NONPARAMETRIC GEOSTATISTICAL ESTIMATION OF SOIL PHYSICAL PROPERTIES

by

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ABSTRACT

The spatial variability of Soil Physical Properties (SPP) was investigated by developing a computer program. The program was based on the Hybrid nonparametric statistical method.

SPP (i.e. bulk density, saturated hydraulic conductivity, available water and field capacity) were measured on two fields cultivated with grain corn on silty clay loam soil (Site A) and sandy loam soil (Site B) respectively. Site A was located on the west of Ormstown, Quebec, near the Chateaugay River. One hundred and twenty one soil samples were taken on a regular grid of 10X10 meters. Site B was located in the Richelieu county, Quebec. One hundred and twenty soil samples were taken on a regular grid of 30X30 meters.

The Hybrid model was applied to estimate the spatial variability of SPP on both fields. The accuracy and reliability of the Hybrid model was verified by comparing the estimated SPP with the measured SPP. It was found that the Hybrid method of estimation has the potential to be a good substitute for Kriging, a parametric estimation method.

RESUME

La variabilité spatiale des propriètés physiques du sol a été examinée à l'aide d'un programme basé sur la méthode statistique "Hybrid nonparametric".

Quelques propriétés physiques du sol, densité, conductivité hydrauliques saturee, eau pondérale et capacité de champs, ont été mesurees dans deux champs de mais: une loam limono argileux (Champs A) et un loam sableux (Champs B). Le champs A etait situe à l'ouest d'Ormstown, Québec, près de la rivière Chateauguay. Tout vingt et un échautillous furent recueuillis à interval réguliers sur une surface de 10 m par 10 m. Le champs B était situG dans le countG Richelieur. Dans ce cas, ou a recueuilli cent vingt échantillons sur une surface quadrillée de 30 m par 30 m.

Le modéle " Hybrid" a été utilisé pour estimer la variabilité spatiale des propriétée physiques du sol des deux champs. La comparaison des valeurs estimées et mesurées du champs a permis de vérifier la précision et la fiabilité du modéle.

Ou peut établir, suite a cette comparison, que la méthode d'estimation " Hybrid" pourrait remplacer la méthode Kriging (estimatour parametrique).

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LIST OF SYMBOLS AND ABREVIATIONS

SPP	Soil physical properties
NGEM	Nonparametric geostatistical estimation method
$\gamma(h)$	Semivariogram
C_0	Nugget
$C_0 + C_1$	Sill
W_d	Distance weighting
W_c	Cluster weighting
τ	Kendal's tau
q	Quantile
θ	Volumetric water content
V.W.C.	Volumetric water content
ρ_b	Soil bulk density
W	Gravimetric water content

CHAPTER 1

Introduction

The demand for accurate estimation of Soil Physical Properties (SPP) has led to the development of many different geostatistical methods. These methods were primarily developed over the past 37 years to estimate ore reserves in mining industries where accurate estimation of the available resources is necessary.

Soil hydrologists have recently started to use the Kriging method in the estimation of the spatial variability of SPP (Burgen and Webster, 1983; Vieira et al., 1983; Naderpour and Prasher, 1985). The studies indicated that with proper assumptions, the Kriging method provided the best unbiased estimation of the unknown soil property. However, the assumptions implicit in Kriging have recently been scrutinized. According to Henley (1981) the assumptions are rarely, if ever, met in nature. The validity of conclusions based on Kriging depends on the degree to which the assumptions are violated . Some of these assumptions, that are explained more in chapter 2.2.2 , are as follow:

1) stationarity of data
2) normality of data
3) additivity
4) subjectivity associated with the use of semivariograms

Fortunately, there are statistical techniques which do not require the above assumptions. These techniques are referred to as "distribution-free" or as "non-parametric" methods. In the past, nonparametric statistics have not been seriously considered. Recently, however, more emphasis has been placed on studies of geological data which violate the above assumptions.

Nonparametric geostatistical methods can be useful for comparing non-normally distributed data, multivariate data with missing values, and data measured even on an ordinal scale. There seems to be only one basic assumption in the nonparametric approach — that the spatial variation of the 'true or measured values' is everywhere continuous.

This thesis documents the first attempt to model a powerful and less restrictive technique called Nonparametric Geostatistical Estimation Method (NGEM) to investigate the spatial variability of SPP. An accurate estimation of these variables can improve the design of drainage (or irrigation) systems and can be achieved by applying the NGEM model. The application of this model minimizes the high cost of labor as well as the required time in estimating the variability of SPP.

Reported by Henley (1981), the Hybrid nonparametric estimation method yields the lowest sum of absolute deviations. Therefore, it was used to construct a model which was applied to estimate the spatial variability of soil bulk density, saturated hydraulic conductivity, available water and field capacity at previously measured or unmeasured locations in two experimental farms in Quebec. In fact, these properties would vary throughout any field with soil types , sampling areas, sampling depth from ground surface and management practice. The estimations made with the NGEM method are compared with the Kriging method at the same location.

1.1 Objectives

The objectives of this study are:

1. To investigate the spatial variability of SPP using a nonparametric geostatistical estimation method

2. To perform the required field measurements

3. To develop a computer program on the IBM Personal Computer to simulate the NGEM

4. To estimate SPP at previously measured (or unmeasured) locations by applying the above program and to compare the estimated values with the original data

5. To compare the two estimation methods (nonparametric geostatistical Hybrid method and parametric geostatistical Kriging method of estimating spatial variability of SPP)

The concepts of this thesis are organized as follows:

Chapter 2. The theory of geostatistics and parametric/nonparametric concepts. A discussion of various nonparametric tests.

Chapter 3. A detailed analysis of a selected nonparametric test (Hybrid method) with the aid of a sample problem. The description of the computer program used to apply the Hybrid method of estimation.

Chapter 4. Site specifications and the techniques for the measurements of SPP.

Chapter 5. Tabulated results of both the Hybrid and Kriging methods including experimental and estimated values.

Chapter 6. Evaluation of the obtained results and the summary of details followed by the authors recommendations.

CHAPTER 2

Literature Review

The application of nonparametric statistics in geology is termed as nonparametric geostatistics which is a relatively new field. To the author's best knowledge, there are no direct previous studies in soil hydrology in which this approach has been used. Limited applications of nonparametric techniques previously used will be discussed in brief and will be followed by the fundamentals of parametric and nonparametric geostatistics.

Parametric and nonparametric geostatistics will be compared and the latter will be explained in detail in this chapter. In chapter 3, the selected nonparametric method for this study will be discussed in detail.

2.1 Background

Lovering (1962) applied the Kolmogorov-Smirnov-nonparametric statistical test to examine whether copper distribution in samples taken from two rock types are significantly different, and the Spearman rank-correlation method to test the significance of the relation between intensity of rock alteration and copper content of the rock.

Nonparametric, or distribution free, statistical tests have been widely used in Psychology and Sociology for sometime, but their application to geological problems are relatively new (Lovering, 1963).

McCuen and James (1972) applied nonparametric statistical methods to detect hydrologic change caused urbanization over a period of time. Parametric statistical methods were not used in the since increase in urbanization may alter the corresponding population distribution causing the violation of conditions which parametric methods are based on. Fortunately, nonparametric methods which do not require identical distribution can be used in this case. McCuen and James (1972) concluded that the urbanization and channelization increased the annual peak flood series but did not significantly affect the dispersion of the series.

Ghassemi and Prasher (1985) applied nonparametric geostatistics to estimate the spatial variability of a soil physical property (i.e. saturated hydraulic conductivity). They used the Hybrid estimation technique to estimate saturated hydraulic conductivities at previously measured locations. It was found that the nonparametric approach gave comparable estimates to those given by Kriging.

Mineral distributions such as lead are highly skewed in rocks. To calculate the total quantity of the mineral in a large volume of rock, the arithmetic mean can be used. But if one is interested in estimating the lead content of a randomly selected sample, the median would be more relevant (Hall, 1983).

Rock (1986) compares the location (median), dispersion (variance) and overall shape of two or more independent groups of data using 5 nonparametric tests programmed in Fortran language. The five nonparametric tests used in the computer package are: Kruskal-Wallis test, Mann-Whitney test, Smirnov test, Squared ranks test, and Vander Waerden test.

2.2 Theory of Geostatistics

The theory of regionalized variables was developed by Krige (1951) and Matheron (1962) to overcome problems concerning ore reserve estimation. A regionalized variable is a random variable that takes different values depending on its position within some region. Also a random variable is the variation measured between individual measurements. Journel and Huijbregts (1978) describe the regionalized variable by the correlation between neighbouring measurements. The theory of regionalized variables has been applied to a variety of subjects in the past. Geostatistics makes use of this theory to construct a model which can estimate variables at locations where no or few measurements were available. When estimating Soil Physical Properties (SPP), a given field is a region. Any location within the field is random and SPP are considered as regionalized variables. The variable reference SPP values are continuous over the entire region.

The Kriging method, based on the theory of regionalized variables, provides the best unbiased estimation of unmeasured values with minimum variance. This method of interpolation uses the degree of dependency between neighboring samples to estimate unknown values within a measured region (Vieira et al., 1983). In geostatistics, variables measured in a given region may be correlated. In this case, values of one variable can be estimated using the measured values from all other variables. These estimations are particularly useful in situations when one variable is more difficult to measure than the other variable.

In all geostatistical techniques, Sampling is preferred at randomly selected sites to provide a better view of the nature of the population (Royle et al., 1980). Samples taken from one site can not be representive of the entire population since a poor or a rich zone gives little information on the nature of the population. Samples taken close together (in a given region) would have similar values, as compared to samples taken far apart. This indicates that there is a correlation between sample values which is a function of distance between the samples. The degree of correlation between sample values is usually measured by the semivariogram function (Plewman, 1981).

The first step in using geostatistics is to construct a semivariogram of sample values. The importance of this step lies in a geostatistical procedure in which a theoretical model is fitted to the semivariogram. Then, the selected theoretical model is used throughout the process of estimation affecting all results and conclusions.

2.2.1 The Semivariogram

A semivariogram is a measure of spatial dependence (or the degree of relationship) among neighbouring samples and expresses characteristics of the regionalized variables (Olea, 1977). A calculated semivariogram (or experimental semivariogram) is a curve representing the structure of a deposit and the grade variation in mining. Consider a number of measured sample values (2N) within a region of area S. The experimental semivariogram is calculated from the following equation

$$\gamma(h) = 1/2N(h) \sum_{i=1}^{N(h)} ((Z(X_i) - Z(X_i + h))^2 \qquad (2.1)$$

where:

$\gamma(h)$ is termed the semivariogram

$N(h)$ is the number of pairs seperated by the distance h

$Z(X_i)$ and $Z(X_i + h)$ are a pair of values seperated by a distance h in a region of area S

An ideal semivariogram is shown in Figure 2.1. A semivariogram value is always positive and decreases to zero as the distance h approaches zero. In reality, however as h approaches zero, $\gamma(h)$ approaches a positive value called the nugget effect, C_0. As the distance h increases, the semivariogram reaches a maximum value called the sill. For a very large distance h, the sill value is equal to

$$C_0 + C_1 = \gamma(\infty) \tag{2.2}$$

Range 'a' is the distance h at which the semivariogram curve levels off (or reaches maximum). Measurements separated beyond distance 'a' are not correlated (Amegee, 1985). A pure nugget effect exists when the range 'a' is smaller than the closest sampling distance. In this case, classical statistical methods or, even better, nonparametric approach can be used instead of a parametric approach.

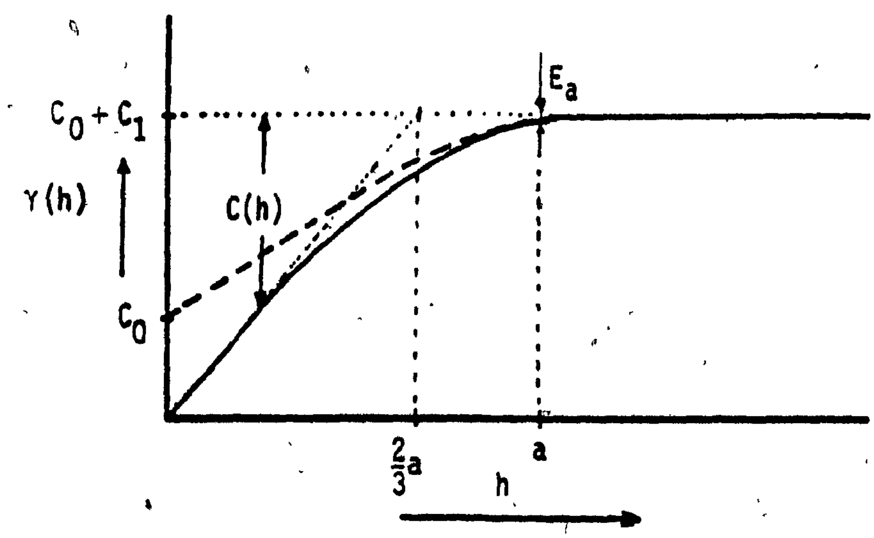

Figure 2.1 Ideal semivariogram curve, after Amegee (1985)

In Figure 2.1, as the distance (h) between sample points increases, the corresponding spatial variability increases as well.

Vieira et al. (1983) defined a semivariogram as a function of distances between sample points as well as the direction of calculation. Semivariograms calculated for different directions are different. Figure 2.2 represents semivariograms calculated in the east-west and north-south directions. The north-south semivariogram ascends much more sharply than the east-west semivariogram.

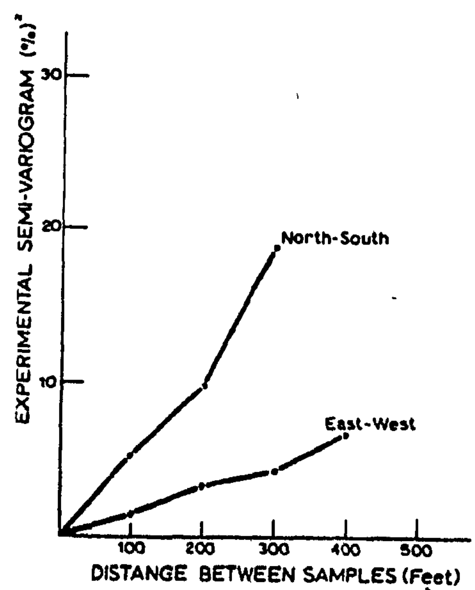

Figure 2.2 Semivariogram in two major directions after Clark (1979).

The above Figure would indicate that there is a greater continuity in the east-west direction. To overcome the above shortcoming, which is called anisotropy in parametric geostatistics, either the coordinates of the semivariogram are adjusted or different semivariograms are fitted for different directions.

2.2.2 Assumptions Associated with the Kriging Method

1) Stationarity of data

It was assumed that all samples no matter where they were taken (in a given area), came from same probability distribution. In other words, the statistics on the random variable $Z(X_i + h)$ are the same for every lag h. The variable is called stationary of order K, depending upon the number of K statistical moments that are constants. Genarally, the assumption of second-order stationarity is sufficient to apply geostatistical methods. This assumption implies that both the mean and the covariance of the random variable exist; the mean does not depend upon the location and the covariance depends only on the seperation distance.

There is another assumption in geostatics referred to as intrinsic hypothesis or quasi-stationarity. In this assumption, the distribution of the difference in measured value between two samples is the same over the entire region. The above distribution depends only on the orientation as well as the distance between the points (Royle et al., 1980).

2) Normality of data

It is assumed that the data are normally distributed. However, in most cases the data fit no simple statistical distribution (i.e. normal, lognormal or gamma distribution).

3) Additivity

Additivity is an assumption associated with parametric geostatistics which is usually ignored in practice. In geostatistical studies, variables must be capable of additive relation (Journel and Huijbregts, 1978). Thus, the Kriging method in parametric geostatistics can not be applied to SPP such as porosity and permeability, since these properties are not additive. In such a case, a transformation is required to convert these properties into a standard form before Kriging. However, the application of the Kriging method on non-additive properties such as temperature, porosity and permeability is not recommended (Journel and Huijbregts, 1978).

4) Subjectivity

The subjectivity associated with the use of a semivariogram may be computed from the data set under investigation or from some other data set which has a postulated relationship with it. The semivariogram will quite often depart significantly from all of the theoretical models, and skillful interpretation is required to fit one or more models to the empirical curve, which is subjective. There is little justification for preferring one model to another.

The other problem of semivariograms is that they are generally anisotropic depending on the direction of calculation (i.e. the semivariogram calculated in north-south direction may differ from the semivariogram calculated in east-west direction).

2.3 Nonparametric Approach

Statistical techniques were developed primarily for biological, medical and agricultural applications. These techniques works well for the case where data are normally distributed or have little deviation from a normal distribution. For the case where data distribution departs significantly from a normal distribution, these techniques will provide misleading results. Nonparametric or "distribution-free" statistics can be applied to many practical problems in geology or soil hydrology where data are non-normally distributed (Hall, 1983).

Nonparametric geostatistic methods have been developed recently, since many existing methods (i.e. Kriging) do not give satisfactory solutions to many practical problem that might be encountered (Henley, 1981). They provide an estimation tool with as great a range of validity as possible, while assuring a solution which is optimum in the sense of minimizing absolute deviations. As Henley (1981) explained, the principles of these techniques are applicable to a wide variety of subjects, including geophysics, meteorology, ecology, geography and oceanography. Actually, nonparametric geostatistics can also be applied to subjects where Kriging (parametric) methods can be used.

Nonparametric methods that require minimum assumptions are called 'distribution-free' statistics. Distribution-free techniques need no detailed assumptions or knowledge of the form of the distributions. The only assumption made is that the spatial variation of the 'true or measured value' is everywhere continuous irrespective of the 'true or measured value' distribution.

In the nonparametric approach, small sample sizes (or small numbers of data) are permissible, whereas in the parametric approach, large sample sizes (or large numbers of data) are required (McCuen and James, 1972). Data measured in any of four scales (i.e. Nominal, Ordinal, Interval or Ratio) can be used in nonparametric methods. Some nonparametric methods are made more powerful by transforming the data from numerical scores to ranks or signs. The loss of information due to such a transformation is less significant than the addition of false information caused by using a parametric technique when the assumptions are violated.

In general, nonparametric methods are easily understood and require simple mathematical computation as compared with parametric methods. Multivariate data are treated simply, variable by variable, regardless of datum distribution. As

Lovering (1963) explained, computer programs are not generally available to apply nonparametric methods in geological estimations.

One of the main reasons for developing nonparametric geostatistical methods is to deal with high coefficients of variation of measured properties (i.e. hydraulic conductivity). For less variant properties (i.e. water table elevation), experimental variograms can be constructed from available data to represent the main feature of the subject under study (Journel, 1983).

In practical geostatistics, two solutions are available to overcome problems concerning highly variant properties.

1) Discard the high-valued data.
This is not acceptable for data carrying the most valuable information about a phenomenon.

2) Smooth out the data by any smooth transformation.
Data can be transformed to a smooth function by taking their square roots, natural logarithms, or normal-score transforms. All smooth transforms are nonlinear and require nonlinear estimation techniques.

To avoid the problems associated with these methods, nonparametric distribution-free techniques should be used. Most of the distribution-free techniques plot a uniform distribution of raw data graphically by ranking the observations into increasing value and work on the new uniform distribution (because ranks are uniformly distributed irrespective of the distribution of the sample or of the population). All the calculations are performed on the ranks and not on the original observations. In any ranking system used in this study, the lowest datum has a rank of one where as the highest datum has a rank of n. In nonparametric geostatistics, anisotropy is considered as a property of the data set.

The transformation of the observed distribution into a uniform distribution is called a first transformation. In some nonparametric techniques a second transformation is required to calculate the cumulative proportion of the distribution. Nonparametric techniques are not concerned with the distribution or parameters of the population from which a sample is drawn. Therefore, they are referred as to nonparametric statistics. The application of nonparametric statistical techniques in geology (or in soil and water) is termed as nonparametric geostatistical methods.

2.4 Nonparametric Tests

In order to choose an appropriate nonparametric test, the following factors should be considered: bias in a test or estimator, consistency of a test, efficiency (or power) and required measurement scale. Two classes of nonparametric statistical tests, including tests for randomness of a data set as well as tests of distribution, will be discussed here.

2.4.1 Test of Randomness

Tests of randomness are used to verify whether a sequential set of data is randomly distributed. Among all tests for randomness, Mann's test and the Runs are explained in more detail.

2.4.1.1 The Runs Test

A run is a set of similar adjacent observations. For numerical data the median is found and each observation is compared to the median. If the observation is higher than the median a (1) sign is assigned and if the observation is lower than or equal to the median a (0) is assigned. If the total number of observations is n, a run is a set of similar adjacent observations with a maximum n of runs and a minimum of two runs (Siegel, 1956). Data sets with an extreme number of runs (high or low number of runs) are expected to be non-randomly distributed, whereas a more moderate number of runs would indicate a random distribution. It is possible to test for randomness using the critical region or probability approach in nonparametric statistics.

2.4.1.2 Mann's Test

This test is used to verify the existence of randomness or trend in a data set. The Kendal coefficient is used to measure the degree of correlation between two variables. Computation of Kendal's tau is explained in more detail in Chapter 3.3.

2.4.2 Test of Distribution

Among several tests used to measure the goodness of fit between a theoretical and an empirical distribution, the Kolmogorov-Smirnov test has a better performance and more flexibility. For example, the chi-square test can be used in grouped data but is not reliable for small sample sizes (Henley, 1981). The Kolmogorov Smirnov test is discussed in more detail in Chapter 3.2.

