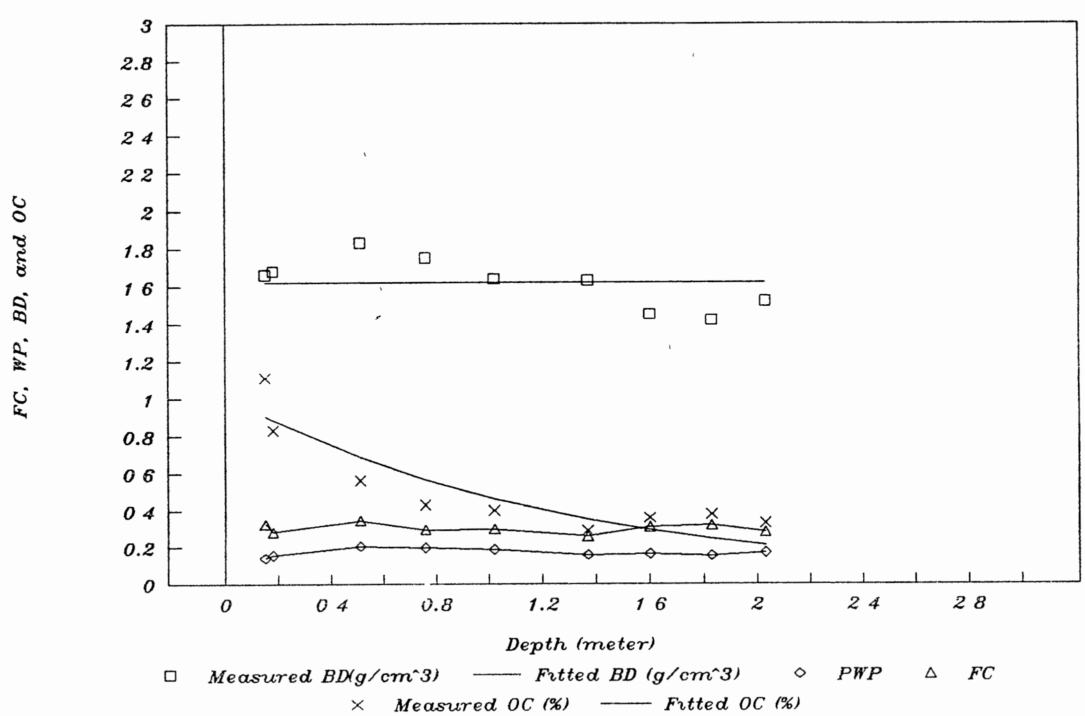
Soil Properties of Richfield Series (2)



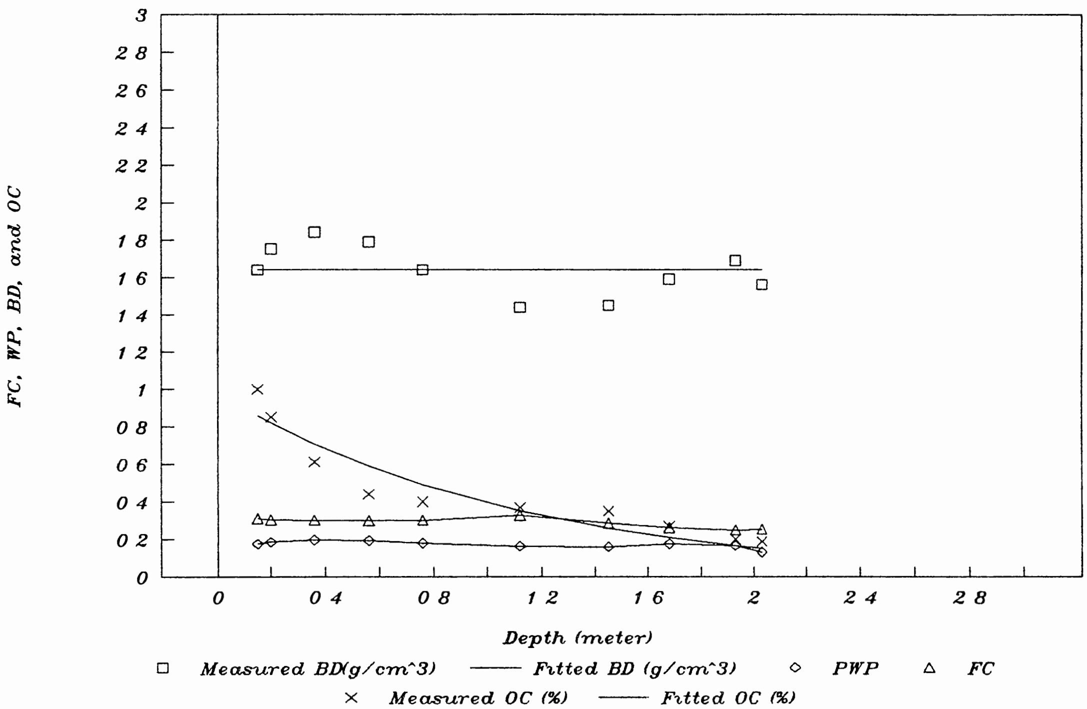
Soil Properties of Mansic Series



Soil Properties of Ulysses Series (2)



Soil Properties of Pullman Series



Soil Properties of Richfield Series (3)

APPENDIX B

CMLS OUTPUT OF SENSITIVITY ANALYSIS

CMLS OUTPUT FOR SENSITIVITY ANALYSIS[1]

REC#	BD	OC_a	OC_b	FC	PWP	K_{OC}	$T_{1/2}$	N	TT0.5M	TT1.0M
1	1.4	.1	1.0	5.0	1.0	0	40	100	41.90	42.92
2	1.4	.1	1.0	5.0	1.0	2	40	100	42.84	43.31
3	1.4	.1	1.0	5.0	1.0	10	40	100	46.07	45.06
4	1.4	.1	1.0	5.0	1.0	50	40	100	69.40	64.75
5	1.4	.1	1.0	5.0	1.0	100	40	100	122.63	101.63
6	1.4	.1	1.0	5.0	1.0	500	40	100	539.32	187.31
7	1.4	.1	1.0	5.0	1.0	1000	40	100	1035.49	253.60
8	1.4	.1	1.0	5.0	1.0	2000	40	100	2044.65	359.84
9	1.4	.1	1.0	15.0	6.0	0	40	100	347.51	275.89
10	1.4	.1	1.0	15.0	6.0	2	40	100	355.29	276.24
11	1.4	.1	1.0	15.0	6.0	10	40	100	375.80	273.91
12	1.4	.1	1.0	15.0	6.0	50	40	100	464.62	289.38
13	1.4	.1	1.0	15.0	6.0	100	40	100	550.73	318.39
14	1.4	.1	1.0	15.0	6.0	500	40	100	1345.94	506.98
15	1.4	.1	1.0	15.0	6.0	1000	40	100	2364.56	633.39
16	1.4	.1	1.0	15.0	6.0	2000	40	100	4273.21	753.72
17	1.4	.1	1.0	15.0	11.0	0	40	100	149.19	118.63
18	1.4	.1	1.0	15.0	11.0	2	40	100	150.97	118.92
19	1.4	.1	1.0	15.0	11.0	10	40	100	161.18	125.35
20	1.4	.1	1.0	15.0	11.0	50	40	100	196.13	135.89
21	1.4	.1	1.0	15.0	11.0	100	40	100	263.15	145.14
22	1.4	.1	1.0	15.0	11.0	500	40	100	649.36	218.24
23	1.4	.1	1.0	15.0	11.0	1000	40	100	1141.42	260.33
24	1.4	.1	1.0	15.0	11.0	2000	40	100	2158.69	365.23
25	1.4	.1	1.0	25.0	11.0	0	40	100	1209.43	762.67
26	1.4	.1	1.0	25.0	11.0	2	40	100	1218.21	765.21
27	1.4	.1	1.0	25.0	11.0	10	40	100	1246.25	774.87
28	1.4	.1	1.0	25.0	11.0	50	40	100	1391.03	804.06
29	1.4	.1	1.0	25.0	11.0	100	40	100	1548.36	822.88
30	1.4	.1	1.0	25.0	11.0	500	40	100	2937.06	1064.77
31	1.4	.1	1.0	25.0	11.0	1000	40	100	4704.92	1335.81
32	1.4	.1	1.0	25.0	11.0	2000	40	100	8200.90	1689.51
33	1.4	.1	1.0	25.0	16.0	0	40	100	590.11	329.16
34	1.4	.1	1.0	25.0	16.0	2	40	100	597.01	330.95
35	1.4	.1	1.0	25.0	16.0	10	40	100	615.92	346.25
36	1.4	.1	1.0	25.0	16.0	50	40	100	699.06	358.08
37	1.4	.1	1.0	25.0	16.0	100	40	100	809.53	386.70
38	1.4	.1	1.0	25.0	16.0	500	40	100	1599.78	585.89
39	1.4	.1	1.0	25.0	16.0	1000	40	100	2573.72	638.66
40	1.4	.1	1.0	25.0	16.0	2000	40	100	4521.76	788.95
41	1.4	.1	1.0	35.0	21.0	0	40	100	1624.35	847.56
42	1.4	.1	1.0	35.0	21.0	2	40	100	1627.95	847.51
43	1.4	.1	1.0	35.0	21.0	10	40	100	1648.99	854.28
44	1.4	.1	1.0	35.0	21.0	50	40	100	1784.85	847.54
45	1.4	.1	1.0	35.0	21.0	100	40	100	1979.82	869.65
46	1.4	.1	1.0	35.0	21.0	500	40	100	3411.59	1084.01
47	1.4	.1	1.0	35.0	21.0	1000	40	100	5165.57	1356.54
48	1.4	.1	1.0	35.0	21.0	2000	40	100	8667.16	1709.31
49	1.4	.1	1.0	35.0	26.0	0	40	100	862.49	403.01
50	1.4	.1	1.0	35.0	26.0	2	40	100	866.65	402.79
51	1.4	.1	1.0	35.0	26.0	10	40	100	883.38	402.66
52	1.4	.1	1.0	35.0	26.0	50	40	100	969.35	392.68
53	1.4	.1	1.0	35.0	26.0	100	40	100	1065.23	400.67
54	1.4	.1	1.0	35.0	26.0	500	40	100	1858.86	590.55
55	1.4	.1	1.0	35.0	26.0	1000	40	100	2801.55	682.16
56	1.4	.1	1.0	35.0	26.0	2000	40	100	4757.58	846.25
57	1.4	.1	1.0	45.0	26.0	0	40	100	3783.92	1629.17
58	1.4	.1	1.0	45.0	26.0	2	40	100	3787.27	1624.88
59	1.4	.1	1.0	45.0	26.0	10	40	100	3816.26	1650.39
60	1.4	.1	1.0	45.0	26.0	50	40	100	4015.53	1746.18
61	1.4	.1	1.0	45.0	26.0	100	40	100	4327.52	1744.80
62	1.4	.1	1.0	45.0	26.0	500	40	100	6616.72	2323.78
65	1.4	.1	1.0	45.0	31.0	0	40	100	2109.59	890.95
66	1.4	.1	1.0	45.0	31.0	2	40	100	2120.91	892.58
67	1.4	.1	1.0	45.0	31.0	10	40	100	2158.27	891.50
68	1.4	.1	1.0	45.0	31.0	50	40	100	2339.62	935.24
69	1.4	.1	1.0	45.0	31.0	100	40	100	2491.04	965.33
70	1.4	.1	1.0	45.0	31.0	500	40	100	3856.85	1138.16
71	1.4	.1	1.0	45.0	31.0	1000	40	100	5653.12	1394.49
72	1.4	.1	1.0	45.0	31.0	2000	40	100	9167.35	1727.23
73	1.4	.1	2.0	5.0	1.0	0	40	100	41.90	42.92
74	1.4	.1	2.0	5.0	1.0	2	40	100	42.12	42.99
75	1.4	.1	2.0	5.0	1.0	10	40	100	44.31	43.05
76	1.4	.1	2.0	5.0	1.0	50	40	100	56.04	57.59
77	1.4	.1	2.0	5.0	1.0	100	40	100	79.48	68.72
78	1.4	.1	2.0	5.0	1.0	500	40	100	367.21	156.00

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1. REC# - record number, BD - bulk density (g/cm^3), OC_a - OC parameter, OC_b - OC parameter, FC - field capacity (%), PWP - permanent wilting point (%), K_{OC} - chemical partition coefficient (mg/g OC), $T_{1/2}$ - degradation half-life, N - number of records used to compute the mean, TT0.5M - travel time to 0.5 meter depth, TT1.0M - travel time to 1 meter depth.

79	1.4	.1	2.0	5.0	1.0	1000	40	100	654.43	211.84
80	1.4	.1	2.0	5.0	1.0	2000	40	100	1303.01	258.36
81	1.4	.1	2.0	15.0	6.0	0	40	100	347.51	275.89
82	1.4	.1	2.0	15.0	6.0	2	40	100	352.93	276.96
83	1.4	.1	2.0	15.0	6.0	10	40	100	360.40	273.99
84	1.4	.1	2.0	15.0	6.0	50	40	100	410.87	269.22
85	1.4	.1	2.0	15.0	6.0	100	40	100	480.54	294.91
86	1.4	.1	2.0	15.0	6.0	500	40	100	949.61	370.64
87	1.4	.1	2.0	15.0	6.0	1000	40	100	1548.58	530.84
88	1.4	.1	2.0	15.0	6.0	2000	40	100	2699.66	659.29
89	1.4	.1	2.0	15.0	11.0	0	40	100	149.19	118.63
90	1.4	.1	2.0	15.0	11.0	2	40	100	150.88	118.83
91	1.4	.1	2.0	15.0	11.0	10	40	100	157.10	124.62
92	1.4	.1	2.0	15.0	11.0	50	40	100	177.90	131.41
93	1.4	.1	2.0	15.0	11.0	100	40	100	211.79	137.89
94	1.4	.1	2.0	15.0	11.0	500	40	100	482.04	176.87
95	1.4	.1	2.0	15.0	11.0	1000	40	100	791.57	228.85
96	1.4	.1	2.0	15.0	11.0	2000	40	100	1413.97	274.84
97	1.4	.1	2.0	25.0	11.0	0	40	100	1209.43	762.67
98	1.4	.1	2.0	25.0	11.0	2	40	100	1211.48	762.25
99	1.4	.1	2.0	25.0	11.0	10	40	100	1233.75	766.72
100	1.4	.1	2.0	25.0	11.0	50	40	100	1309.87	778.08
101	1.4	.1	2.0	25.0	11.0	100	40	100	1426.31	799.36
102	1.4	.1	2.0	25.0	11.0	500	40	100	2243.55	869.64
103	1.4	.1	2.0	25.0	11.0	1000	40	100	3247.33	1046.65
104	1.4	.1	2.0	25.0	11.0	2000	40	100	5277.88	1301.46
105	1.4	.1	2.0	25.0	16.0	0	40	100	590.11	329.16
106	1.4	.1	2.0	25.0	16.0	2	40	100	594.53	329.09
107	1.4	.1	2.0	25.0	16.0	10	40	100	609.75	341.13
108	1.4	.1	2.0	25.0	16.0	50	40	100	664.27	352.93
109	1.4	.1	2.0	25.0	16.0	100	40	100	713.24	361.13
110	1.4	.1	2.0	25.0	16.0	500	40	100	1214.52	457.74
111	1.4	.1	2.0	25.0	16.0	1000	40	100	1795.95	580.20
112	1.4	.1	2.0	25.0	16.0	2000	40	100	2959.36	661.31
113	1.4	.1	2.0	35.0	21.0	0	40	100	1624.35	847.56
114	1.4	.1	2.0	35.0	21.0	2	40	100	1625.04	847.25
115	1.4	.1	2.0	35.0	21.0	10	40	100	1642.22	861.23
116	1.4	.1	2.0	35.0	21.0	50	40	100	1685.65	851.58
117	1.4	.1	2.0	35.0	21.0	100	40	100	1822.62	847.77
118	1.4	.1	2.0	35.0	21.0	500	40	100	2712.60	983.75
119	1.4	.1	2.0	35.0	21.0	1000	40	100	3679.38	1091.62
120	1.4	.1	2.0	35.0	21.0	2000	40	100	5743.98	1396.79
121	1.4	.1	2.0	35.0	26.0	0	40	100	862.49	403.01
122	1.4	.1	2.0	35.0	26.0	2	40	100	864.15	403.45
123	1.4	.1	2.0	35.0	26.0	10	40	100	872.95	401.49
124	1.4	.1	2.0	35.0	26.0	50	40	100	919.54	391.29
125	1.4	.1	2.0	35.0	26.0	100	40	100	988.92	387.60
126	1.4	.1	2.0	35.0	26.0	500	40	100	1453.62	531.80
127	1.4	.1	2.0	35.0	26.0	1000	40	100	2063.91	607.72
128	1.4	.1	2.0	35.0	26.0	2000	40	100	3262.04	669.52
129	1.4	.1	2.0	45.0	26.0	0	40	100	3783.92	1629.17
130	1.4	.1	2.0	45.0	26.0	2	40	100	3783.92	1629.17
131	1.4	.1	2.0	45.0	26.0	10	40	100	3803.36	1643.35
132	1.4	.1	2.0	45.0	26.0	50	40	100	3904.73	1689.26
133	1.4	.1	2.0	45.0	26.0	100	40	100	4063.59	1738.08
134	1.4	.1	2.0	45.0	26.0	500	40	100	5412.44	1931.25
135	1.4	.1	2.0	45.0	26.0	1000	40	100	6951.09	2358.85
137	1.4	.1	2.0	45.0	31.0	0	40	100	2109.59	890.95
138	1.4	.1	2.0	45.0	31.0	2	40	100	2110.85	890.71
139	1.4	.1	2.0	45.0	31.0	10	40	100	2138.66	895.93
140	1.4	.1	2.0	45.0	31.0	50	40	100	2250.24	895.62
141	1.4	.1	2.0	45.0	31.0	100	40	100	2389.04	968.92
142	1.4	.1	2.0	45.0	31.0	500	40	100	3163.73	1066.01
143	1.4	.1	2.0	45.0	31.0	1000	40	100	4119.34	1172.80
144	1.4	.1	2.0	45.0	31.0	2000	40	100	6139.14	1439.99
145	1.4	.1	3.0	5.0	1.0	0	40	100	41.90	42.92
146	1.4	.1	3.0	5.0	1.0	2	40	100	42.04	43.04
147	1.4	.1	3.0	5.0	1.0	10	40	100	43.65	43.16
148	1.4	.1	3.0	5.0	1.0	50	40	100	49.70	46.54
149	1.4	.1	3.0	5.0	1.0	100	40	100	66.39	63.00
150	1.4	.1	3.0	5.0	1.0	500	40	100	250.13	132.25
151	1.4	.1	3.0	5.0	1.0	1000	40	100	469.41	165.62
152	1.4	.1	3.0	5.0	1.0	2000	40	100	896.30	213.49
153	1.4	.1	3.0	15.0	6.0	0	40	100	347.51	275.89
154	1.4	.1	3.0	15.0	6.0	2	40	100	349.56	277.24
155	1.4	.1	3.0	15.0	6.0	10	40	100	358.73	275.20
156	1.4	.1	3.0	15.0	6.0	50	40	100	398.90	268.88
157	1.4	.1	3.0	15.0	6.0	100	40	100	428.95	263.09
158	1.4	.1	3.0	15.0	6.0	500	40	100	725.14	354.49
159	1.4	.1	3.0	15.0	6.0	1000	40	100	1114.63	409.90
160	1.4	.1	3.0	15.0	6.0	2000	40	100	1871.35	566.82
161	1.4	.1	3.0	15.0	11.0	0	40	100	149.19	118.63
162	1.4	.1	3.0	15.0	11.0	2	40	100	149.99	119.53
163	1.4	.1	3.0	15.0	11.0	10	40	100	153.40	121.45
164	1.4	.1	3.0	15.0	11.0	50	40	100	170.29	129.85
165	1.4	.1	3.0	15.0	11.0	100	40	100	188.64	135.01
166	1.4	.1	3.0	15.0	11.0	500	40	100	385.32	156.87
167	1.4	.1	3.0	15.0	11.0	1000	40	100	570.86	192.94
168	1.4	.1	3.0	15.0	11.0	2000	40	100	1015.23	240.64
169	1.4	.1	3.0	25.0	11.0	0	40	100	1209.43	762.67

