



UNSODA

The UNSODA Unsaturated Soil Hydraulic Database

User's Manual Version 1.0

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by

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DISCLAIMERS

The information in this document has been funded in part by the United States Environmental Protection Agency under IAG-DW12933934 to the Agricultural Research Service, U.S. Department of Agriculture. Funding for this project by the Environmental Protection Agency pertained to software development; the collection of soil hydraulic data and other information was outside the scope of this interagency agreement and was conducted independently by the U.S. Salinity Laboratory. This document has not been subjected to the Agency's peer and administrative review and therefore does not necessarily reflect the views of the Agency, and no official endorsement should be inferred. Mention of trade names or commercial products does not constitute endorsement or recommendation for use.

This report documents the UNSODA database management program for information on unsaturated soil hydraulic properties and other soil information. UNSODA is a database for use in the public domain and may be used and copied freely. The database program has been tested by a number of individuals and was found to work correctly for most applications. No warranty can be given, however, that the program is free of errors. The information contained in UNSODA has been verified, as much as possible, by the contributors of the data. However, no guarantee can be given by the authors of UNSODA regarding the validity and usefulness of the data; furthermore, no quality assessment should be inferred from the inclusion or exclusion of data in UNSODA. If problems are encountered with the code, errors in the database information are found, or suggestions for improvement of the database operation and its applications can be made, the authors listed below or the Agency Project Officer can be contacted. Similarly, additional data sets for inclusion in the UNSODA are welcome.

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ABSTRACT

This report contains general documentation and serves as a user manual of the UNSODA program. UNSODA is a database of unsaturated soil hydraulic properties (water retention, hydraulic conductivity, and soil water diffusivity), basic soil properties (particle-size distribution, bulk density, organic matter content, etc.), and additional information regarding the soil and the experimental procedures. The program can be used to (i) store and edit data, (ii) search for data sets based on user-defined query specifications, (iii) write the contents of selected data sets to an output device, and (iv) describe the unsaturated hydraulic data with closed-form analytical expressions.

Mathematical models have become increasingly popular in the research and management of flow and transport processes in the subsurface environment. Because of improvements in computer software and hardware, the usefulness of numerical models hinges more and more on the availability of accurate input parameters. The unsaturated hydraulic functions are key input data in numerical models of vadose zone processes. These functions may be either measured directly, estimated indirectly through prediction from more easily measured data based upon quasi-empirical models, or approximated by using hydraulic data from similar soils. UNSODA serves as a repository of data sets that can be used as a source of surrogate hydraulic data, or for the development and evaluation of indirect methods for estimating the unsaturated hydraulic properties.

UNSODA is written in C and operates in conjunction with the database program KnowledgeMan® for storage of data in tables. This report gives a broad overview of major features and operations of UNSODA and documents the main tables. Furthermore, the data collection process is outlined and each input variable is discussed. UNSODA allows the analytic description of unsaturated hydraulic properties by means of parametric models; six default models are for this purpose included in the program. The program module for optimization of hydraulic model parameters is written in FORTRAN. Users can easily add additional hydraulic models. Three examples are included to show the reader step-by-step how UNSODA can be used to (i) enter and edit data, (ii) search and report data, and (iii) model hydraulic data.

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FOREWORD

The U.S. Environmental Protection Agency is charged by Congress with protecting the Nation's land, air, and water resources. Under a mandate of national environmental laws, the Agency strives to formulate and implement actions leading to a compatible balance between human activities and the ability of natural systems to support and nurture life. To meet these mandates, EPA's research program is providing data and technical support for solving environmental problems today and building a science knowledge base necessary to manage our ecological resources wisely, understand how pollutants affect our health, and prevent or reduce environmental risks in the future.

The National Risk Management Research Laboratory is the Agency's center for investigation of technological and management approaches for reducing risks from threats to human health and the environment. The focus of the Laboratory's research program is on methods for the prevention and control of pollution to air, land, water, and subsurface resources; protection of water quality in public water systems; remediation of contaminated sites and ground water; and prevention and control of indoor air pollution. The goal of this research effort is to catalyze development and implementation of innovative, cost-effective environmental technologies; develop scientific and engineering information needed by EPA to support regulatory and policy decisions; and provide technical support and information transfer to ensure effective implementation of environmental regulations and strategies.

The EPA uses numerous mathematical models to predict and analyze the movement of water and dissolved contaminants in the saturated and unsaturated zones of the subsurface environment. The usefulness of these models, and the accuracy with which model predictions can be made, depends greatly on the ability to reliably characterize the hydraulic properties of the unsaturated zone. The accurate measurement of unsaturated hydraulic properties, *i.e.*, water retention and hydraulic conductivity, is cumbersome and not feasible for many applications such as the assessment of various strategies for dealing with soil contamination. Various indirect methods have been utilized, and will likely be used in the future, for quantifying unsaturated hydraulic properties in an alternative manner. This report documents the UNSODA database program for storing experimental unsaturated soil hydraulic properties. UNSODA serves as a repository of measured unsaturated hydraulic data, including the employed measurement methods, as well as other basic soil properties and other general information. The database can be used to (i) store and edit data, (ii) search for data sets based on user-defined query specifications, (iii) write the contents of selected data sets to an output device, and (iv) describe the unsaturated hydraulic data with closed-form expressions. UNSODA will be helpful for providing a wide variety of surrogate data that can be readily used in computer models for (initial) estimates of flow and transport processes in the vadose zone, for the development and evaluation of indirect methods to generate soil hydraulic properties, and for educational purposes. The information in this report provides a broad outline of UNSODA, and serves as a user's manual.

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1. INTRODUCTION

1.1. *Overview of Manual*

The material in this report is intended to provide the rationale behind the database project and to give a broad overview of the database program. The user is encouraged to peruse the manual to get a general impression of the type of data that can be stored in UNSODA (UNsaturated SOil Database), as well as the type of applications that are possible with UNSODA. However, one can only become familiar with the program by using it; relevant instructions appear on the screen or can be accessed through help menus. The reader should be able to use the program after consulting section 1.4, which outlines the installation and execution procedure, and perhaps section 1.5, which contains information on screen formats and program structure.

Chapter 1 provides the rationale for the database project; it also discusses the utility of indirect methods for estimating the unsaturated hydraulic properties (section 1.2) as well as other potential applications (section 1.3). The three major tasks for which UNSODA can be used are (i) the entry and editing of hydraulic and other soil data, (ii) retrieval of data from UNSODA, and (iii) description of hydraulic data with parametric models. Chapter 2 discusses the data gathering process, the distribution of the data sets over the soil textural groups. This chapter also lists the types of data that can be included in UNSODA, and the main modules constituting UNSODA. These modules are further reviewed in Chapters 3 through 5. The DATA ENTRY AND EDIT module is the topic of Chapter 3, the type of information to be entered is discussed for each field. Standard units for numerical fields are included as well as the averaging procedure for multi-valued tabular data. Chapter 4 briefly reviews the QUERY AND REPORT module; a list of all query variables is included in this chapter. The use of closed-form expressions for describing unsaturated hydraulic data, as done with the module MODELS, is addressed in Chapter 5. This module is mostly based on the RETC program [*van Genuchten et al.*, 1991]. Expressions for the six default models of RETC to describe hydraulic data are included. Chapter 5 also summarizes the optimization of hydraulic parameters. The database management program is briefly discussed in Chapter 6. In addition, a

fairly lengthy description of all menu screens is furnished in section 6.2. This material parallels the information that can be obtained by running the database program. Information on all data tables in UNSODA — the names of tables in which each field is stored, the data format, and the structure of tabular data tables — is contained in section 6.3. Section 6.4 outlines how the Fortran program RETC4, which is used to optimize hydraulic data in UNSODA, can be modified to accommodate user-defined parametric models. Several Appendices illustrate various aspects of how the data were gathered, the database structure, and the use of RETC4. Finally, Chapter 7 contains three examples with screen output, to conveniently let the reader of this manual become a user of the program.

In summary, the reader is encouraged to start using the software, to consult this manual for assistance if necessary, and to become familiar with the capabilities of UNSODA. Chapter 1 explains how to get started, Chapter 2 lists what the program can do, Chapters 3 through 5 discuss how this can be done, Chapter 6 documents the menu and table structure, and Chapter 7 gives a step-by-step illustration of using UNSODA for three different purposes.

1.2. Indirect Methods

Knowledge of the unsaturated hydraulic properties is indispensable to better understand and manage the transport of chemicals and the flow of water in the vadose zone of soils. Such processes have long been important for agriculture since they govern the movement of water and nutrients toward root systems of crops. More recently, this direct interest in flow and transport processes aimed at creating an optimal habitat for crop growth, has been overshadowed by a general concern that the quality of the subsurface environment is being adversely affected by the presence of chemical substances as a result of industrial, agricultural, and other activities.

The movement of chemicals in the subsurface is largely determined by the rate and direction of water flow. Unfortunately, the measurement and description of water flow in unsaturated soils is difficult because of the nonlinearity of the unsaturated soil hydraulic properties. For example, the

value of the unsaturated hydraulic conductivity typically varies several orders of magnitude over the complete range of saturation. Many numerical models have been developed and are now routinely used to investigate and manage the movement of water dissolved substances into and through the unsaturated zone of soils. Methods for the direct measurement of soil water retention and, especially, the unsaturated hydraulic conductivity have not kept pace with advances in numerical modeling. The success of numerical models greatly depends on the availability of reliable input data. Particularly the relationships between water content (θ), pressure head (h), and hydraulic conductivity (K) or soil-water diffusivity (D), are important since they quantify the rate at which water and chemicals move through the vadose zone. Many laboratory and field methods have been developed for measuring these relationships on disturbed or undisturbed porous media [Klute, 1986]. Unfortunately, such methods remain cumbersome and time-consuming despite decades of work by soil physicists and others representing different disciplines. It is not likely that breakthroughs in experimental technology will remedy this situation in the near future, particularly in view of the extensive data requirements for deterministic and stochastic field studies of flow and transport in the vadose zone. Furthermore, experimental results are often subject to considerable uncertainty (especially for K and D), whereas spatial variability in the field may limit their usefulness for modeling purposes. Hence, rather than through direct measurement, a case can be made for the use of alternative methods to quantify the unsaturated hydraulic properties.

An alternative to direct measurement of the unsaturated hydraulic properties is the use, analysis, and/or generalization of experimental data that are already available. The appropriateness of this approach depends on the type of application for which such surrogate hydraulic data are to be used, and the similarity in soil textural and structural properties between soils for which data is available and those for which hydraulic data is lacking. Practitioners can benefit from this approach by having quick estimates of the hydraulic properties of soils for which only limited data are available.

A second alternative is to deduce hydraulic properties from more easily measured soil properties by using physico-empirical models based on a simplified flow process through the porous medium. Since the hydraulic conductivity is the most difficult to measure, many research efforts have been devoted to the prediction of the conductivity from measured soil water retention data. The hydraulic conductivity may be predicted theoretically using statistical pore-size distribution models, which assume water flow through "idealized" cylindrical pores. Water flow is described with the equations of Darcy and Poiseuille [cf. *Mualem*, 1986], while Laplace's law is used to express the pore system in terms of pressure heads instead of pore radii. This approach assumes that estimates of the soil water retention curve are available. Measured input retention data are generally fitted by analytical expressions that are more convenient for calculating of the hydraulic conductivity. Even if no measured retention data are available, they can still be generated from physico-empirical and empirical models using particle-size distribution data and other basic soil properties. The particle-size distribution is then used to estimate the pore-size distribution from which subsequently the pressure head is obtained using Laplace's law. Predictive conductivity equations that fit this mold hence are actually particle-size distribution models.

As a third alternative, purely empirical models can be used to estimate the hydraulic properties. Such approaches predict soil-water retention from a variety of soil information, including data on the particle-size distribution, bulk density, and organic matter content. Lately the term pedo-transfer functions (PTF) has been used to characterize models that translate soil texture and other basic soil properties into soil hydraulic curves [*Wösten and Bouma*, 1992]. Functions for the soil water retention and hydraulic conductivity curves can be obtained through regression analysis [cf. *Vereecken et al.*, 1989; *Vereecken et al.*, 1990] using data sets for which both hydraulic data and other, more easily measured soil properties, are available. This approach has been especially popular for the water retention curve, one of the reasons being the interest of agronomists in the amount of available water in a soil profile. Correlation techniques have not been used as widely for describing the hydraulic conductivity curve. Likely reasons are that relatively few complete conductivity data

sets are available, while the conductivity itself is influenced by many textural and structural soil properties which may be difficult to quantify.

The development or validation of (physico)-empirical models requires the availability of measured $\theta(h)$ and K/D data, as well as basic soil properties that may influence the hydraulic behavior of soils. The hydraulic data should be for a wide variety of soils and experimental procedures. Pertinent information should include data on the hydraulic functions and other soil properties, soil classification, and a description of measurement procedures. Additionally, parametric models are needed to describe the hydraulic data. The objective of the project leading to this manual was to develop an international database containing such information. Data in the UNsaturated SOil DAtabase (UNSODA) were gathered from the literature or were obtained through personal requests to scientists and engineers. UNSODA is intended to facilitate the research and management of flow and transport processes in the vadose zone. A successful database of this type should incorporate different data types with a wide range in quality. Also, an effort was made to always document experimental methods and, whenever possible, to approach a contact person for verification and rating of the data. Still, the approach retains an element of subjectivity. Hence, database users must make a final decision about the appropriateness of the data for their application.