2.5 Nonparametric Geostatistical Estimation Methods

There are several estimation methods such as the linear estimation method, the moving median method, the simple median method and the varying quantile method. They are described briefly in the following pages.

2.5.1 The Linear Estimation Method

The simplest case of a linear estimator can be shown as

$$T^* = W_1 g_1 + W_2 g_2 + \dots + W_n g_n \qquad (2.3)$$

where T^* is the arithmetic mean of all observations g_i (where i=1,...n) with equal weight W_i for all observations (a value of 1/n). Since T^* is an unbiased estimation of a true value T, the estimation error would approach zero (Clark, 1979). The above simple linear estimation model minimizes the sum of squares of deviation between measured and estimated values.

2.5.2 The Moving Median Method

The moving median methods is one of the simplest and most widely used techniques in geostatistical interpolations. For the estimation of an unknown point (P), a search area (circular or square or rectangular) is considered, centering at P. Observation points close to P would have more probability (or weight) of representing the value at point P than observation points further away. The weightings are a function of the distance of a given observation point. This method is explained in Chapter 3.1.

2.5.3 The Simple Median Method

Other techniques such as simple median methods make use of all observation points in the search area with equal weightings. These techniques do not minimize the sum of squared deviation and would result in poor estimation (Henley, 1981).

2.5.4 The Varying Quantile Method

The varying quantile method is very similar to the method used in the nonparametric estimation model (Hybrid method in chapter 3). In this method, the estimator is very flexible and is used for an unbiased estimation of the true value at any given point. As Henley (1981) explained, this method is less stable, resulting in serious problems in estimating near maximum and minimum values, as compared with mean and median methods. A Hybrid method was then proposed to overcome the problems. This method was used throughout this study for the estimation of unknown SPP and is explained in more detail in Chapter 3.

CHAPTER 3

Nonparametric Estimation Model

In the nonparametric method, an optimal solution of the estimation problem is reached by minimizing the sum of absolute deviations. An estimation problem will be approached as follows:

For each point to be estimated, every available observation is assigned a weight which reflects an inferred probability that it is an independent member of a set of points defined as the local neighbourhood of the point to be estimated. There are two strands to the concept of 'independent membership': independent and membership. The probability of membership may be related purely to distance from the center of the set, and some type of distance weighting can be adopted (Henley, 1981). Equal weights are assigned to every observation within a set to indicate the relative independence of each observation from all other observations.

In the present study, the hybrid nonparametric estimation method is applied to estimate the spatial variability of saturated hydraulic conductivity, soil bulk density , available water and field capacity since it is reported by Henley (1981) to yield the lowest sum of absolute deviations. However, the steps involved will be demonstrated by applying this method first to a very simple estimation problem as shown in Figure 3.1 (Ghassemi and Prasher , 1985).

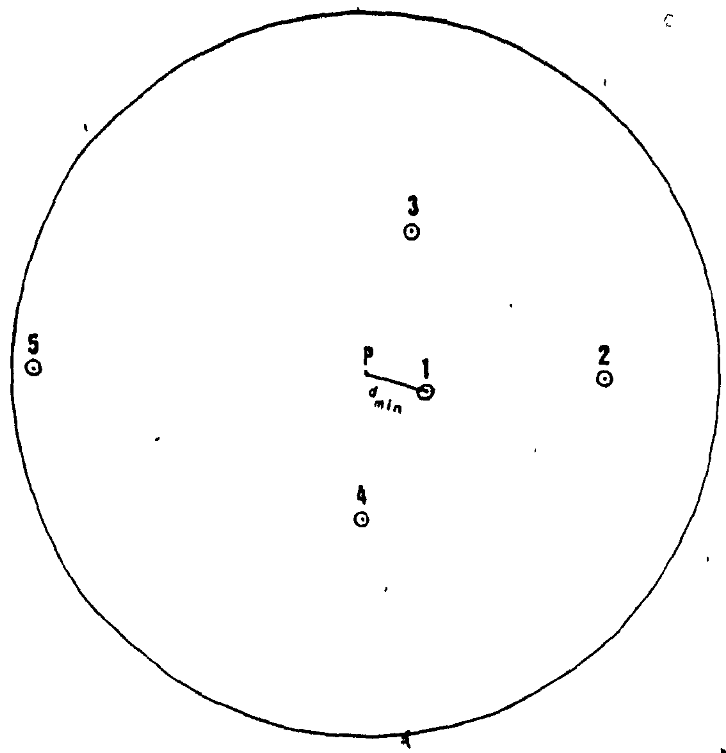

Figure 3.1 A two dimentional estimation problem, after Clark (1979).

3.1 Distance Weighting

Distance weighting is a system of weights in which every point (within the radius of search of a point P which has an unknown value) has some probability of belonging to the neighbourhood of point P. Inside the radius of search, a point closer to the center has a greater probability to represent the point P than one farther away. Any point outside the radius of search has a zero probability.

In the present study, we are dealing with a two dimensional case (plan view of the field) and therefore the weighting function can be expressed as:

$$W_d = (d_{min}/d_i)^2 \qquad (3.1)$$

where W_d is the weighting at the ith point, d_{min} is the distance of the closest point to P, d_i is the distance of the ith point from the point P (Figure 3.1). The distance weights are shown in Table 3.1.

Table 3.1 Weighting for the estimation problem of Figure 3.1

Loc.	Dis. from P (m)	Obs. value	Dis. wt. (W_d)	Cluster wt. (W_c)	Final wt. (W_d * W_c)	Corrected wt.
1	21.54	400	1.000	1.368	1.368	0.355
2	30.00	280	0.516	1.992	1.027	0.266
3	31.62	480	0.464	1.642	0.762	0.198
4	50.00	380	0.186	1.642	0.305	0.079
5	70.00	320	0.095	4.169	0.395	0.103

3.2 Cluster Weighting

The probability of independence is related to the spatial clustering of the observations, and the probabilities of their belonging to each other's local membership sets.

For any set of observations a set of independent or cluster weights can be generated. A cluster of observations grouped more closely than the average sampling density represents a deviation. The degree of deviation of a sample from a theoretical distribution may be tested by Kolmogorov-Smirnov test.

The problem is to determine, for each observation point, the degree of deviation from an ideal random distribution in space. The cluster weight of any observation point (i.e. $W_c(P)$) can be calculated if the distances between that point and N surrounding points are known.

$$W_c(P) = F_{D+} / F^*_{D+} \tag{3.2}$$

where F_{D+} is the ideal distribution and F^*_{D+} is the sampling distribution. If there is no positive deviation from the ideal line, then this maximum occurs at a=1, $F(a) = F^*(a) = 1/N$ and the ratio is thus one. The calculations for cluster weighting of point 4 is shown in Figure 3.2 . Cluster weighting is a function of cumulative area and the number of observation points within a given cumulative area. For example, in Figure 3.2, the cumulative area at point 4 is zero where as the cumulative distribution is 1/5 (or 1/N). Each observation point has an equal distribution weight. Different circles (centered at point 4) with increasing radius were considered (or different square or rectangular areas) and the corresponding cumulative areas as well as the number of points within each cumulative area were measured to construct the Figure 3.2. The last cumulative area contain 5 points and the corresponding cumulative distribution is 5/5 (or N/N).

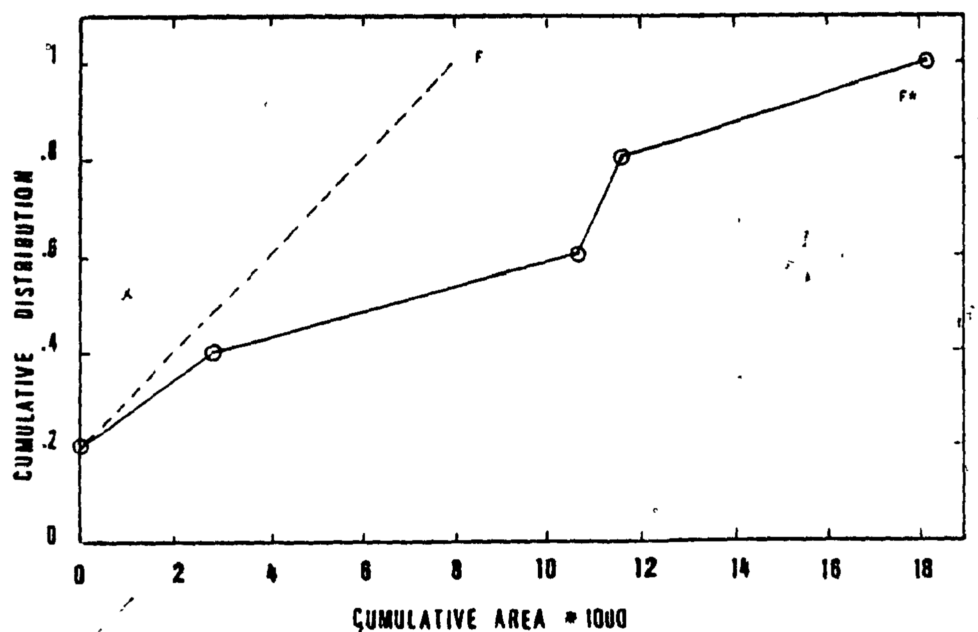

Figure 3.2 Ideal (F)and observed(F^*)distribution function for observation number 4 and every other observation.

The ideal distribution line is drawn with an angle of 45 degree at point 1/N (i.e. 0.2) on Y-axis (Henley, 1981). Cluster weight $W_c(p)$ for point 4 was calculated to be 1.64 where the maximum deviation occur between the measured and the ideal distribution line. Table 3.1 has cluster weighting for all observation points.

The cluster weights have one great advantage over Kriging weights they are intended to replace: that they need to be computed only once for the whole data set, and not separately at each point to be estimated (Henley, 1981).

Because the above two probabilities (distance and cluster weighting) are in fact independent, the resultant weighting is merely their product. This weighting is also shown in table 3.1.

3.3 Computation of Kendal's tau

This parameter estimates the degree of correlation of two variables or of the same variable at two locations. The various steps involved in the computation are as follows:

1) Order the data into a sequence of increasing distance from P within the neighborhood.

2) Compare each variable X_i at location i with each more distant value X_j at location j and record +1 if $X_j < X_i$, -1 if $X_j > X_i$. The calculations are shown in Table 3.2.

3) Sum algebraically the indicators +1 and -1 and calculate Kendal's tau as

$$tau = (\text{Algebraic sum}) /((0.5n(n-1)) \qquad (3.3)$$

where n is number of pairs of (X_i, X_j) considered within the neighborhood.

Kendal's tau can have value between +1 and -1. A value of +1 indicates that all more distant values are lower than all closer values. A value of -1 indicates the reverse. A value of zero implies an absence of trend in values related to distance from point P. Kendal's tau was found to be 0.2 for the test problem. The above technique is used to calculate Kendal's tau in Mann's test.

Table 3.2 Calculation of the Kendal's tau for the test problem of Figure 3.1

Distance from P (ft)	Measured value	Obs. number	Indicators 1	4	3	2	5
21.54	400	1	0	+1	-1	+1	+1
30.00	280	4		0	-1	-1	-1
31.63	450	3			0	+1	+1
50.00	380	2				0	+1
70.00	320	5					0

Kendal's tau (τ) = (actual score)/(maximum possible score)

= 0.2

3.4 Computation of Quantile

The term quantile is used in relation with the data that is reordered into ascending value of X such that for every i, $X_i < X_{i+1}$ then quantile refers to any point between and including the maximum and minimum reordered data values. The value of quantile lies at some value between zero and one. In the hybrid method, the quantile, q, is estimated from

$$q = 0.5 + (tau/2)\ (\sum_{i=1}^{n} W_{di} - 1)/\sum_{i=1}^{n} W_{di} \qquad (3.4)$$

For this test-problem, q, from the above formula, was found to be 0.56. Once the quantile is known, the estimate at P is computed as

$$X(P) = quantile(F_W\ (X)) \qquad (3.5)$$

where F_W is a weighted distribution function in which each X_i value is assigned a weight W_i where W_i is the product of cluster weight and inverse distance weight for observation i, and to ensure unbiassedness,

$$\sum_{i=1}^{n} W_i = 1 \qquad (3.6)$$

The function F_W is plotted in Figure 5. It should be noted that in plotting the F_W-function, values are ranked first in the increasing order. The estimated value for P is read from the Figure 3.3 as 386.1.

It may be noted here that Clark (1979) has estimated a value of 372.8 for the test problem. She used Kriging to estimate the value at P. Our estimated value is very close to the Kriged estimate.

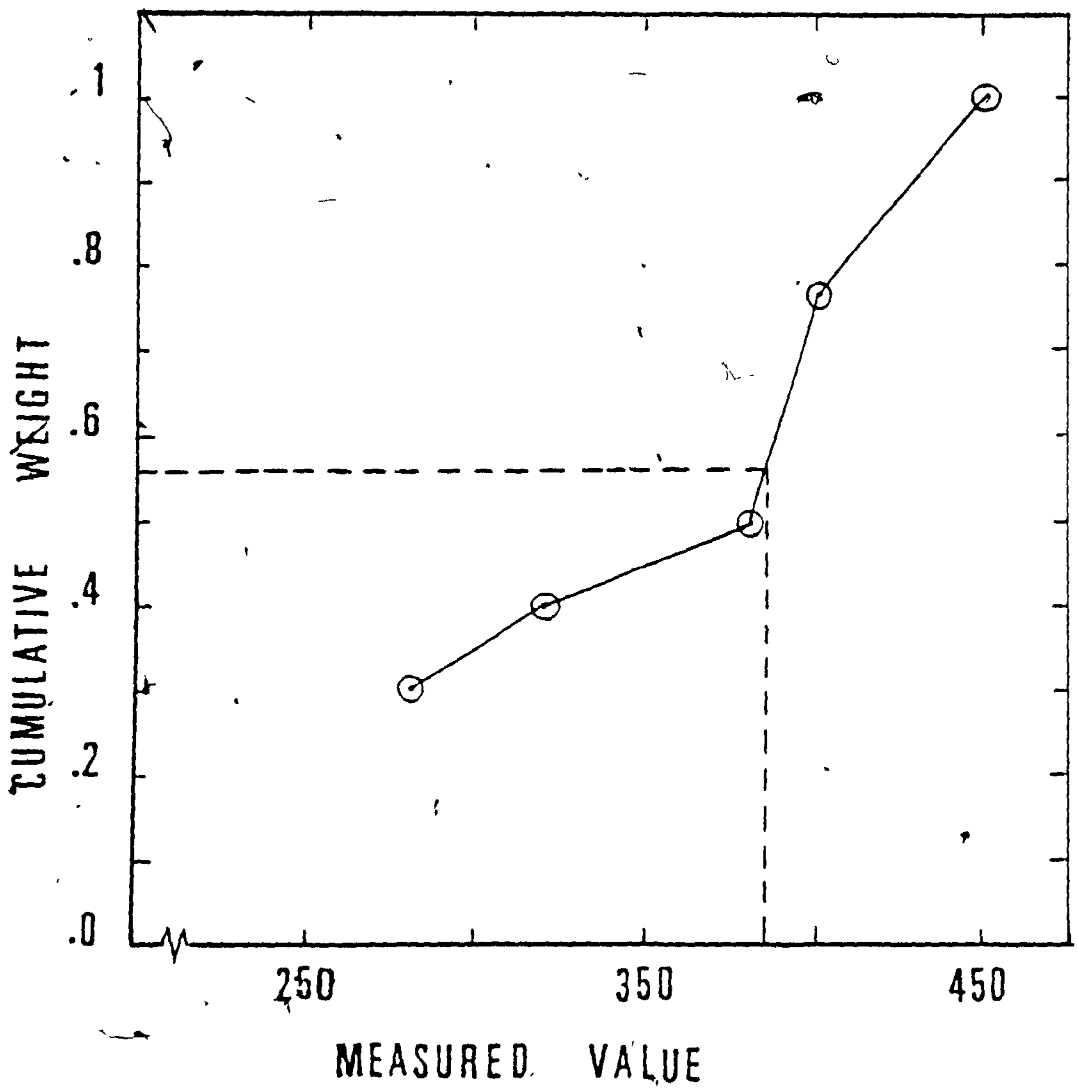

Figure 3.3 Graphical demonstration of the Hybrid method of estimation.

3.5 Description of the Computer Program

The computer program is written in Basic language. It runs on an IBM Personal Computer with 256K bytes memory. It was decided to have the program in a compiled version as this speeds execution. An even faster execution of the program can be achieved by using the 8087 chip.

The program is sufficiently flexible to be used for a random or a fixed sampling taken from a field of any size. For this study, the program was used to estimate the following soil physical properties: soil hydraulic conductivity, soil bulk density, field capacity and available water.

The program consists of a main program and two subroutines: Hybrid and Output.

The main program is used to create/edit a file. A user is prompted to input the raw data (x, y, measured values) for any point (x, y stand for the spatial coordinates of the measured value). These data are collected by the program in a file. This file is then read by the subroutine hybrid. Another feature of the main program is the possibility of editing data. The new data line replaces the old one. Throughout the program an extensive error checking routine is conducted. At the end, control is transferred to the subroutine hybrid.

Subroutine Hybrid consists of several other subroutines, namely, Cluster, Sort, Area and Search.

Cluster : This subroutine calculates cluster weighting for every observation. This value explains whether sampling is performed uniformly or clustered at certain locations. In the latter case, the final estimation will be affected by the nonuniformity of sampling. This subroutine uses subroutines sort, area and search to calculate the final weighting.

Sort : This subroutine is used to sort the distance between any point and 6 other neighbouring points in an increasing order. It also calculates the distance weighting.

Area : This subroutine calculates the area of a circle, by using the values from subroutine Sort as the radius and any given point as the center.

Search : The main calculation for cluster weighting is done in this subroutine. The cluster weighting is calculated as the ratio of the ideal distribution to the sampling distribution where maximum deviation occurs between the two distributions.

Kendal's tau and Quantile (nonparametric terms) are calculated as a part of the subroutine Hybrid.

Kendal's tau : It estimates the degree of correlation of a variable at two locations. Data are sorted in an increasing order of distance. The value at each location is compared with the value from each more distant location. Scores of −1 or +1 are assigned due to decreasing or increasing of values. Kendal's tau is calculated as the ratio of the algebraic sum of the scores to the total number of positive and negative scores. This value is used to calculate the term quantile.

Quantile: The term quantile refers to any point between and including the maximum and minimum recorded data values. The quantile value is used for the final step of the estimation technique and is calculated from the following equation:

$$Q = 0.5 + (tau/2) X (Wtotal - 1)/(Wtotal)$$

Where Wtotal is the total distance weighting. For every point and 6 neighbouring points, the ranked measured values and their cumulative final weights are plotted. Each calculated Q on the Y-axis, corresponds to a value on the X-axis. This is the estimated value for the unknown point.

These results are written to a file. This file has the same name as the data file except for its extension (.out in this case). The program now chains to the main where an opportunity is given to the user to proceed with another data set.

Subroutine Output can be used to print the final results in a formatted form.

A step by step execution of the program can be found in Appendix C.

CHAPTER 4

Field Measurements

4.1 Field Sites

The research was done on two experimental farms, properties of Mr. Peter Finlayson (Site A) and Mr. Leandre Charbonneau (Site B).

4.1.1 Site A

The experimental farm is located approximately three kilometers west of Ormstown, Quebec, parallel to the Chateaugay river. A 13.5 hectare experimental site is cropped under grain corn. The topography of the field is relatively flat with an average slope of 0.2 % toward the Chateaugay river. A new subsurface drainage system was installed in this field in 1983 due to blockage of the previous system which was installed in 1977.

The soil type is classified as an Ormstown silty clay loam. The soil profile consists of three layers as described by Baril and Mailloux (1950). The first layer is up to 12.7 cm thick, consisting of light gray brown silty clay loam. The second layer is white to light yellowish silty clay loam varying from 1.3 to 5.0 cm of thickness. The third layer starts from underneath the second layer and consists of light gray brown silty clay loam.

4.1.2 Site B

This field is located approximately 24 km south of Sorel in Richelieu County, Quebec. A 10 hectare experimental field is cropped under grain corn. The topography of the field is relatively flat with a maximum variation of about 50 cm (Von Hoyningen, 1984). A subsurface drainage system with lateral spacing of 30 meters was installed in this field in 1972.

The soil type is classified as a St. Samuel loamy sand soil consisting of three layers. The top layer is 30 cm thick consisting of a dark brown fine loamy sand. The second layer is 130 cm thick with an olive pale medium sand. The third layer is considered as an impermeable layer with a clay soil starting from underneath the second layer.

4.2 Collection of Undisturbed Soil Samples

Undisturbed soil samples were taken on a regular grid of 10x10 meters at 121 locations from site A (Figure 4.1) with the help of a core sampler (Figure 4.2). One hundred and twenty soil samples were taken from site B on a regular grid of 30x30 meters. These soil samples were measured for SPP such as available water, field capacity and soil bulk density. Naderpour (1986) measured the SPP at the Charbonneau farm.