170	1.4	.1	3.0	25.0	11.0	2	40	100	1210.66	762.67
171	1.4	.1	3.0	25.0	11.0	10	40	100	1227.91	761.89
172	1.4	.1	3.0	25.0	11.0	50	40	100	1260.89	786.37
173	1.4	.1	3.0	25.0	11.0	100	40	100	1341.24	783.92
174	1.4	.1	3.0	25.0	11.0	500	40	100	1771.17	812.27
175	1.4	.1	3.0	25.0	11.0	1000	40	100	2466.28	906.44
176	1.4	.1	3.0	25.0	11.0	2000	40	100	3716.74	1027.09
177	1.4	.1	3.0	25.0	16.0	0	40	100	590.11	329.16
178	1.4	.1	3.0	25.0	16.0	2	40	100	593.62	329.45
179	1.4	.1	3.0	25.0	16.0	10	40	100	602.00	332.66
180	1.4	.1	3.0	25.0	16.0	50	40	100	638.59	341.92
181	1.4	.1	3.0	25.0	16.0	100	40	100	685.15	353.68
182	1.4	.1	3.0	25.0	16.0	500	40	100	990.63	379.76
183	1.4	.1	3.0	25.0	16.0	1000	40	100	1361.73	475.34
184	1.4	.1	3.0	25.0	16.0	2000	40	100	2148.94	595.97
185	1.4	.1	3.0	35.0	21.0	0	40	100	1624.35	847.56
186	1.4	.1	3.0	35.0	21.0	2	40	100	1625.04	847.25
187	1.4	.1	3.0	35.0	21.0	10	40	100	1630.20	854.40
188	1.4	.1	3.0	35.0	21.0	50	40	100	1661.88	858.95
189	1.4	.1	3.0	35.0	21.0	100	40	100	1732.48	845.96
190	1.4	.1	3.0	35.0	21.0	500	40	100	2338.75	914.86
191	1.4	.1	3.0	35.0	21.0	1000	40	100	2896.94	1014.27
192	1.4	.1	3.0	35.0	21.0	2000	40	100	4102.16	1110.80
193	1.4	.1	3.0	35.0	26.0	0	40	100	862.49	403.01
194	1.4	.1	3.0	35.0	26.0	2	40	100	863.48	402.90
195	1.4	.1	3.0	35.0	26.0	10	40	100	867.77	403.04
196	1.4	.1	3.0	35.0	26.0	50	40	100	900.68	397.53
197	1.4	.1	3.0	35.0	26.0	100	40	100	940.53	387.63
198	1.4	.1	3.0	35.0	26.0	500	40	100	1251.52	463.61
199	1.4	.1	3.0	35.0	26.0	1000	40	100	1602.38	563.04
200	1.4	.1	3.0	35.0	26.0	2000	40	100	2400.64	611.02
201	1.4	.1	3.0	45.0	26.0	0	40	100	3783.92	1629.17
202	1.4	.1	3.0	45.0	26.0	2	40	100	3783.92	1629.17
203	1.4	.1	3.0	45.0	26.0	10	40	100	3787.37	1624.89
204	1.4	.1	3.0	45.0	26.0	50	40	100	3858.71	1659.79
205	1.4	.1	3.0	45.0	26.0	100	40	100	3936.57	1689.70
206	1.4	.1	3.0	45.0	26.0	500	40	100	4706.49	1862.14
207	1.4	.1	3.0	45.0	26.0	1000	40	100	5803.66	2081.61
209	1.4	.1	3.0	45.0	31.0	0	40	100	2109.59	890.95
210	1.4	.1	3.0	45.0	31.0	2	40	100	2110.81	890.67
211	1.4	.1	3.0	45.0	31.0	10	40	100	2120.99	892.58
212	1.4	.1	3.0	45.0	31.0	50	40	100	2200.35	903.41
213	1.4	.1	3.0	45.0	31.0	100	40	100	2281.98	894.22
214	1.4	.1	3.0	45.0	31.0	500	40	100	2753.12	1017.62
215	1.4	.1	3.0	45.0	31.0	1000	40	100	3362.28	1055.50
216	1.4	.1	3.0	45.0	31.0	2000	40	100	4583.06	1226.97
217	1.4	.1	4.0	5.0	1.0	0	40	100	41.90	42.92
218	1.4	.1	4.0	5.0	1.0	2	40	100	41.97	42.90
219	1.4	.1	4.0	5.0	1.0	10	40	100	43.18	43.25
220	1.4	.1	4.0	5.0	1.0	50	40	100	47.01	45.93
221	1.4	.1	4.0	5.0	1.0	100	40	100	56.31	54.04
222	1.4	.1	4.0	5.0	1.0	500	40	100	177.21	124.80
223	1.4	.1	4.0	5.0	1.0	1000	40	100	353.36	139.38
224	1.4	.1	4.0	5.0	1.0	2000	40	100	619.72	186.04
225	1.4	.1	4.0	15.0	6.0	0	40	100	347.51	275.89
226	1.4	.1	4.0	15.0	6.0	2	40	100	348.73	275.94
227	1.4	.1	4.0	15.0	6.0	10	40	100	357.98	275.07
228	1.4	.1	4.0	15.0	6.0	50	40	100	383.45	275.72
229	1.4	.1	4.0	15.0	6.0	100	40	100	404.70	269.13
230	1.4	.1	4.0	15.0	6.0	500	40	100	607.52	311.39
231	1.4	.1	4.0	15.0	6.0	1000	40	100	868.90	363.19
232	1.4	.1	4.0	15.0	6.0	2000	40	100	1390.15	449.27
233	1.4	.1	4.0	15.0	11.0	0	40	100	149.19	118.63
234	1.4	.1	4.0	15.0	11.0	2	40	100	149.63	118.84
235	1.4	.1	4.0	15.0	11.0	10	40	100	151.77	118.53
236	1.4	.1	4.0	15.0	11.0	50	40	100	164.73	128.42
237	1.4	.1	4.0	15.0	11.0	100	40	100	178.62	131.81
238	1.4	.1	4.0	15.0	11.0	500	40	100	321.38	146.52
239	1.4	.1	4.0	15.0	11.0	1000	40	100	469.28	165.41
240	1.4	.1	4.0	15.0	11.0	2000	40	100	769.76	218.30
241	1.4	.1	4.0	25.0	11.0	0	40	100	1209.43	762.67
242	1.4	.1	4.0	25.0	11.0	2	40	100	1210.63	762.70
243	1.4	.1	4.0	25.0	11.0	10	40	100	1218.45	762.06
244	1.4	.1	4.0	25.0	11.0	50	40	100	1245.05	774.35
245	1.4	.1	4.0	25.0	11.0	100	40	100	1291.93	780.84
246	1.4	.1	4.0	25.0	11.0	500	40	100	1572.71	804.43
247	1.4	.1	4.0	25.0	11.0	1000	40	100	1976.47	839.34
248	1.4	.1	4.0	25.0	11.0	2000	40	100	2812.20	941.31
249	1.4	.1	4.0	25.0	16.0	0	40	100	590.11	329.16
250	1.4	.1	4.0	25.0	16.0	2	40	100	593.61	329.45
251	1.4	.1	4.0	25.0	16.0	10	40	100	597.80	330.61
252	1.4	.1	4.0	25.0	16.0	50	40	100	631.88	342.59
253	1.4	.1	4.0	25.0	16.0	100	40	100	656.45	353.43
254	1.4	.1	4.0	25.0	16.0	500	40	100	873.69	382.41
255	1.4	.1	4.0	25.0	16.0	1000	40	100	1125.02	411.84
256	1.4	.1	4.0	25.0	16.0	2000	40	100	1624.83	526.42
257	1.4	.1	4.0	35.0	21.0	0	40	100	1624.35	847.56
258	1.4	.1	4.0	35.0	21.0	2	40	100	1625.04	847.25
259	1.4	.1	4.0	35.0	21.0	10	40	100	1627.95	847.51
260	1.4	.1	4.0	35.0	21.0	50	40	100	1652.53	854.35

261	1.4	.1	4.0	35.0	21.0	100	40	100	1667.97	852.75
262	1.4	.1	4.0	35.0	21.0	500	40	100	2054.68	839.66
263	1.4	.1	4.0	35.0	21.0	1000	40	100	2509.31	921.93
264	1.4	.1	4.0	35.0	21.0	2000	40	100	3296.20	1034.75
265	1.4	.1	4.0	35.0	26.0	0	40	100	862.49	403.01
266	1.4	.1	4.0	35.0	26.0	2	40	100	863.48	402.90
267	1.4	.1	4.0	35.0	26.0	10	40	100	866.65	402.79
268	1.4	.1	4.0	35.0	26.0	50	40	100	890.81	393.84
269	1.4	.1	4.0	35.0	26.0	100	40	100	909.82	396.00
270	1.4	.1	4.0	35.0	26.0	500	40	100	1108.08	411.01
271	1.4	.1	4.0	35.0	26.0	1000	40	100	1370.48	472.40
272	1.4	.1	4.0	35.0	26.0	2000	40	100	1883.02	572.75
273	1.4	.1	4.0	45.0	26.0	0	40	100	3783.92	1629.17
274	1.4	.1	4.0	45.0	26.0	2	40	100	3783.92	1629.17
275	1.4	.1	4.0	45.0	26.0	10	40	100	3787.28	1624.88
276	1.4	.1	4.0	45.0	26.0	50	40	100	3812.27	1650.96
277	1.4	.1	4.0	45.0	26.0	100	40	100	3862.96	1658.39
278	1.4	.1	4.0	45.0	26.0	500	40	100	4321.17	1765.57
279	1.4	.1	4.0	45.0	26.0	1000	40	100	5024.51	1913.15
280	1.4	.1	4.0	45.0	26.0	2000	40	100	6171.71	2073.99
281	1.4	.1	4.0	45.0	31.0	0	40	100	2109.59	890.95
282	1.4	.1	4.0	45.0	31.0	2	40	100	2110.81	890.67
283	1.4	.1	4.0	45.0	31.0	10	40	100	2120.91	892.58
284	1.4	.1	4.0	45.0	31.0	50	40	100	2161.13	888.07
285	1.4	.1	4.0	45.0	31.0	100	40	100	2228.82	897.87
286	1.4	.1	4.0	45.0	31.0	500	40	100	2515.37	963.56
287	1.4	.1	4.0	45.0	31.0	1000	40	100	2919.36	1025.33
288	1.4	.1	4.0	45.0	31.0	2000	40	100	3760.98	1041.99
289	1.4	.2	1.0	5.0	1.0	0	40	100	41.90	42.92
290	1.4	.2	1.0	5.0	1.0	2	40	100	43.20	43.27
291	1.4	.2	1.0	5.0	1.0	10	40	100	51.26	53.60
292	1.4	.2	1.0	5.0	1.0	50	40	100	122.63	101.63
293	1.4	.2	1.0	5.0	1.0	100	40	100	232.34	137.19
294	1.4	.2	1.0	5.0	1.0	500	40	100	1035.35	253.59
295	1.4	.2	1.0	5.0	1.0	1000	40	100	2042.33	360.33
296	1.4	.2	1.0	5.0	1.0	2000	40	100	4037.05	454.25
297	1.4	.2	1.0	15.0	6.0	0	40	100	347.51	275.89
298	1.4	.2	1.0	15.0	6.0	2	40	100	358.73	275.20
299	1.4	.2	1.0	15.0	6.0	10	40	100	395.59	271.55
300	1.4	.2	1.0	15.0	6.0	50	40	100	550.73	318.39
301	1.4	.2	1.0	15.0	6.0	100	40	100	734.23	368.46
302	1.4	.2	1.0	15.0	6.0	500	40	100	2363.69	634.52
303	1.4	.2	1.0	15.0	6.0	1000	40	100	4267.66	753.59
304	1.4	.2	1.0	15.0	6.0	2000	40	100	8149.49	1048.44
305	1.4	.2	1.0	15.0	11.0	0	40	100	149.19	118.63
306	1.4	.2	1.0	15.0	11.0	2	40	100	152.27	119.52
307	1.4	.2	1.0	15.0	11.0	10	40	100	168.26	130.08
308	1.4	.2	1.0	15.0	11.0	50	40	100	263.15	145.14
309	1.4	.2	1.0	15.0	11.0	100	40	100	376.87	166.03
310	1.4	.2	1.0	15.0	11.0	500	40	100	1140.89	259.84
311	1.4	.2	1.0	15.0	11.0	1000	40	100	2158.38	365.09
312	1.4	.2	1.0	15.0	11.0	2000	40	100	4152.06	453.05
313	1.4	.2	1.0	25.0	11.0	0	40	100	1209.43	762.67
314	1.4	.2	1.0	25.0	11.0	2	40	100	1229.93	760.38
315	1.4	.2	1.0	25.0	11.0	10	40	100	1276.72	787.03
316	1.4	.2	1.0	25.0	11.0	50	40	100	1548.36	822.88
317	1.4	.2	1.0	25.0	11.0	100	40	100	1873.43	850.63
318	1.4	.2	1.0	25.0	11.0	500	40	100	4699.60	1340.33
319	1.4	.2	1.0	25.0	11.0	1000	40	100	8189.95	1687.67
321	1.4	.2	1.0	25.0	16.0	0	40	100	590.11	329.16
322	1.4	.2	1.0	25.0	16.0	2	40	100	605.26	343.42
323	1.4	.2	1.0	25.0	16.0	10	40	100	638.63	341.93
324	1.4	.2	1.0	25.0	16.0	50	40	100	809.53	386.70
325	1.4	.2	1.0	25.0	16.0	100	40	100	1009.30	383.90
326	1.4	.2	1.0	25.0	16.0	500	40	100	2573.26	638.36
327	1.4	.2	1.0	25.0	16.0	1000	40	100	4516.97	788.80
328	1.4	.2	1.0	25.0	16.0	2000	40	100	8399.99	1057.08
329	1.4	.2	1.0	35.0	21.0	0	40	100	1624.35	847.56
330	1.4	.2	1.0	35.0	21.0	2	40	100	1633.64	855.07
331	1.4	.2	1.0	35.0	21.0	10	40	100	1671.38	857.92
332	1.4	.2	1.0	35.0	21.0	50	40	100	1979.82	869.65
333	1.4	.2	1.0	35.0	21.0	100	40	100	2406.54	967.98
334	1.4	.2	1.0	35.0	21.0	500	40	100	5163.95	1356.02
335	1.4	.2	1.0	35.0	21.0	1000	40	100	8645.38	1729.71
337	1.4	.2	1.0	35.0	26.0	0	40	100	862.49	403.01
338	1.4	.2	1.0	35.0	26.0	2	40	100	868.41	404.27
339	1.4	.2	1.0	35.0	26.0	10	40	100	902.36	398.97
340	1.4	.2	1.0	35.0	26.0	50	40	100	1065.23	400.67
341	1.4	.2	1.0	35.0	26.0	100	40	100	1272.04	496.74
342	1.4	.2	1.0	35.0	26.0	500	40	100	2801.54	682.16
343	1.4	.2	1.0	35.0	26.0	1000	40	100	4753.18	850.03
344	1.4	.2	1.0	35.0	26.0	2000	40	100	8662.05	1115.37
345	1.4	.2	1.0	45.0	26.0	0	40	100	3783.92	1629.17
346	1.4	.2	1.0	45.0	26.0	2	40	100	3799.56	1643.05
347	1.4	.2	1.0	45.0	26.0	10	40	100	3867.62	1662.90
348	1.4	.2	1.0	45.0	26.0	50	40	100	4327.52	1744.80
349	1.4	.2	1.0	45.0	26.0	100	40	100	4957.29	1956.28
353	1.4	.2	1.0	45.0	31.0	0	40	100	2109.59	890.95
354	1.4	.2	1.0	45.0	31.0	2	40	100	2124.28	892.41
355	1.4	.2	1.0	45.0	31.0	10	40	100	2216.22	897.91

356	1.4	.2	1.0	45.0	31.0	50	40	100	2491.04	965.33
357	1.4	.2	1.0	45.0	31.0	100	40	100	2798.19	1040.98
358	1.4	.2	1.0	45.0	31.0	500	40	100	5652.49	1394.88
359	1.4	.2	1.0	45.0	31.0	1000	40	100	9166.86	1726.99
361	1.4	.2	2.0	5.0	1.0	0	40	100	41.90	42.92
362	1.4	.2	2.0	5.0	1.0	2	40	100	42.96	43.34
363	1.4	.2	2.0	5.0	1.0	10	40	100	46.34	46.12
364	1.4	.2	2.0	5.0	1.0	50	40	100	79.48	68.72
365	1.4	.2	2.0	5.0	1.0	100	40	100	155.27	120.18
366	1.4	.2	2.0	5.0	1.0	500	40	100	654.43	211.84
367	1.4	.2	2.0	5.0	1.0	1000	40	100	1302.98	258.34
368	1.4	.2	2.0	5.0	1.0	2000	40	100	2577.22	384.38
369	1.4	.2	2.0	15.0	6.0	0	40	100	347.51	275.89
370	1.4	.2	2.0	15.0	6.0	2	40	100	357.98	275.07
371	1.4	.2	2.0	15.0	6.0	10	40	100	376.14	274.31
372	1.4	.2	2.0	15.0	6.0	50	40	100	480.54	294.91
373	1.4	.2	2.0	15.0	6.0	100	40	100	585.22	309.08
374	1.4	.2	2.0	15.0	6.0	500	40	100	1548.58	530.84
375	1.4	.2	2.0	15.0	6.0	1000	40	100	2699.66	659.29
376	1.4	.2	2.0	15.0	6.0	2000	40	100	5035.18	837.70
377	1.4	.2	2.0	15.0	11.0	0	40	100	149.19	118.63
378	1.4	.2	2.0	15.0	11.0	2	40	100	151.57	118.65
379	1.4	.2	2.0	15.0	11.0	10	40	100	163.38	127.43
380	1.4	.2	2.0	15.0	11.0	50	40	100	211.79	137.89
381	1.4	.2	2.0	15.0	11.0	100	40	100	287.80	144.04
382	1.4	.2	2.0	15.0	11.0	500	40	100	791.18	228.89
383	1.4	.2	2.0	15.0	11.0	1000	40	100	1413.97	274.84
384	1.4	.2	2.0	15.0	11.0	2000	40	100	2688.02	401.18
385	1.4	.2	2.0	25.0	11.0	0	40	100	1209.43	762.67
386	1.4	.2	2.0	25.0	11.0	2	40	100	1219.59	767.04
387	1.4	.2	2.0	25.0	11.0	10	40	100	1246.30	774.84
388	1.4	.2	2.0	25.0	11.0	50	40	100	1426.31	799.36
389	1.4	.2	2.0	25.0	11.0	100	40	100	1569.56	822.46
390	1.4	.2	2.0	25.0	11.0	500	40	100	3247.33	1046.65
391	1.4	.2	2.0	25.0	11.0	1000	40	100	5277.88	1301.46
392	1.4	.2	2.0	25.0	11.0	2000	40	100	9330.31	1700.51
393	1.4	.2	2.0	25.0	16.0	0	40	100	590.11	329.16
394	1.4	.2	2.0	25.0	16.0	2	40	100	597.15	330.86
395	1.4	.2	2.0	25.0	16.0	10	40	100	622.78	347.81
396	1.4	.2	2.0	25.0	16.0	50	40	100	713.24	361.13
397	1.4	.2	2.0	25.0	16.0	100	40	100	848.20	392.14
398	1.4	.2	2.0	25.0	16.0	500	40	100	1795.95	580.20
399	1.4	.2	2.0	25.0	16.0	1000	40	100	2959.16	661.75
400	1.4	.2	2.0	25.0	16.0	2000	40	100	5274.75	879.29
401	1.4	.2	2.0	35.0	21.0	0	40	100	1624.35	847.56
402	1.4	.2	2.0	35.0	21.0	2	40	100	1627.95	847.51
403	1.4	.2	2.0	35.0	21.0	10	40	100	1649.53	854.20
404	1.4	.2	2.0	35.0	21.0	50	40	100	1822.62	847.77
405	1.4	.2	2.0	35.0	21.0	100	40	100	2058.51	849.07
406	1.4	.2	2.0	35.0	21.0	500	40	100	3679.38	1091.62
407	1.4	.2	2.0	35.0	21.0	1000	40	100	5743.98	1396.79
409	1.4	.2	2.0	35.0	26.0	0	40	100	862.49	403.01
410	1.4	.2	2.0	35.0	26.0	2	40	100	866.65	402.79
411	1.4	.2	2.0	35.0	26.0	10	40	100	887.95	400.27
412	1.4	.2	2.0	35.0	26.0	50	40	100	988.92	387.60
413	1.4	.2	2.0	35.0	26.0	100	40	100	1097.02	406.78
414	1.4	.2	2.0	35.0	26.0	500	40	100	2063.91	607.72
415	1.4	.2	2.0	35.0	26.0	1000	40	100	3262.04	669.52
416	1.4	.2	2.0	35.0	26.0	2000	40	100	5548.89	896.85
417	1.4	.2	2.0	45.0	26.0	0	40	100	3783.92	1629.17
418	1.4	.2	2.0	45.0	26.0	2	40	100	3787.28	1624.88
419	1.4	.2	2.0	45.0	26.0	10	40	100	3818.54	1650.52
420	1.4	.2	2.0	45.0	26.0	50	40	100	4063.59	1738.08
421	1.4	.2	2.0	45.0	26.0	100	40	100	4427.07	1769.92
422	1.4	.2	2.0	45.0	26.0	500	40	100	6951.09	2358.85
425	1.4	.2	2.0	45.0	31.0	0	40	100	2109.59	890.95
426	1.4	.2	2.0	45.0	31.0	2	40	100	2120.91	892.58
427	1.4	.2	2.0	45.0	31.0	10	40	100	2164.20	892.63
428	1.4	.2	2.0	45.0	31.0	50	40	100	2389.04	968.92
429	1.4	.2	2.0	45.0	31.0	100	40	100	2536.98	993.44
430	1.4	.2	2.0	45.0	31.0	500	40	100	4119.34	1172.80
431	1.4	.2	2.0	45.0	31.0	1000	40	100	6139.14	1439.99
433	1.4	.2	3.0	5.0	1.0	0	40	100	41.90	42.92
434	1.4	.2	3.0	5.0	1.0	2	40	100	42.84	43.31
435	1.4	.2	3.0	5.0	1.0	10	40	100	44.45	43.31
436	1.4	.2	3.0	5.0	1.0	50	40	100	66.39	63.00
437	1.4	.2	3.0	5.0	1.0	100	40	100	103.12	86.99
438	1.4	.2	3.0	5.0	1.0	500	40	100	469.41	165.62
439	1.4	.2	3.0	5.0	1.0	1000	40	100	896.31	213.49
440	1.4	.2	3.0	5.0	1.0	2000	40	100	1738.34	314.28
441	1.4	.2	3.0	15.0	6.0	0	40	100	347.51	275.89
442	1.4	.2	3.0	15.0	6.0	2	40	100	355.29	276.24
443	1.4	.2	3.0	15.0	6.0	10	40	100	369.32	271.40
444	1.4	.2	3.0	15.0	6.0	50	40	100	428.95	263.09
445	1.4	.2	3.0	15.0	6.0	100	40	100	512.78	303.62
446	1.4	.2	3.0	15.0	6.0	500	40	100	1114.63	409.90
447	1.4	.2	3.0	15.0	6.0	1000	40	100	1871.59	566.71
448	1.4	.2	3.0	15.0	6.0	2000	40	100	3422.14	642.11
449	1.4	.2	3.0	15.0	11.0	0	40	100	149.19	118.63
450	1.4	.2	3.0	15.0	11.0	2	40	100	150.96	118.92