UNSODA does not represent the first effort to combine unsaturated soil hydraulic data. Soil scientists and hydrologists in several countries have established data collections. *Mualem* [1976a] previously established a widely used data catalogue to investigate predictive methods for the unsaturated hydraulic conductivity. *Wösten et al.* [1987] published tabulated functions of averaged hydraulic properties for some 20 different soil groups. These were based on 197 individual curves. Other databases have been established for Australia, Belgium, Hungary, and the United States. However, UNSODA does represent, to the best of the authors' knowledge, the first truly international set of retention and conductivity data compiled in a relational database program published for use in the public domain. The purpose of this manual is to acquaint the reader with the database and to document the data collection and software development.

1.3. Applications of UNSODA

In Chapter 7 the use of UNSODA for several specific purposes will be demonstrated. Some of the general applications of UNSODA are listed below:

1. Research and evaluation of parametric and physico-empirical models to describe $\theta(h)$ and/or K/D by fitting such models to hydraulic data. UNSODA provides a valuable source of hydraulic properties for soils with different textural and structural properties, which are obtained in the field or laboratory on disturbed or undisturbed samples using a variety of methods.
2. Development of empirical equations (pedo-transfer functions) to predict hydraulic properties from such data as particle-size distribution, mineralogy, cation exchange capacity, bulk density, and mineralogy.
3. Determination of parameters in hydraulic models so as to more efficiently represent hydraulic data of different soils and soil horizons. Parametric models can be used for comparative purposes, or for scaling to characterize the spatial variability of soil hydraulic properties.
4. Use hydraulic properties of soils in UNSODA as a surrogate for cases where insufficient data are available. Because hydraulic properties greatly depend on soil texture and soil structure, one may infer the hydraulic properties of a particular soil — for which no hydraulic properties are available — from other soils with a similar texture and structure.
5. Making comparisons of different experimental methods for determining soil hydraulic properties, or for comparing results for disturbed and undisturbed samples.
6. Use as a repository of hydraulic and other soil information to meet general research and educational needs.

1.4. Program Installation

UNSODA was developed with an IBM-PC, DOS compatible computer as the targeted environment. The code is written as a stand-alone program such that no supporting database management system is necessary. The database management program was written in Microsoft® C (version 7.0) using the KnowledgeMan® (version 2.5) KC library from Micro Data Base Systems. The PC on which UNSODA is used must have a base memory of 512 KByte or better, with at least 5 MByte of free disk space on the selected drive. The program can run on machines with INTEL; a math coprocessor is recommended. Output can be written to the screen, disk, or printer. The printer must be connected to the LPT1 port. In most cases, the CONFIG.SYS file should include:

```
files=55  
buffers=20  
device=c:\dos\ansi.sys
```

Instructions regarding the installation procedure can also be found in the READ.ME file, whose information may be more recent than given in this section. It is recommended that users first make a backup of the original disk and save the latter. For the following instructions, it will be assumed that the installation disk containing the (compressed) database program is in drive A. For the program to work from a default directory on the C-drive type "A: " and press <Enter> or ↵ and subsequently type "install C:", *i.e.*,

```
C>a: ↵  
A>install c:↵
```

The subdirectory UNSODA will be created off the root on the C-drive. All UNSODA files, data as well as executable files, will be copied from the A-drive to this subdirectory UNSODA on the C-drive and automatically decompressed. To run UNSODA, type "start" (execute START.EXE):

```
C:\UNSODA\start ↵
```

Users can go from the introductory screen to the main menu by hitting any key. After the data tables have been copied to the default directory, the first operation required as part of the installation

procedure is to reindex all the data tables. To perform this operation select the UTILITIES menu from the **Main** menu, then select **Reindex** Data Tables. Reindexing should also be done when data are changed. For subsequent use of UNSODA — after the installation procedure — the user needs to go directly to the subdirectory C:\UNSODA and type "START."

The executable version of the program can be distributed freely. A disk with the source code files of UNSODA and/or data tables are available upon request from the authors. Updates of UNSODA are anticipated to become available in the future.

1.5. Screen and Program Format

Figure 1 outlines a typical screen. The center (box) of the screen shows selections for the next menu or contents of the database, the bottom box contains keystroke options (keys are denoted by pointed brackets, < >), while the box at the top of the screen typically displays the title of the current menu (--- ---). The right-hand part of the upper box usually contains the sequence of past menus and the name of the soil for which data are being shown. Each data set is denoted with a code shown on the left in the top box. In common database terminology the soil code may be viewed as the *record* number, with each record (soil) having several data types or *fields*. The fields (data) can be numerical (bulk density), tabular (water retention), or alphabetical (keyword). A list of soil codes

Figure 1. Example of UNSODA menu screen.

```

UNSO DA 1.0          --- Tabular Data Type ---          Entry/Append
Code: 4970                                     Series: Troup

```

```

1) Particle Size Distribution
2) Dry Aggregate Size Distribution
3) Mineralogy
4) Field 0(h)
5) Field K(0)
6) Field D(0)
7) Field K(h)
8) Lab 0(h)
9) Lab K(0)
a) Lab D(0)
b) Lab K(h)

```

```

<F1> Help          <↑↓>          <Enter> or <#> Select          <Esc> Quit

```

can be accessed in several modules of UNSODA, for example by selecting UTILITIES from the **Main** menu. Typically, selections for a subsequent screen can be made by typing a number or letter (1, ..., 9, a, b), or by moving the cursor with the arrow key (<↑↓>) to the desired selection and pressing <Enter>. Pressing the <Esc> key usually means a return to a previous menu while abandoning the current task, i.e., nothing is being saved. The **Help** screen is accessed by hitting the function key <F1>. Other keys that may be used, such as <PgUp>, <PgDn>, <Home>, <End>, <F2>, <F10>, are shown in the bottom box. The **Help** screen further explains key functions.

Users are encouraged to peruse this manual before and while running UNSODA. Not all parts of the manual or program may be of interest. One could focus first on the material pertaining to the four main modules of UNSODA as further discussed in section 2.3. These modules are: (1) DATA ENTRY AND EDIT, (2) QUERY AND REPORT, (3) MODELS, and (4) UTILITIES. The first module should be of particular interest to users who have hydraulic data and want to enter them into UNSODA. The second option, QUERY AND REPORT, lets the user search for some or all of the data, and write data to an output device. Thirdly, the user can fit parametric models to hydraulic data with the routine MODELS. Finally, the UTILITIES module may be used to delete, change, or list codes; to reindex, sort, or evaluate tabular data; and to view files in the UTILITIES module. Most screens offer

access to a **Help** screen, which gives more information on the item to be selected or for which a value needs to be specified. This manual provides a broad overview of UNSODA.

2. DATA COLLECTION AND GENERAL OUTLINE OF UNSODA

2.1. *Data Collection*

The data in UNSODA are primarily from contributions by individual scientists, while some data sets were extracted from the literature. A questionnaire¹ was prepared to request information for UNSODA. The questionnaire was partly based on suggestions from participants at an international workshop on soil-hydraulic properties held in Riverside in 1989 [van Genuchten *et al.*, 1992]. The aim was to obtain a fairly wide range of information, including experimental procedures and information on soil classification. This broad information may, among other things, accommodate future users whose needs are presently still unknown. There appeared to be a wide range in quality and quantity in data that were supplied. Hence some subjective judgments were made as to which data were to be included in the database, and to avoid excessive amounts of sometimes esoteric data that could have reduced the efficiency and utility of the database.

Efforts by both data providers and the authors were hopefully minimized through a judicious choice of the format of the questionnaire. The questionnaire, as shown in Appendix A, is tailored to the database format in UNSODA. The questionnaire contains sections for: (1) Descriptor Data, (2) Methodology, (3) Soil Properties, and (4) Unsaturated Hydraulic Properties. Approximately 240 questionnaires were sent to scientists and engineers in many countries to solicit input for UNSODA. There were more than 100 responses varying from simple acknowledgments to forms filled out in detail, and with data provided on floppy disks. Frequently, data sets could not be considered because of a lack of K/D data — the unsaturated hydraulic conductivity, $K(h)$ or $K(\theta)$, and the soil water diffusivity, $D(\theta)$. Almost all remaining data sets required a substantial amount of preparation (reading literature, editing, and digitizing) before entry into UNSODA. After entry of suitable data in UNSODA, the information was sent back to the contributors for review. A preliminary survey

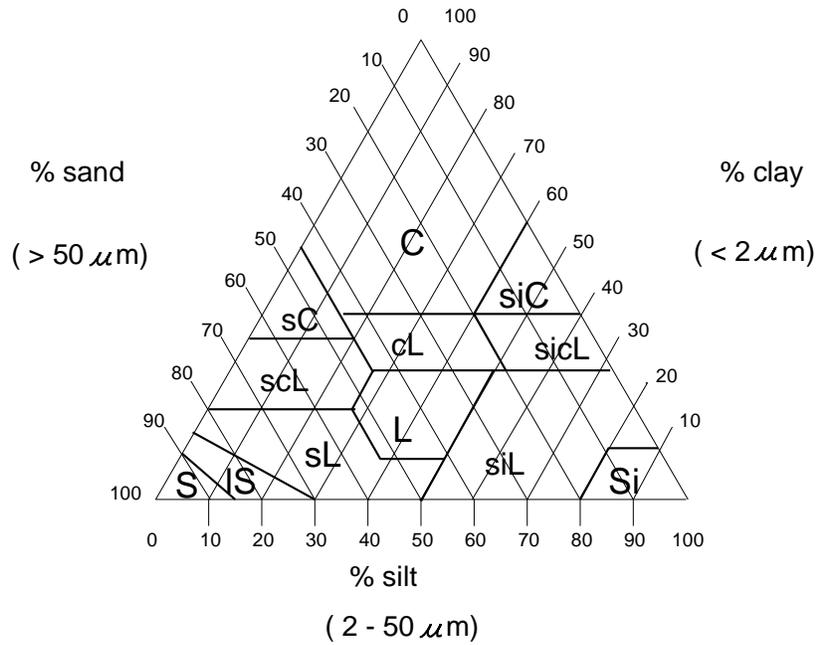
¹The data gathering process for UNSODA was an activity outside the scope of the interagency agreement between USDA and EPA

of the literature for hydraulic data was also conducted; data sets were also extracted from the literature.

Figure 2 shows a textural triangle with percentages clay ($<2\mu\text{m}$), silt ($2\text{-}50\mu\text{m}$), and sand ($>50\mu\text{m}$) according to the USDA-SCS classification scheme. Figure 3 exhibits the distribution of data sets in UNSODA according to this triangle. As is apparent from Figure 3, a large portion of the soils in UNSODA are sands and loamy sands. Table 1 and Figure 4 illustrate that the coarse-textured soils are somewhat over-represented in UNSODA — the relative number of sands is more than four times higher in UNSODA as compared to the much larger database used for soil classification. On the other hand, fine-textured soils (cf. clay loam, silty clay loam, silty clay) are included less in UNSODA. This may reflect a bias of experimentalists towards using soils for which the hydraulic properties are more conveniently determined.

TABLE 1. Distribution of Soil Codes across USDA-SCS Soil Textural Classes in UNSODA and in Soil Survey Information Reports
[after Table 1 of *Carsel and Parrish*, 1988]

Texture class	UNSODA		Soil Survey	
	<i>n</i>	%	<i>n</i>	%
Sand	184	23.59	803	5.10
Loamy sand	64	8.21	881	5.60
Sandy loam	133	17.05	2835	18.01
Sandy clay loam	52	6.67	610	3.88
Silt	3	0.38	115	0.73
Silt loam	142	18.21	3050	19.38
Clay loam	36	4.62	1317	8.37
Loam	70	8.97	1991	12.65
Silty clay loam	33	4.23	1882	11.96
Sandy clay	3	0.38	74	0.47
Silty clay	21	2.69	1002	6.37
Clay	39	5.00	1177	7.48
Total	780	100.00	15737	100.00



S	Sand	cL	clay Loam
IS	loamy Sand	cL	clay Loam
sL	sandy Loam	L	Loam
scL	sandy clay Loam	sicL	silty clay Loam
Si	Silt	sC	sandy Clay
SiL	silt Loam	siC	silty Clay
		C	Clay

Figure 2. USDA-SCS soil textural triangle.