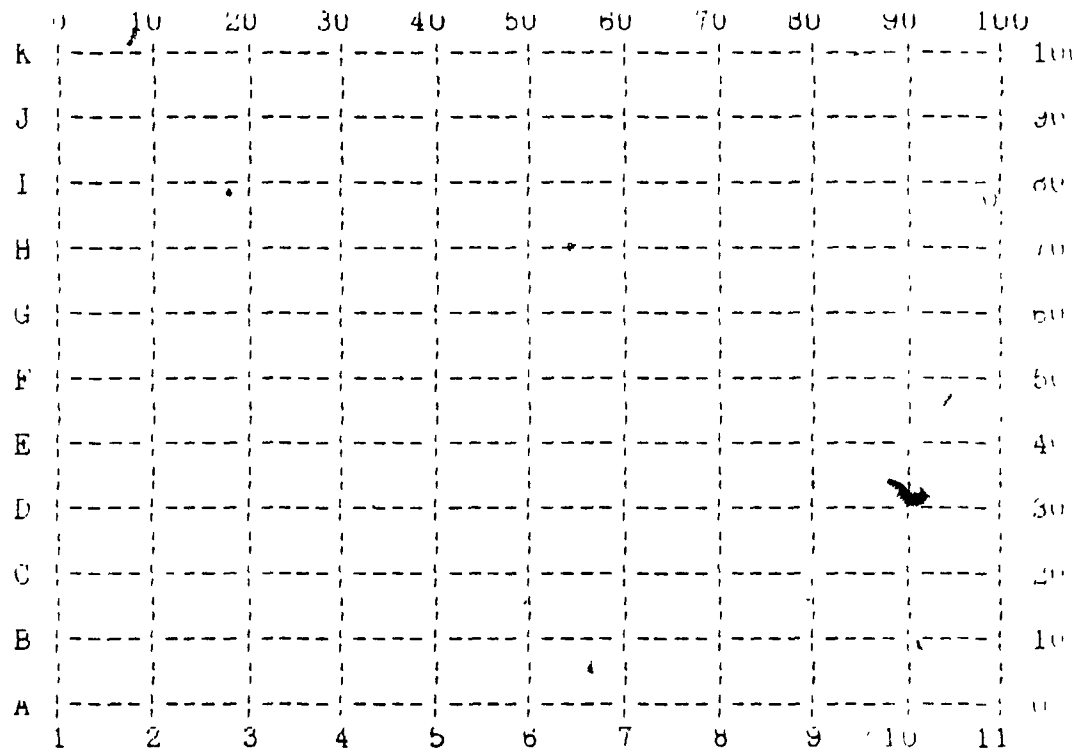

Figure 4.1 Sampling locations at Site A at grid intervals of 10X10 meters.

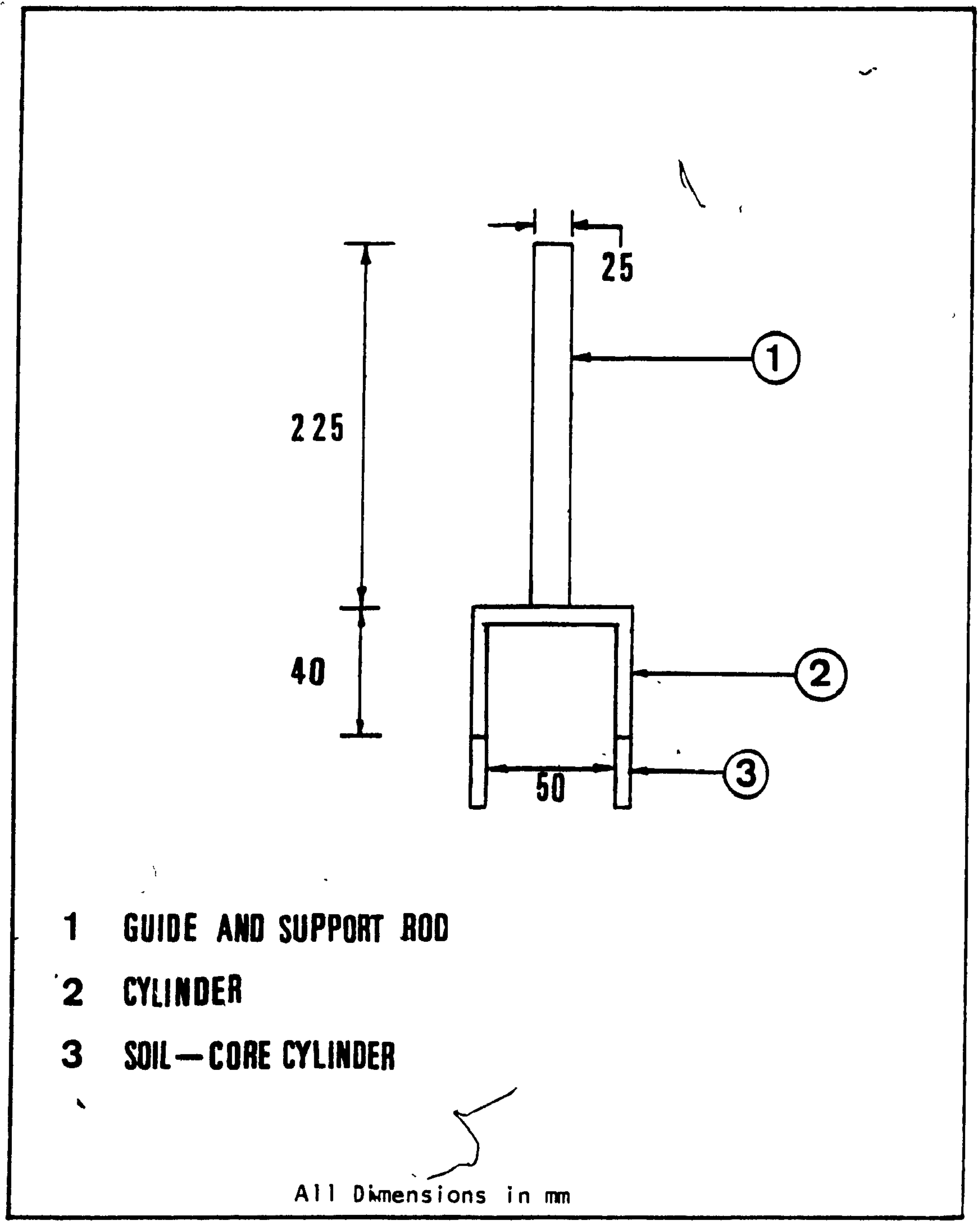

Figure 4.2 Schematic diagram of the core sampler.

After digging the soil to the required depth (25 cm), soil samples were obtained as follows: core samples was used to drive an aluminium cylinder of 50 mm inside diameter and 40 mm axial length into the soil. The cores were removed and the excess soil was trimmed off with a knife. To minimize drying and disturbance of the soil samples, the cores were placed in plastic bags and carried carefully in a box to the laboratory. These samples were stored in a refrigerated room to prevent bacterial growth.

4.3 Measurements of Soil Physical Properties

The core samples obtained from site A were used to measure the following soil physical properties : available water, field capacity and soil bulk density. One end of each core was fitted with a mesh cloth which was held on to the cylinder by an elastic band. The mesh retained the soil during saturation and measurements. The cores were then saturated in a plastic container by adding water to a depth of 10 mm below the top of the cores. Saturation was generally accomplished in one day.

In order to measure the soil moisture retention curve from which available water and field capacity was calculated, different devices were used for different ranges of matric potential. The Haines-funnel was used up to pressure heads of 0.1 bar. Pressure plate was used for pressure heads in the range of 0.1 to 10.0 bars.

4.3.1 Measurement of Saturated Hydraulic Conductivity

Saturated hydraulic conductivities were measured at 120 locations on a regular grid of 10x10 meters in site B using the auger hole method.

4.3.2 Available Water

Available water is the amount of water that is held in the soil between field capacity and permanent wilting point. This amount of water which is available and can be used by plants for transpiration depends on soil texture (MacKenzie et al. 1983). For example, permanent wilting point for silty clay loam soil (Site A) was taken as 10 bar.

The available water is calculated as the difference between the volumetric water content (θ) at 0.33 bar (field capacity) and the permanent wilting point at 10 bars for the silty clay loam soil.

4.3.3 Field Capacity

Volumetric water content at field capacity is defined as the amount of water held in the soil two or three days after it was saturated by rainfall. The two forces acting on a saturated soil are the capillary action (suction) and the gravitational pull (MacKenzie et al, 1983). These two forces cause the water to move from the saturated to the drier soil. The water movement through the soil will eventually become very slow as the soil reaches a relatively constant moisture content (at 0.33 bar). The soil water content at this stage is called field capacity.

4.3.4 Measurement of Soil Bulk Density

At the end of the experiment, the soil samples were oven-dried at 105°C. Soil bulk density was calculated using the following equation

$$\rho_b = M_s/V_t \tag{4.1}$$

where M_s is the mass of oven-dried soil and V_t is the total volume of soil samples.

4.3.5 Haines-Funnel

For a high matric potential range (0 to -0.1 bar), the Haines funnel was used (Figure 4.3). After saturation, the cores were transferred to the Haines suction funnel and each one was pressed firmly on to the surface of a porous plate to establish good contact. To minimize the evaporation rate, the funnel was covered with a large rubber stopper fitted with a capillary tube this allowed equalization of pressure with the atmosphere as suction was increased. Also, the top of the burette was covered.

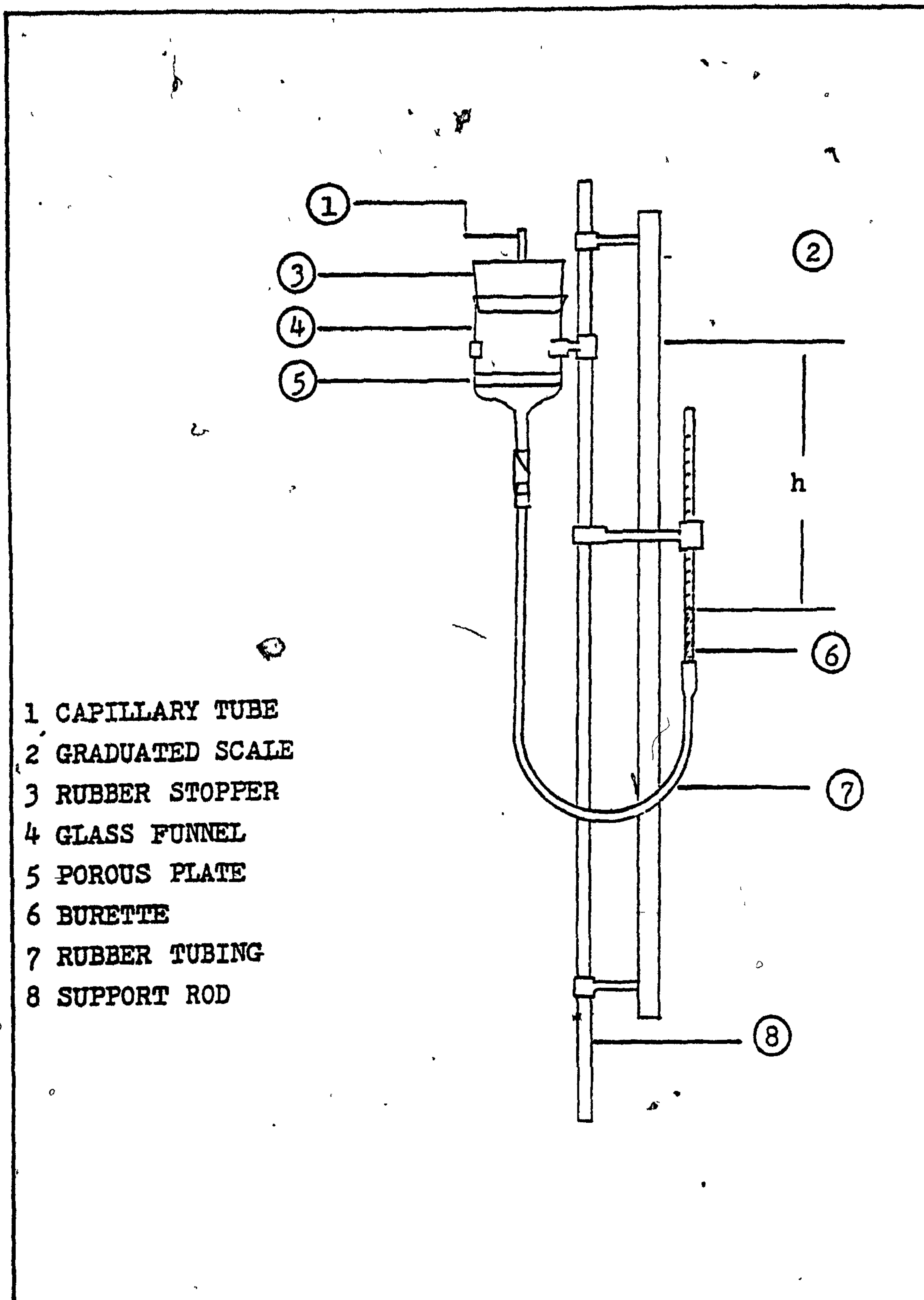

Figure 4.3 Schematic diagram of the Haines suction funnel.

Suction was applied to the bottom of the samples by means of lowering the water level in the burrette and waiting until water outflow ceased. To establish equilibrium, which took about 24 hours, the amount of water extracted from the soil was read from the burrettes to calculate the volumetric water content at each equilibrium point.

The moisture retention curve was established after the last equilibrium was completed. This was calculated by subtracting the saturated weight of the soil sample from the oven-dried weight to get a gravimetric water content, and then calculating the volumetric water content at each equilibrium point. The volumetric water content (θ) can be calculated from following relation:

$$\theta = W(\rho_b / \rho_w) \tag{4.2}$$

where $_b$ is soil bulk density, $_w$ is the density of water, and W is the gravimetric water content calculated as follows:

$$W = M_w/M_s \tag{4.3}$$

where M_w is the mass of the water in the soil and M_s is the mass of oven-dried soil (Mehuys, 1983).

4.3.6 Pressure Plate

For low matric potential, pressure plate extractors capable of a pressure ranging from 0.1 to 15 bars, were used. These consisted of several porous ceramic plates with different pressure capacities (Mehuys, 1983).

The specified capacity of each plate was taken to be that pressure at which air would just begin to enter it, after the plate had been previously saturated with water. These plates were always kept saturated while air pressure was applied during suction testing. The air pressure was supplied by a regulator and a compressed air cylinder and was measured by a manometer or a pressure gauge (Figure 4.4).

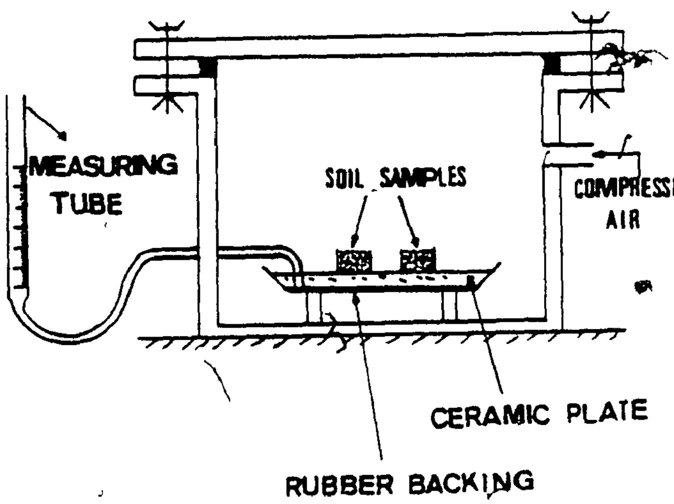

Figure 4.4 Pressure plate extractor for pressure ranging from 0.1 to 15 bars.

CHAPTER 5

Results and Discussion

The computer program developed in the present study is based on the nonparametric Hybrid estimation model. The program description and listing are presented in Section 3.5 and Appendix B, respectively . The program was used to estimate soil physical properties (i.e. bulk density, hydraulic conductivity, field capacity, and available water) at previously measured locations, one by one, to check its accuracy. Estimations from the Hybrid model were also compared with the estimations from the Kriging method (Naderpour, 1986).

The results of the Hybrid estimation method are compared with the measured SPP from Site s A and B. The Kriging method was only applied at Site B. The results from Site A will be discussed first followed by the results from Site B.

5.1 Soil Water Retention (Site A)

From a field of 100X100 meters, one hundred and twenty one soil samples were taken from Site A on a grid of 10X10 meters. The water retention curve of each sample was experimentally determined. The Volumetric Water Contents (V.W.C.) at different suction pressures were measured. These values are shown in Table A5.1 for suction pressures ranging from 0 to -10 bars. The water retention curves were used to calculate the field capacity and the available water.

5.2 Soil Bulk Density (Site A)

Bulk densities were calculated for 121 soil samples (Table A5.2) as described in Section chapter 4.3.4. The Hybrid estimation method was applied to estimate bulk density at the locations from which the soil samples were taken. These estimations are given in Table A5.3. The measured values ranged from 1.21 g/cm^3 to 1.80 g/cm^3 indicating some variation of bulk densities between locations. The estimated values ranged from 1.27 g/cm^3 to 1.69 g/cm^3 showing lesser variation than the measured values. The big difference between the highest and the lowest measured bulk density is probably due to changes in the soil texture throughout the field, soil compaction in parts of the field, large sampling intervals and the small size of the core samples. The estimated and measured values were compared. It was found that 97% of the measured values were in the range of plus/minus two standard deviations of estimated values.

5.3 Field Capacity (Site A)

Field capacity is the maximum soil moisture content that can be obtained under normal agricultural conditions. It was estimated, for 121 soil samples (Table A5.2) from the soil water retention curve at 0.33 bar suction pressure. The Hybrid method was used to estimate the field capacity at 121 locations. The measured and estimated values are shown in Table A5.4. A comparison was made between the measured and estimated values. It was found that 99% of the measured values were in the range of plus/minus two standard deviations of estimated values. The above comparison confirms the validity of the Hybrid estimation method.

5.4 Available Water (Site A)

Soil water content between field capacity (0.33 bar) and permanent wilting point (10 bars, in this case) can be used by plants. This is called available water, an important factor in irrigation scheduling.

The experimentally determined available water values were calculated in volumetric dimension as described in Section 4.3.2. These results are shown in Table A5.2. The Hybrid estimation method was applied to estimate the available water at the 121 locations from which the soil samples were taken. The measured and the estimated values of available water are given in Table A5.5. The measured values range from 2.2 to 9.6 percent per volume. This shows relatively high variation among measured values at different locations. This may affect the estimated values at or near high/low measured values. Since fine textured soil holds more water than coarse textured soil, variation among measured values is due to variation of soil texture throughout the field. The estimated values range from 2.95 to 8.17 percent per volume which vary less than the measured values. In order to check the accuracy of the estimations, the measured values were compared with the estimated values. It was found that 94% of the measured values were in the range of plus/minus two standard deviations of estimated values.

5.5 Soil Bulk Density (Site B)

The Hybrid and Kriging estimation methods were applied to the measured values of soil bulk density from Site B. Soil bulk density values and their corresponding estimations from two different techniques for 120 soil samples are shown in Table A5.6.

The measured soil bulk density values were compared with the estimates obtained by the two estimation methods. The results show that in 45% of the cases, the Hybrid method provided a more accurate estimate, as compared to 55% for the Kriging method. Furthermore, the sum of the absolute values of deviations of the estimated values from the measured values were calculated. A value of 7.30 was found for the Hybrid method compared to a value of 6.53 for the

Kriging method. From the two comparisons, it can be concluded that the estimates from the Hybrid and Kriging methods are not significantly different from the measured values. It was also found that 100% of the measured values were in the range of plus/minus two standard deviations of estimated values for the Hybrid method. A value of 97.5% was obtained for the Kriging method. This indicates that the Kriging method is more sensitive to high/low valued observations than the Hybrid method.

From the above comparisons, one can conclude that the Hybrid method is a valid method for the estimation of soil bulk density.

5.6 Hydraulic Conductivity (Site B)

Both estimation methods (Hybrid and Kriging) were applied to 120 measured values of hydraulic conductivity. The estimated and measured values for both methods are shown in Table A5.7.

The results show that in 43.5% of the cases, the Hybrid method provided a more accurate estimate, as compared to 56.5% for the Kriging method. Furthermore the sums of the absolute values of the deviations of estimated values from the measured values were calculated. A value of 57.11 was found for the Hybrid method compared to a value of 50.36 for the Kriging method. Further, it was found that 100% of the measured values were in the range of plus/minus two standard deviations from the estimates obtained using the Hybrid method. A value of 95% was obtained for the Kriging method. Due to the high variability of hydraulic conductivity throughout the field, it seems difficult to predict a single value for the entire field. This is one of the biggest challenges for the soil hydrologist in drainage design. The best drainage design should take into consideration the variability of hydraulic conductivity (K) by estimating different values of K for different parts of the field. This will result in an efficient drainage system with different drain spacing in different parts of the field.

Since there is no significant difference between either of the estimations (Hybrid, Kriging) and the measured values, it can be concluded that the Hybrid estimation is valid to estimate spatial variability of saturated hydraulic conductivity.

5.7 Available Water (Site B)

Hybrid and Kriging estimation methods were applied to 120 available water values. The estimated and measured values for the two methods are shown in Table A5.8.

The estimated values for both methods were compared to the measured values. The results show that in 49.5% of the cases, the Hybrid method provided a more accurate estimate, as compared to 50.5% for the Kriging method. The sums of the absolute values of the deviations of the estimated values from the measured values were calculated. A value of 157.80 was found for the Hybrid method, as compared to a value of 151.42 for the Kriging method. It is clear that the Hybrid and Kriging estimates are very close to the measured values. There is no significant difference between the two estimated values for available water. It was also found that 100% of the measured values were in the range of plus/minus two standard deviations from the estimates obtained using the Hybrid method. A value of 97.5% was obtained for the Kriging method.