451	1.4	.2	3.0	15.0	11.0	10	40	100	159.44	123.97
452	1.4	.2	3.0	15.0	11.0	50	40	100	188.64	135.01
453	1.4	.2	3.0	15.0	11.0	100	40	100	240.83	136.89
454	1.4	.2	3.0	15.0	11.0	500	40	100	570.87	192.93
455	1.4	.2	3.0	15.0	11.0	1000	40	100	1015.23	240.64
456	1.4	.2	3.0	15.0	11.0	2000	40	100	1856.56	318.19
457	1.4	.2	3.0	25.0	11.0	0	40	100	1209.43	762.67
458	1.4	.2	3.0	25.0	11.0	2	40	100	1212.92	760.85
459	1.4	.2	3.0	25.0	11.0	10	40	100	1239.70	771.91
460	1.4	.2	3.0	25.0	11.0	50	40	100	1341.24	783.92
461	1.4	.2	3.0	25.0	11.0	100	40	100	1456.18	800.56
462	1.4	.2	3.0	25.0	11.0	500	40	100	2469.79	907.71
463	1.4	.2	3.0	25.0	11.0	1000	40	100	3716.74	1027.09
464	1.4	.2	3.0	25.0	11.0	2000	40	100	6162.53	1318.11
465	1.4	.2	3.0	25.0	16.0	0	40	100	590.11	329.16
466	1.4	.2	3.0	25.0	16.0	2	40	100	595.69	328.70
467	1.4	.2	3.0	25.0	16.0	10	40	100	613.93	348.12
468	1.4	.2	3.0	25.0	16.0	50	40	100	685.15	353.68
469	1.4	.2	3.0	25.0	16.0	100	40	100	737.64	366.94
470	1.4	.2	3.0	25.0	16.0	500	40	100	1361.73	475.34
471	1.4	.2	3.0	25.0	16.0	1000	40	100	2149.20	595.82
472	1.4	.2	3.0	25.0	16.0	2000	40	100	3645.93	682.62
473	1.4	.2	3.0	35.0	21.0	0	40	100	1624.35	847.56
474	1.4	.2	3.0	35.0	21.0	2	40	100	1627.95	847.51
475	1.4	.2	3.0	35.0	21.0	10	40	100	1646.05	856.66
476	1.4	.2	3.0	35.0	21.0	50	40	100	1732.48	845.96
477	1.4	.2	3.0	35.0	21.0	100	40	100	1877.87	847.43
478	1.4	.2	3.0	35.0	21.0	500	40	100	2896.94	1014.27
479	1.4	.2	3.0	35.0	21.0	1000	40	100	4102.16	1110.80
480	1.4	.2	3.0	35.0	21.0	2000	40	100	6607.42	1397.62
481	1.4	.2	3.0	35.0	26.0	0	40	100	862.49	403.01
482	1.4	.2	3.0	35.0	26.0	2	40	100	865.46	402.84
483	1.4	.2	3.0	35.0	26.0	10	40	100	876.83	402.68
484	1.4	.2	3.0	35.0	26.0	50	40	100	940.53	387.63
485	1.4	.2	3.0	35.0	26.0	100	40	100	1015.77	382.92
486	1.4	.2	3.0	35.0	26.0	500	40	100	1602.38	563.04
487	1.4	.2	3.0	35.0	26.0	1000	40	100	2400.64	611.02
488	1.4	.2	3.0	35.0	26.0	2000	40	100	3878.51	670.12
489	1.4	.2	3.0	45.0	26.0	0	40	100	3783.92	1629.17
490	1.4	.2	3.0	45.0	26.0	2	40	100	3783.92	1629.17
491	1.4	.2	3.0	45.0	26.0	10	40	100	3803.36	1643.35
492	1.4	.2	3.0	45.0	26.0	50	40	100	3936.57	1689.70
493	1.4	.2	3.0	45.0	26.0	100	40	100	4117.66	1724.02
494	1.4	.2	3.0	45.0	26.0	500	40	100	5803.66	2081.61
497	1.4	.2	3.0	45.0	31.0	0	40	100	2109.59	890.95
498	1.4	.2	3.0	45.0	31.0	2	40	100	2120.12	892.60
499	1.4	.2	3.0	45.0	31.0	10	40	100	2138.89	895.53
500	1.4	.2	3.0	45.0	31.0	50	40	100	2281.98	894.22
501	1.4	.2	3.0	45.0	31.0	100	40	100	2425.13	954.74
502	1.4	.2	3.0	45.0	31.0	500	40	100	3362.28	1055.50
503	1.4	.2	3.0	45.0	31.0	1000	40	100	4583.06	1226.97
504	1.4	.2	3.0	45.0	31.0	2000	40	100	7077.31	1433.54
505	1.4	.2	4.0	5.0	1.0	0	40	100	41.90	42.92
506	1.4	.2	4.0	5.0	1.0	2	40	100	42.12	42.99
507	1.4	.2	4.0	5.0	1.0	10	40	100	44.31	43.05
508	1.4	.2	4.0	5.0	1.0	50	40	100	56.31	54.04
509	1.4	.2	4.0	5.0	1.0	100	40	100	80.91	69.52
510	1.4	.2	4.0	5.0	1.0	500	40	100	353.42	139.40
511	1.4	.2	4.0	5.0	1.0	1000	40	100	620.06	186.42
512	1.4	.2	4.0	5.0	1.0	2000	40	100	1258.72	231.45
513	1.4	.2	4.0	15.0	6.0	0	40	100	347.51	275.89
514	1.4	.2	4.0	15.0	6.0	2	40	100	350.78	276.09
515	1.4	.2	4.0	15.0	6.0	10	40	100	360.40	273.99
516	1.4	.2	4.0	15.0	6.0	50	40	100	404.70	269.13
517	1.4	.2	4.0	15.0	6.0	100	40	100	470.73	281.25
518	1.4	.2	4.0	15.0	6.0	500	40	100	868.90	363.19
519	1.4	.2	4.0	15.0	6.0	1000	40	100	1393.65	448.44
520	1.4	.2	4.0	15.0	6.0	2000	40	100	2433.28	581.70
521	1.4	.2	4.0	15.0	11.0	0	40	100	149.19	118.63
522	1.4	.2	4.0	15.0	11.0	2	40	100	150.88	118.83
523	1.4	.2	4.0	15.0	11.0	10	40	100	157.09	124.62
524	1.4	.2	4.0	15.0	11.0	50	40	100	178.62	131.81
525	1.4	.2	4.0	15.0	11.0	100	40	100	210.82	136.07
526	1.4	.2	4.0	15.0	11.0	500	40	100	469.47	165.23
527	1.4	.2	4.0	15.0	11.0	1000	40	100	769.78	218.30
528	1.4	.2	4.0	15.0	11.0	2000	40	100	1378.59	255.11
529	1.4	.2	4.0	25.0	11.0	0	40	100	1209.43	762.67
530	1.4	.2	4.0	25.0	11.0	2	40	100	1210.68	762.66
531	1.4	.2	4.0	25.0	11.0	10	40	100	1229.90	760.32
532	1.4	.2	4.0	25.0	11.0	50	40	100	1295.38	781.53
533	1.4	.2	4.0	25.0	11.0	100	40	100	1373.38	787.09
534	1.4	.2	4.0	25.0	11.0	500	40	100	1978.82	840.65
535	1.4	.2	4.0	25.0	11.0	1000	40	100	2812.65	941.57
536	1.4	.2	4.0	25.0	11.0	2000	40	100	4402.41	1098.46
537	1.4	.2	4.0	25.0	16.0	0	40	100	590.11	329.16
538	1.4	.2	4.0	25.0	16.0	2	40	100	593.89	329.27
539	1.4	.2	4.0	25.0	16.0	10	40	100	606.48	330.33
540	1.4	.2	4.0	25.0	16.0	50	40	100	656.45	353.43
541	1.4	.2	4.0	25.0	16.0	100	40	100	699.39	349.49
542	1.4	.2	4.0	25.0	16.0	500	40	100	1125.36	412.14

543	1.4	.2	4.0	25.0	16.0	1000	40	100	1633.20	519.11
544	1.4	.2	4.0	25.0	16.0	2000	40	100	2641.33	596.48
545	1.4	.2	4.0	35.0	21.0	0	40	100	1624.35	847.56
546	1.4	.2	4.0	35.0	21.0	2	40	100	1625.04	847.25
547	1.4	.2	4.0	35.0	21.0	10	40	100	1630.20	854.40
548	1.4	.2	4.0	35.0	21.0	50	40	100	1671.65	851.12
549	1.4	.2	4.0	35.0	21.0	100	40	100	1788.62	844.31
550	1.4	.2	4.0	35.0	21.0	500	40	100	2509.31	921.93
551	1.4	.2	4.0	35.0	21.0	1000	40	100	3303.50	1032.34
552	1.4	.2	4.0	35.0	21.0	2000	40	100	4893.18	1204.35
553	1.4	.2	4.0	35.0	26.0	0	40	100	862.49	403.01
554	1.4	.2	4.0	35.0	26.0	2	40	100	864.15	403.45
555	1.4	.2	4.0	35.0	26.0	10	40	100	872.78	401.59
556	1.4	.2	4.0	35.0	26.0	50	40	100	910.62	395.66
557	1.4	.2	4.0	35.0	26.0	100	40	100	976.46	383.35
558	1.4	.2	4.0	35.0	26.0	500	40	100	1373.77	471.91
559	1.4	.2	4.0	35.0	26.0	1000	40	100	1888.87	568.56
560	1.4	.2	4.0	35.0	26.0	2000	40	100	2896.50	622.37
561	1.4	.2	4.0	45.0	26.0	0	40	100	3783.92	1629.17
562	1.4	.2	4.0	45.0	26.0	2	40	100	3783.92	1629.17
563	1.4	.2	4.0	45.0	26.0	10	40	100	3791.97	1627.63
564	1.4	.2	4.0	45.0	26.0	50	40	100	3869.37	1661.90
565	1.4	.2	4.0	45.0	26.0	100	40	100	4013.20	1738.96
566	1.4	.2	4.0	45.0	26.0	500	40	100	5024.59	1913.21
567	1.4	.2	4.0	45.0	26.0	1000	40	100	6180.38	2086.29
569	1.4	.2	4.0	45.0	31.0	0	40	100	2109.59	890.95
570	1.4	.2	4.0	45.0	31.0	2	40	100	2110.85	890.71
571	1.4	.2	4.0	45.0	31.0	10	40	100	2125.28	892.96
572	1.4	.2	4.0	45.0	31.0	50	40	100	2228.82	897.87
573	1.4	.2	4.0	45.0	31.0	100	40	100	2334.59	930.19
574	1.4	.2	4.0	45.0	31.0	500	40	100	2919.42	1025.33
575	1.4	.2	4.0	45.0	31.0	1000	40	100	3764.28	1041.98
576	1.4	.2	4.0	45.0	31.0	2000	40	100	5379.10	1224.73
577	1.4	.5	1.0	5.0	1.0	0	40	100	41.90	42.92
578	1.4	.5	1.0	5.0	1.0	2	40	100	46.07	45.06
579	1.4	.5	1.0	5.0	1.0	10	40	100	69.40	64.75
580	1.4	.5	1.0	5.0	1.0	50	40	100	289.64	143.43
581	1.4	.5	1.0	5.0	1.0	100	40	100	539.07	187.08
582	1.4	.5	1.0	5.0	1.0	500	40	100	2559.44	394.82
583	1.4	.5	1.0	5.0	1.0	1000	40	100	4980.03	523.67
584	1.4	.5	1.0	5.0	1.0	2000	40	100	10004.42	746.15
585	1.4	.5	1.0	15.0	6.0	0	40	100	347.51	275.89
586	1.4	.5	1.0	15.0	6.0	2	40	100	375.80	273.91
587	1.4	.5	1.0	15.0	6.0	10	40	100	464.62	289.38
588	1.4	.5	1.0	15.0	6.0	50	40	100	853.56	390.49
589	1.4	.5	1.0	15.0	6.0	100	40	100	1345.93	506.99
590	1.4	.5	1.0	15.0	6.0	500	40	100	5236.46	911.78
591	1.4	.5	1.0	15.0	6.0	1000	40	100	10144.05	1157.58
593	1.4	.5	1.0	15.0	11.0	0	40	100	149.19	118.63
594	1.4	.5	1.0	15.0	11.0	2	40	100	161.18	125.35
595	1.4	.5	1.0	15.0	11.0	10	40	100	196.13	135.89
596	1.4	.5	1.0	15.0	11.0	50	40	100	419.23	165.93
597	1.4	.5	1.0	15.0	11.0	100	40	100	649.36	218.24
598	1.4	.5	1.0	15.0	11.0	500	40	100	2668.73	410.45
599	1.4	.5	1.0	15.0	11.0	1000	40	100	5107.22	529.85
600	1.4	.5	1.0	15.0	11.0	2000	40	100	10124.86	747.70
601	1.4	.5	1.0	25.0	11.0	0	40	100	1209.43	762.67
602	1.4	.5	1.0	25.0	11.0	2	40	100	1246.25	774.87
603	1.4	.5	1.0	25.0	11.0	10	40	100	1391.03	804.06
604	1.4	.5	1.0	25.0	11.0	50	40	100	2063.48	846.70
605	1.4	.5	1.0	25.0	11.0	100	40	100	2937.06	1064.77
609	1.4	.5	1.0	25.0	16.0	0	40	100	590.11	329.16
610	1.4	.5	1.0	25.0	16.0	2	40	100	615.92	346.25
611	1.4	.5	1.0	25.0	16.0	10	40	100	699.06	358.08
612	1.4	.5	1.0	25.0	16.0	50	40	100	1103.13	417.12
613	1.4	.5	1.0	25.0	16.0	100	40	100	1599.78	585.89
614	1.4	.5	1.0	25.0	16.0	500	40	100	5490.39	922.36
615	1.4	.5	1.0	25.0	16.0	1000	40	100	10390.57	1176.79
617	1.4	.5	1.0	35.0	21.0	0	40	100	1624.35	847.56
618	1.4	.5	1.0	35.0	21.0	2	40	100	1648.99	854.28
619	1.4	.5	1.0	35.0	21.0	10	40	100	1784.85	847.54
620	1.4	.5	1.0	35.0	21.0	50	40	100	2545.26	1004.32
621	1.4	.5	1.0	35.0	21.0	100	40	100	3405.56	1077.97
625	1.4	.5	1.0	35.0	26.0	0	40	100	862.49	403.01
626	1.4	.5	1.0	35.0	26.0	2	40	100	883.38	402.66
627	1.4	.5	1.0	35.0	26.0	10	40	100	969.35	392.68
628	1.4	.5	1.0	35.0	26.0	50	40	100	1350.48	511.71
629	1.4	.5	1.0	35.0	26.0	100	40	100	1854.95	591.70
630	1.4	.5	1.0	35.0	26.0	500	40	100	5726.75	918.18
631	1.4	.5	1.0	35.0	26.0	1000	40	100	10670.47	1184.60
633	1.4	.5	1.0	45.0	26.0	0	40	100	3783.92	1629.17
634	1.4	.5	1.0	45.0	26.0	2	40	100	3816.26	1650.39
635	1.4	.5	1.0	45.0	26.0	10	40	100	4015.53	1746.18
636	1.4	.5	1.0	45.0	26.0	50	40	100	5246.05	1953.98
637	1.4	.5	1.0	45.0	26.0	100	40	100	6616.59	2323.55
641	1.4	.5	1.0	45.0	31.0	0	40	100	2109.59	890.95
642	1.4	.5	1.0	45.0	31.0	2	40	100	2158.27	891.50
643	1.4	.5	1.0	45.0	31.0	10	40	100	2339.62	935.24
644	1.4	.5	1.0	45.0	31.0	50	40	100	2984.66	1057.98
645	1.4	.5	1.0	45.0	31.0	100	40	100	3856.85	1138.16

649	1.4	.5	2.0	5.0	1.0	0	40	100	41.90	42.92
650	1.4	.5	2.0	5.0	1.0	2	40	100	44.31	43.05
651	1.4	.5	2.0	5.0	1.0	10	40	100	56.04	57.59
652	1.4	.5	2.0	5.0	1.0	50	40	100	183.40	131.03
653	1.4	.5	2.0	5.0	1.0	100	40	100	367.21	156.00
654	1.4	.5	2.0	5.0	1.0	500	40	100	1596.88	313.28
655	1.4	.5	2.0	5.0	1.0	1000	40	100	3215.63	419.41
656	1.4	.5	2.0	5.0	1.0	2000	40	100	6324.72	584.54
657	1.4	.5	2.0	15.0	6.0	0	40	100	347.51	275.89
658	1.4	.5	2.0	15.0	6.0	2	40	100	360.40	273.99
659	1.4	.5	2.0	15.0	6.0	10	40	100	410.87	269.22
660	1.4	.5	2.0	15.0	6.0	50	40	100	651.06	340.55
661	1.4	.5	2.0	15.0	6.0	100	40	100	948.60	367.84
662	1.4	.5	2.0	15.0	6.0	500	40	100	3348.34	669.09
663	1.4	.5	2.0	15.0	6.0	1000	40	100	6247.46	919.44
665	1.4	.5	2.0	15.0	11.0	0	40	100	149.19	118.63
666	1.4	.5	2.0	15.0	11.0	2	40	100	157.10	124.62
667	1.4	.5	2.0	15.0	11.0	10	40	100	177.90	131.41
668	1.4	.5	2.0	15.0	11.0	50	40	100	325.02	151.78
669	1.4	.5	2.0	15.0	11.0	100	40	100	482.03	176.88
670	1.4	.5	2.0	15.0	11.0	500	40	100	1736.93	327.36
671	1.4	.5	2.0	15.0	11.0	1000	40	100	3328.18	423.92
672	1.4	.5	2.0	15.0	11.0	2000	40	100	6456.83	596.47
673	1.4	.5	2.0	25.0	11.0	0	40	100	1209.43	762.67
674	1.4	.5	2.0	25.0	11.0	2	40	100	1233.75	766.72
675	1.4	.5	2.0	25.0	11.0	10	40	100	1309.87	778.08
676	1.4	.5	2.0	25.0	11.0	50	40	100	1647.90	836.06
677	1.4	.5	2.0	25.0	11.0	100	40	100	2243.55	869.64
678	1.4	.5	2.0	25.0	11.0	500	40	100	6224.15	1433.85
681	1.4	.5	2.0	25.0	16.0	0	40	100	590.11	329.16
682	1.4	.5	2.0	25.0	16.0	2	40	100	609.75	341.13
683	1.4	.5	2.0	25.0	16.0	10	40	100	664.27	352.93
684	1.4	.5	2.0	25.0	16.0	50	40	100	904.63	382.73
685	1.4	.5	2.0	25.0	16.0	100	40	100	1214.22	458.07
686	1.4	.5	2.0	25.0	16.0	500	40	100	3590.58	715.92
687	1.4	.5	2.0	25.0	16.0	1000	40	100	6480.55	921.85
689	1.4	.5	2.0	35.0	21.0	0	40	100	1624.35	847.56
690	1.4	.5	2.0	35.0	21.0	2	40	100	1642.22	861.23
691	1.4	.5	2.0	35.0	21.0	10	40	100	1685.65	851.58
692	1.4	.5	2.0	35.0	21.0	50	40	100	2183.20	876.78
693	1.4	.5	2.0	35.0	21.0	100	40	100	2712.59	983.75
694	1.4	.5	2.0	35.0	21.0	500	40	100	6692.97	1426.70
697	1.4	.5	2.0	35.0	26.0	0	40	100	862.49	403.01
698	1.4	.5	2.0	35.0	26.0	2	40	100	872.95	401.49
699	1.4	.5	2.0	35.0	26.0	10	40	100	919.54	391.29
700	1.4	.5	2.0	35.0	26.0	50	40	100	1160.90	439.24
701	1.4	.5	2.0	35.0	26.0	100	40	100	1453.62	531.80
702	1.4	.5	2.0	35.0	26.0	500	40	100	3828.83	699.11
703	1.4	.5	2.0	35.0	26.0	1000	40	100	6718.70	933.05
705	1.4	.5	2.0	45.0	26.0	0	40	100	3783.92	1629.17
706	1.4	.5	2.0	45.0	26.0	2	40	100	3803.36	1643.35
707	1.4	.5	2.0	45.0	26.0	10	40	100	3904.73	1689.26
708	1.4	.5	2.0	45.0	26.0	50	40	100	4581.92	1850.19
709	1.4	.5	2.0	45.0	26.0	100	40	100	5412.44	1931.25
713	1.4	.5	2.0	45.0	31.0	0	40	100	2109.59	890.95
714	1.4	.5	2.0	45.0	31.0	2	40	100	2138.66	895.93
715	1.4	.5	2.0	45.0	31.0	10	40	100	2250.24	895.62
716	1.4	.5	2.0	45.0	31.0	50	40	100	2632.21	995.85
717	1.4	.5	2.0	45.0	31.0	100	40	100	3161.22	1065.98
718	1.4	.5	2.0	45.0	31.0	500	40	100	7127.32	1480.95
721	1.4	.5	3.0	5.0	1.0	0	40	100	41.90	42.92
722	1.4	.5	3.0	5.0	1.0	2	40	100	43.65	43.16
723	1.4	.5	3.0	5.0	1.0	10	40	100	49.70	46.54
724	1.4	.5	3.0	5.0	1.0	50	40	100	132.81	106.49
725	1.4	.5	3.0	5.0	1.0	100	40	100	250.14	132.24
726	1.4	.5	3.0	5.0	1.0	500	40	100	1089.67	234.05
727	1.4	.5	3.0	5.0	1.0	1000	40	100	2160.38	340.52
728	1.4	.5	3.0	5.0	1.0	2000	40	100	4265.38	433.08
729	1.4	.5	3.0	15.0	6.0	0	40	100	347.51	275.89
730	1.4	.5	3.0	15.0	6.0	2	40	100	358.73	275.20
731	1.4	.5	3.0	15.0	6.0	10	40	100	398.90	268.88
732	1.4	.5	3.0	15.0	6.0	50	40	100	541.83	305.73
733	1.4	.5	3.0	15.0	6.0	100	40	100	725.37	354.26
734	1.4	.5	3.0	15.0	6.0	500	40	100	2281.74	585.76
735	1.4	.5	3.0	15.0	6.0	1000	40	100	4082.46	690.69
736	1.4	.5	3.0	15.0	6.0	2000	40	100	7831.97	917.15
737	1.4	.5	3.0	15.0	11.0	0	40	100	149.19	118.63
738	1.4	.5	3.0	15.0	11.0	2	40	100	153.40	121.45
739	1.4	.5	3.0	15.0	11.0	10	40	100	170.29	129.85
740	1.4	.5	3.0	15.0	11.0	50	40	100	268.68	139.13
741	1.4	.5	3.0	15.0	11.0	100	40	100	385.37	156.87
742	1.4	.5	3.0	15.0	11.0	500	40	100	1224.34	247.04
743	1.4	.5	3.0	15.0	11.0	1000	40	100	2308.26	354.11
744	1.4	.5	3.0	15.0	11.0	2000	40	100	4371.45	427.85
745	1.4	.5	3.0	25.0	11.0	0	40	100	1209.43	762.67
746	1.4	.5	3.0	25.0	11.0	2	40	100	1227.91	761.89
747	1.4	.5	3.0	25.0	11.0	10	40	100	1260.89	786.37
748	1.4	.5	3.0	25.0	11.0	50	40	100	1506.92	808.96
749	1.4	.5	3.0	25.0	11.0	100	40	100	1771.32	812.35
750	1.4	.5	3.0	25.0	11.0	500	40	100	4299.00	1133.55