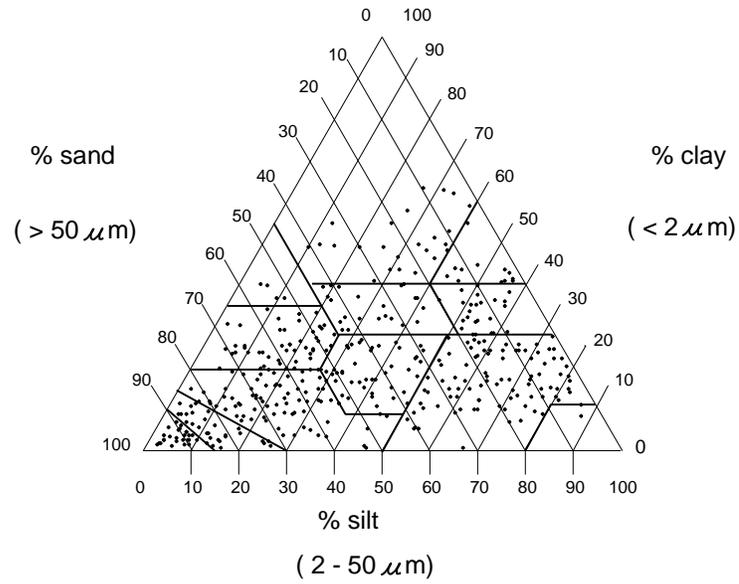


Figure 3. Distribution of soil codes (data sets) across the USDA-SCS soil textural triangle.

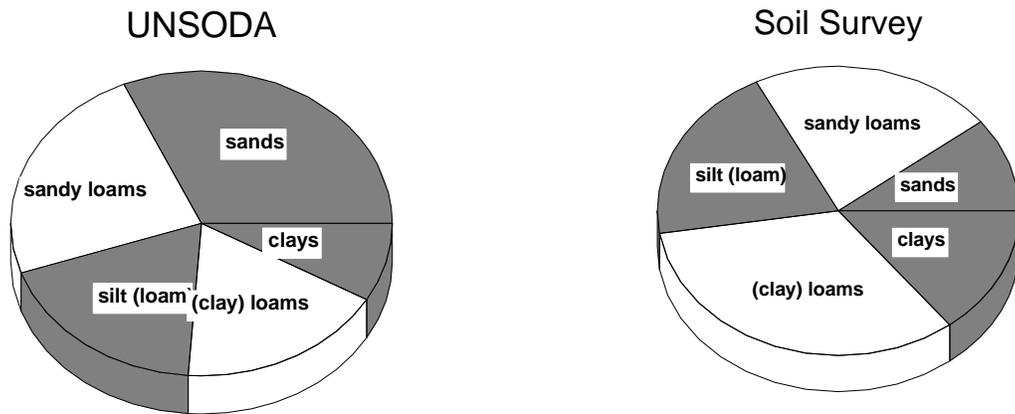


Figure 4. Major soil textural groups in UNSODA and USDA-SCS Soil Survey Reports.

2.2. Data Types

A different code number was used for each individual soil sample or horizon for which a complete set of hydraulic data (soil texture, water retention, and hydraulic conductivity or diffusivity) was available. Because some experiments generate large amounts of similar data, the number of data sets/codes for a particular soil or experiment was limited arbitrarily to avoid repetition and to keep the size of the database manageable. The following data groups were used for each soil code:

Descriptor Data. Family, Series, Texture, Structure, Position and Name of Horizon, Depth to Ground water, Location and Site, Climatic Data, Date, Publication, Contact Address, Rating of Data Quality, Name of Rater, Comment, and Keyword.

Soil Properties. Bulk and Particle Density, Porosity, Organic Matter Content, Saturated Conductivity (K_s), Saturated Water Content, Cation Exchange Capacity (CEC), pH, Electrolyte Level, Sodium Adsorption Ratio (SAR), Exchangeable Sodium Percentage (ESP), Electrical Conductivity (EC), Fe and Al Oxides, Comment.

Methodology. Key Words for Measurement of Field and Laboratory $\theta(h)$, K/D , and K_s , and a Description of Field and Laboratory Procedures.

Tabular Data. Data with an independent and a dependent variable: Particle Size Distribution, Dry Aggregate Size Distribution, Mineralogy, Field and Laboratory $\theta(h)$, $K(\theta)$, $K(h)$, and $D(\theta)$.

Appendix B contains a soil code with actual data from *Dane et al.* [1983]. This appendix, along with the questionnaire, serves as an example of data preparation for potential contributors. The input for UNSODA is discussed in more detail in Chapter 3.

2.3. *Main Modules of UNSODA*

The following overview of the main modules in UNSODA should give readers an impression of the potential applications of UNSODA. The first three modules are discussed in more detail in Chapters 3, 4, and 5.

DATA ENTRY AND EDIT

1. **Create a New Soil Code and Enter Data**
2. **Append Tabular Data for an Existing Code.** Enter tabular data (distribution of particle or aggregate size and mineralogy, hydraulic data). Specify wetting and drying curves for hydraulic data.
3. **Delete Tabular Data for an Existing Code.**
4. **Edit Any Data for an Existing Code.** Modify any data for an existing code.
5. **Conversion Factors for Dimensions.** Specify dimension factors to convert units of "raw" data to standard units for UNSODA.
6. **List Codes and Series Names.** Write contents of UNSODA (code number, series name, and texture) to screen.

QUERY AND REPORT

1. **Specific Codes.** Report the contents of codes meeting query specifications.
2. **All Codes.** Report the contents of the entire database.
3. **Specific Tabular Data.** Write selected tabular of codes meeting query specifications to disk, screen, or printer.
4. **List Codes.** Write contents of UNSODA (code number, series name, and texture) to the screen.

MODELS

1. **Add/Delete Model Name.** Enter or delete names of analytical models for hydraulic functions.
2. **Execute RETC Optimization.** Provide initial estimates for model parameters and conduct parameter optimization with program RETC [*van Genuchten et al.*, 1991]; default initial values are based on soil texture.
3. **View RETC Results or any other File.** View results of the parameter estimations, write results to disk, or store parameters in UNSODA.

UTILITIES

1. **Delete Code.** Delete codes (erase record from UNSODA).
2. **Change Code.** Renumber codes (change number of record).
3. **List Codes.** Write contents of UNSODA (code number, series name, and texture) to the screen.
4. **Reindex Data Tables.** Reindex tabular data tables.
5. **Sort Tabular Data.** Sort tabular data in ascending order and take geometric average.
6. **Check Pointer Tables.** Inspect pointers of tabular data for discrepancies.
7. **View Text or Data Tables.** Display files from specified directories on the screen.

3. DATA ENTRY AND EDIT

This part of the manual describes the "protocol" for data preparation and entry. Because of the wide range in quality and quantity of data as a result of differences in experimental conditions and objectives during data gathering, it is impossible to always adhere to a consistent data format for entry in UNSODA. The description and quantification of information is greatly subjective. It has been the authors' impression that few publications are primarily dedicated to obtain high quality data. In many instances the major objective of a publication was to study various soil physical concepts at the laboratory or field scale, or to report on new or improved methodology. Because of this lack of scientific interest and the scarcity of funding for data collection, there are few soil physical studies whose major thrust is to obtain high-quality hydraulic data. This is in contrast with other soil science disciplines where data collection itself is often the primary concern (*e.g.*, soil survey, soil testing). As a result, no statistical information on hydraulic data is generally provided.

The (input) fields for UNSODA will first be reviewed. This information may be useful when preparing data for input or when using the DATA ENTRY AND EDIT module. The numerical data in UNSODA can be made dimensionally consistent by adhering to the standard units listed in Table 2. Table 2 provides a listing of all input fields. If for some reason the original (unedited) data have different units, UNSODA can automatically change their values to express the same data in standard units. This is done by first specifying appropriate conversion factors (through the main module UTILITIES) before the original values are entered (through the main module DATA ENTRY AND EDIT). Table 2 also states the variable type — character string, integer, or real — for reading data and for internal use, in some cases with a type conversion. The length of the field that can be entered is specified, as well as the minimum and maximum of acceptable values. If no data is entered, the program assigns a default value to the field to identify that no data exist for the field; the last column in Table 2 shows these default values. Ordinarily the user need not be concerned with the information provided in Table 2.

Table 2. Standard Units, Format, Range, and Default Values of Numerical Fields

Field	Unit	Read as	Used as	Length	Minimum	Maximum	Default
Descriptor Data 1							
Family	-	string	string	50	-	-	" "
Series Name	-	string	string	30	-	-	" "
Texture	-	string	string	25	-	-	" "
Structure	-	string	string	35	-	-	" "
Upper Depth	cm	string	integer	8	0.0001	99999999	0
Lower Depth	cm	string	integer	8	0.0001	99999999	0
Horizon	-	string	string	7	-	-	" "
Depth to							
Ground water	cm	string	real	10	0.0001	9999999999	0.0
Location	-	string	string	60	-	-	" "
Site	-	string	string	25	-	-	" "
Annual Rainfall	cm	string	real	10	0.0001	9999999999	0.0001
Avg. Temperature							
January (C)	°C	real	real	10	-999999999	9999999999	-999.0
Avg. Temperature							
July (C)	°C	real	real	10	-999999999	9999999999	-999.0
Descriptor Data 2							
Date	-	string	string	8	-	-	" "
Publication Info.	-	string	string	240	-	-	" "
Contact	-	string	string	240	-	-	" "
Rating (0-10)	-	integer	integer	2	0	10	0
Rated by	-	string	string	40	-	-	" "
Comment	-	string	string	480	-	-	" "
Keyword	-	string	string	111	-	-	" "

Table 2. Continued

Field	Unit	Read as	Used as	Length	Minimum	Maximum	Default
Soil Properties							
Bulk Density	g/cm ³	real	real	10	-999999999	999999999	0.0
Particle Density	g/cm ³	real	real	10	-999999999	999999999	0.0
Porosity	cm ³ /cm ³	real	real	10	-999999999	999999999	0.0
Org. Matter	mass %	real	real	10	-999999999	999999999	0.0
Sat. Conduct.	cm/d	real	real	10	-999999999	999999999	0.0
Sat. Water Cont.	cm ³ /cm ³	real	real	10	-999999999	999999999	0.0
CEC	cmol/kg	real	real	10	-999999999	999999999	0.0
pH	-	real	real	10	-999999999	999999999	0.0
Electrolyte Level	meq/l	real	real	10	-999999999	999999999	0.0
SAR	mmol ^{1/2} /l ^{1/2}	real	real	10	-999999999	999999999	0.0
ESP	%	real	real	10	-999999999	999999999	0.0
EC	dS/m	real	real	10	-999999999	999999999	0.0
Fe and Al Oxide	mass %	real	real	10	-999999999	999999999	0.0
Comment	-	string	string	240	-	-	" "
Tabular Data							
Particle Size	µm	real	real	8	-9999999	99999999	-
Fraction	g/g	real	real	8	0	1.1	-
Mineralogy	-	string	string	30	-	-	" "
Aggregate Size	mm	real	real	8	-9999999	99999999	-
Pressure Head	cm-H ₂ O	real	real	8	-9999999	99999999	-
Water Content	cm ³ /cm ³	real	real	8	0	1	-
Conductivity	cm/d	real	real	8	-9999999	99999999	-
Diffusivity	cm ² /d	real	real	8	-9999999	99999999	-

When creating a database record, a new code number has to be specified. The numbering system is based on increments of 10 for records unrelated to other codes, while an increment of 1 is used for related records (*i.e.*, the same experiment or location but for a different soil horizon or treatment). This numbering system should become clear when using the **List** option. Default code numbers can be selected from the screen when selecting **Create** in the DATA ENTRY AND EDIT module; the fields for this module are listed below as they appear on the screen.

Descriptor Data 1

Family. Enter the soil family name, if available, or a similar identifier, and specify to which classification system the terminology applies (this can also be done as a comment on the next screen). For further information see the publication by the *Soil Survey Staff* [1990].

Series Name. For each code a series name or another distinct name, based on the soil location, should be entered. Identical series names may be numbered.

Texture. For each code the textural classification must be entered based upon the USDA-SCS triangle using the mass fraction corresponding to the equivalent particle diameters between 0-2 μm (clay), 2-50 μm (silt), and >50 μm (sand). Note that in UNSODA only the USDA-SCS classification can be used since queries depend on an exact match while the USDA-ARS classification is also needed to obtain default estimates in the RETC optimization. If the mass fraction is not known for one or more of these equivalent diameters, interpolate or extrapolate from the available particle-size data assuming a lognormal distribution. For Code 2550, for example, the cumulative fractions <2 μm , <20 μm , and <2000 μm are 0.112, 0.259, and 1.000. First, the slope of the log-transformed curve in the silt range is estimated; after which the cumulative fraction, x , for <50 μm can be obtained:

$$\text{slope} = \frac{\log 20 - \log 2}{0.259 - 0.112} = 6.803 \quad \Rightarrow \quad x = \frac{\log 50 - \log 20}{6.803} + 0.259 = 0.317$$

The sample contains 11.2% clay, 20.5% silt, and 68.3% sand and should therefore be classified as a sandy loam according to the textural triangle in Figure 2.

Structure. Describe the soil structure, particularly as it relates to aggregate stability.

Upper Depth. Distance between the soil surface and the top of the sample, core, or profile for which measurements are reported. The preferred unit is cm.

Lower Depth. Give the distance between the soil surface and the bottom of the sample, core, or profile for which measurements are reported. Note that this lower depth is normally greater than the upper depth in the previous field. The preferred unit is cm.

Horizon. Provide the soil horizon according to conventional soil taxonomy.

Depth to Ground Water. Give the distance between the soil surface and a typical position of the ground-water table. The preferred unit is cm.

Location. Provide the approximate location of the *in situ* measurement or sampling site in common geographical terms readily identified on a map (city, state or province, and country).