From the above comparisons, one can conclude that the Hybrid is a valid method for the estimation of available water.

5.8 Field Capacity (Site B)

The Hybrid and Kriging estimation methods were applied to 120 values of field capacity. The values of field capacity and their corresponding estimations from the two estimation methods are shown in Table A5.9.

To verify the accuracy of the Hybrid method, the measured and estimated values were compared to those obtained by the Kriging method. The results show that in 44.5% of the cases, the Hybrid method provided a more accurate estimate, as compared to 55.5% for the Kriging method. Furthermore, the sums of the absolute values of the deviations of the estimated values from the measured values were calculated. A value of 157.81 was found for the Hybrid method, as compared to a value of 151.42 for the Kriging method. It was also found that 100% of the measured values were in the range of plus/minus two standard deviations from the estimates obtained using the Hybrid method. A value of 97.5% was obtained for the Kriging method.

CHAPTER 6

Summary and Conclusions

The Hybrid (nonparametric) and Kriging (parametric) estimation methods were applied to measure the spatial variability of soil bulk density, hydraulic conductivity, available water and field capacity. The Hybrid method was applied to two corn fields (Sites A and B) whereas Kriging was applied only at Site B.

In general, at locations where the measured values of SPP were exceptionally high or low, the estimation is not very good. But this will be the case for most estimation techniques, including Hybrid and Kriging methods. Furthermore, a certain error is expected when each observation is intentionally deleted and a Hybrid estimate is performed for that location using neighbouring observations.

To verify the accuracy of the estimations, the measured and estimated values were compared. It was found that 94% to 99% of the measured values were in the range of plus/minus two standard deviations from estimated values when the Hybrid method was used. This value for the Kriging method varied from 95% to 97.5% which shows that some of the estimations are very far from the measured values (i.e. outside the confidence bounds).

The sums of the absolute values of deviations of the estimated values from the measured values were calculated. This value can be used as an indicator to check the degree of bias between the two estimation methods. It was found that there is no significant difference of bias between the Hybrid and Kriging estimation methods.

Another comparison was made between the estimated values of two methods and the measured values. Kriging estimates were slightly closer to the measured values than Hybrid estimates.

From the overall comparisons, it was found that the Hybrid estimates are comparable with Kriging estimates. This indicates the validity and reliability of the Hybrid method for the estimation of the SPP.

The following conclusions are made based on this study:

1. The Hybrid method gave similar results to those obtained by the Kriging method.
2. The Kriging method of estimation can not be applied to fewer than 50 observations whereas the Hybrid method can.
3. The Hybrid estimations can be useful to soil hydrologists to improve the design of subsurface drainage and irrigation systems.
4. Restrictions due to assumptions vital to the Kriging method do not exist when applying the Hybrid method. These assumptions are pointed out in Chapter 2 (Section 2.2).

Recommendations for Future Research

1. More samples with larger volume should be taken.
2. For better visualization, the spatial variability of soil physical properties should be mapped.
3. The Hybrid technique should be applied to the block estimations as well.
4. Other nonparametric methods should be used in future for both point and block estimations and compared to estimations obtained using the Hybrid and Kriging methods.

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APPENDIX A

Table A5.1 Volumetric water content (v.w.c.) at different pressure heads for Site A. (%/volume)

Column 1 : represents the location of sample (i.e. A1 is at row A and column 1).
2 : bulk density (g/cm^3)
3 : v.w.c. at saturation (%/volume)
4 : v.w.c. at 0.1 bar (%/volume)
5 : v.w.c. at 0.3 bar (%/volume)
6 : v.w.c. at 1 bar (%/volume)
7 : v.w.c. at 5 bars (%/volume)
8 : v.w.c. at 10 bars (%/volume)

1	2	3	4	5	6	7	8
A1	1.27	60.0	38.8	37.5	36.0	34.1	32.5
A2	1.55	53.5	39.3	37.8	37.0	35.9	34.1
A3	1.40	60.9	45.3	44.0	42.5	40.6	38.8
A4	1.67	55.4	42.1	40.4	38.1	36.1	34.4
A5	1.61	55.0	40.0	37.5	35.5	33.2	30.6
A6	1.39	59.5	43.6	41.8	40.0	37.6	34.7
A7	1.00	68.7	45.2	43.8	42.0	40.2	9.1
A8	1.62	52.2	39.4	37.8	35.5	33.3	30.7
A9	1.62	54.2	40.9	39.3	37.3	35.4	34.5
A10	1.61	53.3	42.1	40.7	39.2	37.4	35.9
A11	1.53	56.4	40.0	37.3	34.3	32.6	30.3
B1	1.24	57.7	39.0	37.5	36.1	34.9	33.6
B2	1.66	55.3	41.1	39.4	38.1	36.5	34.6
B3	1.76	51.4	39.8	38.4	37.4	34.6	32.8
B4	1.59	52.1	39.8	38.2	35.9	34.1	32.0
B5	1.60	55.3	39.2	37.2	34.4	33.1	31.4
B6	1.69	50.5	39.4	36.9	34.3	32.5	31.4
B7	1.49	55.0	38.5	36.1	34.3	31.9	30.1
B8	1.56	53.6	38.1	36.3	35.2	33.7	32.1
B9	1.58	54.5	39.0	37.4	35.3	33.8	33.0
B10	1.51	50.5	37.0	35.3	34.4	31.8	29.9
B11	1.52	50.7	37.7	36.2	33.7	31.9	30.6
C1	1.63	50.6	41.1	39.1	38.3	37.3	36.4
C2	1.56	51.5	39.4	37.6	36.4	35.5	34.7
C3	1.47	58.5	38.2	36.1	34.6	33.4	32.6
C4	1.61	52.1	39.7	37.7	36.0	35.3	34.1
C5	1.74	51.2	40.3	38.4	37.2	35.4	33.6
C6	1.21	68.0	43.7	40.1	39.1	37.8	36.5
C7	1.70	54.7	43.5	40.9	39.2	38.1	36.8
C8	1.71	54.0	39.9	38.0	36.6	35.5	34.5
C9	1.55	53.8	39.3	36.3	34.4	32.8	31.0

Table A5.1 continued

1	2	3	4	5	6	7	8
C10	1.60	54.5	40.7	38.2	36.5	35.3	34.2
C11	1.60	55.0	41.0	39.2	37.8	36.2	35.1
D1	1.46	54.8	40.8	39.0	37.1	35.9	35.3
D2	1.60	57.2	41.8	39.4	37.8	36.6	35.3
D3	1.70	54.3	43.7	41.5	40.5	39.3	37.9
D4	1.59	55.1	41.8	39.8	38.1	37.4	36.7
D5	1.54	57.8	40.7	35.9	30.9	28.4	27.6
D6	0.99	70.2	46.9	45.5	44.7	43.9	43.3
D7	1.66	55.4	43.2	40.5	35.0	35.0	35.0
D8	1.65	47.2	37.9	36.2	34.5	33.6	32.4
D9	1.61	55.9	41.4	38.1	35.6	34.9	34.0
D10	1.70	50.2	40.5	39.0	37.1	35.6	34.9
D11	1.55	59.1	42.5	36.5	33.1	31.1	29.6
E1	1.65	52.4	39.8	36.3	32.9	30.3	28.5
E2	1.64	46.0	38.9	37.7	36.5	35.5	33.0
E3	1.66	50.2	40.7	38.9	36.1	35.4	34.1
E4	1.57	51.6	40.6	37.9	36.0	32.0	31.3
E5	1.62	46.0	39.4	38.1	36.4	35.7	34.0
E6	1.63	50.9	41.5	39.0	37.9	32.2	31.3
E7	1.65	57.1	43.2	39.2	35.1	32.9	32.4
E8	1.69	53.1	41.1	37.7	34.8	32.3	31.9
E9	1.64	51.5	42.0	38.6	37.3	34.6	34.2
E10	1.75	56.8	42.5	38.2	35.1	32.6	31.9
E11	1.67	43.7	36.6	39.0	37.3	36.5	35.1
F1	1.47	56.2	43.9	40.5	36.0	32.0	31.2
F2	1.67	51.4	40.9	37.9	34.6	32.1	31.6
F3	1.74	50.0	40.9	38.9	37.0	35.8	29.9
F4	1.67	46.9	40.6	39.8	37.6	36.7	33.1
F5	1.64	56.6	43.8	39.7	37.0	33.1	32.3
F6	1.61	47.0	40.0	38.4	36.0	34.8	29.1
F7	1.62	56.0	45.4	41.4	39.2	35.0	31.4
F8	1.68	52.7	42.8	39.8	39.2	36.3	36.0
F9	1.58	56.0	45.6	41.3	37.1	34.8	33.3
F10	1.69	52.1	40.7	36.6	29.2	27.6	27.3
F11	1.72	49.0	38.1	35.2	33.2	30.1	29.4
G1	1.59	47.7	40.1	37.9	34.8	34.1	30.0
G2	1.58	48.5	40.1	38.0	36.4	35.8	31.6
G3	1.45	46.3	36.3	34.1	30.7	29.9	27.3
G4	1.53	49.4	39.7	35.3	32.4	31.4	24.3
G5	1.57	50.2	39.4	36.0	33.8	32.1	30.0
G6	1.45	56.1	44.3	42.3	41.1	40.3	37.0
G7	1.47	52.5	41.6	40.0	37.9	37.4	33.4
G8	1.53	50.0	42.0	40.6	38.7	38.0	34.5
G9	1.63	49.4	41.3	38.0	34.0	32.7	28.4
G10	1.58	49.2	40.3	38.7	37.6	37.0	34.6
G11	1.46	51.5	40.6	37.0	35.5	34.6	30.0
H1	1.55	51.6	40.3	38.0	36.3	35.0	32.6
H2	1.62	47.3	40.0	37.9	36.3	35.1	32.1
H3	1.60	49.0	39.0	37.4	36.2	35.0	31.7
H4	1.65	57.4	42.5	40.0	37.6	35.7	33.9

Table A5.1 continued

1	2	3	4	5	6	7	8
H5	1.62	56.7	41.0	36.6	34.2	29.7	28.7
H6	1.66	48.0	40.6	39.2	37.7	36.6	33.4
H7	1.67	53.3	40.1	36.8	32.0	30.3	29.8
H8	1.62	52.6	41.3	38.1	35.4	32.1	31.5
H9	1.44	54.4	39.6	34.3	28.6	25.0	24.0
H10	1.71	47.9	42.0	40.3	38.3	37.4	34.6
H11	1.58	45.4	37.0	36.0	34.4	33.0	32.2
I1	1.65	52.3	40.6	37.4	33.7	30.5	29.1
I2	1.72	53.1	45.3	41.3	38.1	36.4	34.3
I3	1.57	52.7	41.3	39.0	37.4	34.6	33.3
I4	1.80	51.7	44.3	40.6	38.7	36.5	35.0
I5	1.32	60.0	45.5	40.8	38.7	37.0	35.8
I6	1.71	50.6	41.2	37.5	35.1	31.6	30.4
I7	1.65	56.1	43.6	39.1	38.1	36.5	36.5
I8	1.60	58.0	41.8	38.7	36.4	34.5	33.2
I9	1.57	58.0	41.0	36.4	32.9	29.7	28.7
I10	1.66	59.6	45.1	41.7	39.7	37.6	36.3
I11	1.67	54.0	43.9	41.0	39.8	37.8	37.1
J1	1.64	60.0	44.9	41.8	40.5	38.5	37.1
J2	1.32	63.4	50.5	46.5	44.4	42.4	41.2
J3	1.56	63.3	54.2	49.8	45.4	43.1	41.5
J4	1.75	52.0	43.2	40.0	36.3	35.0	33.0
J5	1.62	55.1	43.6	40.0	39.1	37.1	37.0
J6	1.51	55.5	45.0	32.5	38.9	36.8	35.4
J7	1.64	53.9	41.5	38.5	34.8	32.5	31.0
J8	1.60	56.6	45.3	41.5	40.0	38.4	37.0
J9	1.56	57.2	43.2	39.0	37.5	35.0	33.8
J10	1.64	55.5	40.8	38.1	36.8	34.6	33.6
J11	1.52	57.5	41.2	39.2	36.8	34.9	33.2
K1	1.64	56.0	44.4	40.1	37.8	36.7	33.4
K2	1.64	51.2	42.5	40.6	38.6	36.5	36.1
K3	1.61	51.0	41.0	37.5	33.1	30.1	29.4
K4	1.60	56.1	44.1	39.5	38.1	36.3	36.0
K5	1.63	53.1	43.6	40.0	39.0	36.9	35.2
K6	1.67	55.8	41.5	37.5	34.7	33.4	31.5
K7	1.60	55.2	44.3	39.6	37.1	34.0	32.3
K8	1.57	55.1	41.8	39.9	36.4	35.2	33.4
K9	1.57	53.2	40.0	38.0	36.9	35.2	33.4
K10	1.56	57.7	42.2	38.8	36.5	34.2	32.6
K11	1.62	52.6	41.7	39.0	36.7	34.8	34.0

Table A5.2 Calculated values of Bulk density (g/cm^3), Field capacity and Available water expressed as (%/volume) for Site A

1. X coordinates (meters)
2. Y coordinates (meters)
3. Bulk density (g/cm^3)
4. Field capacity (%/volume)
5. Available water (%/volume)

1	2	3	4	5
0.0	0.0	1.27	35.00	5.00
0.0	10.0	1.55	36.50	3.70
0.0	20.0	1.40	41.60	5.20
0.0	30.0	1.64	37.10	6.30
0.0	40.0	1.61	34.50	6.90
0.0	50.0	1.39	39.30	7.10
0.0	60.0	1.00	41.40	4.70
0.0	70.0	1.62	34.70	7.10
0.0	80.0	1.62	36.00	4.80
0.0	90.0	1.61	38.30	4.80
0.0	100.0	1.53	33.80	7.00
10.0	0.0	1.24	37.50	3.90
10.0	10.0	1.66	39.40	4.80
10.0	20.0	1.76	38.40	5.60
10.0	30.0	1.59	38.20	6.20
10.0	40.0	1.60	37.20	5.80
10.0	50.0	1.69	36.90	5.50
10.0	60.0	1.49	36.10	6.00
10.0	70.0	1.56	36.30	4.20
10.0	80.0	1.58	37.40	4.40
10.0	90.0	1.51	35.30	5.40
10.0	100.0	1.52	36.20	5.60
20.0	0.0	1.63	39.10	2.70
20.0	10.0	1.56	37.60	2.90
20.0	20.0	1.47	36.10	3.50
20.0	30.0	1.61	37.70	3.60
20.0	40.0	1.74	38.40	4.80
20.0	50.0	1.21	40.10	3.60
20.0	60.0	1.70	40.90	4.10
20.0	70.0	1.71	38.00	3.50
20.0	80.0	1.55	36.30	5.30
20.0	90.0	1.60	38.20	4.00
20.0	100.0	1.60	39.20	4.10
30.0	0.0	1.46	39.00	3.70
30.0	10.0	1.60	39.40	4.10
30.0	20.0	1.70	41.50	3.60
30.0	30.0	1.60	39.80	3.10
30.0	40.0	1.54	35.90	8.30
30.0	50.0	1.00	45.50	2.20

Table A5.2 continued

1	2	3	4	5
30.0	60.0	1.66	40.00	5.50
30.0	70.0	1.65	36.20	3.80
30.0	80.0	1.61	38.10	4.10
30.0	90.0	1.70	39.00	4.10
30.0	100.0	1.55	36.50	6.90
40.0	0.0	1.65	36.30	7.80
40.0	10.0	1.64	37.70	4.70
40.0	20.0	1.66	38.90	4.80
40.0	30.0	1.57	37.90	6.60
40.0	40.0	1.62	38.10	4.10
40.0	50.0	1.63	39.00	7.70
40.0	60.0	1.65	39.20	6.80
40.0	70.0	1.69	37.70	5.80
40.0	80.0	1.64	38.60	4.40
40.0	90.0	1.35	38.20	6.30
40.0	100.0	1.64	39.00	3.90
50.0	0.0	1.47	40.50	9.30
50.0	10.0	1.67	37.90	6.30
50.0	20.0	1.74	38.90	9.00
50.0	30.0	1.67	39.20	6.10
50.0	40.0	1.64	39.70	7.40
50.0	50.0	1.61	38.40	9.30
50.0	60.0	1.62	41.40	0.00
50.0	70.0	1.68	39.80	3.80
50.0	80.0	1.58	41.30	8.00
50.0	90.0	1.69	36.60	9.30
50.0	100.0	1.72	35.20	5.80
60.0	0.0	1.59	37.90	7.90
60.0	10.0	1.58	38.00	6.40
60.0	20.0	1.45	34.10	6.80
60.0	30.0	1.53	35.30	1.00
60.0	40.0	1.57	36.03	6.00
60.0	50.0	1.45	42.30	5.30
60.0	60.0	1.47	40.00	6.60
60.0	70.0	1.53	40.60	6.10
60.0	80.0	1.63	38.00	9.60
60.0	90.0	1.58	38.70	4.10
60.0	100.0	1.46	37.00	7.00
70.0	0.0	1.55	38.00	5.40
70.0	10.0	1.62	37.90	5.80
70.0	20.0	1.60	37.40	5.70
70.0	30.0	1.65	40.00	6.10
70.0	40.0	1.62	36.60	7.90
70.0	50.0	1.66	39.20	5.80
70.0	60.0	1.67	36.80	7.00
70.0	70.0	1.62	38.10	6.60
70.0	80.0	1.44	34.30	0.30
70.0	90.0	1.71	40.30	5.70
70.0	100.0	1.58	36.00	3.80
80.0	0.0	1.65	37.40	8.30

Table A5.2 continued

1	2	3	3	3
80.0	10.0	1.72	41.30	7.00
80.0	20.0	1.57	39.00	5.70
80.0	30.0	1.80	40.60	5.60
80.0	40.0	1.32	40.80	5.00
80.0	50.0	1.71	37.50	7.10
80.0	60.0	1.65	39.10	2.60
80.0	70.0	1.60	36.70	5.50
80.0	80.0	1.57	36.40	7.70
80.0	90.0	1.66	41.70	5.40
80.0	100.0	1.67	41.00	3.90
90.0	0.0	1.64	41.80	4.70
90.0	10.0	1.32	46.50	5.30
90.0	20.0	1.56	49.80	8.30
90.0	30.0	1.75	40.00	7.00
90.0	40.0	1.62	40.00	3.00
90.0	50.0	1.50	42.50	7.10
90.0	60.0	1.64	38.50	7.50
90.0	70.0	1.60	41.50	4.50
90.0	80.0	1.56	39.00	5.20
90.0	90.0	1.64	38.10	4.50
90.0	100.0	1.52	39.20	6.00
100.0	0.0	1.64	40.10	6.70
100.0	10.0	1.64	40.60	4.50
100.0	20.0	1.61	37.50	8.10
100.0	30.0	1.60	39.50	3.50
100.0	40.0	1.63	40.00	4.80
100.0	50.0	1.67	37.50	6.00
100.0	60.0	1.60	39.60	7.30
100.0	70.0	1.57	39.10	5.70
100.0	80.0	1.57	38.00	4.60
100.0	90.0	1.56	38.80	6.20
100.0	100.0	1.62	39.00	5.00

Table A5.3 Bulk density for Hybrid (nonparametric) estimation method (Site A) (g/cm^3)

1. X coordinates (meters)
2. Y coordinates (meters)
3. Measured values (g/cm^3)
4. Hybrid estimates (g/cm^3)
5. Estimated values + two standard deviation
6. Estimated values - two standard deviation

1	2	3	4	5	6
0.0	0.0	1.27	1.27	1.65	0.88
0.0	10.0	1.55	1.34	1.72	0.95
0.0	20.0	1.40	1.62	2.01	1.24
0.0	30.0	1.64	1.60	1.98	1.21
0.0	40.0	1.61	1.60	1.98	1.21
0.0	50.0	1.39	1.55	1.93	1.16
0.0	60.0	1.00	1.47	1.84	1.10
0.0	70.0	1.62	1.56	1.94	1.17
0.0	80.0	1.62	1.61	1.99	1.22
0.0	90.0	1.61	1.52	1.91	1.14
0.0	100.0	1.53	1.52	1.90	1.13
10.0	0.0	1.24	1.57	1.95	1.19
10.0	10.0	1.66	1.65	2.03	1.26
10.0	20.0	1.76	1.45	1.84	1.07
10.0	30.0	1.59	1.61	1.99	1.22
10.0	40.0	1.60	1.71	2.10	1.33
10.0	50.0	1.69	1.43	1.82	1.05
10.0	60.0	1.49	1.52	1.90	1.13
10.0	70.0	1.56	1.59	1.98	1.21
10.0	80.0	1.58	1.52	1.91	1.13
10.0	90.0	1.51	1.59	1.98	1.21
10.0	100.0	1.52	1.53	1.91	1.14
20.0	0.0	1.63	1.45	1.83	1.06
20.0	10.0	1.56	1.47	1.85	1.08
20.0	20.0	1.47	1.68	2.07	1.30
20.0	30.0	1.61	1.60	1.98	1.21
20.0	40.0	1.74	1.27	1.66	0.89
20.0	50.0	1.21	1.70	2.08	1.32
20.0	60.0	1.70	1.66	2.05	1.28
20.0	70.0	1.71	1.56	1.94	1.18
20.0	80.0	1.55	1.61	1.99	1.22
20.0	90.0	1.60	1.59	1.98	1.21
20.0	100.0	1.60	1.52	1.91	1.14
30.0	0.0	1.46	1.58	1.97	1.20
30.0	10.0	1.60	1.46	1.85	1.07
30.0	20.0	1.70	1.46	1.85	1.08
30.0	30.0	1.60	1.54	1.93	1.15
30.0	40.0	1.54	1.60	1.99	1.22
30.0	50.0	1.00	1.50	1.87	1.12