751	1.4	.5	3.0	25.0	11.0	1000	40	100	7367.16	1419.56
753	1.4	.5	3.0	25.0	16.0	0	40	100	590.11	329.16
754	1.4	.5	3.0	25.0	16.0	2	40	100	602.00	332.66
755	1.4	.5	3.0	25.0	16.0	10	40	100	638.59	341.92
756	1.4	.5	3.0	25.0	16.0	50	40	100	795.87	379.58
757	1.4	.5	3.0	25.0	16.0	100	40	100	990.63	379.76
758	1.4	.5	3.0	25.0	16.0	500	40	100	2502.96	605.20
759	1.4	.5	3.0	25.0	16.0	1000	40	100	4337.20	718.35
760	1.4	.5	3.0	25.0	16.0	2000	40	100	8063.56	974.34
761	1.4	.5	3.0	35.0	21.0	0	40	100	1624.35	847.56
762	1.4	.5	3.0	35.0	21.0	2	40	100	1630.20	854.40
763	1.4	.5	3.0	35.0	21.0	10	40	100	1661.88	858.95
764	1.4	.5	3.0	35.0	21.0	50	40	100	1933.16	846.63
765	1.4	.5	3.0	35.0	21.0	100	40	100	2338.75	914.86
766	1.4	.5	3.0	35.0	21.0	500	40	100	4775.04	1252.53
767	1.4	.5	3.0	35.0	21.0	1000	40	100	7839.93	1541.70
769	1.4	.5	3.0	35.0	26.0	0	40	100	862.49	403.01
770	1.4	.5	3.0	35.0	26.0	2	40	100	867.77	403.04
771	1.4	.5	3.0	35.0	26.0	10	40	100	900.68	397.53
772	1.4	.5	3.0	35.0	26.0	50	40	100	1051.25	395.54
773	1.4	.5	3.0	35.0	26.0	100	40	100	1251.52	463.61
774	1.4	.5	3.0	35.0	26.0	500	40	100	2713.80	650.96
775	1.4	.5	3.0	35.0	26.0	1000	40	100	4581.50	755.52
776	1.4	.5	3.0	35.0	26.0	2000	40	100	8313.30	999.05
777	1.4	.5	3.0	45.0	26.0	0	40	100	3783.92	1629.17
778	1.4	.5	3.0	45.0	26.0	2	40	100	3787.37	1624.89
779	1.4	.5	3.0	45.0	26.0	10	40	100	3858.71	1659.79
780	1.4	.5	3.0	45.0	26.0	50	40	100	4205.62	1750.87
781	1.4	.5	3.0	45.0	26.0	100	40	100	4706.49	1862.14
785	1.4	.5	3.0	45.0	31.0	0	40	100	2109.59	890.95
786	1.4	.5	3.0	45.0	31.0	2	40	100	2120.99	892.58
787	1.4	.5	3.0	45.0	31.0	10	40	100	2201.82	900.87
788	1.4	.5	3.0	45.0	31.0	50	40	100	2456.42	968.27
789	1.4	.5	3.0	45.0	31.0	100	40	100	2753.18	1017.83
790	1.4	.5	3.0	45.0	31.0	500	40	100	5226.01	1287.38
791	1.4	.5	3.0	45.0	31.0	1000	40	100	8355.38	1642.16
793	1.4	.5	4.0	5.0	1.0	0	40	100	41.90	42.92
794	1.4	.5	4.0	5.0	1.0	2	40	100	43.18	43.25
795	1.4	.5	4.0	5.0	1.0	10	40	100	47.01	45.93
796	1.4	.5	4.0	5.0	1.0	50	40	100	92.11	74.00
797	1.4	.5	4.0	5.0	1.0	100	40	100	177.70	124.49
798	1.4	.5	4.0	5.0	1.0	500	40	100	805.13	217.23
799	1.4	.5	4.0	5.0	1.0	1000	40	100	1542.92	272.75
800	1.4	.5	4.0	5.0	1.0	2000	40	100	3100.05	386.37
801	1.4	.5	4.0	15.0	6.0	0	40	100	347.51	275.89
802	1.4	.5	4.0	15.0	6.0	2	40	100	357.98	275.07
803	1.4	.5	4.0	15.0	6.0	10	40	100	383.45	275.72
804	1.4	.5	4.0	15.0	6.0	50	40	100	491.86	290.44
805	1.4	.5	4.0	15.0	6.0	100	40	100	610.14	308.65
806	1.4	.5	4.0	15.0	6.0	500	40	100	1639.61	512.21
807	1.4	.5	4.0	15.0	6.0	1000	40	100	2889.02	607.48
808	1.4	.5	4.0	15.0	6.0	2000	40	100	5417.37	854.46
809	1.4	.5	4.0	15.0	11.0	0	40	100	149.19	118.63
810	1.4	.5	4.0	15.0	11.0	2	40	100	151.77	118.53
811	1.4	.5	4.0	15.0	11.0	10	40	100	164.73	128.42
812	1.4	.5	4.0	15.0	11.0	50	40	100	227.91	136.18
813	1.4	.5	4.0	15.0	11.0	100	40	100	321.38	146.52
814	1.4	.5	4.0	15.0	11.0	500	40	100	923.74	223.31
815	1.4	.5	4.0	15.0	11.0	1000	40	100	1673.55	294.44
816	1.4	.5	4.0	15.0	11.0	2000	40	100	3216.32	388.09
817	1.4	.5	4.0	25.0	11.0	0	40	100	1209.43	762.67
818	1.4	.5	4.0	25.0	11.0	2	40	100	1218.45	762.06
819	1.4	.5	4.0	25.0	11.0	10	40	100	1245.05	774.35
820	1.4	.5	4.0	25.0	11.0	50	40	100	1393.46	783.36
821	1.4	.5	4.0	25.0	11.0	100	40	100	1572.71	804.43
822	1.4	.5	4.0	25.0	11.0	500	40	100	3220.55	1012.52
823	1.4	.5	4.0	25.0	11.0	1000	40	100	5244.10	1169.64
824	1.4	.5	4.0	25.0	11.0	2000	40	100	9402.86	1515.40
825	1.4	.5	4.0	25.0	16.0	0	40	100	590.11	329.16
826	1.4	.5	4.0	25.0	16.0	2	40	100	597.80	330.61
827	1.4	.5	4.0	25.0	16.0	10	40	100	631.88	342.59
828	1.4	.5	4.0	25.0	16.0	50	40	100	718.77	357.03
829	1.4	.5	4.0	25.0	16.0	100	40	100	873.70	382.41
830	1.4	.5	4.0	25.0	16.0	500	40	100	1899.26	564.41
831	1.4	.5	4.0	25.0	16.0	1000	40	100	3217.53	600.46
832	1.4	.5	4.0	25.0	16.0	2000	40	100	5698.96	868.18
833	1.4	.5	4.0	35.0	21.0	0	40	100	1624.35	847.56
834	1.4	.5	4.0	35.0	21.0	2	40	100	1627.95	847.51
835	1.4	.5	4.0	35.0	21.0	10	40	100	1652.53	854.35
836	1.4	.5	4.0	35.0	21.0	50	40	100	1828.63	844.95
837	1.4	.5	4.0	35.0	21.0	100	40	100	2054.80	839.49
838	1.4	.5	4.0	35.0	21.0	500	40	100	3714.14	1010.72
839	1.4	.5	4.0	35.0	21.0	1000	40	100	5721.29	1283.60
840	1.4	.5	4.0	35.0	21.0	2000	40	100	9902.30	1594.77
841	1.4	.5	4.0	35.0	26.0	0	40	100	862.49	403.01
842	1.4	.5	4.0	35.0	26.0	2	40	100	866.65	402.79
843	1.4	.5	4.0	35.0	26.0	10	40	100	890.81	393.84
844	1.4	.5	4.0	35.0	26.0	50	40	100	994.02	383.81
845	1.4	.5	4.0	35.0	26.0	100	40	100	1108.23	411.14
846	1.4	.5	4.0	35.0	26.0	500	40	100	2168.36	584.00

847	1.4	.5	4.0	35.0	26.0	1000	40	100	3472.04	636.79
848	1.4	.5	4.0	35.0	26.0	2000	40	100	5912.43	889.86
849	1.4	.5	4.0	45.0	26.0	0	40	100	3783.92	1629.17
850	1.4	.5	4.0	45.0	26.0	2	40	100	3787.28	1624.88
851	1.4	.5	4.0	45.0	26.0	10	40	100	3812.27	1650.96
852	1.4	.5	4.0	45.0	26.0	50	40	100	4047.87	1738.49
853	1.4	.5	4.0	45.0	26.0	100	40	100	4321.17	1765.57
854	1.4	.5	4.0	45.0	26.0	500	40	100	6779.58	2215.00
857	1.4	.5	4.0	45.0	31.0	0	40	100	2109.59	890.95
858	1.4	.5	4.0	45.0	31.0	2	40	100	2120.91	892.58
859	1.4	.5	4.0	45.0	31.0	10	40	100	2161.13	888.07
860	1.4	.5	4.0	45.0	31.0	50	40	100	2364.58	950.06
861	1.4	.5	4.0	45.0	31.0	100	40	100	2515.37	963.56
862	1.4	.5	4.0	45.0	31.0	500	40	100	4082.39	1090.91
863	1.4	.5	4.0	45.0	31.0	1000	40	100	6161.42	1281.67
865	1.4	1.0	1.0	5.0	1.0	0	40	100	41.90	42.92
866	1.4	1.0	1.0	5.0	1.0	2	40	100	51.26	53.60
867	1.4	1.0	1.0	5.0	1.0	10	40	100	122.63	101.63
868	1.4	1.0	1.0	5.0	1.0	50	40	100	539.07	187.08
869	1.4	1.0	1.0	5.0	1.0	100	40	100	1035.35	253.59
870	1.4	1.0	1.0	5.0	1.0	500	40	100	4980.03	523.67
871	1.4	1.0	1.0	5.0	1.0	1000	40	100	10004.35	746.24
873	1.4	1.0	1.0	15.0	6.0	0	40	100	347.51	275.89
874	1.4	1.0	1.0	15.0	6.0	2	40	100	395.59	271.55
875	1.4	1.0	1.0	15.0	6.0	10	40	100	550.73	318.39
876	1.4	1.0	1.0	15.0	6.0	50	40	100	1345.93	506.99
877	1.4	1.0	1.0	15.0	6.0	100	40	100	2363.69	634.52
878	1.4	1.0	1.0	15.0	6.0	500	40	100	10144.05	1157.58
881	1.4	1.0	1.0	15.0	11.0	0	40	100	149.19	118.63
882	1.4	1.0	1.0	15.0	11.0	2	40	100	168.26	130.08
883	1.4	1.0	1.0	15.0	11.0	10	40	100	263.15	145.14
884	1.4	1.0	1.0	15.0	11.0	50	40	100	649.36	218.24
885	1.4	1.0	1.0	15.0	11.0	100	40	100	1140.89	259.84
886	1.4	1.0	1.0	15.0	11.0	500	40	100	5107.22	529.85
887	1.4	1.0	1.0	15.0	11.0	1000	40	100	10124.85	747.69
889	1.4	1.0	1.0	25.0	11.0	0	40	100	1209.43	762.67
890	1.4	1.0	1.0	25.0	11.0	2	40	100	1276.72	787.03
891	1.4	1.0	1.0	25.0	11.0	10	40	100	1548.36	822.88
892	1.4	1.0	1.0	25.0	11.0	50	40	100	2937.05	1064.73
893	1.4	1.0	1.0	25.0	11.0	100	40	100	4699.60	1340.33
897	1.4	1.0	1.0	25.0	16.0	0	40	100	590.11	329.16
898	1.4	1.0	1.0	25.0	16.0	2	40	100	638.63	341.93
899	1.4	1.0	1.0	25.0	16.0	10	40	100	809.53	386.70
900	1.4	1.0	1.0	25.0	16.0	50	40	100	1599.78	585.89
901	1.4	1.0	1.0	25.0	16.0	100	40	100	2573.26	638.36
902	1.4	1.0	1.0	25.0	16.0	500	40	100	10390.57	1176.79
905	1.4	1.0	1.0	35.0	21.0	0	40	100	1624.35	847.56
906	1.4	1.0	1.0	35.0	21.0	2	40	100	1671.38	857.92
907	1.4	1.0	1.0	35.0	21.0	10	40	100	1979.82	869.65
908	1.4	1.0	1.0	35.0	21.0	50	40	100	3405.56	1077.97
909	1.4	1.0	1.0	35.0	21.0	100	40	100	5163.95	1356.02
913	1.4	1.0	1.0	35.0	26.0	0	40	100	862.49	403.01
914	1.4	1.0	1.0	35.0	26.0	2	40	100	902.36	398.97
915	1.4	1.0	1.0	35.0	26.0	10	40	100	1065.23	400.67
916	1.4	1.0	1.0	35.0	26.0	50	40	100	1854.95	591.70
917	1.4	1.0	1.0	35.0	26.0	100	40	100	2801.54	682.16
918	1.4	1.0	1.0	35.0	26.0	500	40	100	10667.69	1186.71
921	1.4	1.0	1.0	45.0	26.0	0	40	100	3783.92	1629.17
922	1.4	1.0	1.0	45.0	26.0	2	40	100	3867.62	1662.90
923	1.4	1.0	1.0	45.0	26.0	10	40	100	4327.52	1744.80
924	1.4	1.0	1.0	45.0	26.0	50	40	100	6616.59	2323.55
929	1.4	1.0	1.0	45.0	31.0	0	40	100	2109.59	890.95
930	1.4	1.0	1.0	45.0	31.0	2	40	100	2216.22	897.91
931	1.4	1.0	1.0	45.0	31.0	10	40	100	2491.04	965.33
932	1.4	1.0	1.0	45.0	31.0	50	40	100	3856.85	1138.16
933	1.4	1.0	1.0	45.0	31.0	100	40	100	5652.49	1394.88
937	1.4	1.0	2.0	5.0	1.0	0	40	100	41.90	42.92
938	1.4	1.0	2.0	5.0	1.0	2	40	100	46.34	46.12
939	1.4	1.0	2.0	5.0	1.0	10	40	100	79.48	68.72
940	1.4	1.0	2.0	5.0	1.0	50	40	100	367.21	156.00
941	1.4	1.0	2.0	5.0	1.0	100	40	100	654.02	212.09
942	1.4	1.0	2.0	5.0	1.0	500	40	100	3215.63	419.41
943	1.4	1.0	2.0	5.0	1.0	1000	40	100	6325.03	584.94
945	1.4	1.0	2.0	15.0	6.0	0	40	100	347.51	275.89
946	1.4	1.0	2.0	15.0	6.0	2	40	100	376.14	274.31
947	1.4	1.0	2.0	15.0	6.0	10	40	100	480.54	294.91
948	1.4	1.0	2.0	15.0	6.0	50	40	100	948.60	367.84
949	1.4	1.0	2.0	15.0	6.0	100	40	100	1546.31	533.13
950	1.4	1.0	2.0	15.0	6.0	500	40	100	6247.46	919.44
953	1.4	1.0	2.0	15.0	11.0	0	40	100	149.19	118.63
954	1.4	1.0	2.0	15.0	11.0	2	40	100	163.38	127.43
955	1.4	1.0	2.0	15.0	11.0	10	40	100	211.79	137.89
956	1.4	1.0	2.0	15.0	11.0	50	40	100	482.03	176.88
957	1.4	1.0	2.0	15.0	11.0	100	40	100	791.18	228.89
958	1.4	1.0	2.0	15.0	11.0	500	40	100	3329.01	424.23
959	1.4	1.0	2.0	15.0	11.0	1000	40	100	6457.04	596.15
961	1.4	1.0	2.0	25.0	11.0	0	40	100	1209.43	762.67
962	1.4	1.0	2.0	25.0	11.0	2	40	100	1246.30	774.84
963	1.4	1.0	2.0	25.0	11.0	10	40	100	1426.31	799.36
964	1.4	1.0	2.0	25.0	11.0	50	40	100	2243.55	869.64

965	1.4	1.0	2.0	25.0	11.0	100	40	100	3247.33	1046.65
969	1.4	1.0	2.0	25.0	16.0	0	40	100	590.11	329.16
970	1.4	1.0	2.0	25.0	16.0	2	40	100	622.78	347.81
971	1.4	1.0	2.0	25.0	16.0	10	40	100	713.24	361.13
972	1.4	1.0	2.0	25.0	16.0	50	40	100	1214.22	458.07
973	1.4	1.0	2.0	25.0	16.0	100	40	100	1795.95	580.20
974	1.4	1.0	2.0	25.0	16.0	500	40	100	6480.55	921.85
977	1.4	1.0	2.0	35.0	21.0	0	40	100	1624.35	847.56
978	1.4	1.0	2.0	35.0	21.0	2	40	100	1649.53	854.20
979	1.4	1.0	2.0	35.0	21.0	10	40	100	1822.62	847.77
980	1.4	1.0	2.0	35.0	21.0	50	40	100	2712.59	983.75
981	1.4	1.0	2.0	35.0	21.0	100	40	100	3679.38	1091.62
985	1.4	1.0	2.0	35.0	26.0	0	40	100	862.49	403.01
986	1.4	1.0	2.0	35.0	26.0	2	40	100	887.95	400.27
987	1.4	1.0	2.0	35.0	26.0	10	40	100	988.92	387.60
988	1.4	1.0	2.0	35.0	26.0	50	40	100	1453.62	531.80
989	1.4	1.0	2.0	35.0	26.0	100	40	100	2063.91	607.72
990	1.4	1.0	2.0	35.0	26.0	500	40	100	6718.78	933.08
993	1.4	1.0	2.0	45.0	26.0	0	40	100	3783.92	1629.17
994	1.4	1.0	2.0	45.0	26.0	2	40	100	3818.54	1650.52
995	1.4	1.0	2.0	45.0	26.0	10	40	100	4063.59	1738.08
996	1.4	1.0	2.0	45.0	26.0	50	40	100	5412.44	1931.25
997	1.4	1.0	2.0	45.0	26.0	100	40	100	6951.09	2358.85
1001	1.4	1.0	2.0	45.0	31.0	0	40	100	2109.59	890.95
1002	1.4	1.0	2.0	45.0	31.0	2	40	100	2164.20	892.63
1003	1.4	1.0	2.0	45.0	31.0	10	40	100	2389.04	968.92
1004	1.4	1.0	2.0	45.0	31.0	50	40	100	3161.22	1065.98
1005	1.4	1.0	2.0	45.0	31.0	100	40	100	4119.34	1172.80
1009	1.4	1.0	3.0	5.0	1.0	0	40	100	41.90	42.92
1010	1.4	1.0	3.0	5.0	1.0	2	40	100	44.45	43.31
1011	1.4	1.0	3.0	5.0	1.0	10	40	100	66.39	63.00
1012	1.4	1.0	3.0	5.0	1.0	50	40	100	250.14	132.24
1013	1.4	1.0	3.0	5.0	1.0	100	40	100	469.41	165.62
1014	1.4	1.0	3.0	5.0	1.0	500	40	100	2160.38	340.52
1015	1.4	1.0	3.0	5.0	1.0	1000	40	100	4265.39	433.07
1016	1.4	1.0	3.0	5.0	1.0	2000	40	100	8449.81	605.40
1017	1.4	1.0	3.0	15.0	6.0	0	40	100	347.51	275.89
1018	1.4	1.0	3.0	15.0	6.0	2	40	100	369.32	271.40
1019	1.4	1.0	3.0	15.0	6.0	10	40	100	429.35	262.61
1020	1.4	1.0	3.0	15.0	6.0	50	40	100	725.37	354.26
1021	1.4	1.0	3.0	15.0	6.0	100	40	100	1115.52	409.41
1022	1.4	1.0	3.0	15.0	6.0	500	40	100	4082.46	690.69
1023	1.4	1.0	3.0	15.0	6.0	1000	40	100	7831.97	917.15
1025	1.4	1.0	3.0	15.0	11.0	0	40	100	149.19	118.63
1026	1.4	1.0	3.0	15.0	11.0	2	40	100	159.44	123.97
1027	1.4	1.0	3.0	15.0	11.0	10	40	100	188.64	135.01
1028	1.4	1.0	3.0	15.0	11.0	50	40	100	385.37	156.87
1029	1.4	1.0	3.0	15.0	11.0	100	40	100	570.87	192.93
1030	1.4	1.0	3.0	15.0	11.0	500	40	100	2308.26	354.11
1031	1.4	1.0	3.0	15.0	11.0	1000	40	100	4371.45	427.85
1032	1.4	1.0	3.0	15.0	11.0	2000	40	100	8569.11	606.40
1033	1.4	1.0	3.0	25.0	11.0	0	40	100	1209.43	762.67
1034	1.4	1.0	3.0	25.0	11.0	2	40	100	1239.70	771.91
1035	1.4	1.0	3.0	25.0	11.0	10	40	100	1341.24	783.92
1036	1.4	1.0	3.0	25.0	11.0	50	40	100	1771.32	812.35
1037	1.4	1.0	3.0	25.0	11.0	100	40	100	2471.12	905.89
1038	1.4	1.0	3.0	25.0	11.0	500	40	100	7367.16	1419.56
1041	1.4	1.0	3.0	25.0	16.0	0	40	100	590.11	329.16
1042	1.4	1.0	3.0	25.0	16.0	2	40	100	613.93	348.12
1043	1.4	1.0	3.0	25.0	16.0	10	40	100	685.15	353.68
1044	1.4	1.0	3.0	25.0	16.0	50	40	100	990.63	379.76
1045	1.4	1.0	3.0	25.0	16.0	100	40	100	1361.73	475.34
1046	1.4	1.0	3.0	25.0	16.0	500	40	100	4337.20	718.35
1047	1.4	1.0	3.0	25.0	16.0	1000	40	100	8063.56	974.34
1049	1.4	1.0	3.0	35.0	21.0	0	40	100	1624.35	847.56
1050	1.4	1.0	3.0	35.0	21.0	2	40	100	1646.05	856.66
1051	1.4	1.0	3.0	35.0	21.0	10	40	100	1732.48	845.96
1052	1.4	1.0	3.0	35.0	21.0	50	40	100	2338.75	914.86
1053	1.4	1.0	3.0	35.0	21.0	100	40	100	2898.72	1013.46
1054	1.4	1.0	3.0	35.0	21.0	500	40	100	7839.93	1541.70
1057	1.4	1.0	3.0	35.0	26.0	0	40	100	862.49	403.01
1058	1.4	1.0	3.0	35.0	26.0	2	40	100	876.83	402.68
1059	1.4	1.0	3.0	35.0	26.0	10	40	100	940.53	387.63
1060	1.4	1.0	3.0	35.0	26.0	50	40	100	1251.52	463.61
1061	1.4	1.0	3.0	35.0	26.0	100	40	100	1602.38	563.04
1062	1.4	1.0	3.0	35.0	26.0	500	40	100	4581.50	755.52
1063	1.4	1.0	3.0	35.0	26.0	1000	40	100	8313.30	999.05
1065	1.4	1.0	3.0	45.0	26.0	0	40	100	3783.92	1629.17
1066	1.4	1.0	3.0	45.0	26.0	2	40	100	3803.36	1643.35
1067	1.4	1.0	3.0	45.0	26.0	10	40	100	3936.57	1689.70
1068	1.4	1.0	3.0	45.0	26.0	50	40	100	4706.49	1862.14
1069	1.4	1.0	3.0	45.0	26.0	100	40	100	5803.69	2081.64
1073	1.4	1.0	3.0	45.0	31.0	0	40	100	2109.59	890.95
1074	1.4	1.0	3.0	45.0	31.0	2	40	100	2138.89	895.53
1075	1.4	1.0	3.0	45.0	31.0	10	40	100	2281.98	894.22
1076	1.4	1.0	3.0	45.0	31.0	50	40	100	2753.18	1017.83
1077	1.4	1.0	3.0	45.0	31.0	100	40	100	3362.28	1055.50
1078	1.4	1.0	3.0	45.0	31.0	500	40	100	8355.38	1642.16
1081	1.4	1.0	4.0	5.0	1.0	0	40	100	41.90	42.92
1082	1.4	1.0	4.0	5.0	1.0	2	40	100	44.31	43.05