Site. Provide the site of the *in situ* measurement or sampling site in more detail than is entered under Location.

Annual Rainfall. Give the average annual precipitation (rainfall) in the proximity of the site. The preferred unit is cm.

Avg. Temperature January (C). Specify the average temperature in January at or close to the site. The preferred unit is degrees Celsius.

Avg. Temperature July (C). Specify the average temperature in July near the site. The preferred unit is degrees Celsius.

Descriptor Data 2 (at least one field must be entered)

Date. Give the date of the measurements as month/day/year, e.g., 06/18/92. Approximate if the measurements are taken over a period of time, e.g., 03-07/92 for experiments from March to July 1992.

Publication Info. Provide one or more references which contain data for the soil code or outline experimental procedures. Provide only essential information, i.e., abbreviated journal name, page numbers, and number and year of issue. Sources that are relatively accessible are preferred.

Contact. Give the name, address, and phone and fax numbers of the individual to be contacted for further information regarding the data or methodology for the soil code.

Rating (0-10). Rate the quality of the data on a scale of 1 through 10, where 10 denotes the best possible way to quantify the soil hydraulic properties with current methodology and 0 implies that no rating is available.

Rated by. Enter name of the individual who provided the rating.

Comment. Enter short comment regarding the above general information, e.g., agricultural use of soil, geological or topographical information.

Keyword. Enter keywords describing the type of data or study for possible use queries. A distinction is often made between disturbed and undisturbed samples. Other keywords could characterize the objectives of the study. Typical entries are: Disturbed, Horizontal, Hysteresis, Multiphase, Overburden, Salinity, Soltrol, Tillage, Undisturbed, and Vertical.

Soil Properties

Bulk Density. Provide dry bulk density as mass of solids per bulk volume.

Particle Density. Provide particle density as mass of solids per volume of solids.

Porosity. Provide measured porosity of soil as volume of voids per bulk volume. Do not specify a value calculated from the bulk and particle densities.

Organic Matter Content. Enter the mass of organic matter content as a percentage of the total solid mass. If necessary estimate organic matter content based on carbon content and explain in the comment field.

Saturated Conductivity. Enter the measured saturated hydraulic conductivity. If necessary state as a comment if the value is obtained in the field or the lab, and on a vertical or a horizontal sample.

Saturated Water Content. Enter the experimental water content of a water-saturated sample. Explain in a comment how the measurement was made (e.g., capillary rise).

Cation Exchange Capacity. Enter the value for the CEC in cmol of charge per kg of dry soil (i.e., meq/100 g soil).

pH. Enter the value of the measured soil pH. Describe the type of suspension as a comment.

Electrolyte Level. Enter the approximate total solute concentration of the soil solution during the experiments.

SAR. Enter the Sodium Adsorption Ratio.

ESP. Enter the Exchangeable Sodium Percentage.

EC. Enter the electrical conductivity of the saturation extract.

Free Fe and Al Oxide. Enter the mass fraction of these oxides as a percentage of the total solid phase.

Comment. Describe with some keywords the experimental procedures used to obtain the basic soil properties listed in this table. Adhere to terminology as used in *Klute* [1986] and *Page et al.* [1982].

Methodology

The methodology section consists of a maximum of six short characteristic comments regarding the measurement of hydraulic properties and two longer comments regarding laboratory and field procedures. A list with short characteristic comments is included in Appendix C. The list is admittedly somewhat subjective; it reflects a lack of standard procedures for determining soil hydraulic properties.

Field $\theta(h)$. Describe the field measurement of the water retention curve, $\theta(h)$, with a few keywords for the equipment used. Specify how the water content (e.g., neutron scattering) and the pressure head (suction) were determined (e.g., tensiometry).

Lab $\theta(h)$. Describe the laboratory measurement of $\theta(h)$; specify how water content and pressure head (suction) were determined using a few keywords to describe equipment.

Field K/D . Describe the field measurement of the hydraulic conductivity, $K(\theta)$ or $K(h)$, or soil water diffusivity, $D(\theta)$, with a few keywords to outline the concept of the measurement. Specify the methodology (e.g., instantaneous profile) and, if applicable, whether diffusivity was measured instead of conductivity.

Lab K/D . Describe the laboratory measurement of the hydraulic conductivity, $K(\theta)$ or $K(h)$, or soil water diffusivity, $D(\theta)$, with a few keywords to outline the concept of the measurement. Specify the methodology (e.g., double plate) and, if applicable, whether diffusivity was measured instead of conductivity.

Field K_{sat} . Describe the field measurement of the saturated hydraulic conductivity, K_s , with a few keywords (e.g., double ring infiltrometer).

Lab K_{sat} . Describe the laboratory measurement of K_s using a few keywords to outline the concept of the measurement (e.g., constant head).

Field Comment. Describe the experimental procedures in the field, e.g., sampling technique, installation of equipment, sample and plot sizes, frequency of measurements, data analysis.

Lab Comment. Describe the experimental procedures in the laboratory, e.g., installation and type of equipment, sample sizes, frequency of measurements, ambient temperature, data analysis.

Tabular Data Type

Tabular data consist of pairs of independent and dependent variables. By specifying the appropriate conversion factors, one can enter values in the original units which are subsequently converted automatically to the standard units of UNSODA. Upon completion of data entry, the data can be sorted and averaged in the UTILITIES module by selecting the **Sort Tabular Data Option**. Sorting occurs in ascending order for the independent variable. Averaging is done to avoid multi-valued functions. If there are n values of the dependent variable, y_i , for the same value of the independent variable, the program will take the geometric mean according to:

$$\bar{y} = \exp\left(\frac{1}{n} \sum_{i=1}^n \ln(y_i)\right)$$

Particle Size Distribution. Cumulative fraction of soil mass as a function of the equivalent particle size or diameter (the preferred unit is μm).

Dry Aggregate Size Distribution. Cumulative fraction of soil mass as a function of the equivalent dry aggregate size or diameter (the preferred unit is mm).

Mineralogy. Mass fraction (g/g) of individual soil or clay minerals.

Field $\theta(h)$. Volumetric water content, θ (cm^3/cm^3), as a function of soil pressure head, h (cm), for observations in the field.

Field $K(\theta)$. Hydraulic conductivity, K (cm/d), as a function of volumetric water content, θ (cm^3/cm^3), for observations in the field.

Field $D(\theta)$. Soil water diffusivity, D (cm^2/d), as a function of volumetric water content, θ (cm^3/cm^3), for observations in the field.

Field $K(h)$. Hydraulic conductivity, K (cm/d), as a function of soil matric head, h (cm), for observations in the field.

Lab $\theta(h)$. Volumetric water content, θ (cm^3/cm^3), as a function of soil matric head, h (cm), for observations in the laboratory.

Lab $K(\theta)$. Hydraulic conductivity, K (cm/d), as a function of volumetric water content, θ (cm^3/cm^3), for observations in the laboratory.

Lab $D(\theta)$. Soil water diffusivity, D (cm²/d), as a function of volumetric water content, θ (cm³/cm³), for observations in the laboratory.

Lab $K(h)$. Hydraulic conductivity, K (cm/d), as a function of soil matric head, h (cm), for observations in the laboratory.

4. QUERY AND REPORT

UNSODA facilitates queries for parameters characterizing the soil, the invoked experimental procedures, or the location. Data for codes that match the query profile can be written in ASCII form to the screen, printer, or disk. The data can be made up of the entire contents of a record (code) or pre-defined tabular data. This latter option is attractive when hydraulic data are needed for other applications.

A list of query variables is given below. It may be advisable to browse through the database contents (query **All Codes** and write contents to screen) before starting a search. Note that this module does not distinguish between upper and lower case spelling.

Code. Enter a code number. A search can be conducted for code numbers less, less or equal, equal, greater or equal, or greater than the specified value.

Rating. A search can also be conducted based on a (subjective) rating of the quality of the data (1-10) as provided by the contributor. UNSODA can search for codes with a rating less, less or equal, equal, greater or equal, or greater than the specified value.

Family. Conduct a search based on the soil family name by specifying the shortest character string that uniquely identifies the targeted family name.

Series Name. Conduct a search based on the series name by specifying the shortest character string that uniquely identifies the targeted family name. The **List** module contains all series names in UNSODA.

Texture. Specify the exact textural classification according to the USDA-SCS triangle (cf. Table 1). There should be a one-to-one correspondence between specified and targeted texture. The **List** module displays the texture of most codes.

Structure. Conduct a search based on the soil structure by specifying the shortest character string that uniquely identifies the targeted structure type.

Horizon. Enter a character string that matches part of the targeted horizon.

Location. Specify character string occurring in the names of a city, state, or country.

Contact. Enter complete or partial family name to search for codes for which the named individual may provide further information.

Keyword. Enter complete or partial keywords to identify codes with matching characteristics. Examples are disturbed, undisturbed, horizontal, hysteresis, multiphase, salinity, and tillage.

Field Wat. Ret.. Select a number from the list of methods to identify which method was used to determine the water retention curve, $\theta(h)$, in the field.

Lab Wat. Ret.. Select a number from the list of methods to identify which method was used to determine the retention curve, $\theta(h)$, in the laboratory.

Field Hydr. Cond.. Select a number from list of methods to identify which method was used to determine the hydraulic conductivity, $K(\theta)$ or $K(h)$, or soil water diffusivity, $D(\theta)$, in the field.

Lab Hydr. Cond.. Select a number from the list of methods to identify which method was used to determine the hydraulic conductivity, $K(\theta)$ or $K(h)$, or soil water diffusivity, $D(\theta)$, in the laboratory.

Field Ksat.. Select a number from the list of methods to identify which method was used to measure the saturated hydraulic conductivity, K_s , in the field.

Lab Ksat.. Select a number from the list of methods to identify which method was used to measure the saturated hydraulic conductivity, K_s , in the laboratory.

5. PARAMETRIC MODELS FOR SOIL HYDRAULIC FUNCTIONS

Soil water retention and hydraulic conductivity/diffusivity data are often described with closed-form analytical models. The use of mathematical expressions for the retention and hydraulic conductivity curves offers several advantages [van Genuchten *et al.*, 1991]. They allow for a more efficient representation and comparison of the hydraulic properties of different soils and soil horizons, and facilitate the use of scaling procedures for characterizing the spatial variability of soil hydraulic properties. Analytical models also permit more efficient data handling in unsaturated flow models. They offer a way for interpolating or extrapolating to parts of the retention and hydraulic conductivity curves for which little or no data is available. Finally, closed-form expressions have been frequently used in conjunction with indirect methods for estimating soil hydraulic properties [van Genuchten *et al.*, 1992].

The module MODELS of UNSODA facilitates the description of unsaturated soil hydraulic properties with parametric models. An adapted version of the program RETC [van Genuchten *et al.*, 1991] is used to optimize model parameters by fitting the closed-form mathematical expression to the hydraulic data. In addition to the six models included in RETC, users can describe the data in UNSODA with their own models. These alternative models must be included by the user in the original FORTRAN program for RETC as discussed in section 6.4 and as shown in Appendix C. Note that other optimization packages can also be used as long as the input/output structure conforms to the C program for operating the Models section of UNSODA.

The default retention models in UNSODA are based on the retention functions by van Genuchten [1980]

$$S_e = \frac{\theta - \theta_r}{\theta_s - \theta_r} = [1 + (\alpha h)^n]^{-m}$$

and *Brooks and Corey* [1964]

$$S_e = \frac{\theta - \theta_r}{\theta_s - \theta_r} = \begin{cases} (\alpha h)^{-\lambda} & (\alpha h > 1) \\ 1 & (\alpha h \leq 1) \end{cases}$$

where S_e is the effective degree of saturation or the reduced water content ($0 \leq S_e \leq 1$), θ_r and θ_s are the residual and saturated water contents, respectively, α is a parameter inversely related to the air entry value (L^{-1}), and λ , m , and n are parameters that affect the slope or the location of the inflection point of the retention curve. The physical significance of these parameters should not be overestimated; they are primarily of an empirical nature.

The hydraulic conductivity is described with the general models by *Mualem* [1976b] and *Burdine* [1953], respectively:

$$K(S_e) = K_s S_e^\ell \left[\frac{f(S_e)}{f(1)} \right]^2 \quad \text{with} \quad f(S_e) = \int_0^{S_e} \frac{dx}{h(x)}$$

$$K(S_e) = K_s S_e^\ell \left[\frac{g(S_e)}{g(1)} \right] \quad \text{with} \quad g(S_e) = \int_0^{S_e} \frac{dx}{[h(x)]^2}$$

where K_s is the saturated hydraulic conductivity (LT^{-1}) and ℓ is a pore-connectivity parameter. The expressions can be further refined through substitution of the previous retention functions, and integration of the resulting expressions is based on some simplifying assumptions. Details regarding the derivation and the resulting conductivity expressions can be found in *van Genuchten et al.* [1991]. The van Genuchten retention function in conjunction with the conductivity models uses either a flexible value for m or a value for m fixed m at $1-1/n$ for the Mualem model and $1-2/n$ for the Burdine model. Together with the Brooks-Corey retention function this leads to a total of six hydraulic models in conjunction with the Mualem and Burdine models. Table 3 schematically list

the default expressions in RETC (MTYPE \leq 6) as well as possible user-specified models for UNSODA.