Table A5.3 continued

1	2	3	4	5	6
30.0	60.0	1.66	1.54	1.92	1.15
30.0	70.0	1.65	1.68	2.07	1.30
30.0	80.0	1.61	1.66	2.04	1.27
30.0	90.0	1.70	1.44	1.82	1.05
30.0	100.0	1.55	1.44	1.82	1.05
40.0	0.0	1.65	1.56	1.95	1.18
40.0	10.0	1.64	1.62	2.01	1.24
40.0	20.0	1.66	1.68	2.07	1.30
40.0	30.0	1.57	1.65	2.04	1.27
40.0	40.0	1.62	1.56	1.94	1.17
40.0	50.0	1.63	1.60	1.98	1.22
40.0	60.0	1.65	1.68	2.07	1.30
40.0	70.0	1.69	1.68	2.07	1.30
40.0	80.0	1.64	1.35	1.74	0.97
40.0	90.0	1.35	1.67	2.05	1.29
40.0	100.0	1.64	1.69	2.07	1.30
50.0	0.0	1.47	1.64	2.02	1.25
50.0	10.0	1.67	1.61	2.00	1.23
50.0	20.0	1.74	1.66	2.05	1.28
50.0	30.0	1.67	1.66	2.05	1.28
50.0	40.0	1.64	1.62	2.00	1.23
50.0	50.0	1.61	1.53	1.91	1.14
50.0	60.0	1.62	1.60	1.99	1.22
50.0	70.0	1.68	1.56	1.94	1.17
50.0	80.0	1.58	1.68	2.07	1.30
50.0	90.0	1.69	1.68	2.07	1.30
50.0	100.0	1.72	1.50	1.98	1.22
60.0	0.0	1.59	1.55	1.94	1.17
60.0	10.0	1.58	1.53	1.92	1.15
60.0	20.0	1.45	1.56	1.95	1.18
60.0	30.0	1.53	1.61	1.99	1.22
60.0	40.0	1.57	1.52	1.90	1.13
60.0	50.0	1.45	1.55	1.94	1.17
60.0	60.0	1.47	1.53	1.91	1.14
60.0	70.0	1.53	1.63	2.01	1.24
60.0	80.0	1.63	1.51	1.89	1.12
60.0	90.0	1.58	1.60	1.99	1.22
60.0	100.0	1.46	1.61	1.99	1.22
70.0	0.0	1.55	1.62	2.01	1.24
70.0	10.0	1.62	1.65	2.04	1.27
70.0	20.0	1.60	1.60	1.98	1.21
70.0	30.0	1.65	1.62	2.01	1.24
70.0	40.0	1.62	1.60	1.98	1.21
70.0	50.0	1.66	1.67	2.05	1.28
70.0	60.0	1.67	1.63	2.02	1.24
70.0	70.0	1.62	1.49	1.88	1.10
70.0	80.0	1.44	1.64	2.02	1.25
70.0	90.0	1.71	1.64	2.02	1.25
70.0	100.0	1.58	1.67	2.05	1.28

Table A5.3 continued

1	2	3	4	5	6
80.0	0.0	1.65	1.64	2.02	1.25
80.0	10.0	1.72	1.57	1.95	1.18
80.0	20.0	1.57	1.64	2.02	1.25
80.0	30.0	1.80	1.61	2.00	1.23
80.0	40.0	1.32	1.64	2.03	1.26
80.0	50.0	1.71	1.50	1.89	1.12
80.0	60.0	1.65	1.62	2.01	1.24
80.0	70.0	1.60	1.60	1.99	1.22
80.0	80.0	1.57	1.55	1.93	1.16
80.0	90.0	1.66	1.66	2.05	1.28
80.0	100.0	1.67	1.53	1.92	1.15
90.0	0.0	1.64	1.51	1.90	1.12
90.0	10.0	1.32	1.51	1.89	1.13
90.0	20.0	1.56	1.60	1.99	1.22
90.0	30.0	1.75	1.62	2.00	1.24
90.0	40.0	1.62	1.45	1.84	1.07
90.0	50.0	1.50	1.65	2.03	1.26
90.0	60.0	1.64	1.65	2.03	1.26
90.0	70.0	1.60	1.57	1.95	1.18
90.0	80.0	1.56	1.57	1.95	1.18
90.0	90.0	1.64	1.52	1.91	1.14
90.0	100.0	1.52	1.64	2.02	1.25
100.0	0.0	1.64	1.64	2.02	1.25
100.0	10.0	1.64	1.59	1.98	1.21
100.0	20.0	1.61	1.58	1.97	1.20
100.0	30.0	1.60	1.62	2.01	1.24
100.0	40.0	1.63	1.63	2.01	1.24
100.0	50.0	1.67	1.60	1.99	1.22
100.0	60.0	1.60	1.62	2.01	1.24
100.0	70.0	1.57	1.59	1.98	1.20
100.0	80.0	1.57	1.56	1.95	1.17
100.0	90.0	1.56	1.58	1.97	1.20
100.0	100.0	1.62	1.52	1.91	1.13

Table A5.4 Field capacity for Hybrid (nonparametric) estimation method (Site A) (%/volume)

1. X coordinates (meters)
2. Y coordinates (meters)
3. Measured values (%/volume)
4. Estimated values (%/volume)
5. Estimated values + two standard deviation
6. Estimated values - two standard deviation

1	2	3	4	5	6
0.0	0.0	35.00	36.66	45.09	28.23
0.0	10.0	36.50	39.46	47.90	31.01
0.0	20.0	41.60	37.28	45.71	28.85
0.0	30.0	37.10	36.80	45.25	28.35
0.0	40.0	34.50	37.15	45.57	28.73
0.0	50.0	39.30	37.07	45.52	28.62
0.0	60.0	41.40	35.73	44.16	27.30
0.0	70.0	34.70	36.10	44.53	27.68
0.0	80.0	36.00	37.69	46.13	29.24
0.0	90.0	38.30	33.80	42.25	25.35
0.0	100.0	33.80	36.16	44.57	27.75
10.0	0.0	37.50	38.38	46.86	29.93
10.0	10.0	39.40	37.52	45.97	29.07
10.0	20.0	38.40	38.95	47.40	30.49
10.0	30.0	38.20	37.44	45.89	28.98
10.0	40.0	37.20	35.56	44.01	27.11
10.0	50.0	36.90	36.43	44.87	27.98
10.0	60.0	36.10	39.63	48.07	31.19
10.0	70.0	36.30	37.03	45.47	28.59
10.0	80.0	37.40	35.30	43.75	26.85
10.0	90.0	35.30	37.81	46.25	29.38
10.0	100.0	36.20	35.10	43.55	26.66
20.0	0.0	39.10	37.60	46.05	29.15
20.0	10.0	37.60	39.14	47.59	30.69
20.0	20.0	36.10	38.07	46.51	29.63
20.0	30.0	37.70	38.60	47.05	30.14
20.0	40.0	38.40	37.37	45.82	28.92
20.0	50.0	40.10	40.85	49.30	32.41
20.0	60.0	40.90	38.63	47.07	30.19
20.0	70.0	38.00	36.27	44.72	27.82
20.0	80.0	36.30	38.13	46.58	29.69
20.0	90.0	38.20	39.03	47.48	30.58
20.0	100.0	39.20	36.17	44.62	27.72
30.0	0.0	39.00	37.79	46.24	29.34
30.0	10.0	39.40	38.99	47.43	30.54
30.0	20.0	41.50	39.33	47.77	30.90
30.0	30.0	39.80	36.51	44.96	28.06
30.0	40.0	35.90	38.63	46.97	30.08

Table A5.4 continued

1	2	3	4	5	6
30.0	50.0	45.50	39.21	47.56	30.86
30.0	60.0	40.50	38.63	47.07	30.18
30.0	70.0	36.20	38.06	46.51	29.62
30.0	80.0	38.10	38.62	47.07	30.17
30.0	90.0	39.00	36.50	44.95	28.05
30.0	100.0	36.50	39.11	47.56	30.67
40.0	0.0	36.30	38.53	46.97	30.08
40.0	10.0	37.70	37.58	46.03	29.13
40.0	20.0	38.90	37.86	46.31	29.41
40.0	30.0	37.90	39.09	47.54	30.64
40.0	40.0	38.10	37.90	46.35	29.45
40.0	50.0	39.00	38.75	47.20	30.30
40.0	60.0	39.20	40.27	48.72	31.82
40.0	70.0	37.70	38.78	47.23	30.33
40.0	80.0	38.60	38.17	46.62	29.72
40.0	90.0	38.20	38.17	46.62	29.72
40.0	100.0	39.00	35.33	43.78	26.88
50.0	0.0	40.50	37.72	46.16	29.28
50.0	10.0	37.90	38.28	46.73	29.82
50.0	20.0	38.90	38.35	46.80	29.90
50.0	30.0	39.20	38.01	46.46	29.55
50.0	40.0	39.70	37.16	45.61	28.71
50.0	50.0	38.40	40.95	49.41	32.50
50.0	60.0	41.40	39.85	48.28	31.42
50.0	70.0	39.80	40.85	49.30	32.40
50.0	80.0	41.30	37.29	45.72	28.85
50.0	90.0	36.60	37.18	45.62	28.73
50.0	100.0	35.20	38.46	46.90	30.03
60.0	0.0	37.90	38.54	46.99	30.09
60.0	10.0	38.00	37.47	45.92	29.02
60.0	20.0	34.10	35.55	43.97	27.13
60.0	30.0	35.30	36.42	44.85	27.98
60.0	40.0	36.03	39.48	47.92	31.04
60.0	50.0	42.30	38.74	47.16	30.32
60.0	60.0	40.00	39.87	48.31	31.42
60.0	70.0	40.60	37.66	46.10	29.21
60.0	80.0	38.00	40.00	48.45	31.55
60.0	90.0	38.70	38.58	47.03	30.13
60.0	100.0	37.00	35.31	43.75	26.86
70.0	0.0	38.00	37.81	46.26	29.36
70.0	10.0	37.90	37.81	46.26	29.36
70.0	20.0	37.40	38.75	47.20	30.00
70.0	30.0	40.00	36.99	45.43	28.54
70.0	40.0	36.60	38.68	47.13	30.23
70.0	50.0	39.20	36.77	45.22	28.32
70.0	60.0	36.80	38.61	47.06	30.17
70.0	70.0	38.10	36.71	45.17	28.26
70.0	80.0	34.30	37.80	46.22	29.38
70.0	90.0	40.30	38.16	46.60	29.71
70.0	100.0	36.00	40.26	48.70	31.82

Table A5.4 continued

1	2	3	4	5	6
80.0	0.0	37.40	41.36	49.81	32.91
80.0	10.0	41.30	39.77	48.20	31.34
80.0	20.0	39.00	41.06	49.51	32.61
80.0	30.0	40.60	40.43	48.88	31.99
80.0	40.0	40.80	37.50	45.94	29.06
80.0	50.0	37.50	40.77	49.22	32.32
80.0	60.0	39.10	38.29	46.74	29.84
80.0	70.0	38.70	39.04	47.49	30.59
80.0	80.0	36.40	38.86	47.31	30.42
80.0	90.0	41.70	40.50	48.93	32.07
80.0	100.0	41.00	38.64	47.07	30.20
90.0	0.0	41.80	38.81	47.23	30.38
90.0	10.0	46.50	41.68	50.00	33.36
90.0	20.0	49.80	38.63	46.81	30.45
90.0	30.0	40.00	39.75	48.20	31.31
90.0	40.0	40.00	41.79	50.24	33.34
90.0	50.0	42.50	41.79	50.21	33.37
90.0	60.0	38.50	41.49	49.94	33.04
90.0	70.0	41.50	39.07	47.51	30.64
90.0	80.0	39.00	37.45	45.90	29.00
90.0	90.0	38.10	37.45	45.90	29.00
90.0	100.0	39.20	38.96	47.41	30.51
100.0	0.0	40.10	40.56	49.00	32.11
100.0	10.0	40.60	39.73	48.17	31.29
100.0	20.0	37.50	40.36	48.81	31.91
100.0	30.0	39.50	40.36	48.81	31.91
100.0	40.0	40.00	38.60	47.05	30.15
100.0	50.0	37.50	38.60	47.05	30.15
100.0	60.0	39.60	38.57	47.02	30.13
100.0	70.0	39.10	39.23	47.68	30.78
100.0	80.0	38.00	38.78	47.23	30.33
100.0	90.0	38.80	38.06	46.51	29.60
100.0	100.0	39.00	38.66	47.11	30.21

Table A5.5 Available water for Hybrid (nonparametric) estimation method (Site A) (%/volume)

1. X coordinates (meters)
2. Y coordinates (meters)
3. Measured values (%/volume)
4. Estimated values (%/volume)
5. Estimated values + two standard deviation
6. Estimated values - two standard deviation

1	2	3	4	5	6
0.0	0.0	5.00	3.50	7.19	-0.18
0.0	10.0	3.70	4.86	8.52	1.19
0.0	20.0	5.20	5.08	8.76	1.40
0.0	30.0	6.30	5.86	9.55	2.18
0.0	40.0	6.90	6.41	10.09	2.74
0.0	50.0	7.10	4.75	8.43	1.08
0.0	60.0	4.70	4.75	8.43	1.07
0.0	70.0	7.10	4.49	8.16	0.81
0.0	80.0	4.80	4.64	8.32	0.96
0.0	90.0	4.80	6.18	9.86	2.50
0.0	100.0	7.00	5.48	9.15	1.80
10.0	0.0	3.90	3.23	6.90	-0.44
10.0	10.0	4.80	3.69	7.37	0.01
10.0	20.0	5.60	4.77	8.45	1.08
10.0	30.0	6.20	5.40	9.08	1.72
10.0	40.0	5.80	5.39	9.08	1.71
10.0	50.0	5.50	5.92	9.61	2.24
10.0	60.0	6.00	4.15	7.83	0.47
10.0	70.0	4.20	5.23	8.90	1.56
10.0	80.0	4.40	5.36	9.04	1.68
10.0	90.0	5.40	4.48	8.16	0.79
10.0	100.0	5.60	4.88	8.56	1.20
20.0	0.0	2.70	3.25	6.90	-0.39
20.0	10.0	2.90	3.30	6.95	-0.35
20.0	20.0	3.50	3.47	7.14	-0.19
20.0	30.0	3.60	3.44	7.10	-0.22
20.0	40.0	4.80	4.81	8.49	1.13
20.0	50.0	3.60	2.58	6.24	-1.09
20.0	60.0	4.10	3.65	7.33	-0.02
20.0	70.0	3.50	4.13	7.79	0.46
20.0	80.0	5.30	3.86	7.54	0.18
20.0	90.0	4.00	3.86	7.53	0.19
20.0	100.0	4.10	5.68	9.35	2.01
30.0	0.0	3.70	3.89	7.55	0.22
30.0	10.0	4.10	3.63	7.30	-0.04
30.0	20.0	3.60	3.43	7.10	-0.23
30.0	30.0	3.10	5.29	8.95	1.64
30.0	40.0	8.30	2.95	6.60	-0.71

Table A5.5 continued

1	2	3	4	5	6
30.0	50.0	2.20	6.88	10.51	3.26
30.0	60.0	5.50	4.06	7.75	0.38
30.0	70.0	3.80	4.23	7.90	0.56
30.0	80.0	4.10	4.24	7.91	0.57
30.0	90.0	4.10	6.50	10.17	2.83
30.0	100.0	6.90	3.99	7.66	0.31
40.0	0.0	7.80	4.48	8.15	0.82
40.0	10.0	4.70	5.42	9.10	1.74
40.0	20.0	4.80	6.54	10.22	2.86
40.0	30.0	6.60	3.35	7.03	0.33
40.0	40.0	4.10	7.68	11.35	4.01
40.0	50.0	7.70	5.05	8.71	1.38
40.0	60.0	[illegible].80	8.05	11.72	4.37
40.0	70.0	5.80	8.05	11.73	4.36
40.0	80.0	4.40	6.22	9.90	2.54
40.0	90.0	6.30	3.99	7.67	0.31
40.0	100.0	3.90	5.96	9.63	2.29
50.0	0.0	9.30	6.62	10.24	2.99
50.0	10.0	6.30	7.76	11.44	4.08
50.0	20.0	9.00	5.97	9.60	2.33
50.0	30.0	6.10	9.39	13.07	5.70
50.0	40.0	7.40	6.01	9.68	2.34
50.0	50.0	9.30	7.60	11.23	3.96
50.0	60.0	10.00	6.49	10.09	2.89
50.0	70.0	3.80	7.76	11.43	4.09
50.0	80.0	8.00	8.01	11.67	4.35
50.0	90.0	9.30	5.94	9.57	2.32
50.0	100.0	5.80	6.73	10.41	3.05
60.0	0.0	7.90	5.96	9.62	2.30
60.0	10.0	6.40	6.08	9.76	2.40
60.0	20.0	6.80	8.17	11.85	4.49
60.0	30.0	11.00	6.00	9.55	2.45
60.0	40.0	6.00	6.40	10.08	2.72
60.0	50.0	5.30	5.91	9.59	2.22
60.0	60.0	6.60	6.84	10.52	3.16
60.0	70.0	6.10	6.84	10.52	3.16
60.0	80.0	9.60	6.02	9.63	2.41
60.0	90.0	4.10	6.85	10.52	3.18
60.0	100.0	7.00	4.02	7.70	0.35
70.0	0.0	5.40	7.91	11.59	4.23
70.0	10.0	5.80	7.91	11.59	4.23
70.0	20.0	5.70	5.77	9.45	2.08
70.0	30.0	6.10	6.08	9.76	2.40
70.0	40.0	7.90	5.60	9.26	1.94
70.0	50.0	5.80	7.04	10.72	3.36
70.0	60.0	7.00	5.99	9.66	2.31
70.0	70.0	8.60	6.02	9.70	2.34
70.0	80.0	10.30	7.50	11.08	3.91
70.0	90.0	5.70	3.92	7.60	0.24
70.0	100.0	3.80	5.24	8.91	1.58

Table A5.5 continued

1	2	3	4	5	6
80.0	0.0	8.30	5.33	8.98	1.68
80.0	10.0	7.00	5.56	9.24	1.89
80.0	20.0	5.70	6.70	10.39	3.02
80.0	30.0	5.60	5.58	9.26	1.89
80.0	40.0	5.00	6.08	9.76	2.40
80.0	50.0	7.10	4.57	8.25	0.90
80.0	60.0	2.60	7.04	10.68	3.40
80.0	70.0	5.50	4.96	8.64	1.28
80.0	80.0	7.70	5.32	8.99	1.65
80.0	90.0	5.40	4.44	8.13	0.76
80.0	100.0	3.90	5.31	8.98	1.64
90.0	0.0	4.70	5.28	8.96	1.60
90.0	10.0	5.30	5.56	9.24	1.87
90.0	20.0	8.30	7.25	10.91	3.60
90.0	30.0	7.00	3,27	6.95	-0.40
90.0	40.0	3.00	4.98	8.63	1.33
90.0	50.0	7.10	7.26	10.94	3.59
90.0	60.0	7.50	5.90	9.57	2.23
90.0	70.0	4.50	5.25	8.93	1.57
90.0	80.0	5.20	5.25	8.93	1.57
90.0	90.0	4.50	6.15	9.83	2.47
90.0	100.0	6.00	4.66	8.34	0.97
100.0	0.0	6.70	4.50	8.18	0.82
100.0	10.0	4.50	7.02	10.70	3.35
100.0	20.0	8.10	4.36	8.02	0.71
100.0	30.0	3.50	5.68	9.35	2.02
100.0	40.0	4.80	3.12	6.80	-0.56
100.0	50.0	6.00	7.15	10.83	3.47
100.0	60.0	7.30	5.95	9.62	2.27
100.0	70.0	5.70	4.54	8.23	0.86
100.0	80.0	4.60	5.84	9.52	2.16
100.0	90.0	6.20	4.55	8.23	0.87
100.0	100.0	5.00	5.78	9.46	2.10

Table A5.6 Bulk density for Hybrid (nonparametric) and Kriging (parametric) estimation methods (Site B) (g/cm^3)

1. X coordinates (meters)
2. Y coordinates (meters)
3. Measured values (g/cm^3)
4. Hybrid estimates (g/cm^3)
5. Kriged estimates (g/cm^3)