1083	1.4	1.0	4.0	5.0	1.0	10	40	100	56.31	54.04
1084	1.4	1.0	4.0	5.0	1.0	50	40	100	177.70	124.49
1085	1.4	1.0	4.0	5.0	1.0	100	40	100	353.42	139.40
1086	1.4	1.0	4.0	5.0	1.0	500	40	100	1542.83	272.72
1087	1.4	1.0	4.0	5.0	1.0	1000	40	100	3098.84	387.07
1088	1.4	1.0	4.0	5.0	1.0	2000	40	100	6100.42	525.75
1089	1.4	1.0	4.0	15.0	6.0	0	40	100	347.51	275.89
1090	1.4	1.0	4.0	15.0	6.0	2	40	100	360.40	273.99
1091	1.4	1.0	4.0	15.0	6.0	10	40	100	404.70	269.13
1092	1.4	1.0	4.0	15.0	6.0	50	40	100	610.14	308.65
1093	1.4	1.0	4.0	15.0	6.0	100	40	100	868.90	363.19
1094	1.4	1.0	4.0	15.0	6.0	500	40	100	2889.02	607.48
1095	1.4	1.0	4.0	15.0	6.0	1000	40	100	5417.13	854.46
1096	1.4	1.0	4.0	15.0	6.0	2000	40	100	10514.53	1064.68
1097	1.4	1.0	4.0	15.0	11.0	0	40	100	149.19	118.63
1098	1.4	1.0	4.0	15.0	11.0	2	40	100	157.09	124.62
1099	1.4	1.0	4.0	15.0	11.0	10	40	100	178.62	131.81
1100	1.4	1.0	4.0	15.0	11.0	50	40	100	321.38	146.52
1101	1.4	1.0	4.0	15.0	11.0	100	40	100	469.38	165.28
1102	1.4	1.0	4.0	15.0	11.0	500	40	100	1671.61	292.41
1103	1.4	1.0	4.0	15.0	11.0	1000	40	100	3215.42	389.33
1104	1.4	1.0	4.0	15.0	11.0	2000	40	100	6209.88	532.27
1105	1.4	1.0	4.0	25.0	11.0	0	40	100	1209.43	762.67
1106	1.4	1.0	4.0	25.0	11.0	2	40	100	1229.90	760.32
1107	1.4	1.0	4.0	25.0	11.0	10	40	100	1291.93	780.84
1108	1.4	1.0	4.0	25.0	11.0	50	40	100	1572.71	804.43
1109	1.4	1.0	4.0	25.0	11.0	100	40	100	1978.82	840.65
1110	1.4	1.0	4.0	25.0	11.0	500	40	100	5244.10	1169.64
1111	1.4	1.0	4.0	25.0	11.0	1000	40	100	9395.38	1512.63
1113	1.4	1.0	4.0	25.0	16.0	0	40	100	590.11	329.16
1114	1.4	1.0	4.0	25.0	16.0	2	40	100	606.48	330.33
1115	1.4	1.0	4.0	25.0	16.0	10	40	100	656.45	353.43
1116	1.4	1.0	4.0	25.0	16.0	50	40	100	873.70	382.41
1117	1.4	1.0	4.0	25.0	16.0	100	40	100	1125.31	412.13
1118	1.4	1.0	4.0	25.0	16.0	500	40	100	3217.53	600.46
1119	1.4	1.0	4.0	25.0	16.0	1000	40	100	5698.96	868.18
1120	1.4	1.0	4.0	25.0	16.0	2000	40	100	10795.62	1062.92
1121	1.4	1.0	4.0	35.0	21.0	0	40	100	1624.35	847.56
1122	1.4	1.0	4.0	35.0	21.0	2	40	100	1630.20	854.40
1123	1.4	1.0	4.0	35.0	21.0	10	40	100	1668.01	852.74
1124	1.4	1.0	4.0	35.0	21.0	50	40	100	2054.79	839.49
1125	1.4	1.0	4.0	35.0	21.0	100	40	100	2509.31	921.93
1126	1.4	1.0	4.0	35.0	21.0	500	40	100	5717.93	1281.78
1127	1.4	1.0	4.0	35.0	21.0	1000	40	100	9898.83	1591.26
1129	1.4	1.0	4.0	35.0	26.0	0	40	100	862.49	403.01
1130	1.4	1.0	4.0	35.0	26.0	2	40	100	872.78	401.59
1131	1.4	1.0	4.0	35.0	26.0	10	40	100	910.62	395.66
1132	1.4	1.0	4.0	35.0	26.0	50	40	100	1108.23	411.14
1133	1.4	1.0	4.0	35.0	26.0	100	40	100	1370.48	472.40
1134	1.4	1.0	4.0	35.0	26.0	500	40	100	3472.00	636.78
1135	1.4	1.0	4.0	35.0	26.0	1000	40	100	5911.34	891.15
1136	1.4	1.0	4.0	35.0	26.0	2000	40	100	11038.00	1111.21
1137	1.4	1.0	4.0	45.0	26.0	0	40	100	3783.92	1629.17
1138	1.4	1.0	4.0	45.0	26.0	2	40	100	3791.97	1627.63
1139	1.4	1.0	4.0	45.0	26.0	10	40	100	3869.37	1661.90
1140	1.4	1.0	4.0	45.0	26.0	50	40	100	4321.17	1765.57
1141	1.4	1.0	4.0	45.0	26.0	100	40	100	5024.51	1913.15
1145	1.4	1.0	4.0	45.0	31.0	0	40	100	2109.59	890.95
1146	1.4	1.0	4.0	45.0	31.0	2	40	100	2125.28	892.96
1147	1.4	1.0	4.0	45.0	31.0	10	40	100	2228.82	897.87
1148	1.4	1.0	4.0	45.0	31.0	50	40	100	2515.37	963.56
1149	1.4	1.0	4.0	45.0	31.0	100	40	100	2919.36	1025.33
1150	1.4	1.0	4.0	45.0	31.0	500	40	100	6161.33	1281.70
1153	1.4	2.0	1.0	5.0	1.0	0	40	100	41.90	42.92
1154	1.4	2.0	1.0	5.0	1.0	2	40	100	63.84	63.68
1155	1.4	2.0	1.0	5.0	1.0	10	40	100	232.34	137.19
1156	1.4	2.0	1.0	5.0	1.0	50	40	100	1035.35	253.59
1157	1.4	2.0	1.0	5.0	1.0	100	40	100	2042.33	360.33
1158	1.4	2.0	1.0	5.0	1.0	500	40	100	10004.35	746.24
1161	1.4	2.0	1.0	15.0	6.0	0	40	100	347.51	275.89
1162	1.4	2.0	1.0	15.0	6.0	2	40	100	442.87	282.78
1163	1.4	2.0	1.0	15.0	6.0	10	40	100	734.23	368.46
1164	1.4	2.0	1.0	15.0	6.0	50	40	100	2363.69	634.52
1165	1.4	2.0	1.0	15.0	6.0	100	40	100	4267.68	753.60
1169	1.4	2.0	1.0	15.0	11.0	0	40	100	149.19	118.63
1170	1.4	2.0	1.0	15.0	11.0	2	40	100	186.81	135.06
1171	1.4	2.0	1.0	15.0	11.0	10	40	100	376.87	166.03
1172	1.4	2.0	1.0	15.0	11.0	50	40	100	1140.89	259.84
1173	1.4	2.0	1.0	15.0	11.0	100	40	100	2158.38	365.09
1174	1.4	2.0	1.0	15.0	11.0	500	40	100	10124.85	747.69
1177	1.4	2.0	1.0	25.0	11.0	0	40	100	1209.43	762.67
1178	1.4	2.0	1.0	25.0	11.0	2	40	100	1349.71	786.43
1179	1.4	2.0	1.0	25.0	11.0	10	40	100	1873.43	850.63
1180	1.4	2.0	1.0	25.0	11.0	50	40	100	4699.60	1340.33
1181	1.4	2.0	1.0	25.0	11.0	100	40	100	8189.95	1687.67
1185	1.4	2.0	1.0	25.0	16.0	0	40	100	590.11	329.16
1186	1.4	2.0	1.0	25.0	16.0	2	40	100	690.43	354.68
1187	1.4	2.0	1.0	25.0	16.0	10	40	100	1009.30	383.90
1188	1.4	2.0	1.0	25.0	16.0	50	40	100	2573.26	638.36
1189	1.4	2.0	1.0	25.0	16.0	100	40	100	4516.97	788.80

1193	1.4	2.0	1.0	35.0	21.0	0	40	100	1624.35	847.56
1194	1.4	2.0	1.0	35.0	21.0	2	40	100	1764.45	860.28
1195	1.4	2.0	1.0	35.0	21.0	10	40	100	2406.54	967.98
1196	1.4	2.0	1.0	35.0	21.0	50	40	100	5163.95	1356.02
1197	1.4	2.0	1.0	35.0	21.0	100	40	100	8645.38	1729.71
1201	1.4	2.0	1.0	35.0	26.0	0	40	100	862.49	403.01
1202	1.4	2.0	1.0	35.0	26.0	2	40	100	945.21	387.65
1203	1.4	2.0	1.0	35.0	26.0	10	40	100	1272.04	496.74
1204	1.4	2.0	1.0	35.0	26.0	50	40	100	2801.54	682.16
1205	1.4	2.0	1.0	35.0	26.0	100	40	100	4753.18	850.03
1209	1.4	2.0	1.0	45.0	26.0	0	40	100	3783.92	1629.17
1210	1.4	2.0	1.0	45.0	26.0	2	40	100	3973.76	1724.25
1211	1.4	2.0	1.0	45.0	26.0	10	40	100	4957.29	1956.28
1217	1.4	2.0	1.0	45.0	31.0	0	40	100	2109.59	890.95
1218	1.4	2.0	1.0	45.0	31.0	2	40	100	2311.00	924.71
1219	1.4	2.0	1.0	45.0	31.0	10	40	100	2798.19	1040.98
1220	1.4	2.0	1.0	45.0	31.0	50	40	100	5652.49	1394.88
1221	1.4	2.0	1.0	45.0	31.0	100	40	100	9166.86	1726.99
1225	1.4	2.0	2.0	5.0	1.0	0	40	100	41.90	42.92
1226	1.4	2.0	2.0	5.0	1.0	2	40	100	53.47	54.03
1227	1.4	2.0	2.0	5.0	1.0	10	40	100	155.27	120.18
1228	1.4	2.0	2.0	5.0	1.0	50	40	100	654.02	212.09
1229	1.4	2.0	2.0	5.0	1.0	100	40	100	1302.98	258.34
1230	1.4	2.0	2.0	5.0	1.0	500	40	100	6325.03	584.94
1233	1.4	2.0	2.0	15.0	6.0	0	40	100	347.51	275.89
1234	1.4	2.0	2.0	15.0	6.0	2	40	100	402.43	269.10
1235	1.4	2.0	2.0	15.0	6.0	10	40	100	585.22	309.08
1236	1.4	2.0	2.0	15.0	6.0	50	40	100	1546.31	533.13
1237	1.4	2.0	2.0	15.0	6.0	100	40	100	2699.62	659.30
1241	1.4	2.0	2.0	15.0	11.0	0	40	100	149.19	118.63
1242	1.4	2.0	2.0	15.0	11.0	2	40	100	173.21	130.17
1243	1.4	2.0	2.0	15.0	11.0	10	40	100	287.80	144.04
1244	1.4	2.0	2.0	15.0	11.0	50	40	100	791.18	228.89
1245	1.4	2.0	2.0	15.0	11.0	100	40	100	1413.79	274.74
1246	1.4	2.0	2.0	15.0	11.0	500	40	100	6457.04	596.15
1249	1.4	2.0	2.0	25.0	11.0	0	40	100	1209.43	762.67
1250	1.4	2.0	2.0	25.0	11.0	2	40	100	1285.20	783.05
1251	1.4	2.0	2.0	25.0	11.0	10	40	100	1569.56	822.46
1252	1.4	2.0	2.0	25.0	11.0	50	40	100	3247.33	1046.65
1253	1.4	2.0	2.0	25.0	11.0	100	40	100	5277.88	1301.46
1257	1.4	2.0	2.0	25.0	16.0	0	40	100	590.11	329.16
1258	1.4	2.0	2.0	25.0	16.0	2	40	100	646.54	344.91
1259	1.4	2.0	2.0	25.0	16.0	10	40	100	848.20	392.14
1260	1.4	2.0	2.0	25.0	16.0	50	40	100	1795.95	580.20
1261	1.4	2.0	2.0	25.0	16.0	100	40	100	2953.24	661.08
1265	1.4	2.0	2.0	35.0	21.0	0	40	100	1624.35	847.56
1266	1.4	2.0	2.0	35.0	21.0	2	40	100	1676.90	855.53
1267	1.4	2.0	2.0	35.0	21.0	10	40	100	2053.67	848.74
1268	1.4	2.0	2.0	35.0	21.0	50	40	100	3679.38	1091.62
1269	1.4	2.0	2.0	35.0	21.0	100	40	100	5743.98	1396.79
1273	1.4	2.0	2.0	35.0	26.0	0	40	100	862.49	403.01
1274	1.4	2.0	2.0	35.0	26.0	2	40	100	905.86	398.80
1275	1.4	2.0	2.0	35.0	26.0	10	40	100	1097.02	406.78
1276	1.4	2.0	2.0	35.0	26.0	50	40	100	2063.91	607.72
1277	1.4	2.0	2.0	35.0	26.0	100	40	100	3262.04	669.52
1281	1.4	2.0	2.0	45.0	26.0	0	40	100	3783.92	1629.17
1282	1.4	2.0	2.0	45.0	26.0	2	40	100	3889.01	1672.47
1283	1.4	2.0	2.0	45.0	26.0	10	40	100	4427.07	1769.92
1284	1.4	2.0	2.0	45.0	26.0	50	40	100	6951.09	2358.85
1289	1.4	2.0	2.0	45.0	31.0	0	40	100	2109.59	890.95
1290	1.4	2.0	2.0	45.0	31.0	2	40	100	2239.95	895.01
1291	1.4	2.0	2.0	45.0	31.0	10	40	100	2536.98	993.44
1292	1.4	2.0	2.0	45.0	31.0	50	40	100	4119.34	1172.80
1293	1.4	2.0	2.0	45.0	31.0	100	40	100	6139.14	1439.99
1297	1.4	2.0	3.0	5.0	1.0	0	40	100	41.90	42.92
1298	1.4	2.0	3.0	5.0	1.0	2	40	100	48.73	46.97
1299	1.4	2.0	3.0	5.0	1.0	10	40	100	103.12	86.99
1300	1.4	2.0	3.0	5.0	1.0	50	40	100	469.41	165.62
1301	1.4	2.0	3.0	5.0	1.0	100	40	100	896.34	213.52
1302	1.4	2.0	3.0	5.0	1.0	500	40	100	4265.38	433.08
1303	1.4	2.0	3.0	5.0	1.0	1000	40	100	8449.81	605.40
1305	1.4	2.0	3.0	15.0	6.0	0	40	100	347.51	275.89
1306	1.4	2.0	3.0	15.0	6.0	2	40	100	390.16	271.33
1307	1.4	2.0	3.0	15.0	6.0	10	40	100	512.78	303.62
1308	1.4	2.0	3.0	15.0	6.0	50	40	100	1115.52	409.41
1309	1.4	2.0	3.0	15.0	6.0	100	40	100	1871.63	566.70
1310	1.4	2.0	3.0	15.0	6.0	500	40	100	7831.78	917.20
1313	1.4	2.0	3.0	15.0	11.0	0	40	100	149.19	118.63
1314	1.4	2.0	3.0	15.0	11.0	2	40	100	167.35	128.64
1315	1.4	2.0	3.0	15.0	11.0	10	40	100	240.83	136.89
1316	1.4	2.0	3.0	15.0	11.0	50	40	100	570.87	192.93
1317	1.4	2.0	3.0	15.0	11.0	100	40	100	1015.23	240.64
1318	1.4	2.0	3.0	15.0	11.0	500	40	100	4371.45	427.85
1319	1.4	2.0	3.0	15.0	11.0	1000	40	100	8569.09	606.41
1321	1.4	2.0	3.0	25.0	11.0	0	40	100	1209.43	762.67
1322	1.4	2.0	3.0	25.0	11.0	2	40	100	1250.48	782.05
1323	1.4	2.0	3.0	25.0	11.0	10	40	100	1456.18	800.56
1324	1.4	2.0	3.0	25.0	11.0	50	40	100	2471.12	905.89
1325	1.4	2.0	3.0	25.0	11.0	100	40	100	3716.74	1027.09
1329	1.4	2.0	3.0	25.0	16.0	0	40	100	590.11	329.16