TABLE 3. Type of Retention and Conductivity Functions in UNSODA

MTYPE	Retention Model	Conductivity Model
1	van Genuchten (flexible m)	Mualem
2	van Genuchten (flexible m)	Burdine
3	van Genuchten ($m=1-1/n$)	Mualem
4	van Genuchten ($m=1-2/n$)	Burdine
5	Brooks-Corey	Mualem
6	Brooks-Corey	Burdine
7	User-specified models	
.	.. (if applicable)	
.	..	
etc.		

The hydraulic conductivity can be based on either the water content, *i.e.*, $K(\theta)$, or the soil water pressure head (suction), *i.e.*, $K(h)$. Because the Richards equation for water flow in unsaturated soils is sometimes formulated with the soil water diffusivity, $D(\theta)$, instead of the hydraulic conductivity, the use of $D(\theta)$ is included as a third option. The soil-water diffusivity can be readily based on a selected conductivity and retention models according to

$$D(\theta) = K(h)/C(h)$$

where $C(h)=-d\theta/dh$ is the soil water capacity. Expressions for $D(\theta)$ are derived from the previously given closed-form functions of $\theta(h)$ and $K(h)$ or $K(\theta)$. The hydraulic parameters in the six default models in Table 3, or any user-specified model, are optimized with the program RETC.

RETC allows a maximum number of seven fitting parameters, the parameters are contained in the parameter vector $\mathbf{b} = \{ \theta_r, \theta_s, \alpha, n, m, \ell, K_s \}$. Optimal values for the model parameters are found by iteratively minimizing the residual sum of squares. The program allows optimization of: (i) retention data, (ii) conductivity or diffusivity data, and (iii) retention *and* conductivity or diffusivity data. For a simultaneous fit of retention and conductivity or diffusivity data this sum is defined by the objective function

$$O(\mathbf{b}) = \sum_{i=1}^N \{ [\theta_i - \hat{\theta}_i(\mathbf{b})] \}^2 + \sum_{i=N+1}^M \{ W_1 W_2 [Y_i - \hat{Y}_i(\mathbf{b})] \}^2$$

where θ_i and $\hat{\theta}_i$ are the observed and fitted water contents, respectively, Y_i and \hat{Y}_i are the logarithms of observed and fitted conductivity or diffusivity data, N is the number of observed retention data, whereas M denotes the total number of data points (i.e., including K/D). The coefficient W_1 assigns a different weight to the entire K/D data set relative to the retention data while W_2 is calculated internally, it compensates for variations between retention and conductivity/diffusivity data due to differences in the number and/or magnitude of the observations, or as a result of using other units. The default value for W_1 in UNSODA is unity. The relative conductivity is defined as

$$K_r = K/K_s$$

The value for K_r varies between 0 and 1. Its use may be convenient for comparing conductivity curves of different soils or if no reliable value for K_s is yet available. By fixing K_r to 1.0 in the optimization procedure, the values for Y_i and \hat{Y}_i are automatically considered relative values.

It should be emphasized that many data sets in UNSODA exhibit considerable scatter; the objective function for these cases may not converge to a minimum, and the optimization will then be terminated at a hard coded maximum number of 30 iterations. Furthermore, the minimum of the objective function may not always be a global minimum and an incorrect solution of the inversion problem is obtained. Nonunique solutions may also arise when the objective function represents a very flat response surface. This is typical when many parameters are optimized simultaneously using data sets with little resolution (narrow ranges in θ or h). Nonlinear parameter models such as those in RETC require that initial parameters be specified. A judicious choice of initial parameters may

limit the occurrence of nonunique solutions, however, it is advisable to rerun the optimization using a wide variety of initial estimates for \mathbf{b} to ensure that a particular solution for \mathbf{b} is indeed the "best" possible. Parameters can be excluded from the fitting process by fixing them, for instance, if parameters are known independently or are highly correlated with other parameters. UNSODA has a viewing routine to inspect the output file of RETC with statistical information regarding, which can be used to assess the goodness of fit.

UNSODA allows three different ways to specify the initial estimates for the hydraulic parameters in the RETC code. First, the initial estimates can be based on soil texture using the values reported by *Carsel and Parrish* [1988]. A second option for providing initial estimates is the use of retrieved values consisting of the elements of the vector \mathbf{b} from the last optimization. Thirdly, users can specify their own values for the elements in the parameter vector \mathbf{b} . This option is recommended for user-specified models, particularly for the first optimization; subsequent optimizations may then use the second option for specifying initial estimates (i.e., retrieved values). The user should be familiar with the selected hydraulic model to avoid mathematically unrealistic initial estimates which could lead to run time errors during execution of the optimization program.

Carsel and Parrish [1988] provided average values of θ_r , θ_s , α , n , and K_s for 12 soil textural groups of the USDA-SCS classification system. Based on the textural classification for the soil code, initial estimates will be displayed on the screen (Note that this is one of the reasons that it is imperative to specify the texture field exactly according the USDA-SCS system). The values for θ_r , θ_s , α , n , and K_s are shown in Table 4. Additional estimates for the remaining parameters m and ℓ are generated internally. They are independent of texture and based on the selected default model:

- 1 van Genuchten & Mualem (flexible m): $m=1-1/n$, $\ell=0.5$
- 2 van Genuchten & Burdine (flexible m): $m=1-2/n$ ($n>2$) or $m=0.5$ ($n<2$), $\ell=2$
- 3 van Genuchten & Mualem (fixed $m=1-1/n$): $\ell=0.5$
- 4 van Genuchten & Burdine (fixed $m=1-2/n$): $n=2.25$ (if $n<2$ in Table 4), $\ell=2$

- 5 Brooks-Corey & Mualem: $m=1$ and $\ell=0.5$ ($\lambda=n$)
- 6 Brooks-Corey & Burdine: $m=1$ and $\ell=2$ ($\lambda=n$)

TABLE 4. Default Initial Estimates of Selected Parameters in Models for Unsaturated Hydraulic Functions [after *Carsel and Parrish, 1988*]

Texture class	θ_r	θ_s	α 1/cm	n	K_s cm/d
Sand	0.045	0.43	0.145	2.68	712.80
Loamy sand	0.057	0.41	0.124	2.28	350.16
Sandy loam	0.065	0.41	0.075	1.89	106.08
Loam	0.078	0.43	0.036	1.56	24.96
Silt	0.034	0.46	0.016	1.37	6.00
Silt loam	0.067	0.45	0.020	1.41	10.80
Sandy clay loam	0.100	0.39	0.059	1.48	31.44
Clay loam	0.095	0.41	0.019	1.31	6.24
Silty clay loam	0.089	0.43	0.010	1.23	1.68
Sandy clay	0.100	0.38	0.027	1.23	2.88
Silty clay	0.070	0.36	0.005	1.09	0.48
Clay	0.068	0.38	0.008	1.09	4.80

6. DATABASE PROGRAM

6.1. *Software*

The different types of data in UNSODA are stored in 43 tables, which were created with KnowledgeMan® (version 2.5). The tables were designed according to principles of relational database design to minimize duplication and to reduce the size of the tables. Formal database design is further discussed by *Date* [1986] and *Walters* [1987], among others. Each table in UNSODA contains a key field code, which is used by UNSODA to access pertinent records during a query operation. Because of the large number of entries, and the disparity in the number of data points between soil codes, a special "pointer table" was created for each tabular data table to locate the data for individual soil codes. Comments regarding the measurement of hydraulic properties were assigned numerical values, which are tied to separate tables containing the actual comments. This approach avoids repetition of long character strings for each code, e.g., field measurements on different horizons, or identical laboratory experiments on soil cores.

A database management program to store and access the data was written in Microsoft® C version 7.0 using the KC library from Micro Data Base Systems. This library contains all necessary functions to access and manipulate the above database tables. The program consists of 42 modules with a total of approximately 11,000 lines of code. Several special scrolling and edit routines were developed for UNSODA. Furthermore, the program was linked to the Fortran program RETC for fitting the parametric models by van Genuchten or Brooks-Corey to $\theta(h)$ and the models by Mualem and Burdine to the K/D data.

6.2. *Description of Menu Structure*

The structure of the screen menus and the working of UNSODA will be outlined in this section. A general overview is given of all the current modules of the database program such as data entry and editing, queries, and the use of hydraulic models.

The operation of UNSODA is generally based on the code or record number; as was discussed earlier, a code number is assigned to each data set for a particular soil material. The data for the soil can be determined in the laboratory or in the field on a disturbed or "undisturbed" medium. Although the measurement of various properties may be done on different samples (textural and chemical analysis, hydraulic data from in situ or laboratory measurements), it is assumed that these samples are representative for the same type of porous medium. The management program of UNSODA can perform various tasks on the fields of one or more records. In this section we will discuss the different levels of the menu system. A list of menus is given in Appendix D.

Four distinctive modules are offered in the Main Menu (cf. section 2.3). Users who want to add their own data or who wish to modify existing data have to select module 1 (DATA ENTRY AND EDIT). Module 2 (QUERY AND REPORT GENERATION) allows a user to search for records that match the query fields, selected tabular data or the complete information for matching codes can be written to an output device. Module 3 (MODELS) concerns the use of closed-form expressions for describing selected hydraulic data for a specified code. This module is based on the RETC program [*van Genuchten et al.*, 1991] as was explained in Chapter 5. Finally, several operations on the codes and tables of UNSODA can be done with module 4 (UTILITIES); codes can be deleted or code numbers changed, data tables can be reindexed after their contents have been modified, and the contents of files in a directory to be specified can be viewed.

1. DATA ENTRY AND EDIT

The Data Entry menu appears with six selections. **Create** (1) is selected when a "complete" data set is to be entered for a new soil code, **Append** (2) and **Delete** (3) allow the addition or deletion of tabular data for an existing code, **Edit** (4) is chosen when any type of data is to be changed or deleted for an existing code, **Conversion** (5) allows the automatic change of original units, for data entered, to standard units in UNSODA by defining multiplication factors, and **List** (6) will display a table of all codes in UNSODA with their series name and texture.

1.1. Create a New Soil Code and Enter Data

The Create selection requires that a new unique code number be entered in the Specify New Code # menu for each (soil) record for which data are to be entered. The code numbering is arbitrary; however, it was arbitrarily chosen to use multiples of 10 for code numbers of an independent data set and to increment the last code number by 1, if there is a similarity between the previously added code and the record to be created. This similarity may consist of data being from the same experiment but obtained from a different soil layer or a change in experimental conditions (temperature, salinity). The two numbers for the new code according to this convention are shown on the screen and may be selected by pressing <N> (new) or <P> (previous), respectively. Users may want to use their own numbering convention, for example to optimize the query and report procedure for this purpose; press <I> to input an arbitrary number. Once a code number is provided, the actual data entry can start. The input should be prepared according to Chapter 3, an example is given in Appendix B. The user may want to define conversion factors to directly enter data with units differing from the standard UNSODA units.

The Descriptor Data 1 menu allows entry for fields involving soil classification, location, and climate. It is important that a series name be given, preferably according to an official classification system; otherwise a name based on the location should be chosen to uniquely identify the code(s). The texture name is according to the USDA-SCS system. Data are first typed in, or can be overwritten, by moving from field to field using the <Enter> or <←> key. Pressing the <F10> key for the first time allows one to edit the data for all fields on the screen. Press the upper or lower case letter corresponding to the field that needs changing. To continue data entry, move on to the next screen by pressing <F10> again. Leave the data entry menu without any data allocation for this code (its number will be disregarded) by pressing <Esc>. The use of <F10>, <Esc>, <Enter>, and <LETTER> keys is similar for other screens.

The Descriptor Data 2 menu allows further background information to be entered. Note that in version 1.0 of UNSODA, no data allocation is possible unless some type of (fictitious) information

is provided for at least one of the fields from Descriptor Data 2. The Soil Properties menu contains fields for numerical data of basic soil properties. Since a fairly wide range of soil properties is included it is unlikely that there are data for all fields. For missing data no value should be entered. Note that only one value can be entered for each field, the user may need to average multiple data to get a value most characteristic for the soil material. Upon completion, the user will be asked whether the new code should be included in UNSODA.

If the data entry session for the code is continued; the Methodology menu appears for the purpose of entering comments on the measurement of water retention (**Field and Lab $\theta(h)$**), hydraulic conductivity (**Field and Lab K/D**), saturated conductivity (**Field and Lab K_{sat}**), and general field and laboratory procedures (**Field and Lab Comment**). These comments can be selected from a list with existing comments. Existing comments may be viewed using the up $\langle \uparrow \rangle$ and down $\langle \downarrow \rangle$ arrow keys. The number of the displayed comment is shown on the left side of the screen while the initially displayed or selected comment number is shown on the right-hand side. If there is no appropriate comment available, a new comment can be added by copying a similar comment and editing it to obtain the desired formulation or by bypassing the copy feature and by formulating a new comment from scratch. It is generally not advisable to edit an existing comment without copying it first, as the comment may also be used for other codes. Select "no comment" if data will be entered but if the method of determination is unknown and select "NA" if no data exist. A list of Methodology comments is provided in Appendix E.