1	2	3	4	5
0.0	0.0	1.55	1.54	1.53
10.0	0.0	1.51	1.55	1.53
20.0	0.0	1.52	1.51	1.52
30.0	0.0	1.45	1.52	1.51
40.0	0.0	1.59	1.45	1.47
50.0	0.0	1.45	1.48	1.47
60.0	0.0	1.37	1.48	1.45
70.0	0.0	1.45	1.26	1.41
80.0	0.0	1.39	1.43	1.42
90.0	0.0	1.47	1.37	1.42
0.0	10.0	1.55	1.52	1.53
10.0	10.0	1.54	1.52	1.52
20.0	10.0	1.65	1.52	1.50
30.0	10.0	1.50	1.46	1.50
40.0	10.0	1.49	1.46	1.46
50.0	10.0	1.50	1.53	1.46
60.0	10.0	1.48	1.22	1.43
70.0	10.0	1.19	1.47	1.44
80.0	10.0	1.35	1.39	1.42
90.0	10.0	1.41	1.41	1.43
0.0	20.0	1.52	1.41	1.54
10.0	20.0	1.41	1.41	1.54
20.0	20.0	1.49	1.44	1.52
30.0	20.0	1.45	1.44	1.50
40.0	20.0	1.35	1.49	1.50
50.0	20.0	1.55	1.47	1.46
60.0	20.0	1.45	1.48	1.45
70.0	20.0	1.52	1.46	1.42
80.0	20.0	1.46	1.37	1.42
90.0	20.0	1.43	1.43	1.43
0.0	30.0	1.59	1.55	1.54
10.0	30.0	1.55	1.46	1.53
20.0	30.0	1.52	1.56	1.52
30.0	30.0	1.53	1.50	1.49
40.0	30.0	1.49	1.48	1.48
50.0	30.0	1.53	1.48	1.46
60.0	30.0	1.42	1.44	1.45
70.0	30.0	1.48	1.43	1.43
80.0	30.0	1.38	1.45	1.45

Table A5.6 continued

1	2	3	4	5
90.0	30.0	1.46	1.41	1.44
0.0	40.0	1.64	1.56	1.54
10.0	40.0	1.50	1.52	1.54
20.0	40.0	1.58	1.57	1.51
30.0	40.0	1.52	1.46	1.49
40.0	40.0	1.40	1.47	1.47
50.0	40.0	1.48	1.42	1.45
60.0	40.0	1.36	1.43	1.45
70.0	40.0	1.43	1.43	1.44
80.0	40.0	1.36	1.51	1.47
90.0	40.0	1.51	1.40	1.46
0.0	50.0	1.63	1.56	1.54
10.0	50.0	1.46	1.54	1.54
20.0	50.0	1.58	1.43	1.49
30.0	50.0	1.49	1.52	1.46
40.0	50.0	1.41	1.41	1.45
50.0	50.0	1.48	1.45	1.43
60.0	50.0	1.43	1.38	1.43
70.0	50.0	1.44	1.38	1.45
80.0	50.0	1.57	1.50	1.46
90.0	50.0	1.49	1.58	1.49
0.0	60.0	1.60	1.58	1.53
10.0	60.0	1.52	1.49	1.52
20.0	60.0	1.38	1.42	1.50
30.0	60.0	1.46	1.47	1.47
40.0	60.0	1.39	1.45	1.45
50.0	60.0	1.45	1.39	1.43
60.0	60.0	1.38	1.37	1.44
70.0	60.0	1.40	1.37	1.46
80.0	60.0	1.52	1.57	1.48
90.0	60.0	1.59	1.44	1.48
0.0	70.0	1.52	1.44	1.53
10.0	70.0	1.54	1.44	1.51
20.0	70.0	1.40	1.51	1.50
30.0	70.0	1.50	1.51	1.46
40.0	70.0	1.46	1.41	1.45
50.0	70.0	1.41	1.46	1.44
60.0	70.0	1.29	1.43	1.45
70.0	70.0	1.44	1.54	1.46
80.0	70.0	1.56	1.43	1.48
90.0	70.0	1.42	1.54	1.51
0.0	80.0	1.52	1.52	1.54
10.0	80.0	1.46	1.52	1.52
20.0	80.0	1.51	1.48	1.50
30.0	80.0	1.53	1.45	1.47
40.0	80.0	1.43	1.52	1.47
50.0	80.0	1.53	1.48	1.44
60.0	80.0	1.48	1.44	1.44
70.0	80.0	1.55	1.53	1.46
80.0	80.0	1.52	1.51	1.48

Table A5.6 continued

1	2	3	4	5
90.0	80.0	1.51	1.49	1.49
0.0	90.0	1.61	1.55	1.53
10.0	90.0	1.61	1.50	1.51
20.0	90.0	1.54	1.48	1.50
30.0	90.0	1.47	1.52	1.49
40.0	90.0	1.50	1.43	1.46
50.0	90.0	1.51	1.52	1.45
60.0	90.0	1.27	1.46	1.46
70.0	90.0	1.53	1.39	1.45
80.0	90.0	1.47	1.51	1.48
90.0	90.0	1.51	1.48	1.49
0.0	100.0	1.56	1.48	1.54
10.0	100.0	1.49	1.48	1.52
20.0	100.0	1.44	1.48	1.51
30.0	100.0	1.50	1.39	1.48
40.0	100.0	1.39	1.56	1.48
50.0	100.0	1.56	1.56	1.44
60.0	100.0	1.39	1.34	1.44
70.0	100.0	1.38	1.40	1.44
80.0	100.0	1.48	1.49	1.46
90.0	100.0	1.49	1.50	1.47
0.0	110.0	1.61	1.53	1.52
10.0	110.0	1.52	1.54	1.51
20.0	110.0	1.47	1.42	1.49
30.0	110.0	1.40	1.50	1.48
40.0	110.0	1.54	1.42	1.45
50.0	110.0	1.45	1.47	1.44
60.0	110.0	1.34	1.34	1.44
70.0	110.0	1.31	1.38	1.45
80.0	110.0	1.51	1.49	1.44
90.0	110.0	1.49	1.50	1.47

Table A5.7 Hydraulic Conductivity for Hybrid (nonparametric) and Kriging (parametric) methods (Site B) (m/day)

1. X coordinates (meters)
2. Y coordinates (meters)
3. Measured values (m/day)
4. Hybrid estimates (m/day)
5. Kriged estimates (m/day)

1	2	3	4	5
0.0	0.0	0.47	1.17	1.12
10.0	0.0	0.81	1.17	0.82
20.0	0.0	1.17	0.81	0.86
30.0	0.0	0.72	0.74	1.26
40.0	0.0	0.69	1.95	1.68
50.0	0.0	4.38	0.72	1.25
60.0	0.0	1.00	1.70	1.82
70.0	0.0	0.91	0.81	1.22
80.0	0.0	1.12	0.45	0.78
90.0	0.0	0.47	0.84	0.90
0.0	10.0	1.29	0.57	0.83
10.0	10.0	0.47	0.57	0.88
20.0	10.0	1.07	0.59	0.84
30.0	10.0	0.75	1.07	1.21
40.0	10.0	2.15	1.01	1.44
50.0	10.0	1.57	2.21	1.92
60.0	10.0	1.96	0.97	1.44
70.0	10.0	0.54	0.84	1.16
80.0	10.0	0.43	0.84	0.84
90.0	10.0	0.84	0.44	0.73
0.0	20.0	1.32	0.60	0.80
10.0	20.0	0.81	0.48	0.81
20.0	20.0	0.62	0.96	0.94
30.0	20.0	0.86	0.98	1.21
40.0	20.0	1.28	2.19	1.59
50.0	20.0	2.23	1.26	1.57
60.0	20.0	1.23	1.52	1.50
70.0	20.0	0.94	1.03	1.10
80.0	20.0	0.71	0.74	0.82
90.0	20.0	0.71	0.82	0.81
0.0	30.0	0.58	0.94	0.95
10.0	30.0	0.40	0.96	0.96
20.0	30.0	1.01	0.60	0.95
30.0	30.0	1.34	0.99	1.21
40.0	30.0	2.19	1.32	1.39
50.0	30.0	1.36	2.07	1.67
60.0	30.0	1.30	1.22	1.47
70.0	30.0	1.64	0.88	1.07

Table A5.7 continued

1	2	3	4	5
90.0	30.0	0.88	0.78	0.86
0.0	40.0	0.93	0.55	0.85
10.0	40.0	1.66	1.20	0.86
20.0	40.0	1.11	1.01	1.09
30.0	40.0	0.99	1.11	1.27
40.0	40.0	1.07	1.36	1.58
50.0	40.0	1.79	1.24	1.68
60.0	40.0	1.18	1.41	1.70
70.0	40.0	0.79	0.54	1.35
80.0	40.0	0.80	1.13	1.06
90.0	40.0	0.79	0.76	0.97
0.0	50.0	0.25	0.74	0.94
10.0	50.0	1.43	1.00	0.89
20.0	50.0	1.13	1.32	1.07
30.0	50.0	1.14	0.99	1.22
40.0	50.0	1.31	1.14	1.54
50.0	50.0	2.23	2.28	1.82
60.0	50.0	3.59	1.01	1.58
70.0	50.0	0.52	1.21	1.71
80.0	50.0	1.13	0.77	1.25
90.0	50.0	0.76	1.05	1.24
0.0	60.0	0.34	0.36	0.80
10.0	60.0	0.95	1.12	0.85
20.0	60.0	1.18	0.90	0.93
30.0	60.0	0.98	1.14	1.12
40.0	60.0	1.13	1.10	1.44
50.0	60.0	2.26	2.00	1.76
60.0	60.0	2.17	2.11	1.97
70.0	60.0	1.44	1.90	1.83
80.0	60.0	2.18	1.58	1.49
90.0	60.0	1.68	1.34	1.33
0.0	70.0	0.47	0.79	0.75
10.0	70.0	1.09	0.69	0.72
20.0	70.0	0.64	0.76	0.83
30.0	70.0	0.88	0.73	0.92
40.0	70.0	0.77	1.04	1.28
50.0	70.0	1.89	1.60	1.57
60.0	70.0	2.24	1.81	1.79
70.0	70.0	1.84	1.43	1.80
80.0	70.0	2.14	1.50	1.62
90.0	70.0	1.44	1.67	1.61
0.0	80.0	0.75	0.44	0.64
10.0	80.0	0.94	0.74	0.66
20.0	80.0	0.70	0.62	0.71
30.0	80.0	0.71	0.82	0.81
40.0	80.0	0.83	0.71	1.08
50.0	80.0	1.35	1.37	1.48
60.0	80.0	1.54	1.95	1.75
70.0	80.0	0.94	1.42	1.86
80.0	80.0	1.38	1.82	1.72

Table A5.7 continued

1	2	3	4	5
90.0	80.0	1.64	1.21	1.48
0.0	90.0	0.42	0.61	0.69
10.0	90.0	0.72	0.50	0.66
20.0	90.0	0.49	1.57	0.76
30.0	90.0	0.73	0.40	0.80
40.0	90.0	0.67	1.29	1.15
50.0	90.0	1.27	2.27	1.54
60.0	90.0	2.26	1.66	1.63
70.0	90.0	1.76	1.17	1.69
80.0	90.0	2.37	1.33	1.45
90.0	90.0	1.21	1.70	1.55
0.0	100.0	0.50	0.43	0.63
10.0	100.0	0.54	1.02	0.74
20.0	100.0	1.71	0.50	0.61
30.0	100.0	0.40	1.24	1.04
40.0	100.0	1.33	0.99	1.24
50.0	100.0	2.51	1.21	1.48
60.0	100.0	1.86	2.61	1.86
70.0	100.0	0.92	1.77	1.90
80.0	100.0	1.28	1.02	1.54
90.0	100.0	1.52	1.13	1.26
0.0	110.0	0.45	0.52	0.72
10.0	110.0	0.83	0.50	0.71
20.0	110.0	0.60	0.80	0.94
30.0	110.0	0.92	0.88	1.08
40.0	110.0	1.78	0.68	1.25
50.0	110.0	0.73	2.24	1.98
60.0	110.0	2.87	1.75	1.66
70.0	110.0	2.65	1.24	1.59
80.0	110.0	1.10	0.88	1.57
90.0	110.0	0.69	1.30	1.51

Table A5.8 Available water for Hybrid (nonparametric) and Kriging (parametric) estimation methods (Site B) (%/volume)

1. X coordinates (meters)
2. Y coordinates (meters)
3. Measured values (%/volume)
4. Hybrid estimates (%/volume)
5. Kriged estimates (%/volume)

1	2	3	4	5
0.0	0.0	2.01	1.38	3.71
30.0	0.0	3.99	1.25	3.34
60.0	0.0	2.62	2.75	3.89
90.0	0.0	2.75	2.62	4.33
120.0	0.0	2.86	5.89	5.00
150.0	0.0	6.04	5.40	5.53
180.0	0.0	7.25	5.85	6.17
210.0	0.0	6.31	8.48	6.62
240.0	0.0	8.94	5.66	5.79
270.0	0.0	8.70	2.65	5.46
0.0	30.0	1.38	4.90	3.91
30.0	30.0	4.29	1.92	3.67
60.0	30.0	4.00	3.96	4.07
90.0	30.0	3.81	3.96	4.52
120.0	30.0	6.33	3.85	4.96
150.0	30.0	5.69	6.13	6.03
180.0	30.0	5.37	7.13	6.70
210.0	30.0	8.40	6.00	6.13
240.0	30.0	2.23	5.32	6.37
270.0	30.0	2.70	5.49	5.93
0.0	60.0	6.44	2.08	3.28
30.0	60.0	4.19	5.64	4.23
60.0	60.0	5.53	4.91	4.40
90.0	60.0	5.19	5.07	4.85
120.0	60.0	4.98	5.04	5.66
150.0	60.0	6.79	7.15	6.35
180.0	60.0	7.01	6.78	6.73
210.0	60.0	6.77	7.57	6.35
240.0	60.0	6.25	3.20	5.19
270.0	60.0	4.93	2.25	4.59
0.0	90.0	3.10	4.08	4.00
30.0	90.0	4.17	5.02	4.49
60.0	90.0	4.99	4.48	4.98
90.0	90.0	5.20	5.07	5.36
120.0	90.0	4.28	4.26	6.06
150.0	90.0	7.81	7.79	6.45
180.0	90.0	8.04	7.89	6.89
210.0	90.0	8.76	6.93	6.05
240.0	90.0	2.77	1.66	5.55

Table A5.8 continued

1	2	3	4	5
270.0	90.0	.66	4.27	5.08
0.0	120.0	1.39	3.56	4.23
30.0	120.0	5.94	4.80	4.38
60.0	120.0	5.18	5.50	5.39
90.0	120.0	8.25	5.19	5.29
120.0	120.0	3.31	6.78	6.37
150.0	120.0	7.76	7.77	6.43
180.0	120.0	7.85	7.79	6.81
210.0	120.0	7.98	5.71	6.07
240.0	120.0	3.63	3.82	5.52
270.0	120.0	5.95	3.[illegible]4	4.53
0.0	150.0	3.64	0.83	3.53
30.0	150.0	5.14	4.17	4.68
60.0	150.0	4.70	10.60	5.82
90.0	150.0	5.43	4.43	5.87
120.0	150.0	3.87	4.72	6.31
150.0	150.0	7.68	7.67	6.26
180.0	150.0	6.30	5.70	6.67
210.0	150.0	6.05	6.36	6.27
240.0	150.0	2.86	6.09	6.01
270.0	150.0	6.11	6.32	5.18
0.0	180.0	0.77	2.89	3.92
30.0	180.0	4.44	4.30	4.82
60.0	180.0	12.48	5.53	5.00
90.0	180.0	4.95	5.35	6.21
120.0	180.0	4.30	4.87	6.18
150.0	180.0	8.30	6.50	5.96
180.0	180.0	5.69	6.27	6.44
210.0	180.0	6.45	5.92	6.06
240.0	180.0	6.75	6.34	5.67
270.0	180.0	6.80	6.02	5.38
0.0	210.0	2.38	0.93	3.29
30.0	210.0	4.29	4.40	4.54
60.0	210.0	7.92	5.16	5.40
90.0	210.0	5.61	5.72	5.91
120.0	210.0	4.82	4.99	5.94
150.0	210.0	7.17	5.75	5.83
180.0	210.0	6.06	6.48	6.07
210.0	210.0	5.90	5.83	6.04
240.0	210.0	5.49	5.37	5.82
270.0	210.0	5.76	6.02	5.68
0.0	240.0	1.41	1.91	3.20
30.0	240.0	3.95	4.33	4.08
60.0	240.0	4.39	6.28	5.29
90.0	240.0	5.78	4.38	5.51
120.0	240.0	4.37	5.75	5.78
150.0	240.0	5.22	4.19	5.75
180.0	240.0	6.49	6.22	5.80
210.0	240.0	6.38	6.12	5.75
240.0	240.0	5.25	5.02	5.51

Table A5.8 continued

1	2	3	4	5
270.0	240.0	5.28	4.73	5.40
0.0	270.0	1.60	0.93	2.93
30.0	270.0	4.41	4.51	3.82
60.0	270.0	6.53	4.39	4.67
90.0	270.0	5.69	6.23	5.38
120.0	270.0	6.46	3.42	5.35
150.0	270.0	3.30	6.80	5.95
180.0	270.0	6.24	6.18	5.80
210.0	270.0	6.45	6.09	5.60
240.0	270.0	2.76	5.05	5.75
270.0	270.0	4.96	5.32	5.31
0.0	300.0	0.53	1.38	3.46
30.0	300.0	4.75	4.80	3.80
60.0	300.0	4.19	4.63	4.93
90.0	300.0	5.51	5.61	5.20
120.0	300.0	3.51	5.07	5.82
150.0	300.0	8.12	5.07	5.40
180.0	300.0	6.30	6.33	5.89
210.0	300.0	6.12	4.71	5.67
240.0	300.0	6.07	6.15	5.34
270.0	300.0	5.51	4.44	5.19
0.0	330.0	1.34	4.91	3.80
30.0	330.0	6.46	2.62	3.62
60.0	330.0	4.63	6.29	5.00
90.0	330.0	6.28	4.63	5.07
120.0	330.0	4.83	5.84	5.61
150.0	330.0	6.02	6.33	5.77
180.0	330.0	6.35	4.71	5.79
210.0	330.0	4.71	6.39	5.97
240.0	330.0	6.42	4.52	5.38
270.0	330.0	4.52	6.00	5.62

Table A5.9 Field capacity for Hybrid (nonparametric) and Kriging (parametric) estimation methods (Site B) (%/volume)

1. X coordinates (meters)
2. Y coordinates (meters)
3. Measured values (%/volume)
4. Hybrid estimates (%/volume)
5. Kriged estimates (%/volume)

1	2	3	4	5
0.0	0.0	30.72	22.64	20.60
30.0	0.0	15.50	14.38	21.47
60.0	0.0	14.00	14.61	19.93
90.0	0.0	13.59	13.57	20.09
120.0	0.0	19.44	25.28	21.37
150.0	0.0	29.31	20.23	22.45
180.0	0.0	26.01	19.37	24.24
210.0	0.0	19.37	26.29	25.70
240.0	0.0	26.30	22.94	25.20
270.0	0.0	27.92	28.50	24.84
0.0	30.0	29.87	17.14	21.20
30.0	30.0	14.49	15.49	21.21
60.0	30.0	28.19	13.97	17.69
90.0	30.0	12.68	13.87	19.56
120.0	30.0	25.25	19.99	20.12
150.0	30.0	20.28	26.14	23.46
180.0	30.0	27.74	29.52	24.20
210.0	30.0	30.23	18.88	24.61
240.0	30.0	28.20	27.68	24.85
270.0	30.0	29.63	18.92	24.70
0.0	60.0	20.76	29.05	23.15
30.0	60.0	15.18	18.01	21.34
60.0	60.0	15.53	14.62	19.30
90.0	60.0	13.88	17.29	19.27
120.0	60.0	22.88	19.72	19.92
150.0	60.0	22.76	23.10	22.59
180.0	60.0	30.71	23.05	23.55
210.0	60.0	18.26	28.37	25.73
240.0	60.0	19.49	15.81	25.49
270.0	60.0	15.81	29.47	26.56
0.0	90.0	30.92	27.72	22.44
30.0	90.0	22.55	19.27	21.46
60.0	90.0	17.10	19.54	19.90
90.0	90.0	18.15	15.99	19.16
120.0	90.0	15.39	15.82	20.68
150.0	90.0	21.33	23.74	22.22
180.0	90.0	23.54	22.34	23.96
210.0	90.0	27.17	25.70	24.54
240.0	90.0	25.54	28.69	25.10

Table A5.9 continued

1	2	3	4	5
270.0	90.0	34.06	25.61	23.68
0.0	120.0	30.65	16.42	23.16
30.0	120.0	20.00	29.12	22.81
60.0	120.0	21.93	20.16	20.61
90.0	120.0	25.06	15.05	19.38
120.0	120.0	15.82	22.92	21.07
150.0	120.0	24.52	20.48	21.92
180.0	120.0	18.99	25.13	24.31
210.0	120.0	26.45	21.12	24.40
240.0	120.0	26.96	27.44	24.81
270.0	120.0	25.84	26.74	24.50
0.0	150.0	16.42	30.71	26.09
30.0	150.0	27.23	16.42	22.71
60.0	150.0	20.39	23.36	21.57
90.0	150.0	14.73	17.71	20.97
120.0	150.0	20.16	19.37	20.94
150.0	150.0	28.74	24.70	21.86
180.0	150.0	26.03	22.87	23.33
210.0	150.0	21.55	26.20	24.38
240.0	150.0	33.17	19.19	22.65
270.0	150.0	18.99	24.30	23.99
0.0	180.0	32.25	19.27	24.50
30.0	180.0	20.96	25.58	24.38
60.0	180.0	~~25.51~~	20.47	21.64
90.0	180.0	14.78	17.21	21.38
120.0	180.0	19.74	21.97	21.13
150.0	180.0	24.62	24.67	22.20
180.0	180.0	24.84	22.76	22.88
210.0	180.0	20.29	21.57	23.22
240.0	180.0	19.64	19.64	22.54
270.0	180.0	21.48	17.84	21.40
0.0	210.0	31.36	31.26	25.26
30.0	210.0	23.11	26.04	24.47
60.0	210.0	26.31	19.86	21.77
90.0	210.0	19.07	19.50	21.13
120.0	210.0	22.16	19.16	20.76
150.0	210.0	24.55	20.79	21.56
180.0	210.0	23.48	24.82	22.37
210.0	210.0	21.71	20.16	21.96
240.0	210.0	16.75	17.20	21.21
270.0	210.0	17.24	18.56	20.47
0.0	240.0	31.23	28.76	25.42
30.0	240.0	21.48	20.81	24.59
60.0	240.0	20.38	20.90	22.30
90.0	240.0	19.09	19.21	21.12
120.0	240.0	15.67	20.32	21.36
150.0	240.0	14.01	15.27	22.15
180.0	240.0	30.83	21.20	20.88
210.0	240.0	23.72	27.90	21.43
240.0	240.0	19.31	16.88	20.50