1330	1.4	2.0	3.0	25.0	16.0	2	40	100	635.01	342.30
1331	1.4	2.0	3.0	25.0	16.0	10	40	100	737.64	366.94
1332	1.4	2.0	3.0	25.0	16.0	50	40	100	1361.73	475.34
1333	1.4	2.0	3.0	25.0	16.0	100	40	100	2149.54	595.45
1334	1.4	2.0	3.0	25.0	16.0	500	40	100	8063.56	974.34
1337	1.4	2.0	3.0	35.0	21.0	0	40	100	1624.35	847.56
1338	1.4	2.0	3.0	35.0	21.0	2	40	100	1657.05	859.28
1339	1.4	2.0	3.0	35.0	21.0	10	40	100	1877.87	847.43
1340	1.4	2.0	3.0	35.0	21.0	50	40	100	2898.72	1013.46
1341	1.4	2.0	3.0	35.0	21.0	100	40	100	4102.16	1110.80
1345	1.4	2.0	3.0	35.0	26.0	0	40	100	862.49	403.01
1346	1.4	2.0	3.0	35.0	26.0	2	40	100	893.62	394.42
1347	1.4	2.0	3.0	35.0	26.0	10	40	100	1015.77	382.92
1348	1.4	2.0	3.0	35.0	26.0	50	40	100	1602.38	563.04
1349	1.4	2.0	3.0	35.0	26.0	100	40	100	2400.64	611.02
1350	1.4	2.0	3.0	35.0	26.0	500	40	100	8313.30	999.05
1353	1.4	2.0	3.0	45.0	26.0	0	40	100	3783.92	1629.17
1354	1.4	2.0	3.0	45.0	26.0	2	40	100	3818.57	1650.52
1355	1.4	2.0	3.0	45.0	26.0	10	40	100	4117.66	1724.02
1356	1.4	2.0	3.0	45.0	26.0	50	40	100	5803.69	2081.64
1361	1.4	2.0	3.0	45.0	31.0	0	40	100	2109.59	890.95
1362	1.4	2.0	3.0	45.0	31.0	2	40	100	2183.08	892.11
1363	1.4	2.0	3.0	45.0	31.0	10	40	100	2425.13	954.74
1364	1.4	2.0	3.0	45.0	31.0	50	40	100	3362.28	1055.50
1365	1.4	2.0	3.0	45.0	31.0	100	40	100	4587.50	1226.00
1369	1.4	2.0	4.0	5.0	1.0	0	40	100	41.90	42.92
1370	1.4	2.0	4.0	5.0	1.0	2	40	100	46.59	44.80
1371	1.4	2.0	4.0	5.0	1.0	10	40	100	80.91	69.52
1372	1.4	2.0	4.0	5.0	1.0	50	40	100	353.42	139.40
1373	1.4	2.0	4.0	5.0	1.0	100	40	100	619.89	186.07
1374	1.4	2.0	4.0	5.0	1.0	500	40	100	3099.17	387.23
1375	1.4	2.0	4.0	5.0	1.0	1000	40	100	6100.44	525.75
1376	1.4	2.0	4.0	5.0	1.0	2000	40	100	12079.35	774.18
1377	1.4	2.0	4.0	15.0	6.0	0	40	100	347.51	275.89
1378	1.4	2.0	4.0	15.0	6.0	2	40	100	375.40	273.85
1379	1.4	2.0	4.0	15.0	6.0	10	40	100	470.73	281.25
1380	1.4	2.0	4.0	15.0	6.0	50	40	100	868.90	363.19
1381	1.4	2.0	4.0	15.0	6.0	100	40	100	1390.15	449.27
1382	1.4	2.0	4.0	15.0	6.0	500	40	100	5417.13	854.46
1383	1.4	2.0	4.0	15.0	6.0	1000	40	100	10517.10	1060.20
1385	1.4	2.0	4.0	15.0	11.0	0	40	100	149.19	118.63
1386	1.4	2.0	4.0	15.0	11.0	2	40	100	163.38	127.43
1387	1.4	2.0	4.0	15.0	11.0	10	40	100	210.82	136.07
1388	1.4	2.0	4.0	15.0	11.0	50	40	100	469.38	165.28
1389	1.4	2.0	4.0	15.0	11.0	100	40	100	769.77	218.29
1390	1.4	2.0	4.0	15.0	11.0	500	40	100	3215.64	389.20
1391	1.4	2.0	4.0	15.0	11.0	1000	40	100	6210.03	532.39
1392	1.4	2.0	4.0	15.0	11.0	2000	40	100	12205.97	766.38
1393	1.4	2.0	4.0	25.0	11.0	0	40	100	1209.43	762.67
1394	1.4	2.0	4.0	25.0	11.0	2	40	100	1241.68	774.61
1395	1.4	2.0	4.0	25.0	11.0	10	40	100	1373.38	787.09
1396	1.4	2.0	4.0	25.0	11.0	50	40	100	1978.82	840.65
1397	1.4	2.0	4.0	25.0	11.0	100	40	100	2812.59	941.68
1398	1.4	2.0	4.0	25.0	11.0	500	40	100	9396.69	1511.19
1401	1.4	2.0	4.0	25.0	16.0	0	40	100	590.11	329.16
1402	1.4	2.0	4.0	25.0	16.0	2	40	100	621.16	348.51
1403	1.4	2.0	4.0	25.0	16.0	10	40	100	699.39	349.49
1404	1.4	2.0	4.0	25.0	16.0	50	40	100	1125.36	412.14
1405	1.4	2.0	4.0	25.0	16.0	100	40	100	1628.32	521.03
1406	1.4	2.0	4.0	25.0	16.0	500	40	100	5698.96	868.18
1407	1.4	2.0	4.0	25.0	16.0	1000	40	100	10795.67	1062.99
1409	1.4	2.0	4.0	35.0	21.0	0	40	100	1624.35	847.56
1410	1.4	2.0	4.0	35.0	21.0	2	40	100	1652.51	854.35
1411	1.4	2.0	4.0	35.0	21.0	10	40	100	1788.62	844.31
1412	1.4	2.0	4.0	35.0	21.0	50	40	100	2509.31	921.93
1413	1.4	2.0	4.0	35.0	21.0	100	40	100	3303.50	1032.34
1414	1.4	2.0	4.0	35.0	21.0	500	40	100	9898.83	1591.26
1417	1.4	2.0	4.0	35.0	26.0	0	40	100	862.49	403.01
1418	1.4	2.0	4.0	35.0	26.0	2	40	100	883.07	399.61
1419	1.4	2.0	4.0	35.0	26.0	10	40	100	976.46	383.35
1420	1.4	2.0	4.0	35.0	26.0	50	40	100	1370.48	472.40
1421	1.4	2.0	4.0	35.0	26.0	100	40	100	1885.82	570.81
1422	1.4	2.0	4.0	35.0	26.0	500	40	100	5911.34	891.15
1423	1.4	2.0	4.0	35.0	26.0	1000	40	100	11039.08	1112.00
1425	1.4	2.0	4.0	45.0	26.0	0	40	100	3783.92	1629.17
1426	1.4	2.0	4.0	45.0	26.0	2	40	100	3806.31	1641.65
1427	1.4	2.0	4.0	45.0	26.0	10	40	100	4013.20	1738.96
1428	1.4	2.0	4.0	45.0	26.0	50	40	100	5024.51	1913.15
1429	1.4	2.0	4.0	45.0	26.0	100	40	100	6171.78	2073.94
1433	1.4	2.0	4.0	45.0	31.0	0	40	100	2109.59	890.95
1434	1.4	2.0	4.0	45.0	31.0	2	40	100	2159.82	886.84
1435	1.4	2.0	4.0	45.0	31.0	10	40	100	2334.59	930.19
1436	1.4	2.0	4.0	45.0	31.0	50	40	100	2919.36	1025.33
1437	1.4	2.0	4.0	45.0	31.0	100	40	100	3760.98	1041.99

APPENDIX C

DATA USED TO MAKE SENSITIVITY PLOTS

DATA USED TO MAKE SENSITIVITY PLOTS

Note: N1,N2 - REC# in Appendix B, CP - curve parameter, p_i,Y,S_l - variables in Equation 5.1.

N1	N2	p_i	CP	Y	S_l
Figure 1					
1	2	1.00	5.00	42.37	.0111
2	3	6.00	5.00	44.46	.0545
3	4	30.00	5.00	57.74	.3031
4	5	75.00	5.00	96.01	.8316
5	6	300.00	5.00	330.98	.9442
6	7	750.00	5.00	787.41	.9452
7	8	1500.00	5.00	1540.07	.9829
9	10	1.00	15.00	351.40	.0111
10	11	6.00	15.00	365.54	.0421
11	12	30.00	15.00	420.21	.1585
12	13	75.00	15.00	507.67	.2544
13	14	300.00	15.00	948.33	.6289
14	15	750.00	15.00	1855.25	.8236
15	16	1500.00	15.00	3318.89	.8626
33	34	1.00	25.00	593.56	.0058
34	35	6.00	25.00	606.46	.0234
35	36	30.00	25.00	657.49	.0948
36	37	75.00	25.00	754.30	.2197
37	38	300.00	25.00	1204.66	.4920
38	39	750.00	25.00	2086.75	.7001
39	40	1500.00	25.00	3547.74	.8236
41	42	1.00	35.00	1626.15	.0011
42	43	6.00	35.00	1638.47	.0096
43	44	30.00	35.00	1716.92	.0593
44	45	75.00	35.00	1882.33	.1554
45	46	300.00	35.00	2695.71	.3983
46	47	750.00	35.00	4288.58	.6135
47	48	1500.00	35.00	6916.37	.7594
65	66	1.00	45.00	2115.25	.0027
66	67	6.00	45.00	2139.59	.0131
67	68	30.00	45.00	2248.95	.0605
68	69	75.00	45.00	2415.33	.0940
69	70	300.00	45.00	3173.95	.3227
70	71	750.00	45.00	4754.99	.5666
71	72	1500.00	45.00	7410.23	.7114
Figure 2					
289	290	1.00	5.00	42.55	.0153
290	291	6.00	5.00	47.23	.1280
291	292	30.00	5.00	86.94	.6156
292	293	75.00	5.00	177.49	.9272
293	294	300.00	5.00	633.84	.9502
294	295	750.00	5.00	1538.84	.9816
295	296	1500.00	5.00	3039.69	.9843
297	298	1.00	15.00	353.12	.0159
298	299	6.00	15.00	377.16	.0733
299	300	30.00	15.00	473.16	.2459
300	301	75.00	15.00	642.48	.4284
301	302	300.00	15.00	1548.96	.7890
302	303	750.00	15.00	3315.68	.8613
303	304	1500.00	15.00	6208.58	.9379
321	322	1.00	25.00	597.68	.0127
322	323	6.00	25.00	621.95	.0402
323	324	30.00	25.00	724.08	.1770
324	325	75.00	25.00	909.42	.3295
325	326	300.00	25.00	1791.28	.6548
326	327	750.00	25.00	3545.12	.8224
327	328	1500.00	25.00	6458.48	.9018
329	330	1.00	35.00	1628.99	.0029
330	331	6.00	35.00	1652.51	.0171
331	332	30.00	35.00	1825.60	.1267
332	333	75.00	35.00	2193.18	.2919
333	334	300.00	35.00	3785.25	.5463
334	335	750.00	35.00	6904.67	.7563
353	354	1.00	45.00	2116.94	.0035
354	355	6.00	45.00	2170.25	.0318
355	356	30.00	45.00	2353.63	.0876
356	357	75.00	45.00	2644.61	.1742
357	358	300.00	45.00	4225.34	.5066
358	359	750.00	45.00	7409.68	.7114
Figure 3					
577	578	1.00	5.00	43.99	.0474
578	579	6.00	5.00	57.74	.3031
579	580	30.00	5.00	179.52	.9201
580	581	75.00	5.00	414.36	.9030
581	582	300.00	5.00	1549.26	.9781
582	583	750.00	5.00	3769.73	.9632
583	584	1500.00	5.00	7492.22	1.0059
585	586	1.00	15.00	361.65	.0391
586	587	6.00	15.00	420.21	.1585
587	588	30.00	15.00	659.09	.4426
588	589	75.00	15.00	1099.74	.6716
589	590	300.00	15.00	3291.20	.8866
590	591	750.00	15.00	7690.25	.9572
609	610	1.00	25.00	603.02	.0214
610	611	6.00	25.00	657.49	.0948
611	612	30.00	25.00	901.09	.3363
612	613	75.00	25.00	1351.46	.5512
613	614	300.00	25.00	3545.08	.8231
614	615	750.00	25.00	7940.48	.9257
617	618	1.00	35.00	1636.67	.0075
618	619	6.00	35.00	1716.92	.0593
619	620	30.00	35.00	2165.05	.2634
620	621	75.00	35.00	2975.41	.4337
641	642	1.00	45.00	2133.93	.0114
642	643	6.00	45.00	2248.95	.0605
643	644	30.00	45.00	2662.14	.1817
644	645	75.00	45.00	3420.75	.3825
Figure 4					
865	866	1.00	5.00	46.58	.1005
866	867	6.00	5.00	86.94	.6156
867	868	30.00	5.00	330.85	.9440
868	869	75.00	5.00	787.21	.9456
869	870	300.00	5.00	3007.69	.9836
870	871	750.00	5.00	7492.19	1.0059
873	874	1.00	15.00	371.55	.0647
874	875	6.00	15.00	473.16	.2459
875	876	30.00	15.00	948.33	.6289
876	877	75.00	15.00	1854.81	.8231
877	878	300.00	15.00	6253.87	.9331
897	898	1.00	25.00	614.37	.0395
898	899	6.00	25.00	724.08	.1770
899	900	30.00	25.00	1204.66	.4920
900	901	75.00	25.00	2086.52	.6998
901	902	300.00	25.00	6481.92	.9045
905	906	1.00	35.00	1647.86	.0143
906	907	6.00	35.00	1825.60	.1267
907	908	30.00	35.00	2692.69	.3971
908	909	75.00	35.00	4284.75	.6156
929	930	1.00	45.00	2162.91	.0246
930	931	6.00	45.00	2353.63	.0876
931	932	30.00	45.00	3173.95	.3227
932	933	75.00	45.00	4754.67	.5665
Figure 5					
1153	1154	1.00	5.00	52.87	.2075
1154	1155	6.00	5.00	148.09	.8534
1155	1156	30.00	5.00	633.84	.9502
1156	1157	75.00	5.00	1538.84	.9816
1157	1158	300.00	5.00	6023.34	.9914
1161	1162	1.00	15.00	395.19	.1207
1162	1163	6.00	15.00	588.55	.3713
1163	1164	30.00	15.00	1548.96	.7890
1164	1165	75.00	15.00	3315.69	.8614
1185	1186	1.00	25.00	640.27	.0783
1186	1187	6.00	25.00	849.86	.2814
1187	1188	30.00	25.00	1791.28	.6548
1188	1189	75.00	25.00	3545.12	.8224
1193	1194	1.00	35.00	1694.40	.0413
1194	1195	6.00	35.00	2085.50	.2309

1195	1196	30.00	35.00	3785.25	.5463
1196	1197	75.00	35.00	6904.67	.7563
1217	1218	1.00	45.00	2210.29	.0456
1218	1219	6.00	45.00	2554.59	.1430
1219	1220	30.00	45.00	4225.34	.5066
1220	1221	75.00	45.00	7409.68	.7114

Figure 6

33	34	1.00	.10	593.56	.0058
34	35	6.00	.10	606.46	.0234
35	36	30.00	.10	657.49	.0948
36	37	75.00	.10	754.30	.2197
37	38	300.00	.10	1204.66	.4920
38	39	750.00	.10	2086.75	.7001
39	40	1500.00	.10	3547.74	.8236
321	322	1.00	.20	597.68	.0127
322	323	6.00	.20	621.95	.0402
323	324	30.00	.20	724.08	.1770
324	325	75.00	.20	909.42	.3295
325	326	300.00	.20	1791.28	.6548
326	327	750.00	.20	3545.12	.8224
327	328	1500.00	.20	6458.48	.9018
609	610	1.00	.50	603.02	.0214
610	611	6.00	.50	657.49	.0948
611	612	30.00	.50	901.09	.3363
612	613	75.00	.50	1351.46	.5512
613	614	300.00	.50	3545.08	.8231
614	615	750.00	.50	7940.48	.9257
897	898	1.00	1.00	614.37	.0395
898	899	6.00	1.00	724.08	.1770
899	900	30.00	1.00	1204.66	.4920
900	901	75.00	1.00	2086.52	.6998
901	902	300.00	1.00	6481.92	.9045
1185	1186	1.00	2.00	640.27	.0783
1186	1187	6.00	2.00	849.86	.2814
1187	1188	30.00	2.00	1791.28	.6548
1188	1189	75.00	2.00	3545.12	.8224

Figure 7

897	898	1.00	1.00	614.37	.0395
898	899	6.00	1.00	724.08	.1770
899	900	30.00	1.00	1204.66	.4920
900	901	75.00	1.00	2086.52	.6998
901	902	300.00	1.00	6481.92	.9045
969	970	1.00	2.00	606.45	.0269
970	971	6.00	2.00	668.01	.1016
971	972	30.00	2.00	963.73	.3899
972	973	75.00	2.00	1505.08	.5798
973	974	300.00	2.00	4138.25	.8490
1041	1042	1.00	3.00	602.02	.0198
1042	1043	6.00	3.00	649.54	.0822
1043	1044	30.00	3.00	837.89	.2734
1044	1045	75.00	3.00	1176.18	.4733
1045	1046	300.00	3.00	2849.47	.7832
1046	1047	750.00	3.00	6200.38	.9015
1113	1114	1.00	4.00	598.29	.0137
1114	1115	6.00	4.00	631.46	.0594
1115	1116	30.00	4.00	765.08	.2130
1116	1117	75.00	4.00	999.51	.3776
1117	1118	300.00	4.00	2171.42	.7226
1118	1119	750.00	4.00	4458.25	.8349
1119	1120	1500.00	4.00	8247.29	.9270

Figure 8

33	321	.15	.00	590.11	.0000
34	322	.15	2.00	601.14	.0206
35	323	.15	10.00	627.28	.0543
36	324	.15	50.00	754.30	.2197
37	325	.15	100.00	909.42	.3295
38	326	.15	500.00	2086.52	.6998
39	327	.15	1000.00	3545.35	.8222
40	328	.15	2000.00	6460.88	.9004
321	609	.35	.00	590.11	.0000
322	610	.35	2.00	610.59	.0204
323	611	.35	10.00	668.84	.1054
324	612	.35	50.00	956.33	.3582
325	613	.35	100.00	1304.54	.5281
326	614	.35	500.00	4031.83	.8441
327	615	.35	1000.00	7453.77	.9193
609	897	.75	.00	590.11	.0000
610	898	.75	2.00	627.28	.0543
611	899	.75	10.00	754.30	.2197
612	900	.75	50.00	1351.46	.5512
613	901	.75	100.00	2086.52	.6998
614	902	.75	500.00	7940.48	.9257
897	1185	1.50	.00	590.11	.0000
898	1186	1.50	2.00	664.53	.1169
899	1187	1.50	10.00	909.42	.3295
900	1188	1.50	50.00	2086.52	.6998
901	1189	1.50	100.00	3545.12	.8224

Figure 9

105	393	.15	.00	590.11	.0000
106	394	.15	2.00	595.84	.0066
107	395	.15	10.00	616.27	.0317
108	396	.15	50.00	688.76	.1066
109	397	.15	100.00	780.72	.2593
110	398	.15	500.00	1505.23	.5794
111	399	.15	1000.00	2377.55	.7339
112	400	.15	2000.00	4117.06	.8436
393	681	.35	.00	590.11	.0000
394	682	.35	2.00	603.45	.0244
395	683	.35	10.00	643.53	.0752
396	684	.35	50.00	808.93	.2760
397	685	.35	100.00	1031.21	.4141
398	686	.35	500.00	2693.27	.7774
399	687	.35	1000.00	4719.85	.8704
681	969	.75	.00	590.11	.0000
682	970	.75	2.00	616.27	.0317
683	971	.75	10.00	688.76	.1066
684	972	.75	50.00	1059.43	.4383
685	973	.75	100.00	1505.08	.5798
686	974	.75	500.00	5035.56	.8609
969	1257	1.50	.00	590.11	.0000
970	1258	1.50	2.00	634.66	.0562
971	1259	1.50	10.00	780.72	.2593
972	1260	1.50	50.00	1505.08	.5798
973	1261	1.50	100.00	2374.59	.7310

Figure 10

177	465	.15	.00	590.11	.0000
178	466	.15	2.00	594.66	.0052
179	467	.15	10.00	607.96	.0294
180	468	.15	50.00	661.87	.1055
181	469	.15	100.00	711.40	.1107
182	470	.15	500.00	1176.18	.4733
183	471	.15	1000.00	1755.46	.6729
184	472	.15	2000.00	2897.44	.7750
465	753	.35	.00	590.11	.0000
466	754	.35	2.00	598.84	.0123
467	755	.35	10.00	626.26	.0459
468	756	.35	50.00	740.51	.1744
469	757	.35	100.00	864.14	.3416
470	758	.35	500.00	1932.34	.6890
471	759	.35	1000.00	3243.20	.7871
472	760	.35	2000.00	5854.75	.8803
753	1041	.75	.00	590.11	.0000
754	1042	.75	2.00	607.96	.0294
755	1043	.75	10.00	661.87	.1055
756	1044	.75	50.00	893.25	.3271
757	1045	.75	100.00	1176.18	.4733
758	1046	.75	500.00	3420.08	.8045
759	1047	.75	1000.00	6200.38	.9015
1041	1329	1.50	.00	590.11	.0000
1042	1330	1.50	2.00	624.47	.0506
1043	1331	1.50	10.00	711.40	.1107
1044	1332	1.50	50.00	1176.18	.4733
1045	1333	1.50	100.00	1755.64	.6731
1046	1334	1.50	500.00	6200.38	.9015

Figure 11

249	537	.15	.00	590.11	.0000
250	538	.15	2.00	593.75	.0007
251	539	.15	10.00	602.14	.0216

252	540	.15	50.00	644.17	.0572
253	541	.15	100.00	677.92	.0950
254	542	.15	500.00	999.53	.3777
255	543	.15	1000.00	1379.11	.5527
256	544	.15	2000.00	2133.08	.7148
537	825	.35	.00	590.11	.0000
538	826	.35	2.00	595.84	.0077
539	827	.35	10.00	619.18	.0479
540	828	.35	50.00	687.61	.1057
541	829	.35	100.00	786.55	.2586
542	830	.35	500.00	1512.31	.5970
543	831	.35	1000.00	2425.36	.7621
544	832	.35	2000.00	4170.15	.8554
825	1113	.75	.00	590.11	.0000
826	1114	.75	2.00	602.14	.0216
827	1115	.75	10.00	644.17	.0572
828	1116	.75	50.00	796.23	.2919
829	1117	.75	100.00	999.51	.3776
830	1118	.75	500.00	2558.40	.7729
831	1119	.75	1000.00	4458.25	.8349
832	1120	.75	2000.00	8247.29	.9270
1113	1401	1.50	.00	590.11	.0000
1114	1402	1.50	2.00	613.82	.0359
1115	1403	1.50	10.00	677.92	.0950
1116	1404	1.50	50.00	999.53	.3777
1117	1405	1.50	100.00	1376.81	.5480
1118	1406	1.50	500.00	4458.25	.8349
1119	1407	1.50	1000.00	8247.31	.9270

Figure 12

5	293	.15	5.00	177.49	.9272
13	301	.15	15.00	642.48	.4284
37	325	.15	25.00	909.42	.3295
45	333	.15	35.00	2193.18	.2919
69	357	.15	45.00	2644.61	.1742
293	581	.35	5.00	385.71	.9278
301	589	.35	15.00	1040.08	.6861
325	613	.35	25.00	1304.54	.5281
333	621	.35	35.00	2906.05	.4011
357	645	.35	45.00	3327.52	.3712
581	869	.75	5.00	787.21	.9456
589	877	.75	15.00	1854.81	.8231
613	901	.75	25.00	2086.52	.6998
621	909	.75	35.00	4284.75	.6156
645	933	.75	45.00	4754.67	.5665
869	1157	1.50	5.00	1538.84	.9816
877	1165	1.50	15.00	3315.69	.8614
901	1189	1.50	25.00	3545.12	.8224
909	1197	1.50	35.00	6904.67	.7563
933	1221	1.50	45.00	7409.68	.7114