The Tabular Data Type menu will automatically appear after quitting the menu on methodology comments. There are 11 types that can be selected, viz.: **Particle Size Distribution, Dry Aggregate Size Distribution, Mineralogy, Field $\theta(h)$, Field $K(\theta)$, Field $D(\theta)$, Field $K(h)$, Lab $\theta(h)$, Lab $K(\theta)$, Lab $D(\theta)$, and Lab $K(h)$** . For hydraulic data the user should specify whether the data are for a drying or wetting branch of the retention curve; only one type of wetting and drying branch can be entered for each code number.

The entry of data pairs is fairly straightforward, using the <F2> key for changes in entered data, the <Esc> key to return to the Tabular Data Type menu without saving the tabular data, and the <F10> to finish entering data with the option to append the data for this code to the appropriate UNSODA table for all codes.

Upon completion of the data entry, the user may want to go to the UTILITIES module to take the geometric average of multivalued tabular data (i.e., one independent value has more than one dependent value) and to sort tabular data, or to reindex the pointers for the tables.

1.2. Append Tabular Data for an Existing Code

The Append option is used to add tabular data to an existing soil code. A number of an existing soil code needs to be entered in the Append Tabular Data menu. The number may be selected from the list of codes in UNSODA — press <Ins> to display the list, move the cursor to the desired code, and press <Enter> — or a number can be typed in by the user. After the type of data is specified through the Tabular Data Type menu, UNSODA will display the appropriate tabular data screen to enter the independent and dependent variables. Similar key strokes are used as in the **Create** routine. The screen also contains the number of data pairs already stored in UNSODA for this code number; use the Edit option to alter existing data.

1.3. Delete Tabular Data for an Existing Code

Upon choosing the Delete Tabular Data option, the user is prompted to provide a code number on the Tabular Data to be Deleted menu; again, this can be done by typing in a code number or by making a selection from the code list. Subsequently a list with types of tabular data appears on the Tabular Data to be Deleted menu, select the type from which some or all data pairs are to be deleted. For hydraulic data a wetting or drying cycle needs to be specified. Individual observations are marked (*) for deletion by typing the displayed number (#), press <F10> when the marking of records is finished. The user has to confirm deletion of the marked records.

1.4. Edit Any Data for an Existing Code

The screen Edit Data prompts the user to specify the code number for which data are to be edited. In the Select Type of Data menu a choice can be made between:

General Information Data. Select this option if descriptor data and basic soil properties must be changed. The selection accesses the Descriptor Data 1, Descriptor Data 2, and Soil Properties menus. Press the letter for the field to be edited. The user is asked whether the changes should be saved.

Tabular Data. For the hydraulic data first specify if data from the wetting, <W>, or drying, <D>, curve need to be edited. The data pair to be edited is selected by typing its number (1<#<9). Possible additional data pairs can be viewed by using the arrow keys (<↑> and <↓>).

Methodology. Comments on field and laboratory methodology can be edited by selecting the Methodology option. The appropriate comment is selected similarly as in the **Create** routine.

1.5. Conversion Factors for Dimensions

Selection of Conversion allows a user to set all conversion factors to the default value of 1 or to enter different values for selected fields with the Conversion Factors for Dimensions menu. In case of the latter choice, a list with 18 conversion factors appears. The "standard" units for UNSODA are given in parentheses. The use of the conversion feature allows the entry of "raw" data for fields having units that differ from the standard UNSODA units. The data will be automatically multiplied by the conversion factor, which has the dimension of standard UNSODA units over "raw" data unit. Conversion factors have to be specified for each session of UNSODA, otherwise default unit values will be used.

1.6. List Codes and Series Names

The final option of the data entry menu lets the user go through the contents of UNSODA, displaying code numbers with corresponding series name and texture, using the List menu.

2. QUERY AND REPORT GENERATION

The second and probably most utilized module of the main menu concerns the search for codes that meet query specifications for all selected fields and the reporting of database information to an output device. The Data to be Searched menu offers the choice to: (1) query for one or more fields and retrieve **Specific Codes** that match specifications, these specifications are subsequently written to an output device; (2) report contents of **All Codes** in UNSODA to an output device, *i.e.*, the query feature is bypassed; (3) query as under (1) but only report **Specific Tabular Data** to an output device; and (4) display the contents of UNSODA, again, with **List Codes**.

2.1. Specific Codes

Data for one or more fields to be searched are specified with the Specify Search Fields menu. To conduct a search, move the cursor to the name of a field to be searched, set the field by pressing <Enter> — this is a toggle key that can also be used to "unset" or disable search fields, type the search string, press <Enter> again. Additional search strings can be specified in this way, or the search can be started by pressing <F10>. For alphabetical search fields the program will try to match the specified character string with the data for all codes in UNSODA for the designated field. In case texture is used as the search field, codes will not be found unless the search field completely matches the texture entry in UNSODA, and vice versa. Identical names as in the USDA-SCS textural triangle should therefore be used for the texture field. For example, if "sand" is specified as a query in the texture field, no codes with "sandy loam" as texture will be retrieved. For fields other than texture, a less restrictive search can be conducted by specifying an incomplete entry.

Queries for comments on the methodology are specified with the current table of comments. For numerical values (code number or rating), the program can search for codes with values greater than, equal to, or lesser than the specified numerical values. If the code number is a search field, the screen Code: will appear to specify the code range of interest with respect to the specified value (*i.e.*, >, ≥, =, ≤, or <). A similar screen, Rating:, will appear if rating is selected as a search field. After completion of the search the Device Settings menu will be displayed. Data for the codes that match

the search profile can be reported by first selecting the output device (the <Enter> key again acts as a toggle switch): (1) screen, (2) disk, or (3) printer; and then (4) compile the report. The **screen** option allows the user to scroll through the complete contents of a matching code, using <↓> and <↑>, or to move to different matching codes, using <PgDn> and <PgUp>. The database contents for matching codes can be written to a file on a floppy or hard disk with the **disk** option; the user will need to provide a file name and, if desired, the directory on the Filename menu. Similarly, a hard copy can be obtained by selecting the **printer** option. The user should check printer requirements for this option, and the program may be exited to specify the device.

2.2. All Codes

No search will be conducted for this option and the program will directly go to Device Settings menu; output can be generated in the same manner as for **Specific Codes**. This selection is probably most useful for writing the database contents to the screen and perusing the data.

2.3. Specific Tabular Data

Most users of UNSODA are likely interested in hydraulic data per se, in which case there is no need for general information or basic soil properties. The **Specific Tabular Data** option lets the user write specified tabular data sets to an output device after a search has been conducted. Although the **Specific Tabular Data** option is essentially the same as the **Specific Codes** option; the user must specify after the search is completed which data are to be written to an output device from the Select Table to Print From menu. Because the output is limited to tabular data, less editing is required before the data can be used as input to other application software (e.g., numerical simulation of soil water flow, research of indirect methods for estimating unsaturated hydraulic properties).

2.4. List Codes

Use the List screen to view code numbers, series name, and soil texture.

3. MODELS

This module needs to be selected for describing the unsaturated hydraulic data in UNSODA. The Models menu offers the option to (1) update model names and numbers (**Add/Delete Model Name**), (2) describe hydraulic data with any of these models using the optimization program RETC as outlined in Chapter 5 (**Execute RETC Optimization**), or (3) view any file in the default directory (**View RETC Results or any other File**).

3.1. Add/Delete Model Name

A list of all current parametric models in UNSODA will be displayed on the Add/Delete Model screen. Typically only the six RETC models will be shown [*van Genuchten*, 1991]. A name can be deleted from the list by pressing <F9> whereas a name can be added by first pressing <F10> and then typing a name. The number (MTYPE) to identify the model with this name in the program RETC4.FOR (section 4.4). The addition or deletion of model names is of little consequence as long as the RETC4.FOR program does not reflect them.

3.2. Execute RETC Optimization

The user should know the code number and the precise type of hydraulic data to be modeled. The code number is specified with the Code to be Modeled screen; the number can be typed in or selected from the List routine by first pressing <Ins>. The retention and conductivity/diffusivity data need to be from the same type of wetting or drying cycle; this is specified on the Hydraulic Curve screen. The hydraulic model to be optimized to the data with the RETC code is selected from the Select Models for RETC menu. A choice can be made with the Type of Hydraulic Data menu which data should be optimized by RETC: (1) **Retention and Conductivity/Diffusivity Data**, (2) **Retention Data only**, or (3) **Conductivity/Diffusivity Data only**. Depending on the preference, field or laboratory data need to be specified and the type of K/D data (i.e., K(h), K(θ), or D(θ)).

An important part of the optimization is the selection of the initial estimates, this is done on the Initial Parameters screen. As explained in Chapter 5, the initial estimates can be specified in three

different ways. Estimates for the default RETC models based on the texture of the soil code using the data from *Carsel and Parrish* [1988] are shown as the suggested <S> parameters. Retrieved <R> values are based on the results of the last optimization. Users <U> can also specify their own initial values for the model parameters. This last option will normally be needed for user-specified models (MTYPE>6). Note that the parameter names appearing on the screen correspond to those of the seven-parameter models in RETC, their meaning may be quite different for other hydraulic models. Each parameter can be fixed, i.e., the parameter remains equal to its initial estimate during the entire optimization. After the Summary of Options screen appears, which may be used for debugging purposes, the Output screen requires specification of a file name and, if desired, a path to another directory. The fitting results are not automatically written to UNSODA.

The results of the RETC execution can be inspected with the View Model Output screen. The user can now decide whether or not to (i) perform another optimization, (ii) write the model results to UNSODA, or (iii) abandon the optimization. Note that run-time errors may easily occur during execution of RETC4.FOR because of incorrect or incomplete data, poor initial estimates, or an inadequate model. The user will have to make a decision whether and how the optimization can be improved, after which UNSODA can be started again. Upon review of the output file, the results can be stored in UNSODA using the Store Model Output menu. The results are parameter values (θ_r , θ_s , α , n , K_{sat} , l , m), type of mathematical model, type of hydraulic data, sum of squares, and the regression coefficient for goodness of fit.

3.3. View RETC Results or any other File

The last option of the Models module allows the user to view files in the directory of the database, among them are files of the output of the RETC optimization.

4. UTILITIES

The final choice of the main menu is the Utilities module for updating the database contents and improve the efficiency of the table structure.

4.1. Delete Code

Codes can be selected for deletion through the Delete Code menu by specifying a code number (either by typing in the number or choosing it from the list of codes). The code number and all the information pertaining to the code will be removed from UNSODA. Subsequently, the program will automatically reindex the tables.

4.2. Change Code

This option allows the renumbering of codes. The Change Code menu asks for the old code number (from a list or direct entry) and a new number. Note that this is not a copy procedure, upon completion, the old number will no longer exist.

4.3. List Codes

Use this command to list all code numbers in UNSODA with, if available, their series name and texture.

4.4. Reindex Data Tables

With the Reindex menu the pointer tables for data in UNSODA can be updated. Reindexing is necessary if (external) tabular data are used in the management program. Reindexing should also be done immediately after installation of UNSODA. Note that UNSODA cannot work correctly if the pointers do not correspond to the correct tabular data (cf. section 6.3). Further use of the database without reindexing may corrupt the data tables.

4.5. Sort Tabular Data

Tabular data can be sorted using the Sort Tabular Data menu. The code number and the data type need to be specified. Data will be sorted in ascending order and the geometric mean will be taken of data pairs with the same value for the independent variable (i.e., pressure head for retention and pressure head or water content for K/D). It is assumed that the data obey a lognormal distribution.

4.6. Check Pointer Tables

The Pointer Table Checker detects "gaps" and "overlaps" in the pointers of tabular data. In case an error is detected and reindexing does not rectify the problem, the user should read in an older, correct version of the relevant data table.

4.7. View Text or Data Tables

The View Text or Data Tables routine allows one to read ASCII files in the default directory or any other directory specified by the user, while running the database program. Press <F1> for more information on using the different keys.

6.3. Table Structure

The data in UNSODA are stored in a variety of data tables within the KMAN database system. The tables are structured for flexibility and efficiency in data storage and manipulation for a wide variety of different properties and characteristics. Table 5 shows a general database structure for different types of tables, the first column contains the general table name, the second column describes the format including the length of character strings, and the third column describes the type of data (fields) that follow the format of the general table. Although real values for numerical data appear to have only a limited number of decimal places (typically 5) during I/O operations, the number of significant digits that can be stored in UNSODA is considerably higher. The actual number is hardware dependent.