Table A5.9 continued

1	2	3	4	5
270.0	240.0	16.92	15.19	20.17
0.0	270.0	30.86	26.96	24.97
30.0	270.0	20.68	21.00	20.20
60.0	270.0	20.84	20.49	22.18
90.0	270.0	21.92	26.49	21.32
120.0	270.0	29.76	14.00	20.27
150.0	270.0	13.28	19.33	22.30
180.0	270.0	17.22	19.41	22.05
210.0	270.0	28.34	21.91	20.67
240.0	270.0	19.57	16.48	20.81
270.0	270.0	15.19	21.87	20.93
0.0	300.0	30.13	30.40	24.57
30.0	300.0	19.53	22.74	23.99
60.0	300.0	17.28	15.89	22.57
90.0	300.0	25.67	22.05	21.34
120.0	300.0	21.71	22.50	22.10
150.0	300.0	24.70	21.45	21.67
180.0	300.0	18.49	18.04	22.02
210.0	300.0	23.15	17.27	21.16
240.0	300.0	21.09	24.68	21.19
270.0	300.0	24.02	15.71	19.92
0.0	330.0	30.36	24.34	24.41
30.0	330.0	23.67	18.00	23.18
60.0	330.0	15.89	21.71	23.34
90.0	330.0	22.29	18.32	22.21
120.0	330.0	22.50	25.84	22.63
150.0	330.0	30.11	22.06	21.25
180.0	330.0	18.84	17.27	22.21
210.0	330.0	17.27	23.83	21.87
240.0	330.0	24.77	17.51	20.49
270.0	330.0	16.83	24.26	21.25

APPENDIX B

```
10 '
20 '***************  THIS IS THE MAIN PROGRAM  ********************
30 '
40 OPTION BASE 1
50 CLEAR,,5000
60 DIM GRID(170,10)
70 IF CODE = 1 THEN 230
80 KEY OFF
90 CLS
100 CFLAG$ = "false"
110 GF$ = SPACE$(1)
120 FILE$ = SPACE$(1)
130 LOCATE 8,18,0: PRINT "Please enter drive containing data disk."
140 LOCATE 10,25,0: PRINT "( Enter  A  or  B ): _"
150 A$ = INKEY$: IF A$ = "" THEN 150
160 IF A$ = "A" OR A$ = "a" THEN GOTO 190
170 IF A$ = "B" OR A$ = "b" THEN GOTO 200
180 BEEP: GOTO 150
190 DRIVE$ = "a:" : GOTO 210
200 DRIVE$ = "b:"
210 CLS
220 '
230 '********************* MAIN MENU **********************************
240 '
250 CLS
260 LOCATE 22,50,0: PRINT "Current File: "; FILE$
270 LOCATE 5,36,0: PRINT "MAIN MENU"
280 LOCATE 7,25,0: PRINT "1          Create a New File"
290 LOCATE 8,25,0: PRINT "2          Edit an Existing File"
300 LOCATE 9,25,0: PRINT "3          Run Program using an Existing File"
310 LOCATE 11,25,0: PRINT "Esc        Exit from Program"
320 LOCATE 16,27,0: PRINT "Enter Choice ==>"
330 A$ = INKEY$
340 IF A$ = "" THEN 330
350 IF A$ = "1" THEN 410
360 IF A$ = "2" THEN 830
370 IF A$ = "3" THEN GOTO 1280
380 IF ASC(A$) = 27 THEN 3670
390 BEEP: GOTO 330
400 '
410 '*********************************************************************
420 '
430 CLS
440 LOCATE 5,8,0
450 PRINT "Enter the name of the new file (maximum 8 characters) ==>"
460 LOCATE 10,12,0: PRINT "WARNING: Using a file name that already exist will"
470 LOCATE 11,21,0: PRINT "replace the data in the old file."
480 LOCATE 22,50,0: PRINT "Current File: "; FILE$
490 LOCATE 5,67,0: INPUT " ",FILE$
500 IF FILE$ = "" THEN 490
510 IF LEN(FILE$) <= 8 THEN 600
520 BEEP:BEEP:BEEP:BEEP
530 LOCATE 15,17,0
540 PRINT "*** Error: The file name is more than 8 characters ***"
```

```
550 FOR I= 1 TO 2500: NEXT I
560 LOCATE 15,17,0: PRINT SPACE$(60)
570 LOCATE 5,67,0: PRINT SPACE$(14)
580 LOCATE 6,1,0: PRINT SPACE$(80)
590 GOTO 490
600 LOCATE 22,63,0: PRINT SPACE$(18)
610 LOCATE 22,50,0: PRINT "Current File: "; FILE$
620 FOR I = 1 TO 2000: NEXT I
630 CTR1 = 0
640 GOSUB 1740
650 GOSUB 1950
660 GOSUB 3440
670 CLS: LOCATE 12,30,0: PRINT "Saving File ";FILE$;"...";
680 FOR I = 1 TO 2000: NEXT I
690 IF CTR1 <> 0 THEN 730
700 PRINT "  NOT SAVED"
710 FOR I = 1 TO 2500: NEXT I
720 GOTO 250
730 DFILE$ = DRIVE$ + FILE$ + DAT$
740 OPEN DFILE$ FOR OUTPUT AS £1
750 FOR I = 1 TO CTR1
760 WRITE £1, GRID(I,1), GRID(I,2), GRID(I,3)
770 NEXT I
780 PRINT "Done"
790 FOR I = 1 TO 1500: NEXT I
800 CLOSE £1
810 GOTO 250
820 '
830 '****************************************************************
840 '
850 GOSUB 1420
860 GOSUB 1740
870 GOSUB 1840
880 GOSUB 1990
890 IF CFLAG$ = "false" THEN 1260
900 CLS
910 LOCATE 22,50,0: PRINT "Current File: "; FILE$
920 LOCATE 8,15,0: PRINT "Would you like to replace the updated data into"
930 LOCATE 9,15,0: PRINT "a new file (i.e. leave the old file unchanged)"
940 LOCATE 10,35,1: PRINT "(Y/N) ==>"
950 A$ = INKEY$: IF A$ = "" THEN 950
960 IF A$ ="Y" OR A$ ="y" THEN 990
970 IF A$ = "N" OR A$ = "n" THEN 1140
980 BEEP: GOTO 950
990 LOCATE 15,8,0
1000 INPUT "Enter name of new file (max 8 characters) ==> "; FILE$
1010 IF FILE$ = "" THEN 1000
1020 IF LEN(FILE$) <= 8 THEN 1100
1030 BEEP:BEEP:BEEP:BEEP
1040 LOCATE 18,13,0
1050 PRINT "*** Error: The file name is more than 8 characters ***"
1060 FOR I = 1 TO 2500: NEXT I
1070 LOCATE 18,13,0: PRINT SPACE$(60)
1080 LOCATE 15,54,0: PRINT SPACE$(26)
```

```
1090 GOTO 990
1100 DFILE$ = "b:" + FILE$ + ".DAT"
1110 LOCATE 15,8,0: PRINT SPACE$(73)
1120 LOCATE 22,63,0: PRINT SPACE$(18)
1130 LOCATE 22,50,0: PRINT "Current File: "; FILE$
1140 LOCATE 15,30,0: PRINT "Saving File "; FILE$; "...";
1150 IF CTR1 <> 0 THEN 1180
1160 PRINT "NOT SAVED"
1170 GOTO 1240
1180 OPEN DFILE$ FOR OUTPUT AS £1
1190 FOR I = 1 TO CTR1
1200 WRITE £1, GRID(I,1), GRID(I,2), GRID(I,3)
1210 NEXT I
1220 PRINT "Done"
1230 CLOSE £1
1240 FOR I = 1 TO 1500: NEXT I
1250 CFLAG$ = "false"
1260 GOTO 250
1270 '
1280 '*******************************************************************
1290 '
1300 GOSUB 1420
1310 OPEN "INFO.DAT" FOR OUTPUT AS£5
1320 OUT$ = ".OUT"
1330 WRITE £5, DRIVE$,FILE$,DAT$,OUT$
1340 PRINT £5, CTR1
1350 FOR I = 1 TO CTR1        'Maximum number of data
1360    FOR J = 1 TO 3
1370         PRINT £5, GRID(I,J)     'Writing the data into a file
1380    NEXT J
1390 NEXT I
1400 CLOSE £5
1410 CHAIN "a:hybrid"      'Chaining to the subroutine hybrid
1420 '*******************************************************************
1430 CLS
1440 LOCATE 5,20,0: PRINT "Enter File (maximum 8 characters) ==>"
1450 LOCATE 22,50,0: PRINT "Current File: "; FILE$
1460 LOCATE 5,57,1: INPUT " "; F$
1470 IF F$ = "" THEN 1460
1480 IF LEN(F$) <= 8 THEN 1560
1490 BEEP:BEEP:BEEP:BEEP
1500 LOCATE 12,16,0
1510 PRINT "*** Error: The file name is more than 8 characters ***"
1520 FOR I = 1 TO 2500: NEXT I
1530 LOCATE 12,16,0: PRINT SPACE$(60)
1540 LOCATE 5,57,0: PRINT SPACE$(24)
1550 GOTO 1460
1560 IF F$ = FILE$ THEN 1720
1570 FILE$ = F$
1580 LOCATE 12,30,0: PRINT "Loading File "; FILE$; "...";
1590 DAT$ = ".DAT"
1600 DFILE$ = DRIVE$ + FILE$ + DAT$
1610 OPEN DFILE$ FOR INPUT AS £1
1620 CTR1 = 0
```

```
1630 IF EOF(1) THEN 1670
1640 CTR1 = CTR1 + 1
1650 INPUT £1, GRID(CTR1,1), GRID(CTR1,2), GRID(CTR1,3)
1660 GOTO 1630
1670 PRINT "Done"
1680 LOCATE 22,63,0: PRINT SPACE$(18)
1690 LOCATE 22,50,0: PRINT "Current File: "; FILE$
1700 FOR I = 1 TO 2500: NEXT I
1710 CLOSE £1
1720 RETURN
1730 '
1740 '************************************************************************
1750 '
1760 CLS
1770 LOCATE 1,5,0: PRINT "Enter:  X co-ordinate, Y co-ordinate, Weight"
1780 LOCATE 2,5,0: PRINT "..............................................
1790 LOCATE 2,57,0: PRINT "...................."
1800 LOCATE 16,5,0: PRINT "..............................................
1810 LOCATE 16,56,0: PRINT "....................."
1820 RETURN
1830 '
1840 '****************************************************************
1850 '
1860 LOCATE 18,6,0
1870 PRINT "*** Enter  Esc  when all the data has been entered ***"
1880 LOCATE 20,6,0: PRINT "Hit:   U - Scroll Up          D - Scroll Down"
1890 LOCATE 21,6,0: PRINT "       I - Insert a Line      O - Omit a Line"
1900 LOCATE 21,55,0: PRINT"C - Change a Line"
1910 RETURN
1920 '
1930 '**************************************************************
1940 '
1950 LOCATE 18,6,0
1960 PRINT "*** Enter  0,0,0 when all the data has been entered ***"
1970 RETURN
1980 '
1990 '**************************************************************
2000 '
2010 N=4: CTR2=1: CTR3=0
2020 IF CTR3 = CTR1 OR N = 14 THEN 2080
2030 CTR3 = CTR3 + 1
2040 LOCATE N,6,0: PRINT CTR3;": ";GRID(CTR3,1);" ";GRID(CTR3,2);" ";
2050 PRINT GRID(CTR3,3)
2060 N = N + 1
2070 GOTO 2020
2080 A$ = INKEY$: IF A$ = "" THEN 2080
2090 IF A$ = "U" OR A$ = "u" THEN 2260
2100 IF A$ = "D" OR A$ = "d" THEN 2190
2110 IF A$ = "I" OR A$ = "i" THEN 2330
2120 IF A$ = "O" OR A$ = "o" THEN 2510
2130 IF A$ = "C" OR A$ = "c" THEN 2710
2140 IF ASC(A$) = 27 THEN RETURN
2150 BEEP: GOTO 2080
2160 '
```

```
2170 '*********************  DOWN SCREEN  ****************************
2180 '
2190 IF CTR3 <> CTR1 THEN 2210
2200 BEEP: GOTO 2080
2210 GOSUB 3140
2220 GOTO 2080
2230 '
2240 '*********************  UP SCREEN  *******************************
2250 '
2260 IF CTR2 <> 1 THEN 2280
2270 BEEP: GOTO 2080
2280 GOSUB 3270
2290 GOTO 2080
2300 '
2310 '*********************  INSERT  ******************************
2320 '
2330 FOR I = 18 TO 22
2340 LOCATE I,1,0: PRINT SPACE$(80)
2350 NEXT I
2360 LOCATE 18,10,0: INPUT "Enter line number to insert after: "; L
2370 IF ((L > CTR1) OR (L < 0)) THEN 2430
2380 GOSUB 3030
2390 LOCATE 20,5,0: INPUT "Enter X,Y,Weight:  "; X,Y,W
2400 GOSUB 2920
2410 L = L+1
2420 GOSUB 3030
2430 FOR I = 18 TO 22
2440 LOCATE I,1,0: PRINT SPACE$(80)
2450 NEXT I
2460 GOSUB 1860
2470 GOTO 2080
2480 '
2490 '*********************  DELETE  ******************************
2500 '
2510 FOR I = 18 TO 22
2520 LOCATE I,1,0: PRINT SPACE$(80)
2530 NEXT I
2540 LOCATE 18,10,0: INPUT "Enter the line number to delete: "; L
2550 IF ((L < 1) OR (L > CTR1)) THEN 2630
2560 FOR I = L TO CTR1
2570 GRID(I,1) = GRID(I+1,1): GRID(I,2) = GRID(I+1,2): GRID(I,3) = GRID(I+1,3)
2580 NEXT I
2590 CTR1 = CTR1 - 1
2600 CFLAG$ = "true"
2610 L = L - 1
2620 GOSUB 3030
2630 FOR I = 18 TO 22
2640 LOCATE I,1,0: PRINT SPACE$(80)
2650 NEXT I
2660 GOSUB 1860
2670 GOTO 2080
2680 '
2690 '*********************  CHANGE  ******************************
2700 '
```

```
2710 FOR I = 18 TO 22
2720 LOCATE I,1,0: PRINT SPACE$(80)
2730 NEXT I
2740 LOCATE 18,10,0: INPUT "Enter line number to be changed: "; L
2750 IF ((L < 1) OR (L > CTR1)) THEN 2840
2760 GOSUB 3030
2770 FOR I = 19 TO 22
2780 LOCATE I,1,0: PRINT SPACE$(80)
2790 NEXT I
2800 LOCATE 20,5,0: INPUT "Enter X,Y,Weight:  "; X,Y,W
2810 GRID(L,1) = X: GRID(L,2) = Y: GRID(L,3) = W
2820 CFLAG$ = "true"
2830 GOSUB 3030
2840 FOR I = 18 TO 22
2850 LOCATE I,1,0: PRINT SPACE$(80)
2860 NEXT I
2870 GOSUB 1860
2880 GOTO 2080
2890 '
2900 '*******************  INSERT INTO ARRAY  **********************
2910 '
2920 COUNT = L + 1
2930 FOR I = CTR1 TO COUNT STEP -1
2940 GRID(I+1,1) = GRID(I,1)
2950 GRID(I+1,2) = GRID(I,2)
2960 GRID(I+1,3) = GRID(I,3)
2970 NEXT I
2980 GRID(COUNT,1) = X: GRID(COUNT,2) = Y: GRID(COUNT,3) = W
2990 CTR1 = CTR1 + 1
3000 CFLAG$ = "true"
3010 RETURN
3020 '
3030 '********************  POSITION SCREEN  ************************
3040 '
3050 IF (L<> -1) THEN 3080
3060 CTR2 = 9
3070 GOTO 3090
3080 CTR2 = L + 9
3090 GOSUB 3290
3100 RETURN
3110 '
3120 '*******************  SCROLL DOWN  *****************************
3130 '
3140 CTR2 = CTR3-3: CTR3 = CTR2-1: N=4
3150 IF CTR3 <> CTR1 THEN 3200
3160 LOCATE N,6,0: PRINT SPACE$(74)
3170 N = N + 1
3180 IF N <> 15 THEN 3160
3190 RETURN
3200 IF N=14 THEN RETURN
3210 CTR3 = CTR3+1
3220 LOCATE N,6,0: PRINT SPACE$(74)
3230 LOCATE N,6,0: PRINT CTR3;": "; GRID(CTR3,1); " "; GRID(CTR3,2);
3240 PRINT " "; GRID(CTR3,3)
```

```
3250 N = N + 1: GOTO 3150
3260 '
3270 '******************  SCROLL UP  **********************************
3280 '
3290 CTR2 = CTR2-9
3300 IF CTR2 < 1 THEN CTR2 = 1
3310 CTR3 = CTR2-1: N = 4
3320 IF (N = 14) THEN RETURN
3330 IF CTR1<>CTR3 THEN 3380
3340 FOR I = N TO 14
3350 LOCATE I,1,0: PRINT SPACE$(80)
3360 NEXT I
3370 RETURN
3380 CTR3 = CTR3 + 1
3390 LOCATE N,6,0: PRINT SPACE$(74)
3400 LOCATE N,6,0: PRINT CTR3;": "; GRID(CTR3,1); " "; GRID(CTR3,2);
3410 PRINT " "; GRID(CTR3,3)
3420 N = N + 1: GOTO 3320
3430 '
3440 '*************************************************************
3450 '
3460 CTR1 = 0: N = 4
3470 FLAG$ = "true"
3480 WHILE FLAG$ = "true"
3490 CTR1 = CTR1 + 1
3500 LOCATE N,6,0: PRINT CTR1; ": "
3510 LOCATE N,10,0: INPUT X,Y,W
3520 IF ((X <> 0) OR (Y <> 0) OR (W <> 0)) THEN 3550
3530 FLAG$ = "false": CTR1 = CTR1 - 1
3540 GOTO 3620
3550 GRID(CTR1,1) = X: GRID(CTR1,2) = Y: GRID(CTR1,3) = W
3560 ROW = CSRLIN: N = ROW
3570 IF (N<12) THEN 3620
3580 FOR N = 4 TO 15
3590 LOCATE N,1,0: PRINT SPACE$(80)
3600 NEXT N
3610 N = 4
3620 WEND
3630 RETURN
3640 '
3650 '*************************************************************
3660 '
3670 CLS
3680 END
```

```
10  '******************  SUBROUTINE HYBRID ***************************
20  '
30  'This subroutine is called from the main program to determine the
40  'estimated value of a point. Hybrid calls some other subroutines.
50  'After calculating the estimated values for all data points,
60  'control is transfered to the main program.
70  '
80  '****************************************************************
90  '
100 'D         = One dimentional array, distance between two points on
110 '            x-coordinate
120 'DX        = One dimentional array, distance between two points on
130 '            y-coordinate
140 'WDI       = One dimentional array, representing distance weighting
150 'CW        = One dimentional array, representing cluster weighting
160 'TWD       = One dimentional array, representing final weight
170 '            which is the product of distance and cluster weighting
180 'VALID     = Two dimentional array, x, y and measured values (input)
190 'KVALID    = Dummy array for valid
200 'P         = Dummy array for valid
210 'GRID      = Dummy array for valid
220 'INDICATE = Two dimentional dummy array for valid, used in
230 '            calculating Kendal's tau
240 '
250 '**************************************************************************
260 '
270 CLEAR,,5000
280 DIM D(2),WDI(40),DX(2),CW(40),TWD(40)
290 DIM P(1,3),KVALID(170,10),VALID(170,10),INDICATE(7,7),GRID(170,10)
300 OPEN "INFO.DAT" FOR INPUT AS£5        'Opening the data file
310 INPUT £5, DRIVE$,FILE$,DAT$,OUT$
320 INPUT £5, CTR1          'Maximum no. of data
330 FOR I = 1 TO CTR1
340     FOR J = 1 TO 3
350         INPUT £5, GRID(I,J)        'Reading data
360         IF EOF(5) THEN 390
370     NEXT J
380 NEXT I
390 CLOSE £5
400 CLS: LOCATE 10,35,0:PRINT "running program"
410 OFILE$ = DRIVE$ + FILE$ + OUT$          'Open the output file
420 OPEN OFILE$ FOR OUTPUT AS £2
430 PRINT" 1- X coordinates (meters)"
440 PRINT" 2- Y Coordinates (meters)"
450 PRINT" 3- Measured Values "
460 PRINT" 4- Estimated              "
470 PRINT" 5- Estimated Value + Two Standard Deviation"
480 PRINT" 6- Estimated Value - Two Standard Deviation"
490 PRINT
500 PRINT
510 PRINT
```

```
520 X$="        1               2               3               4               5               6"
530 Y$="..............................................................................."
540 PRINT X$
550 PRINT Y$
560 PRINT
570 PRINT
580 KTR1=CTR1        'Total no. of data lines in the data file
590 PRINT CTR1
600 T = 1
610 IF (T > KTR1) THEN 2560     'Checking for the end of data
620 SUMSQ = 0:SUMM = 0         'Sum of square and sum of measured points
630 FOR K = 1 TO KTR1
640 IF (K >= T ) THEN 670
650 VALID(K,1)=GRID(K,1):VALID(K,2)=GRID(K,2):VALID(K,3)=GRID(K,3) 'Transferin
660 SUMSQ = SUMSQ + VALID(K,3)^2:SUMM = SUMM + VALID(K,3):GOTO 710 'sum of
670 IF (K>T) THEN 690          'square and sum of measured values
680 P(1,1)=GRID(K,1):P(1,2)=GRID(K,2):P(1,3)=GRID(K,3):GOTO 710
690 VALID(K-1,1)=GRID(K,1):VALID(K-1,2)=GRID(K,2):VALID(K-1,3)=GRID(K,3)
700 SUMSQ = SUMSQ + VALID(K-1,3)^2:SUMM = SUMM + VALID(K-1,3)
710 NEXT K
720 CTR1=KTR1
730 SIGMA = SQR((SUMSQ - (SUMM^2)/CTR1)/(CTR1-1))
740 COUNT = 6                  'Estimating a point is based on 6 surrounding
750 FOR I=1 TO CTR1            'observations
760 FOR J= 1 TO 2
770 D(J)=P(1,J)- VALID(I,J)
780 NEXT J
790 DISTANCE = SQR((D(1)+.05)^2 + (D(2)+9.000001E-02)^2)  'Distance
800 VALID(I,4) = DISTANCE             'between any two points
810 NEXT I
820 SORT = 4
830 NUM = 4
840 GOSUB 900    'Sort the distances in an increasing order
850 GOTO 1090
860 '
870 '******************  SUBROUTINE SORT  ****************************
880 '
890 'This subroutine sorts the distance between any piont and 6
900 'neighbouring points in an increasing order. It also calculates
910 'the distance weighting for the above 6 points.
920 '
930 ' ******************************************************************
940 '
950 J=0
960 FOR I=1 TO CTR1-2
970 J=I+1
980 IF J> CTR1 - 1 THEN 1070         'Checking for end of data
990 IF VALID(I,SORT)<VALID(J,SORT) THEN 1060  'Comparing any 2 values
1000 IF VALID(I,SORT) > VALID(J,SORT) THEN 1030
1010 R = RND
1020 IF R > .5 THEN 1060
1030 FOR K=1 TO NUM
1040 SWAP VALID(I,K),VALID(J,K)  'Sorting in an increasing order
1050 NEXT K
```

```
1060 J= J+1  : GOTO 980
1070 NEXT I
1080 RETURN
1090 WTOTAL  = 0        'Total distance weighting
1100 FOR I= 1 TO COUNT
1110 WDI(I)  = VALID(1,4)^2/VALID(I,4)^2
1120 WTOTAL  = WTOTAL + WDI(I)
1130 NEXT I
1140 '
1150 '****************   SUBROUTINE  CLUSTER  *************************
1160 '
1170 'This subroutine uses subroutines area, sort and search to
1180 'calculate cluster weighting.
1190 '
1200 '*****************************************************************
1210 '
1220 CDPT = 1/COUNT
1230 CA=((1-CDPT)/.1)*1000
1240 FOR H=1  TO COUNT
1250 SORT = 5 :NUM=6
1260 GOSUB 1370       'Calculate the area
1270 GOSUB 900
1280 SORT = 6
1290 GOSUB 1540
1300 SORT = 4
1310 GOSUB 900     'Sort the distance
1320 NEXT H
1330 GOTO 1610     'Calculate Kendal's tau
1340 '
1350 '******************   SUBROUTINE AREA   ***************************
1360 '
1370 'This subroutine calculates the area of a circle. Center is at any
1380 'point to be estimated. Radius is the distance between that point
1390 'and any of 6 neighbouring points.
1400 '
1410 '********************************************************************
1420 '
1430 FOR I= 1 TO CTR1
1440 FOR J= 1 TO 2
1450 DX(J) = VALID(H,J)-VALID(I,J)
1460 NEXT J
1470 VALID(I,SORT)=SQR((DX(1)+.05)^2+(DX(2)+9.000001E-02)^2) 'Cal. radius
1480 VALID(I,6) = 3.14 * VALID(I,SORT)^2     'Area of circle
1490 NEXT I
1500 RETURN
```

```
1510 '
1520 '****************** SUBROUTINE SEARCH **********************************
1530 '
1540 'The main calculation for cluster weighting is done in this
1550 'subroutine. Cluster weighting is calculated as the ratio of the
1560 'ideal distribution and sampling distribution where maximum
1570 'deviation occurs between the two distributions.
1580 '
1590 '************************************************************************
1600 '
1610 I=1
1620 IF (I > 120) THEN 1660
1630 IF (VALID(I,SORT)< CA AND VALID(I+1,SORT) > CA) THEN 1650
1640 I=I+1:GOTO 1620
1650 SLOPE = ((I+1)/COUNT - I/COUNT)/(VALID(I+1,SORT)-VALID(I,SORT)):GOTO 1670
1660 Y = VALID(I,SORT): GOTO 1680
1670 Y = (SLOPE * CA + I/COUNT)
1680 MAX =ABS(1- Y):TRUE = 1      'Diff. between ideal and measured weight
1690 FOR L=1 TO I
1700 INITY =VALID(L,6)/10000 + 1/COUNT
1710 INIT =ABS(INITY-(L/COUNT))
1720 IF INIT< MAX THEN 1740  'Check for location where absolute value
1730 MAX = INIT:Y=L/COUNT: TRUE = VALID(L,6)/10000  'of max. deviation
1740 NEXT L                                          'occurs
1750 TRUE = TRUE + 1/COUNT
1760 CW(H)=TRUE/Y    'Calculation of cluster weighting
1770 RETURN
1780 '
1790 '********************* KENDAL'S TAU ***************************
1800 '
1810 'The distance between every point and 6 neighbouring points are
1820 'sorted in an increasing order. The measured value of each point
1830 'is compared with each more distant value and a -1 or +1 score is
1840 'assigned depending on the direction of increase or decrease of
1850 'measured values. Kendal's tau is calculated from the following
1860 'equation:
1870 'Kendal's tau = (algebraic sum of scores/total number of scores)
1880 '
1890 '************************************************************
1900 '
1910 J=0
1920 FOR I= 1 TO COUNT    'Maximum number of data point
1930 J=I
1940 IF J>COUNT THEN 2010
1950 IF VALID(I,3)> VALID(J,3) THEN 1980   'Comparing measured value
1960 IF VALID(I,3) = VALID(J,3) THEN 1990  'of each point with each
1970 INDICATE(I,J) =-1 : GOTO 2000         'more distant
1980 INDICATE(I,J) = 1 : GOTO 2000
1990 INDICATE(I,J)=0
2000 J=J+1 : GOTO 1940
2010 NEXT I
2020 ASUM =0          'Algebraic sum of scores
2030 SUM=0            'Total number of positive and negative scores
2040 FOR I=1 TO COUNT
```

```
2050 FOR J= I TO COUNT
2060 ASUM = ASUM + INDICATE(I,J)
2070 SUM = SUM + ABS(INDICATE(I,J))
2080 NEXT J
2090 NEXT I
2100 TAU = ASUM/SUM  'Nonparametric test value
2110 '
2120 '**********************  QUANTILE  *****************************
2130 '
2140 'For any unknown point to be estimated, the ranked measured
2150 'values of 6 surrounding points and their cumulative final weight
2160 'are plotted. Each calculated Q on the Y-axis, corresponds to a
2170 'value on the X-axis. This is the estimated value for the unknown
2180 'point.
2190 '*************************************************************
2200 '
2210 SUM = 0
2220 FOR I= 1 TO COUNT      'Maximum number of data
2230 TWD(I) = CW(I) * WDI(I)      'Final weight
2240 SUM = SUM+ TWD(I)
2250 NEXT I
2260 FOR I= 1 TO COUNT
2270 VALID(I,5)= TWD(I)/SUM      'Corrected final weight
2280 NEXT I
2290 FOR I= 1 TO COUNT
2300 NEXT I
2310 Q = .5 + (TAU/2)*(WTOTAL-1)/WTOTAL   'Nonparametric test value
2320 SORT=3
2330 CTR1=COUNT
2340 GOSUB 900       'Sort the measured values
2350 VALID(1,6)=VALID(1,5)
2360 FOR I= 2 TO COUNT
2370 VALID(I,6)= VALID(I,5)+VALID(I-1,6)
2380 NEXT I
2390 I=1
2400 IF (Q<VALID(1,6)) THEN 2480  'Checking for the intervals of
2410 IF (Q>VALID(COUNT,6)) THEN 2490 'measured values in which Q value
2420 IF (VALID(I,6)< Q AND VALID(I+1,6)>Q) THEN 2440 'would fall in
2430 I=I+1 : GOTO 2420
2440 DENOM = VALID(I+1,3) - VALID(I,3)
2450 IF (DENOM = 0!) THEN 2500
2460 SLOPE=(VALID(I+1,6) - VALID(I,6))/ DENOM
2470 PINT = ( Q - VALID(I,6))/SLOPE + VALID(I,3):GOTO 2500
2480 PINT = VALID(I,3) :GOTO 2500
2490 PINT = VALID(COUNT,3) 'Estimated value for the unknown point
2500 Z$=" ££££.£££    ££££.£££  ££££.£££   ££££.££££ .  ££££.££££  ££££.££££"
2510 SIGMA1 = PINT + 2*SIGMA 'Estimated value + 2 standard deviation
2520 SIGMA2 = PINT - 2*SIGMA 'Estimated value - 2 standard deviation
2530 PRINT USING Z$;P(1,1);P(1,2);P(1,3);PINT;SIGMA1;SIGMA2 'Printing
2540 WRITE £2,P(1,1),P(1,2),P(1,3),PINT,SIGMA1,SIGMA2 'the results
2550 T= T+1:GOTO 610
2560 CODE = 1
2570 CHAIN "a:main"  'Chaining to the main program
2580 END
```

```
10 '
20 '**********************   SUBROUTINE OUTPUT   ****************************
30 '
40 ' This subroutine prints the results in a formated form.
50 '
60 '**************************************************************************
70 '
80  CLS
90  DIM GRID(170,6)
100 LOCATE 5,20,0: PRINT "enter file (maximum 8 characters) ==>"
110 LOCATE 22,50,0: PRINT "current file: ";FILE$
120 LOCATE 5,57,1:INPUT " ";FILE$
130 DFILE$ = "a:" + FILE$ + ".out"
135 OPEN "A:OUTPUT" FOR OUTPUT AS£2
140 OPEN DFILE$ FOR INPUT AS £1
150 PRINT £2, "   1. X coordinates (meters)"
160 PRINT £2, "   2. Y coordinates (meters)"
170 PRINT £2, "   3. Measured values of bulk density (g/cm3)"
180 PRINT £2, "   4. Hybrid estimates (g/cm3)"
190 PRINT £2, "   5. Estimated Value + Two Standard Deviation"
200 PRINT £2, "   6. Estimated Value + Two Standard Deviation"
210 PRINT £2, " "
220 PRINT £2, " "
230 X$ =" £££££.£££   £££££.£££   £££££.£££  £££££.£££   £££££.£££  £££££.£££"
240 Y$ ="     1           2           3          4           5          6   "
250 Z$ ="................................................................."
260 PRINT £2, Y$
270 PRINT £2, Z$
280 C =0
290 IF EOF(1) THEN 330
300 C = C +1
310 INPUT £1,GRID(C,1),GRID(C,2),GRID(C,3),GRID(C,4),GRID(C,5),GRID(C,6)
320 GOTO 290
330 PRINT"done"
340 CLOSE £1
350 FOR I=1 TO C
360 PRINT £2, USING X$ ;GRID(I,1);GRID(I,2);GRID(I,3);GRID(I,4);GRID(I,5);GRID
370 NEXT I
380 END
```