Figure 13

33	105	1.50	.00	590.11	.0000
34	106	1.50	2.00	595.77	-.0062
35	107	1.50	10.00	612.83	-.0151
36	108	1.50	50.00	681.67	-.0766
37	109	1.50	100.00	761.39	-.1897
38	110	1.50	500.00	1407.15	-.4107
39	111	1.50	1000.00	2184.83	-.5340
40	112	1.50	2000.00	3740.56	-.6265
105	177	2.50	.00	590.11	.0000
106	178	2.50	2.00	594.08	-.0038
107	179	2.50	10.00	605.88	-.0320
108	180	2.50	50.00	651.43	-.0986
109	181	2.50	100.00	699.20	-.1004
110	182	2.50	500.00	1102.57	-.5077
111	183	2.50	1000.00	1578.84	-.6876
112	184	2.50	2000.00	2554.15	-.7932
177	249	3.50	.00	590.11	.0000
178	250	3.50	2.00	593.61	-.0001
179	251	3.50	10.00	599.90	-.0245
180	252	3.50	50.00	635.23	-.0370
181	253	3.50	100.00	670.80	-.1497
182	254	3.50	500.00	932.16	-.4391
183	255	3.50	1000.00	1243.38	-.6663
184	256	3.50	2000.00	1886.89	-.9722

Figure 14

321	393	1.50	.00	590.11	.0000
322	394	1.50	2.00	601.21	-.0202
323	395	1.50	10.00	630.71	-.0377
324	396	1.50	50.00	761.39	-.1897
325	397	1.50	100.00	928.75	-.2602
326	398	1.50	500.00	2184.60	-.5337
327	399	1.50	1000.00	3738.06	-.6251
328	400	1.50	2000.00	6837.37	-.6856
393	465	2.50	.00	590.11	.0000
394	466	2.50	2.00	596.42	-.0061
395	467	2.50	10.00	618.35	-.0358
396	468	2.50	50.00	699.20	-.1004
397	469	2.50	100.00	792.92	-.3486
398	470	2.50	500.00	1578.84	-.6876
399	471	2.50	1000.00	2554.18	-.7928
400	472	2.50	2000.00	4460.34	-.9129
465	537	3.50	.00	590.11	.0000
466	538	3.50	2.00	594.79	-.0106
467	539	3.50	10.00	610.20	-.0427
468	540	3.50	50.00	670.80	-.1497
469	541	3.50	100.00	718.52	-.1863
470	542	3.50	500.00	1243.54	-.6653
471	543	3.50	1000.00	1891.20	-.9549
472	544	3.50	2000.00	3143.63	-1.1185

Figure 15

609	681	1.50	.00	590.11	.0000
610	682	1.50	2.00	612.83	-.0151
611	683	1.50	10.00	681.67	-.0766
612	684	1.50	50.00	1003.88	-.2966
613	685	1.50	100.00	1407.00	-.4110
614	686	1.50	500.00	4540.49	-.6276
615	687	1.50	1000.00	8435.56	-.6953
681	753	2.50	.00	590.11	.0000
682	754	2.50	2.00	605.88	-.0320
683	755	2.50	10.00	651.43	-.0986
684	756	2.50	50.00	850.25	-.3198
685	757	2.50	100.00	1102.43	-.5070
686	758	2.50	500.00	3046.77	-.8924
687	759	2.50	1000.00	5408.88	-.9907
753	825	3.50	.00	590.11	.0000
754	826	3.50	2.00	599.90	-.0245
755	827	3.50	10.00	635.23	-.0370
756	828	3.50	50.00	757.32	-.3563
757	829	3.50	100.00	932.17	-.4390
758	830	3.50	500.00	2201.11	-.9599
759	831	3.50	1000.00	3777.37	-1.0375
760	832	3.50	2000.00	6881.26	-1.2027

Figure 16

897	969	1.50	.00	590.11	.0000
898	970	1.50	2.00	630.71	-.0377
899	971	1.50	10.00	761.39	-.1897
900	972	1.50	50.00	1407.00	-.4110
901	973	1.50	100.00	2184.60	-.5337
902	974	1.50	500.00	8435.56	-.6953
969	1041	2.50	.00	590.11	.0000
970	1042	2.50	2.00	618.35	-.0358
971	1043	2.50	10.00	699.20	-.1004
972	1044	2.50	50.00	1102.43	-.5070
973	1045	2.50	100.00	1578.84	-.6876
974	1046	2.50	500.00	5408.88	-.9907
1041	1113	3.50	.00	590.11	.0000
1042	1114	3.50	2.00	610.20	-.0427
1043	1115	3.50	10.00	670.80	-.1497
1044	1116	3.50	50.00	932.17	-.4390
1045	1117	3.50	100.00	1243.52	-.6654
1046	1118	3.50	500.00	3777.37	-1.0375
1047	1119	3.50	1000.00	6881.26	-1.2027

Figure 17

1185	1257	1.50	.00	590.11	.0000
1186	1258	1.50	2.00	668.48	-.0985
1187	1259	1.50	10.00	928.75	-.2602
1188	1260	1.50	50.00	2184.60	-.5337
1189	1261	1.50	100.00	3735.10	-.6280
1257	1329	2.50	.00	590.11	.0000

1258	1330	2.50	2.00	640.78	-.0450
1259	1331	2.50	10.00	792.92	-.3486
1260	1332	2.50	50.00	1578.84	-.6876
1261	1333	2.50	100.00	2551.39	-.7875
1329	1401	3.50	.00	590.11	.0000
1330	1402	3.50	2.00	628.08	-.0772
1331	1403	3.50	10.00	718.52	-.1863
1332	1404	3.50	50.00	1243.54	-.6653
1333	1405	3.50	100.00	1888.93	-.9658
1334	1406	3.50	500.00	6881.26	-1.2027

Figure 18

1156	1228	1.50	5.00	844.68	-.6772
1164	1236	1.50	15.00	1955.00	-.6271
1188	1260	1.50	25.00	2184.60	-.5337
1196	1268	1.50	35.00	4421.67	-.5036
1220	1292	1.50	45.00	4885.92	-.4707
1228	1300	2.50	5.00	561.72	-.8216
1236	1308	2.50	15.00	1330.92	-.8092
1260	1332	2.50	25.00	1578.84	-.6876
1268	1340	2.50	35.00	3289.05	-.5934
1292	1364	2.50	45.00	3740.81	-.5059
1300	1372	3.50	5.00	411.42	-.9868
1308	1380	3.50	15.00	992.21	-.8699
1332	1404	3.50	25.00	1243.54	-.6653
1340	1412	3.50	35.00	2704.02	-.5040
1364	1436	3.50	45.00	3140.82	-.4936

Figure 20

81	105	20.00	.00	468.81	1.0350
82	106	20.00	2.00	473.73	1.0200
83	107	20.00	10.00	485.08	1.0281
84	108	20.00	50.00	537.57	.9428
85	109	20.00	100.00	596.89	.7797
86	110	20.00	500.00	1082.06	.4896
87	111	20.00	1000.00	1672.26	.2959
88	112	20.00	2000.00	2829.51	.1836
105	121	30.00	.00	726.30	1.1251
106	122	30.00	2.00	729.34	1.1090
107	123	30.00	10.00	741.35	1.0651
108	124	30.00	50.00	791.91	.9670
109	125	30.00	100.00	851.08	.9718
110	126	30.00	500.00	1334.07	.5377
111	127	30.00	1000.00	1929.93	.4165
112	128	30.00	2000.00	3110.70	.2919

Figure 21

657	681	20.00	.00	468.81	1.0350
658	682	20.00	2.00	485.08	1.0281
659	683	20.00	10.00	537.57	.9428
660	684	20.00	50.00	777.84	.6520
661	685	20.00	100.00	1081.41	.4912
662	686	20.00	500.00	3469.46	.1396
663	687	20.00	1000.00	6364.00	.0733
681	697	30.00	.00	726.30	1.1251
682	698	30.00	2.00	741.35	1.0651
683	699	30.00	10.00	791.91	.9670
684	700	30.00	50.00	1032.77	.7444
685	701	30.00	100.00	1333.92	.5384
686	702	30.00	500.00	3709.71	.1927
687	703	30.00	1000.00	6599.63	.1083

Figure 22

1233	1257	20.00	.00	468.81	1.0350
1234	1258	20.00	2.00	524.48	.9309
1235	1259	20.00	10.00	716.71	.7339
1236	1260	20.00	50.00	1671.13	.2988
1237	1261	20.00	100.00	2826.43	.1795
1257	1273	30.00	.00	726.30	1.1251
1258	1274	30.00	2.00	776.20	1.0023
1259	1275	30.00	10.00	972.61	.7675
1260	1276	30.00	50.00	1929.93	.4165
1261	1277	30.00	100.00	3107.64	.2981

Figure 23

876	900	20.00	1.00	1472.85	.3447
900	916	30.00	1.00	1727.36	.4432
948	972	20.00	2.00	1081.41	.4912
972	988	30.00	2.00	1333.92	.5384
1020	1044	20.00	3.00	858.00	.6183
1044	1060	30.00	3.00	1121.07	.6981
1092	1116	20.00	4.00	741.92	.7100
1116	1132	30.00	4.00	990.96	.7204

Figure 24

873	897	11.00	.00	468.81	.5692
874	898	11.00	2.00	517.11	.5170
875	899	11.00	10.00	680.13	.4186
876	900	11.00	50.00	1472.85	.1896
877	901	11.00	100.00	2468.48	.0934
878	902	11.00	500.00	10267.31	.0264
897	913	21.00	.00	726.30	.7876
898	914	21.00	2.00	770.49	.7188
899	915	21.00	10.00	937.38	.5728
900	916	21.00	50.00	1727.36	.3102
901	917	21.00	100.00	2687.40	.1784
902	918	21.00	500.00	10529.13	.0553

Figure 25

73	81	6.50	.00	194.71	2.0405
74	82	6.50	2.00	197.52	2.0456
75	83	6.50	10.00	202.35	2.0307
76	84	6.50	50.00	233.46	1.9759
77	85	6.50	100.00	280.01	1.8620
78	86	6.50	500.00	658.41	1.1499
79	87	6.50	1000.00	1101.51	1.0553
80	88	6.50	2000.00	2001.33	.9072
81	97	11.50	.00	778.47	2.5466
82	98	11.50	2.00	782.20	2.5245
83	99	11.50	10.00	797.08	2.5201
84	100	11.50	50.00	860.37	2.4033
85	101	11.50	100.00	953.43	2.2815
86	102	11.50	500.00	1596.58	1.8640
87	103	11.50	1000.00	2397.96	1.6294
88	104	11.50	2000.00	3988.77	1.4867
97	129	16.50	.00	2496.68	3.4029
98	130	16.50	2.00	2497.70	3.3987
99	131	16.50	10.00	2518.56	3.3669
100	132	16.50	50.00	2607.30	3.2843
101	133	16.50	100.00	2744.95	3.1706
102	134	16.50	500.00	3828.00	2.7318
103	135	16.50	1000.00	5099.21	2.3969

Figure 26

361	369	6.50	.00	194.71	2.0405
362	370	6.50	2.00	200.47	2.0428
363	371	6.50	10.00	211.24	2.0296
364	372	6.50	50.00	280.01	1.8620
365	373	6.50	100.00	370.24	1.5096
366	374	6.50	500.00	1101.51	1.0553
367	375	6.50	1000.00	2001.32	.9072
368	376	6.50	2000.00	3806.20	.8395
369	385	11.50	.00	778.47	2.5466
370	386	11.50	2.00	788.78	2.5123
371	387	11.50	10.00	811.22	2.4671
372	388	11.50	50.00	953.43	2.2815
373	389	11.50	100.00	1077.39	2.1014
374	390	11.50	500.00	2397.96	1.6294
375	391	11.50	1000.00	3988.77	1.4867
376	392	11.50	2000.00	7182.75	1.3754
385	417	16.50	.00	2496.68	3.4029
386	418	16.50	2.00	2503.44	3.3847
387	419	16.50	10.00	2532.42	3.3519
388	420	16.50	50.00	2744.95	3.1706
389	421	16.50	100.00	2998.31	3.1450
390	422	16.50	500.00	5099.21	2.3969

Figure 27

649	657	6.50	.00	194.71	2.0405
650	658	6.50	2.00	202.35	2.0307
651	659	6.50	10.00	233.46	1.9759
652	660	6.50	50.00	417.23	1.4571
653	661	6.50	100.00	657.90	1.1488
654	662	6.50	500.00	2472.61	.9208
655	663	6.50	1000.00	4731.54	.8330
657	673	11.50	.00	778.47	2.5466
658	674	11.50	2.00	797.08	2.5201
659	675	11.50	10.00	860.37	2.4033
660	676	11.50	50.00	1149.48	1.9946
661	677	11.50	100.00	1596.07	1.8661
662	678	11.50	500.00	4786.25	1.3820
673	705	16.50	.00	2496.68	3.4029
674	706	16.50	2.00	2518.56	3.3669
675	707	16.50	10.00	2607.30	3.2843
676	708	16.50	50.00	3114.91	3.1084
677	709	16.50	100.00	3828.00	2.7318

Figure 28

937	945	6.50	.00	194.71	2.0405
938	946	6.50	2.00	211.24	2.0296
939	947	6.50	10.00	280.01	1.8620
940	948	6.50	50.00	657.90	1.1488
941	949	6.50	100.00	1100.17	1.0544
942	950	6.50	500.00	4731.54	.8330
945	961	11.50	.00	778.47	2.5466
946	962	11.50	2.00	811.22	2.4671
947	963	11.50	10.00	953.43	2.2815
948	964	11.50	50.00	1596.07	1.8661
949	965	11.50	100.00	2396.82	1.6323
961	993	16.50	.00	2496.68	3.4029
962	994	16.50	2.00	2532.42	3.3519
963	995	16.50	10.00	2744.95	3.1706
964	996	16.50	50.00	3828.00	2.7318
965	997	16.50	100.00	5099.21	2.3969

Figure 29

1225	1233	6.50	.00	194.71	2.0405
1226	1234	6.50	2.00	227.95	1.9901
1227	1235	6.50	10.00	370.24	1.5096
1228	1236	6.50	50.00	1100.17	1.0544
1229	1237	6.50	100.00	2001.30	.9072
1233	1249	11.50	.00	778.47	2.5466
1234	1250	11.50	2.00	843.81	2.4062
1235	1251	11.50	10.00	1077.39	2.1014
1236	1252	11.50	50.00	2396.82	1.6323
1237	1253	11.50	100.00	3988.75	1.4867
1249	1281	16.50	.00	2496.68	3.4029
1250	1282	16.50	2.00	2587.10	3.3213
1251	1283	16.50	10.00	2998.31	3.1450
1252	1284	16.50	50.00	5099.21	2.3969

Figure 30

868	876	6.50	1.00	942.50	1.1129
876	892	11.50	1.00	2141.49	1.7089
892	924	16.50	1.00	4776.82	2.5420
940	948	6.50	2.00	657.90	1.1488
948	964	11.50	2.00	1596.07	1.8661
964	996	16.50	2.00	3828.00	2.7318
1012	1020	6.50	3.00	487.76	1.2666
1020	1036	11.50	3.00	1248.34	1.9271
1036	1068	16.50	3.00	3238.91	2.9905
1084	1092	6.50	4.00	393.92	1.4271
1092	1108	11.50	4.00	1091.43	2.0285
1108	1140	16.50	4.00	2946.94	3.0777

Figure 31

873	897	20.00	.00	468.81	1.0350
874	898	20.00	2.00	517.11	.9400
875	899	20.00	10.00	680.13	.7610
876	900	20.00	50.00	1472.85	.3447
877	901	20.00	100.00	2468.48	.1698
878	902	20.00	500.00	10267.31	.0480
897	913	30.00	.00	726.30	1.1251
898	914	30.00	2.00	770.49	1.0269
899	915	30.00	10.00	937.38	.8183
900	916	30.00	50.00	1727.36	.4432
901	917	30.00	100.00	2687.40	.2548
902	918	30.00	500.00	10529.13	.0790

Figure 32

897	898	1.00	1.00	614.37	.0395
898	899	6.00	1.00	724.08	.1770
899	900	30.00	1.00	1204.66	.4920
900	901	75.00	1.00	2086.52	.6998
901	902	300.00	1.00	6481.92	.9045
969	970	1.00	2.00	606.45	.0269
970	971	6.00	2.00	668.01	.1016
971	972	30.00	2.00	963.73	.3899
972	973	75.00	2.00	1505.08	.5798
973	974	300.00	2.00	4138.25	.8490
1041	1042	1.00	3.00	602.02	.0198
1042	1043	6.00	3.00	649.54	.0822
1043	1044	30.00	3.00	837.89	.2734
1044	1045	75.00	3.00	1176.18	.4733
1045	1046	300.00	3.00	2849.47	.7832
1046	1047	750.00	3.00	6200.38	.9015
1113	1114	1.00	4.00	598.29	.0137
1114	1115	6.00	4.00	631.46	.0594
1115	1116	30.00	4.00	765.08	.2130
1116	1117	75.00	4.00	999.51	.3776
1117	1118	300.00	4.00	2171.42	.7226
1118	1119	750.00	4.00	4458.25	.8349
1119	1120	1500.00	4.00	8247.29	.9270

Figure 33

33	321	.15	.00	590.11	.0000
34	322	.15	2.00	601.14	.0206
35	323	.15	10.00	627.28	.0543
36	324	.15	50.00	754.30	.2197
37	325	.15	100.00	909.42	.3295
38	326	.15	500.00	2086.52	.6998
39	327	.15	1000.00	3545.35	.8222
40	328	.15	2000.00	6460.88	.9004
321	609	.35	.00	590.11	.0000
322	610	.35	2.00	610.59	.0204
323	611	.35	10.00	668.84	.1054
324	612	.35	50.00	956.33	.3582
325	613	.35	100.00	1304.54	.5281
326	614	.35	500.00	4031.83	.8441
327	615	.35	1000.00	7453.77	.9193
609	897	.75	.00	590.11	.0000
610	898	.75	2.00	627.28	.0543
611	899	.75	10.00	754.30	.2197
612	900	.75	50.00	1351.46	.5512
613	901	.75	100.00	2086.52	.6998
614	902	.75	500.00	7940.48	.9257
897	1185	1.50	.00	590.11	.0000
898	1186	1.50	2.00	664.53	.1169
899	1187	1.50	10.00	909.42	.3295
900	1188	1.50	50.00	2086.52	.6998
901	1189	1.50	100.00	3545.12	.8224

Figure 34

869	877	6.50	1.00	1699.52	1.0161
877	893	11.50	1.00	3531.65	1.5213
941	949	6.50	2.00	1100.17	1.0544
949	965	11.50	2.00	2396.82	1.6323
965	997	16.50	2.00	5099.21	2.3969
1013	1021	6.50	3.00	792.47	1.0599
1021	1037	11.50	3.00	1793.32	1.7386
1037	1069	16.50	3.00	4137.41	2.6581
1085	1093	6.50	4.00	611.16	1.0965
1093	1109	11.50	4.00	1423.86	1.7929
1109	1141	16.50	4.00	3501.66	2.8703

Figure 35

897	969	1.50	.00	590.11	.0000
898	970	1.50	2.00	630.71	-.0377
899	971	1.50	10.00	761.39	-.1897
900	972	1.50	50.00	1407.00	-.4110
901	973	1.50	100.00	2184.60	-.5337
902	974	1.50	500.00	8435.56	-.6953
969	1041	2.50	.00	590.11	.0000
970	1042	2.50	2.00	618.35	-.0358
971	1043	2.50	10.00	699.20	-.1004
972	1044	2.50	50.00	1102.43	-.5070
973	1045	2.50	100.00	1578.84	-.6876
974	1046	2.50	500.00	5408.88	-.9907
1041	1113	3.50	.00	590.11	.0000
1042	1114	3.50	2.00	610.20	-.0427
1043	1115	3.50	10.00	670.80	-.1497
1044	1116	3.50	50.00	932.17	-.4390
1045	1117	3.50	100.00	1243.52	-.6654
1046	1118	3.50	500.00	3777.37	-1.0375
1047	1119	3.50	1000.00	6881.26	-1.2027

Figure 36

12	13	1.7	15	507.67	0.6179
1162	1163	2.12	15	588.55	0.7028
300	301	2.4	15	642.48	0.7344
13	14	3.8	15	948.33	0.8535
588	589	4.5	15	1099.74	0.8634
1163	1164	6.6	15	1548.96	0.9299
14	15	8	15	1855.25	0.9412
1164	1165	15	15	3315.69	0.9229
303	304	29	15	6208.58	0.9714
590	591	36	15	7690.25	0.9846
610	611	1.17	25	657.49	0.6593
898	899	1.34	25	724.08	0.7039
324	325	1.84	25	909.42	0.7218
37	38	2.68	25	1204.66	0.7849
612	613	3.1	25	1351.46	0.8137
1187	1188	4.36	25	1791.28	0.8497
38	39	5.2	25	2086.75	0.8668
613	614	9.4	25	3545.08	0.9211
327	328	17.8	25	6458.48	0.9555
614	615	22	25	7940.48	0.9698
52	53	1.3	35	1017.29	0.6126
1202	1203	1.48	35	1108.63	0.6817
627	628	1.6	35	1159.92	0.6572
915	916	2.2	35	1460.09	0.7437
628	629	2.5	35	1602.71	0.7869
1203	1204	3.4	35	2036.79	0.7979
916	917	4	35	2328.25	0.8131
629	630	7	35	3790.85	0.8937
917	918	13	35	6734.62	0.949
630	631	16	35	8198.61	0.9648