TABLE 5. Table Structure of UNSODA

Table Name	Data Format	Comment
LCOMMENT	character (800)	Long comment for field or laboratory procedures
SCOMMENT	character (80)	Short comment for measurement of hydraulic properties
MINERAL	character (20)	Mineral name
	real	Mass fraction of mineral
MODELS	integer	Number of model for unsaturated hydraulic properties
	character (65)	Name of model
RAW_PTR	integer	CODE: record number for pointers of hydraulic functions
	integer	BR: beginning of data for record in a hydraulic table
	integer	ER: end of data for record in a hydraulic table
LOCATION	character (1)	DCURVE: drying (D) or wetting (W) curve
	integer	CODE: record number
	character (60)	LOCATION: names of city, state or province, and country
	character (25)	SITE: more detailed description of location
	character (6)	HORIZON: name of soil horizon
	integer	LOW: upper position (minimum depth) of horizon
RAW_DATA	integer	HIGH: upper position (minimum depth) of horizon
	real	D1: independent variable of hydraulic data table
METHODO	real	D2: dependent variable of hydraulic data table
	integer	CODE: record number
	integer	FWATRET: comment number for field water retention
	integer	LWATRET: comment number for lab water retention
	integer	FHYCOND: comment number for field hydraulic conductivity
	integer	LHYCOND: comment number for lab hydraulic conductivity
	integer	FKSAT: comment number for field saturated conductivity
	integer	LKSAT: comment number for lab saturated conductivity
	integer	FCOMMNUM: comment number for field procedures
integer	LCOMMNUM: comment number for laboratory procedures	
CLASSIF	integer	CODE: record number
	character (35)	STRUCTUR: description of soil structure
	character (25)	TEXTURE: soil texture
	character (50)	FAMILY: name of soil family
CLIMATE	character (30)	SERIES: name of soil series
	integer	CODE: record number
	real	ANNRAIN: amount of annual rain
	real	AVTEMJAN: average temperature in January
	real	AVTEMJUL: average temperature in July
	real	DEPTH: depth of ground-water table

TABLE 5. Continued

Table Name	Data Format	Comment
SOILPR1	integer	CODE: record number
	real	BD: bulk density
	real	POROSITY: porosity
	real	KSAT: saturated hydraulic conductivity
	real	THSAT: saturated water content
	character (240)	COMMENT: information on basic soil properties
SOILPR2	integer	CODE: record number
	real	PARTDEN: particle density
	real	ORGMAT: organic matter
SOILPR2	real	CEC: cation exchange capacity
	real	FEALOX: Fe and Al oxide content
PDM_PTR	integer	CODE: record number for pointer table of particle- and aggregate-size distributions and mineralogy
	integer	BR: beginning of data for a particular record
PSD	integer	ER: end of data for a particular record
	real	SIZE: particle size
	real	CUMFRAC: cumulative mass fraction
MODPARAM	integer	CODE: record number
	integer	MODEL: model number of unsaturated hydraulic function
	integer	METHOD: K(h), K(θ) or D(θ) data
	real	THR: θ_r in RETC
	real	THS: θ_s in RETC
	real	ALPHA: α in RETC
	real	N: n in RETC
	real	KS: K_{sat} in RETC
	real	M: m in RETC
	real	L: ℓ in RETC
	real	RSQUARE: r^2 for regression of fitted and observed data
	real	SSQ: sum of squares for regression
	integer	DTYPE: field or laboratory data
	character (1)	DCURVE: drying (D) or wetting (W) curve
SOILPR3	integer	CODE: record number
	real	PH: pH
	real	ELECTR: total electrolyte level
	real	SAR: sodium adsorption ratio
	real	ESP: exchangeable sodium percentage
	real	EC: electrical conductivity

TABLE 5. Continued

Table Name	Data Format	Comment
TXTHYPRM	character (25)	TEXTURE: Textural classification for initial values of parameters in hydraulic models
	real	THR: θ_r in RETC
	real	THS: θ_s in RETC
	real	ALPHA: α in RETC
	real	N: n in RETC
	real	KS: K_{sat} in RETC
GENINFO	integer	CODE: record number
	character (240)	PUB: published literature on data and measurement
	character (240)	CONTACT: contact for further information
	character (480)	COMMENT: topology, geology, or agriculture at site
	integer	RATING: quality rating
	character (40)	RNAME: name of rater
	character (8)	DATE: approximate date of measurements
PSD_DASD	character (111)	KEYWORD: keywords characterizing experiment
	real	SIZE: equivalent aggregate diameter
HELPTBL	real	CUMFRAC: cumulative mass fraction
	character (1200)	ID DESC: text for help comments

Table 5 pertains to the general structure. The data itself are stored in files with extension ITB as shown in Table 6. An effort was made to combine similar fields that are infrequently used in the same file to increase the efficiency of UNSODA. The Methodology comments consist of a table with numbers for all eight different comments for each code (METHODO.ITB), i.e., the integers in Table 5. These numbers, in turn, are linked to actual comments in eight different files (e.g., FHDRCON.ITB in Table 6) with the LCOMMENT or SCOMMENT structure.

TABLE 6. Files for Data Tables in UNSODA

File Name	Table Name	Description of Field
CLASSIF.ITB	CLASSIF	Soil structure, texture, family, series
CLIMATE.ITB	CLIMATE	Rain, temperature, depth of ground water table
DASD.ITB	PSD_DASD	Dry aggregate-size distribution
FHYDRCON.ITB	SCOMMENT	Comment on field K/D measurement
FKSAT.ITB	SCOMMENT	Comment on field K_{sat} measurement
FLDCOMM.ITB	LCOMMENT	Comment on field procedures
FRAWHK.ITB	RAW_DATA	Field K(h)
FRAWHT.ITB	RAW_DATA	Field θ (h)
FWATRET.ITB	SCOMMENT	Comment on field θ (h) measurement
FRAWTD.ITB	RAW_DATA	Field D(θ)
FRAWTK.ITB	RAW_DATA	Field K(θ)
GENINFO.ITB	GENINFO	Publication information, contact, comment, rating, rater, date, keyword
HELPTBL.ITB	HELPTBL	Help comments for UNSODA menus
LABCOMM.ITB	LCOMMENT	Comment on laboratory procedures
LHYDRCON.ITB	SCOMMENT	Comment on laboratory K(h) measurement
LKSAT.ITB	SCOMMENT	Comment on laboratory K_{sat} measurement
LOCATION.ITB	LOCATION	Location, site, horizon, depth
LRAWHK.ITB	RAW_DATA	Laboratory K(h)
LRAWHT.ITB	RAW_DATA	Laboratory θ (h)
LRAWTD.ITB	RAW_DATA	Laboratory D(θ)
LRAWTK.ITB	RAW_DATA	Laboratory K(θ)
LWATRET.ITB	SCOMMENT	Comment on laboratory θ (h) measurement
METHODO.ITB	METHODO	Comment numbers for laboratory and field measurements (SCOMMENT and LCOMMENT)
MINERAL.ITB	MINERAL	Mineralogy
MODELS.ITB	MODELS	Number and name of hydraulic model
MODPARAM.ITB	MODPARAM	Optimized hydraulic model parameters ($\theta_r, \theta_s, \alpha, n, m, \ell, K_s$)
PSD.ITB	PSD	Particle-size distribution
SOILPR1.ITB	SOILPR1	Bulk density, porosity, K_{sat} , θ_{sat} , comment
SOILPR2.ITB	SOILPR2	Particle density, organic matter, CEC, Fe and Al
SOILPR3.ITB	SOILPR3	pH, concentration, SAR, ESP, EC
TXTHYPRM.ITB	TXTHYPRM	Soil-texture based initial estimates for soil hydraulic models

Tabular data are stored sequentially, the beginning and end of a sequence is denoted with pointers for each record (code). This procedure allows optimal use of the tables regardless of the number of codes that actually possess a particular type of data, or the number of data pairs. Below is an example of a pointer table for laboratory $D(\theta)$ data. The first column in Table 7 contains the code number, the second and third columns denote the beginning (BR) and end (ER) of the data in the data table for that particular code, whereas the fourth column indicates a drying (D) or wetting (W) curve. Note that code 1340 contains ten $D(\theta)$ data (drying curve), these are contained in the data table LRAWTD.ITB and are shown in the last two columns of Table 7.

TABLE 7. Illustration of Pointer Table for Laboratory $D(\theta)$ Data

CODE	BR	ER	Wet/Dry
1340	1	10	D
1341	11	20	D
1342	21	30	D
1350	31	40	D
1351	41	50	D
1352	51	60	D
1420	61	68	W
1430	69	73	W
1450	74	78	D

θ	$D(\theta)$
0.38	52742.00
0.35	1826.00
0.33	227.48
0.31	69.76
0.29	38.44
0.25	14.87
0.23	11.83
0.20	9.03
0.14	5.67
0.13	4.46
0.38	953.00

etc.

Pointer tables for the particle- and aggregate-size distributions, the mineralogy, and the hydraulic data are given below. Whenever (external) tabular data are imported, the pointer table should be reindexed to correctly link general information and tabular data to the soil codes. This is done through the Utilities module of the main menu.

TABLE 8. Pointer Tables for Tabular Data

Table Name	Description
DASDREC.ITB	Dry aggregate-size distribution
MINREC.ITB	Mineralogy
PFHK.ITB	Field $K(h)$
PFHT.ITB	Field $\theta(h)$
PFTD.ITB	Field $D(\theta)$
PFTK.ITB	Field $K(\theta)$
PLHK.ITB	Laboratory $K(h)$
PLHT.ITB	Laboratory $\theta(h)$
PLTD.ITB	Laboratory $D(\theta)$
PLTK.ITB	Laboratory $K(\theta)$
PSDREC.ITB	Particle-size distribution

6.4. Models

Additional models, with $MTYPE > 6$ as shown in Table 3, can be included in the Fortran program RETC4.FOR by the user; this program needs to be recompiled. The modifications should be in a manner consistent with the default models so that the input and output conform to the requirements of the "C" program for interaction with UNSODA and the Fortran program for the optimization. Appendix C contains parts of the program RETC4.FOR that are relevant for user-specified models. The lines that are dependent on the hydraulic model are marked by asterisks, each part is followed by some brief comments. UNSODA prepares the input file RETC.IN based on menu selections by the user and the hydraulic data stored in UNSODA for the selected code. The same input file can be used for models that are not included in RETC. An outline of RETC.IN is given in Table 9.

TABLE 9. Outline of the Input File RETC.IN

Line	Format	Variable	Description
1	A60	TITLE	Number of soil code selected for modeling.
2	A60	TITLE2	Series name for selected soil code.
3	A12	OUTFIL	Name of file to which results of optimization will be written. The default drive is the same as for UNSODA, pathways for other (disk) drives can be included in OUTFIL (cf. A:RETC.OUT).
4	8I8	MTYPE	Type of model to be fitted to the data.
		METHOD	Type of conductivity/diffusivity data to be entered, i.e., $K(\theta)$, $K(h)$, or $D(\theta)$. The log transforms of these data will be used during the optimization.
		KWATER	Input variable for type of fitting. For optimization of $\theta(h)$ and K/D , only $\theta(h)$, only K/D , or no data KWATER equals 0, 1, 2, or 3, respectively.
5	7F11.4	B(I)	Initial estimates for the model parameters. The parameter vector is given by $\mathbf{b} = \{\theta_s, \theta_r, \alpha, n, m, l, K_s\}$. Different parameter vectors can be defined for models used in conjunction with UNSODA which are not included in RETC as long as the order of the elements of \mathbf{b} is consistent.
6	8I8	IT	Number of $\theta(h)$ data.
		IHK	Number of $K(h)$ data.
		ITHK	Number of $K(\theta)$ data.
		ITHD	Number of $D(\theta)$ data.
7	8I8	INDEX(I)	Indices for the coefficients B(I) indicating if the Ith coefficient is an unknown and must be fitted to the data (INDEX(I)=I) or if there is no need to fit the coefficient because it is assumed to be known independently.
8	A	JUNK	Heading for lab and/or field hydraulic data.
If IT>0 ($\theta(h)$ data)			
	2F11.4	X(I)	Pressure head, h.
		Y(I)	Volumetric water content, θ .
IT lines			
If IHK>0 ($K(h)$ data)			
	2F11.4	X(I)	Pressure head, h.
		Y(I)	Hydraulic conductivity, K.
IHK lines			
If ITHK>0 ($K(\theta)$ data)			
	2F11.4	X(I)	Pressure head, h.
		Y(I)	Hydraulic conductivity, K.
ITHK lines			
If ITHD>0 ($D(\theta)$ data)			
	2F11.4	X(I)	Volumetric water content, θ .
		Y(I)	Soil water diffusivity.
ITHD lines			

Users ordinarily need not be concerned with this file since it is generated automatically by the database program. Other common variables that may need to be adjusted are given in Table 10.

TABLE 10. Miscellaneous Key Parameters in RETC4.FOR

NWC	Number of water retention data (=IT)
NOB	Total number of observed hydraulic data, i.e., retention and conductivity/diffusivity data. Initially NOB is set to 0, it is then calculated as IT+IHK or IT+ITHK or IT+ITHD.
KITER	Improved estimates for the unknown coefficients are printed during the first KITER iterations of the optimization. Results for the last iteration are always printed. UNSODA uses KITER=4 as its default value.
MIT	Maximum number of iterations. MIT=30 is the default value.
W1	Weighting coefficient in objective function to give the relative weight of K/D data with respect to retention data. The default value for W1 is 1.

7. EXAMPLES

The purpose of this chapter is to familiarize readers with the database management program by taking the user of UNSODA step-by-step through three examples. The examples are illustrated in this manual using screen output. The number of screen that is shown will be given in parentheses in the text. The examples provide a convenient introduction to the program and also demonstrate potential applications of UNSODA.