APPENDIX C

Please enter drive containing data disk.

(Enter A or B): _

First screen to specify the disk containing the data.

MAIN MENU

1 Create a New File
2 Edit an Existing File
3 Run Program using an Existing File

Esc Exit from Program

Enter Choice ==>

Current File:

Second screen with the main menu.

Enter the name of the new file (maximum 8 characters) ==> test

WARNING: Using a file name that already exist will
replace the data in the old file.

Current File:

Option 1. Create a new file.

Enter: X co-ordinate. Y co-ordinate. weight

---

1 :? 2.2.1.16.3
2 :?

*** Enter 0.0.0 when all the data has been entered ***

Raw data entry to a file.

Enter File (maximum 8 characters) ==> ? test6

Loading File test6...

Current File:

Option 2. Edit an existing file.

Enter: X co-ordinate. Y co-ordinate. Weight

```
1 :  0  0   1.27
2 :  0  10  1.55
3 :  0  20  1.4
4 :  0  30  1.64
5 :  0  40  1.61
6 :  0  50  1.39
7 :  0  60  1
8 :  0  70  1.62
9 :  0  80  1.62
10 : 0  90  1.61
```

*** Enter Esc when all the data has been entered ***

Hit: U - Scroll Up D - Scroll Down
I - Insert a Line O - Omit a Line C - Change a Line

A sample of a raw data file (created by option 1).

Enter File (maximum 8 characters) => ? test6

Loading File test6...Done

Current File: test6

Option 3. Runing an existing file.

running program

1- X coordinates (meters)
2- Y Coordinates (meters)
3- Measured Values
4- Estimated
5- Estimated Value + Two Standard Deviation
6- Estimated Value - Two Standard Deviation

1	2	3	4	5	6

120

A sample of an output file with 120 points. Results are shown in the following pages.

1- X coordinates (meters)
2- Y coordinates (meters)
3- Measured values of bulk density (g/cm3)
4- Hybrid estimates (g/cm3)
5- Estimated Value + Two Standard Deviation
6- Estimated Value - Two Standard Deviation

1	2	3	4	5	6
0.000	0.000	1.270	1.266	1.647	0.884
0.000	10.000	1.550	1.338	1.724	0.952
0.000	20.000	1.400	1.623	2.007	1.238
0.000	30.000	1.640	1.599	1.984	1.213
0.000	40.000	1.610	1.598	1.983	1.212
0.000	50.000	1.390	1.547	1.931	1.163
0.000	60.000	1.000	1.466	1.838	1.095
0.000	70.000	1.620	1.558	1.944	1.173
0.000	80.000	1.620	1.607	1.993	1.222
0.000	90.000	1.610	1.521	1.907	1.135
0.000	100.000	1.530	1.518	1.903	1.132
10.000	0.000	1.240	1.566	1.946	1.185
10.000	10.000	1.660	1.647	2.032	1.262
10.000	20.000	1.760	1.453	1.837	1.069
10.000	30.000	1.590	1.608	1.994	1.222
10.000	40.000	1.600	1.712	2.098	1.327
10.000	50.000	1.690	1.430	1.815	1.045
10.000	60.000	1.490	1.515	1.901	1.130
10.000	70.000	1.560	1.593	1.979	1.208
10.000	80.000	1.580	1.520	1.905	1.134
10.000	90.000	1.510	1.593	1.979	1.208
10.000	100.000	1.520	1.526	1.912	1.140
20.000	0.000	1.630	1.447	1.833	1.062
20.000	10.000	1.560	1.465	1.851	1.079
20.000	20.000	1.470	1.681	2.066	1.295
20.000	30.000	1.610	1.598	1.984	1.212
20.000	40.000	1.740	1.274	1.659	0.890
20.000	50.000	1.210	1.695	2.075	1.315
20.000	60.000	1.700	1.664	2.049	1.280
20.000	70.000	1.710	1.559	1.944	1.175
20.000	80.000	1.550	1.605	1.991	1.220
20.000	90.000	1.600	1.593	1.978	1.207
20.000	100.000	1.600	1.523	1.909	1.138
30.000	10.000	1.460	1.580	1.965	1.195
30.000	10.000	1.600	1.460	1.846	1.074
30.000	20.000	1.700	1.460	1.845	1.075
30.000	30.000	1.600	1.540	1.926	1.154
30.000	40.000	1.540	1.602	1.988	1.217
30.000	50.000	1.000	1.495	1.866	1.124
30.000	60.000	1.660	1.538	1.923	1.153
30.000	70.000	1.650	1.684	2.070	1.299
30.000	80.000	1.610	1.656	2.042	1.271
30.000	90.000	1.700	1.435	1.820	1.050
30.000	100.000	1.550	1.435	1.820	1.049

40.000	0.000	1.650	1.562	1.947	1.176
40.000	10.000	1.640	1.621	2.007	1.236
40.000	20.000	1.660	1.682	2.067	1.297
40.000	30.000	1.570	1.653	2.039	1.267
40.000	40.000	1.620	1.557	1.942	1.171
40.000	60.000	1.650	1.681	2.066	1.295
40.000	70.000	1.690	1.681	2.065	1.296
40.000	80.000	1.640	1.350	1.735	0.965
40.000	90.000	1.350	1.677	2.054	1.287
40.000	100.000	1.640	1.686	2.072	1.301
50.000	0.000	1.470	1.637	2.023	1.252
50.000	10.000	1.670	1.611	1.996	1.225
50.000	20.000	1.740	1.663	2.047	1.278
50.000	30.000	1.670	1.663	2.048	1.278
50.000	40.000	1.640	1.615	2.000	1.229
50.000	50.000	1.610	1.529	1.914	1.143
50.000	60.000	1.620	1.603	1.989	1.218
50.000	70.000	1.680	1.557	1.942	1.172
50.000	80.000	1.580	1.683	2.069	1.298
50.000	90.000	1.690	1.683	2.068	1.298
50.000	100.000	1.720	1.599	1.984	1.215
60.000	0.000	1.590	1.552	1.937	1.166
60.000	10.000	1.580	1.532	1.918	1.147
60.000	20.000	1.450	1.560	1.945	1.175
60.000	30.000	1.530	1.605	1.990	1.219
60.000	40.000	1.570	1.517	1.902	1.131
60.000	50.000	1.450	1.553	1.938	1.168
60.000	60.000	1.470	1.528	1.913	1.143
60.000	70.000	1.530	1.629	2.014	1.243
60.000	80.000	1.630	1.505	1.890	1.119
60.000	90.000	1.580	1.604	1.989	1.218
60.000	100.000	1.460	1.608	1.993	1.223
70.000	0.000	1.550	1.623	2.008	1.237
70.000	10.000	1.620	1.652	2.038	1.267
70.000	20.000	1.600	1.597	1.982	1.211
70.000	30.000	1.650	1.620	2.005	1.234
70.000	40.000	1.620	1.597	1.983	1.212
70.000	50.000	1.660	1.665	2.050	1.279
70.000	60.000	1.670	1.630	2.015	1.245
70.000	70.000	1.620	1.490	1.875	1.104
70.000	80.000	1.440	1.636	2.020	1.251
70.000	90.000	1.710	1.636	2.020	1.251
70.000	100.000	1.580	1.667	2.052	1.281
80.000	0.000	1.650	1.636	2.022	1.251
80.000	10.000	1.720	1.565	1.950	1.181
80.000	20.000	1.570	1.635	2.021	1.250
80.000	30.000	1.800	1.614	1.997	1.231
80.000	40.000	1.320	1.642	2.025	1.259
80.000	50.000	1.710	1.503	1.888	1.119
80.000	60.000	1.650	1.620	2.005	1.235
80.000	70.000	1.600	1.603	1.988	1.217
80.000	80.000	1.570	1.548	1.934	1.168
80.000	90.000	1.660	1.664	2.049	1.279
80.000	100.000	1.670	1.532	1.917	1.147

90.000	0.000	1.640	1.510	1.895	1.124
90.000	10.000	1.320	1.510	1.893	1.127
90.000	20.000	1.560	1.601	1.987	1.215
90.000	30.000	1.750	1.620	2.004	1.236
90.000	40.000	1.620	1.453	1.838	1.067
90.000	50.000	1.500	1.648	2.034	1.263
90.000	60.000	1.640	1.648	2.033	1.263
90.000	70.000	1.600	1.567	1.952	1.181
90.000	80.000	1.560	1.567	1.952	1.181
90.000	90.000	1.640	1.520	1.905	1.135
90.000	100.000	1.530	1.635	2.020	1.249
100.000	0.000	1.640	1.635	2.020	1.249
100.000	10.000	1.640	1.590	1.975	1.205
100.000	20.000	1.610	1.584	1.969	1.198
100.000	30.000	1.600	1.624	2.009	1.238
100.000	40.000	1.630	1.626	2.011	1.240
100.000	50.000	1.670	1.602	1.987	1.217
100.000	60.000	1.600	1.624	2.009	1.238
100.000	70.000	1.570	1.590	1.975	1.204
100.000	80.000	1.570	1.560	1.946	1.174
100.000	90.000	1.560	1.584	1.970	1.199
100.000	100.000	1.620	1.520	1.906	1.134