APPENDIX D

COMPUTER PROGRAM USED TO GENERATE MULTIVARIATE LOGNORMAL VARIABLES

```
C*******************************************************************
C*     PROGRAM USED TO GENERATE MULTIVARIATE LOGNORMAL VARIABLES *
C*                                                               *
C*******************************************************************
C
C      VARIABLE DEFINITION:
C             N    - size of the correlation matrix.
C             NOBS - number of pseudo multivariate lognormal variables
C                    to be generated
C             A    - array used to store loading factors from SYSTAT
C             AROT - array used to rotate array A
C             Z    - array used to store random normal variate
C             OBS  - array used to store generated lognormal variables
C             VAR  - array contains standard deviations
C             MEAN - array contains means
C
C      DECLARATION
C
       INTEGER N,NOBS
       PARAMETER(N=4,NOBS=1000)
       REAL A(N,N),AROT(N,N),Z(N),OBS(NOBS,N),VAR(N),MEAN(N)
       REAL DEPTH
       CHARACTER*40 OUT
C
C      OPEN OUTPUT FILE
C
       OPEN(UNIT=8,FILE=OUT)
C
C      INITIALIZATION (VALUES ARE TAKEN FROM TABLE 4)
C
       DATA VAR /0.06991,0.29356,0.19804,0.29356/
       DATA MEAN /0.39566,2.26746,3.04784,0.14256/
       DATA A /-0.432,0.913,0.863,0.738,
      +         0.843,0.286,0.326,-0.240,
      +         -0.318,0.073,0.299,-0.626,
      +         0.021,-0.282,0.246,0.074/
C
C      GET SEED FROM INTERNAL CLOCK
C
       CALL GETTIM(IHR,IMIN,ISEC,I100TH)
       CALL SEED(I100TH)
C
C TRANSPOSE A MATRIX TO ARRAY AROT
C
       DO 40 I=1,N
              DO 30 J=1,N
                     AROT(J,I) = A(I,J)
30            CONTINUE
40     CONTINUE
C
C
C COMPUTE MATRIX X BY MULTIPLYING MATRIX Z AND TRANSPOSE A
C
       DEPTH=0.1
       DO 60 M=1,NOBS
C
C             CALL SUBROUTINE TO GENERATE RANDOM NORMAL VARIATE
C
44            CALL NORMAL(N,Z)
              DO 50 J=1,N
C
C                    RESET OBS(M,J) TO ZERO IF PROCESS IS REPEATED
C
                     OBS(M,J)=0
                     DO 45 I=1,N
                            OBS(M,J) = OBS(M,J) + Z(I)*AROT(I,J)
45                   CONTINUE
C
C                    REVERSE TRANSFORMATION
C
                     OBS(M,J) = EXP( OBS(M,J)*VAR(J)+MEAN(J) )
50            CONTINUE
C
C             TEST IF THE GENERATED DATA COMPLY WITH PHYSICAL LAWS
C
              IF(OBS(M,2).GE.OBS(M,3)) GOTO 44
              IF(OBS(M,3).GE.(1-OBS(M,1)/2.65)*100 ) GOTO 44
C
C             OUTPUT PARAMETERS FOR A PROFILE.
C
              WRITE(8,200) (OBS(M,K),K=1,N)
60     CONTINUE
C
C
200    FORMAT(4(F10.4))
C
       STOP
       END
```

```
      SUBROUTINE NORMAL(N,Z)
C
C***********************************************************************
C   THE FOLLOWING SUBROUTINE GENERATES A NORMAL N~(0,1)                *
C   VECTOR OF SIZE N.   THIS SUBROUTINE IS CALLED NOBS TIMES          *
C   IN ORDER TO GENERATE NOBS BY N SETS PSEUDO OBSERVATIONS           *
C***********************************************************************
C
      INTEGER N,K
      REAL Z(N)
C
C GENERATE A STANDARD N(0,1) VECTOR OF SIZE N
C
      K=N/2
      DO 10 J=1,K
            CALL RANDOM(U1)
            CALL RANDOM(U2)
            Z(J)   = ((-2*ALOG(U1))**0.5)*COS(2*3.14159*U2)
            Z(J+K) = ((-2*ALOG(U1))**0.5)*SIN(2*3.14159*U2)
10    CONTINUE
C
      RETURN
      END
```

APPENDIX E

PLOTTING POSITIONS USED TO MAKE FREQUENCY DISTRIBUTION PLOTS

PLOTTING POSITIONS USED TO MAKE FREQUENCY DISTRIBUTION PLOTS[1]

FIGURE 40				FIGURE 41				FIGURE 42			
PROB	POS	PROB	FIT	PROB	POS	PROB	FIT	PROB	POS	PROB	FIT
0.1	2002	94.97	9949	0.09	8438	99.00	2477	0.09	13661	99.00	1375
0.5	2567	94.95	9884	0.49	7768	80.00	3556	0.47	12546	80.00	2715
0.89	2575	94.95	9884	0.89	7378	70.00	3834	0.85	11833	70.00	3129
1.29	2575	94.71	9267	1.29	7239	60.00	4075	1.23	10946	60.00	3509
1.69	2575	94.69	9213	1.69	6978	50.00	4362	1.61	10591	50.00	3988
2.09	2704	94.51	8950	2.09	6916	43.00	4557	1.99	10241	43.00	4331
2.49	2704	94.51	8941	2.49	6655	30.00	4950	2.37	9878	30.00	5060
2.89	2704	92.59	7715	2.89	6594	20.00	5350	2.75	9505	20.00	5859
3.29	2704	92.47	7677	3.29	6415	15.00	5589	3.13	9162	15.00	6362
3.69	2704	92.47	7677	3.69	6345	10.00	5954	3.51	8846	10.00	7166
4.09	2704	92.47	7675	4.09	6306	7.00	6281	3.89	8574	7.00	7926
4.49	2713	91.71	7432	4.49	6284	5.00	6507	4.27	8478	5.00	8469
4.89	2713	91.71	7432	4.89	6239	4.00	6675	4.66	8408	4.00	8886
5.29	2713	91.71	7432	5.29	6228	2.00	7180	5.04	8343	2.00	10195
5.69	2713	91.38	7352	5.69	6224	1.00	7680	5.42	8181	1.00	11573
6.09	2714	89.32	6922	6.09	6212	0.20	8785	5.80	8054	0.20	14907
6.49	2949	89.32	6921	6.49	6017	0.10	9246	6.18	8051	0.10	16411
6.89	2949	89.32	6921	6.89	6000			6.56	7713		
7.29	2949	89.32	6921	7.29	5988			6.94	7691		
7.68	2949	89.32	6921	7.69	5977			7.32	7675		
8.08	2949	89.32	6921	8.09	5935			7.70	7666		
8.48	2949	89.32	6921	8.49	5925			8.08	7468		
8.88	3095	89.32	6921	8.89	5911			8.46	7450		
9.28	3279	87.79	6690	9.29	5901			8.84	7341		
9.68	3279	87.79	6690	9.69	5890			9.23	7319		
10.08	3289	85.65	6447	10.08	5885			9.60	7094		
10.48	3289	84.79	6353	10.48	5870			9.98	7007		
10.88	3289	84.79	6353	10.88	5858			10.36	6976		
11.28	3289	84.79	6353	11.28	5852			10.74	6942		
11.68	3289	84.79	6353	11.68	5846			11.12	6931		
12.08	3289	81.43	6047	12.08	5770			11.50	6733		
12.48	3289	81.43	6047	12.48	5663			11.88	6708		
12.88	3289	81.43	6047	12.88	5633			12.26	6660		
13.28	3289	81.43	6047	13.28	5619			12.64	6645		
13.68	3289	81.22	6034	13.68	5611			13.02	6607		
14.08	3289	80.55	5987	14.08	5596			13.40	6387		
14.48	3289	80.55	5987	14.48	5576			13.79	6373		
14.88	3291	80.55	5987	14.88	5566			14.17	6356		
15.28	3291	77.17	5759	15.28	5552			14.55	6333		
15.68	3321	75.03	5617	15.68	5542			14.93	6280		
16.08	3321	75.03	5617	16.08	5525			15.31	6264		
16.48	3321	75.03	5617	16.48	5518			15.69	6252		
16.88	3431	75.03	5617	16.88	5513			16.07	6229		
17.28	3431	75.03	5617	17.28	5505			16.45	6229		
17.68	3702	75.03	5617	17.68	5498			16.83	6022		
18.08	3703	73.05	5517	18.08	5487			17.21	5995		
18.48	3703	73.05	5517	18.48	5481			17.59	5976		
18.88	3703	65.49	5155	18.88	5463			17.97	5963		
19.28	3704	65.49	5155	19.28	5436			18.36	5929		
19.68	3745	65.49	5153	19.68	5324			18.74	5899		
20.08	3790	65.49	5153	20.07	5319			19.11	5879		
20.48	4027	65.49	5153	20.47	5290			19.49	5869		
20.88	4027	65.49	5153	20.87	5277			19.87	5858		
21.28	4027	65.49	5152	21.27	5266			20.25	5852		
21.68	4027	65.49	5150	21.67	5262			20.63	5849		
22.07	4027	65.49	5150	22.07	5257			21.01	5818		
22.47	4043	65.49	5150	22.47	5252			21.39	5738		
22.87	4043	65.16	5145	22.87	5249			21.77	5663		
23.27	4043	65.16	5141	23.27	5242			22.15	5617		
23.67	4043	65.16	5141	23.67	5207			22.53	5604		
24.07	4043	65.16	5141	24.07	5193			22.92	5572		
24.47	4043	65.16	5139	24.47	5181			23.30	5541		
24.87	4043	65.16	5139	24.87	5178			23.68	5530		
25.27	4043	65.16	5139	25.27	5170			24.06	5510		
25.67	4043	65.16	5139	25.67	5163			24.44	5498		
26.07	4079	65.16	5139	26.07	5162			24.82	5492		
26.47	4079	58.82	4884	26.47	5159			25.20	5480		
26.87	4079	58.82	4884	26.87	5153			25.58	5285		
27.27	4079	58.82	4884	27.27	5151			25.96	5269		
27.67	4079	58.82	4884	27.67	5145			26.34	5260		
28.06	4079	58.82	4884	28.07	5143			26.72	5255		
28.46	4079	58.82	4884	28.47	5135			27.10	5241		
28.86	4079	58.82	4884	28.87	5129			27.48	5233		
29.26	4079	58.82	4884	29.27	5127			27.87	5184		
29.66	4079	58.82	4884	29.67	5119			28.25	5164		
30.06	4087	58.82	4884	30.06	5102			28.62	5151		

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1. PROB - probability, POS - plotting position, FIT - lognormal or modified lognormal fitted plotting position

30.46	4087	58.82	4883	30.46	5049	29.00	5133
30.86	4087	58.82	4883	30.86	4954	29.38	5128
31.26	4105	58.82	4883	31.26	4933	29.76	5123
31.66	4105	58.82	4883	31.66	4920	30.14	5082
32.06	4105	58.82	4883	32.06	4915	30.52	4925
32.46	4105	58.82	4883	32.46	4904	30.90	4895
32.86	4165	58.46	4875	32.86	4899	31.28	4892
33.26	4165	58.46	4875	33.26	4894	31.66	4886
33.66	4165	58.46	4874	33.66	4889	32.04	4872
34.06	4165	58.46	4874	34.06	4883	32.43	4831
34.46	4171	58.46	4874	34.46	4880	32.81	4828
34.86	4171	57.37	4831	34.86	4857	33.19	4820
35.26	4172	57.37	4831	35.26	4841	33.57	4811
35.66	4172	57.37	4830	35.66	4831	33.95	4784
36.06	4172	57.37	4830	36.06	4824	34.33	4777
36.46	4173	57.37	4830	36.46	4814	34.71	4773
36.85	4173	57.37	4830	36.86	4810	35.09	4768
37.25	4173	57.37	4830	37.26	4804	35.47	4761
37.65	4173	57.37	4830	37.66	4795	35.85	4751
38.05	4173	57.37	4830	38.06	4789	36.23	4670
38.45	4174	57.37	4830	38.46	4787	36.61	4606
38.85	4174	57.37	4830	38.86	4780	37.00	4548
39.25	4174	56.26	4787	39.26	4776	37.38	4536
39.65	4174	56.26	4786	39.66	4771	37.76	4526
40.05	4174	56.26	4786	40.05	4767	38.13	4513
40.45	4174	56.26	4786	40.45	4763	38.51	4506
40.85	4174	49.49	4554	40.85	4759	38.89	4485
41.25	4174	49.49	4554	41.25	4754	39.27	4474
41.65	4174	49.49	4554	41.65	4752	39.65	4448
42.05	4174	49.49	4554	42.05	4736	40.03	4429
42.45	4174	49.49	4554	42.45	4717	40.41	4425
42.85	4174	49.49	4554	42.85	4592	40.79	4422
43.25	4174	49.49	4554	43.25	4568	41.17	4405
43.65	4174	49.49	4554	43.65	4552	41.56	4403
44.05	4248	49.49	4554	44.05	4542	41.94	4391
44.45	4248	49.49	4554	44.45	4536	42.32	4349
44.85	4248	49.49	4554	44.85	4529	42.70	4191
45.25	4248	49.49	4554	45.25	4523	43.08	4177
45.65	4248	49.49	4554	45.65	4516	43.46	4172
46.05	4248	49.49	4554	46.05	4513	43.84	4152
46.45	4248	49.49	4554	46.45	4488	44.22	4147
46.85	4248	49.49	4554	46.85	4480	44.60	4113
47.25	4248	40.05	4248	47.25	4474	44.98	4096
47.65	4248	40.05	4248	47.65	4456	45.36	4074
48.05	4554	40.05	4248	48.05	4454	45.74	4064
48.45	4554	40.05	4248	48.45	4448	46.12	4057
48.85	4554	40.05	4248	48.85	4440	46.51	4045
49.25	4554	40.05	4248	49.25	4427	46.89	4038
49.65	4554	40.05	4248	49.65	4425	47.27	4033
50.05	4554	40.05	4248	50.04	4422	47.64	4030
50.45	4554	40.05	4248	50.44	4414	48.02	4023
50.85	4554	40.05	4248	50.84	4414	48.40	4019
51.25	4554	46.40	4174	51.24	4407	48.78	4016
51.64	4554	46.40	4174	51.64	4406	49.16	4002
52.04	4554	46.40	4174	52.04	4404	49.54	3814
52.44	4554	46.40	4174	52.44	4403	49.92	3807
52.84	4554	46.40	4174	52.84	4401	50.30	3794
53.24	4554	46.40	4174	53.24	4398	50.68	3787
53.64	4554	46.40	4174	53.64	4394	51.07	3776
54.04	4554	46.40	4174	54.04	4390	51.45	3750
54.44	4786	46.40	4174	54.44	4385	51.83	3728
54.84	4786	46.40	4174	54.84	4373	52.21	3724
55.24	4786	46.40	4174	55.24	4372	52.59	3714
55.63	4787	46.40	4174	55.64	4335	52.97	3703
56.03	4830	46.40	4174	56.04	4221	53.35	3691
56.43	4830	46.40	4174	56.44	4204	53.73	3688
56.83	4830	46.40	4173	56.84	4187	54.11	3680
57.23	4830	46.40	4173	57.24	4182	54.49	3678
57.63	4830	46.40	4173	57.64	4176	54.87	3671
58.03	4830	46.40	4173	58.04	4175	55.25	3666
58.43	4830	46.40	4173	58.44	4172	55.64	3663
58.83	4830	46.40	4172	58.84	4166	56.02	3656
59.23	4830	46.40	4172	59.24	4165	56.40	3652
59.63	4831	46.40	4172	59.64	4159	56.78	3624
60.03	4831	46.40	4171	60.03	4155	57.15	3588
60.43	4874	46.40	4171	60.43	4149	57.53	3511
60.83	4874	37.47	4165	60.83	4145	57.91	3480
61.23	4874	37.47	4165	61.23	4139	58.29	3455
61.63	4875	37.47	4165	61.63	4121	58.67	3444
62.03	4875	37.47	4165	62.03	4111	59.05	3429
62.43	4883	35.65	4105	62.43	4100	59.43	3422
62.83	4883	35.65	4105	62.83	4091	59.81	3412
63.23	4883	35.65	4105	63.23	4081	60.20	3406
63.63	4883	35.65	4105	63.63	4079	60.58	3373
64.03	4883	35.29	4087	64.03	4069	60.96	3359
64.43	4883	35.29	4087	64.43	4057	61.34	3335
64.83	4884	35.29	4087	64.83	4055	61.72	3324
65.23	4884	34.93	4079	65.23	4051	62.10	3318
65.63	4884	34.93	4079	65.63	4048	62.48	3314
66.02	4884	34.93	4079	66.03	4046	62.86	3304

66.42	4884	34.93	4079	66.43	4040	63.24	3297
66.82	4884	34.93	4079	66.83	4033	63.62	3291
67.22	4884	34.93	4079	67.23	4024	64.00	3288
67.62	4884	34.93	4079	67.63	4008	64.38	3286
68.02	4884	34.93	4079	68.03	3998	64.77	3285
68.42	4884	34.93	4079	68.43	3960	65.15	3272
68.82	5139	34.93	4079	68.83	3873	65.53	3202
69.22	5139	33.86	4043	69.23	3858	65.91	3083
69.62	5139	33.86	4043	69.63	3830	66.29	3076
70.02	5139	33.86	4043	70.02	3820	66.66	3074
70.42	5139	33.86	4043	70.42	3810	67.04	3070
70.82	5141	33.86	4043	70.82	3806	67.42	3052
71.22	5141	33.86	4043	71.22	3795	67.80	3045
71.62	5141	33.86	4043	71.62	3788	68.18	3008
72.02	5145	33.86	4043	72.02	3780	68.56	3006
72.42	5150	33.86	4043	72.42	3749	68.94	2991
72.82	5150	33.16	4027	72.82	3745	69.33	2984
73.22	5150	33.16	4027	73.22	3740	69.71	2972
73.62	5152	33.16	4027	73.62	3733	70.09	2968
74.02	5153	33.16	4027	74.02	3728	70.47	2965
74.42	5153	33.16	4027	74.42	3722	70.85	2958
74.82	5153	26.11	3790	74.82	3705	71.23	2948
75.22	5153	24.86	3745	75.22	3702	71.61	2945
75.62	5155	23.64	3704	75.62	3698	71.99	2935
76.02	5155	23.64	3703	76.02	3694	72.37	2927
76.42	5517	23.64	3703	76.42	3692	72.75	2919
76.82	5517	23.64	3703	76.82	3687	73.13	2898
77.22	5617	23.64	3702	77.22	3682	73.51	2749
77.62	5617	16.29	3431	77.62	3681	73.89	2728
78.02	5617	16.29	3431	78.02	3675	74.28	2726
78.42	5617	13.55	3321	78.42	3672	74.66	2724
78.82	5617	13.55	3321	78.82	3671	75.04	2716
79.22	5617	13.55	3321	79.22	3667	75.42	2710
79.62	5759	12.92	3291	79.62	3665	75.80	2706
80.02	5987	12.92	3291	80.01	3662	76.17	2699
80.42	5987	12.92	3289	80.41	3659	76.55	2685
80.81	5987	12.92	3289	80.81	3647	76.93	2666
81.21	6034	12.92	3289	81.21	3628	77.31	2631
81.61	6047	12.92	3289	81.61	3609	77.69	2619
82.01	6047	12.92	3289	82.01	3476	78.07	2607
82.41	6047	12.92	3289	82.41	3466	78.45	2606
82.8	6047	12.92	3289	82.81	3445	78.84	2589
83.2	6353	12.92	3289	83.21	3441	79.22	2583
83.6	6353	12.92	3289	83.61	3432	79.60	2577
84	6353	12.92	3289	84.01	3426	79.98	2569
84.4	6353	12.92	3289	84.41	3419	80.36	2564
84.8	6447	12.92	3289	84.81	3413	80.74	2548
85.2	6690	12.71	3279	85.21	3387	81.12	2534
85.6	6690	12.71	3279	85.61	3374	81.50	2524
86	6921	8.89	3095	86.01	3364	81.88	2484
86.4	6921	6.48	2949	86.41	3355	82.26	2379
86.8	6921	6.48	2949	86.81	3337	82.64	2368
87.2	6921	6.48	2949	87.21	3329	83.02	2336
87.6	6921	6.48	2949	87.61	3316	83.41	2324
88	6921	6.48	2949	88.01	3305	83.79	2316
88.4	6921	6.48	2949	88.41	3296	84.17	2285
88.8	6922	3.49	2714	88.81	3290	84.55	2263
89.2	7352	3.49	2713	89.21	3255	84.93	2239
89.6	7432	3.49	2713	89.61	3101	85.31	2235
90	7432	3.49	2713	90	3087	85.68	2230
90.4	7432	3.49	2713	90.4	3067	86.06	2214
90.8	7675	3.42	2704	90.8	3062	86.44	2204
91.2	7677	3.42	2704	91.2	3054	86.82	2195
91.6	7677	3.42	2704	91.6	3048	87.20	2192
92	7715	3.42	2704	92	3008	87.58	2174
92.4	8941	3.42	2704	92.4	2998	87.97	2034
92.8	8950	3.42	2704	92.8	2980	88.35	1996
93.2	9213	2.32	2575	93.2	2966	88.73	1983
93.6	9267	2.32	2575	93.6	2958	89.11	1932
94	9884	2.32	2575	94	2952	89.49	1898
94.4	9884	2.28	2567	94.4	2943	89.87	1867
94.8	9949	0.20	2002	94.8	2934	90.25	1851
				95.2	2925	90.63	1843
				95.6	2747	91.01	1833
				96	2722	91.39	1830
				96.4	2703	91.77	1783
				96.8	2687	92.15	1627
				97.2	2637	92.53	1607
				97.6	2599	92.92	1593
				98	2383	93.30	1543
				98.4	2363	93.68	1497
				98.8	2347	94.06	1460
				99.2	2224	94.44	1229
				99.6	2012	94.82	1144

v

VITA

Hao Zhang

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Doctor of Philosophy

Thesis: ASSESSMENT OF UNCERTAINTIES OF ESTIMATED SOLUTE TRANSPORT TO GROUND WATER

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