7.1. Data Entry and Edit

Assuming that data have been prepared according to Chapter 3, an example to consider the case illustrated in Appendix B with retention and conductivity data from the field, and retention data as well as some other properties determined in the laboratory is presented. After starting UNSODA by typing "start" and passing through the introductory screen by pressing any key, the Main Menu (1) appears. The first option is selected by pressing <1> or <Enter> and the Data Entry menu (2) will be displayed. For this example, a value for K_s will be entered with units of cm/h. To let UNSODA convert this automatically to the standard unit (cm/d) upon entry press <5> and select <2> from the Conversion Factors for Dimensions menu (3) to reach the screen with Conversion Factors for Dimensions. Next, press <F> and type the value 24.00 h/d (4). Return to the Data Entry menu by pressing <Enter> and <Esc> and select <1> to reach the Specify New Code# screen (5). There are two suggested numbers on the screen based on the last code number that was created, say 4960. If the data are unrelated to those in code 4960, a completely new set of code numbers can be started by pressing <N>, *i.e.*, the code number will be 4970. If the data are somehow related to those of code 4960, *e.g.*, the next horizon of a soil profile, then the suggested number 4961 is obtained by adding 1 to the previous code (<P>). The user can specify an arbitrary number as well (<I>). For this example by pressing <N>, the Descriptor Data 1 screen (6) appears. Information according to Appendix B can now be typed. Move from field to field in the entry mode by pressing <Enter>. When data entry is completed or if a mistake was made (no editing is possible in the entry mode), press <F10>. To correct, for example, a misspelled series name Troop (6), press <A> and a new

set of keys can be used for cursor movement as shown at the bottom of the screen (7). After the series name has been corrected, press <Enter> and <F10> to enter data in the Descriptor Data 2 screen (8). Upon completion of data entry, press <F10> twice and the Soil Properties screen (9) is reached. Notice the value of the conversion factor at the bottom of the screen for each field. When a saturated conductivity value of 7.13 cm/h is specified, a value of 24 h/d is displayed for the conversion factor. The value for K_s will automatically be recalculated to 171.4 cm/d after pressing <Enter> (10).

The <F10> key can be pressed at any time for corrections. Pressing <F10> again will elicit a response from the user whether or not this code should actually be established (11). After responding with <y>, the program reaches the Methodology menu (12). To specify the procedure for determining, for example, the saturated conductivity in the laboratory, press <6>. The comments currently used can be viewed by moving through the Lab Ksat Comments menu. The initial (ninth) comment (13) is not applicable and the cursor is moved up to the first comment with the <↑> key to reach the first comment. This comment is selected by pressing <S> (14). The entry of Methodology comments can be discontinued by pressing <Esc> to go to the Tabular Data Type menu (15). Press <8>, for instance, to enter laboratory retention data; specify that the data are from the drying curve (16) and start typing data with the Lab $\theta(h)$ screen (17). Press <Enter> each time a number has been entered. Assuming that a mistake was made in the sixth row (17), press <F2> and <6> to type the correct data pair with the keys shown at the bottom of the screen (18), correct the mistake, and press <F5> to continue data entry. Upon entry of all data press <F10>, <y>, and <Esc>.

Assuming that additional retention data have become available for a particular code, these can be added by using the second (Append) option of the Data Entry menu (19). Select the number by pressing the <Ins> key (20), go to the end of the List screen and hit <Enter> to specify the number (21) and confirm the selection (22). Press <8> (23) and <D>, and enter the data (24). These data are in decreasing order and have the same pressure head — in this example — as the existing data. Upon appending the data, press <Esc> twice to return to the Main Menu from which the UTILITIES

module was selected (25). Type <5> to sort tabular data and press <Ins> to again specify the code number through the List option. Confirm the number for sorting (26), and press <8> (27) and <D> to sort and average all laboratory retention data from the drying curve. Press <Esc> twice to return to the Main Menu and press <4> to inspect the data through the Edit option (28); better methods for viewing data will be discussed in section 7.2. Upon reaching the Select Type of Data screen (29), press <2> and then <8> and <D> to view the retention data after sorting and averaging. As can be seen (30), the data are in ascending order for the pressure head and each value of the pressure head occurs only once; the water contents at each of the pressure heads of 100, 500, and 1000 cm have been averaged. Contents of the above (example) code can be eliminated by returning to the Main Menu, selecting the UTILITIES module, and then pressing the **Delete Code** option (31). Press <Ins> to again display a list of codes and hit return when the cursor reaches code number 4970, which needs deletion. The program will ask to confirm the deletion (32) and update the data tables accordingly. Return to the Utilities menu by pressing <Esc> and check whether the code has actually been deleted using the **List Codes** option <3>. As can be seen (33), the total number of records is reduced by one and code number 4970 has disappeared from the list. This completes the first example session and the Main Menu can be returned to by pressing <Esc> four times.

(1)

```

UNSODA 1.0                --- Main Menu ---

1) Data Entry and Edit
2) Query and Report Generation
3) Models
4) Utilities

<F1> Help      <↑↓>      <Enter> or <#> Select      <Esc> Quit

```

(2)

UNSODA 1.0 --- Data Entry ---

```

1) Create a New Soil Code and Enter Data
2) Append Tabular Data for an Existing Code
3) Delete Tabular Data for an Existing Code
4) Edit Any Data for an Existing Code
5) Conversion Factors for Dimensions
6) List Codes and Series Names
    
```

<F1> Help <↑↓> <Enter> or <#> Select <Esc> Quit

(3)

UNSODA 1.0 --- Conversion Factors for Dimensions ---

```

1) Initialize Conversion Factors to 1.0
2) Edit Conversion Factors
    
```

<F1> Help <↑↓> <Enter> or <#> Select <Esc> Quit

(4)

UNSODA 1.0 --- Conversion Factors for Dimensions ---

```

A)                    Length (cm):    1.000
B)                    Bulk Density (g/cm3): 1.000
C)                    Particle Density (g/cm3): 1.000
D)                    Porosity (cm3/cm3): 1.000
E)                    Organic Matter Content (%): 1.000
F)                    Saturated Conductivity (cm/d): 24.00
G)                    Saturated Water Content (cm3/cm3): 1.000
H)                    Cation Exchange Capacity (cmol/kg): 1.000
I)                    Electrolyte Level (meq/l): 1.000
J)                    EC (dS/m): 1.000
K)                    Free Fe and Al Oxide (%): 1.000
L)                    Particle Size Distr.- Size (um): 1.000
M)                    Cum. Fraction (g/g): 1.000
N)                    Mass Fraction (%): 1.000
O)                    Dry Aggr. Size Distr. - Size (mm): 1.000
P)                    Water Retention (cm): 1.000
Q)                    Conductivity (cm/d): 1.000
R)                    Diffusivity (cm2/d): 1.000
    
```

<F1> Help <Letter> Edit factor <Esc> Quit

(5)

```
UNSODA 1.0          --- Specify New Code# ---          Entry/Create
```

```
N) New Data Set Code Number: 4970
P) Previous Data Set Code Number: 4961
I) Input Arbitrary Code Number
```

```
Selection: _
```

```
<F1> Help          <↑↓>          <Enter> or <#> Select          <Esc> Quit
```

(6)

```
UNSODA 1.0          --- Descriptor Data 1 ---          Entry/Create
Code: 4970
```

```
A)          Family: Loamy, siliceous thermic Grossarenic Pal
B)          Series Name: Troop
C)          Texture: loamy sand
D)          Structure: weak granular
E)          Upper Depth:
F)          Lower Depth: 24
G)          Horizon: Ap
H)          Depth to Groundwater:
I)          Location: Union Springs, AL, USA
J)          Site: West plot_
K)          Annual Rainfall:
L)          Avg. Temperature January <C>:
M)          Avg. Temperature July <C>:
```

```
<F1> Help          <Enter> Next Line          <F10> Continue          <Esc> Quit
```

(7)

```
UNSODA 1.0          --- Descriptor Data 1 ---          Entry/Create
Code: 4970
```

```
A)          Family: Loamy, siliceous thermic Grossarenic Pal
B)          Series Name: Troop
C)          Texture: loamy sand
D)          Structure: weak granular
E)          Upper Depth:
F)          Lower Depth: 24
G)          Horizon: Ap
H)          Depth to Groundwater:
I)          Location: Union Springs, AL, USA
J)          Site: West plot
K)          Annual Rainfall:
L)          Avg. Temperature January <C>:
M)          Avg. Temperature July <C>:
```

```
<F1> Help          <←→> <Delete> <Backspace> <Insert> <Home> <End> <Enter>
```

(8)

UNSOEDA 1.0 Code: 4970	--- Descriptor Data 2 ---	Entry/Create
---------------------------	---------------------------	--------------

```
A)                                     Date: 1979
B)           Publication Info: SCS Bull. 262_
C)               Contact:
D)           Rating (0-10):
E)           Rated by:
F)           Comment:
G)           Keyword:
```

NOTE:
In order for the database to function properly, at least one item on this screen must be entered!

<F1> Help <Enter> Next Line <F10> Continue <Esc> Quit

(9)

UNSOEDA 1.0 Code: 4970	-- Soil Properties --	Entry/Create
---------------------------	-----------------------	--------------

```
A)           Bulk Density (g/cm3): 1.64
B)           Particle Density (g/cm3): 2.64
C)           Porosity (cm3/cm3): 0.394
D)           Organic Matter Content (%):
E)           Saturated Conductivity (cm/d): 7.13
F)           Saturated Water Content (cm3/cm3):
G)           Cation Exchange Capacity (cmol/kg):
H)           pH:
I)           Electrolyte Level (meq/l):
J)           SAR (mmol/l)^1/2:
K)           ESP (%):
L)           EC (dS/m):
M)           Free Fe and Al Oxide (%):
N)           Comment:
```

Conversion Factor: 24.000000

<F1> Help <Enter> Next Line <F10> Continue <Esc> Quit

(10)

UNSOEDA 1.0 Code: 4970	-- Soil Properties --	Entry/Create
---------------------------	-----------------------	--------------

```
A)           Bulk Density (g/cm3): 1.64
B)           Particle Density (g/cm3): 2.64
C)           Porosity (cm3/cm3): 0.394
D)           Organic Matter Content (%):
E)           Saturated Conductivity (cm/d): 171.1
F)           Saturated Water Content (cm3/cm3): 0.384_
G)           Cation Exchange Capacity (cmol/kg):
H)           pH:
I)           Electrolyte Level (meq/l):
J)           SAR (mmol/l)^1/2:
K)           ESP (%):
L)           EC (dS/m):
M)           Free Fe and Al Oxide (%):
N)           Comment:
```

Conversion Factor: 1.000000

<F1> Help <Enter> Next Line <F10> Continue <Esc> Quit

(11)

UNSODA 1.0 Code: 4970	-- Soil Properties --	Entry/Create
--------------------------	-----------------------	--------------

```

A)          Bulk Density (g/cm3): 1.64
B)          Particle Density (g/cm3): 2.64
C)          Porosity (cm3/cm3): 0.394
D)          Organic Matter Content (%):
E)          Saturated Conductivity (cm/d): 171.1
F)          Saturated Water Content (cm3/cm3): 0.384
G)          Cation Exchange Capacity (cmol/kg):
H)          pH:
I)          Electrolyte Level (meq/l):
J)          SAR (mmol/l)^1/2:
K)          ESP (%):
L)          EC (dS/m):
M)          Free Fe and Al Oxide (%):
N)          Comment:

```

Do you wish to save this information to the database (y/n)? _

(12)

UNSODA 1.0 Code: 4970	--- Methodology ---	Entry/Create&Edit Series: Troup
--------------------------	---------------------	------------------------------------

1) Field 0(h) 2) Lab 0(h) 3) Field K/D 4) Lab K/D 5) Field Ksat 6) Lab Ksat 7) Field Comment 8) Lab Comment
--

<F1> Help	<↑↓>	<Enter> or <#> Select	<Esc> Quit
-----------	------	-----------------------	------------

(13)

UNSODA 1.0 Code: 4970	--- Lab Ksat Comments ---	Entry/C&E/Meth Series: Troup
--------------------------	---------------------------	---------------------------------

Comment number 9

Selected comment number: 9

Permeameter

<F1> Help	<↑↓>, <E> Edit, <A> Add, <S> Select Comment	<ESC> Quit
-----------	---	------------

(14)

UNSO DA 1.0 Code: 4970	--- Lab Ksat Comments ---	Entry/C&E/Meth Series: Troup
---------------------------	---------------------------	---------------------------------

Comment number 1 Selected comment number: 1

Constant head

<F1> Help	<↑↓>, <E> Edit, <A> Add, <S> Select Comment	<ESC> Quit_
-----------	---	-------------

(15)

UNSO DA 1.0 Code: 4970	--- Tabular Data Type ---	Entry/Append Series:
---------------------------	---------------------------	-------------------------

- | |
|---|
| <ul style="list-style-type: none"> 1) Particle Size Distribution 2) Dry Aggregate Size Distribution 3) Mineralogy 4) Field 0(h) 5) Field K(0) 6) Field D(0) 7) Field K(h) <li style="background-color: black; color: white;">8) Lab 0(h) 9) Lab K(0) a) Lab D(0) b) Lab K(h) |
|---|

<F1> Help	<↑↓>	<Enter> or <#> Select	<Esc> Quit
-----------	------	-----------------------	------------

(16)

UNSO DA 1.0 Code: 4970	--- Lab 0(h) ---	Entry/Append Series:
---------------------------	------------------	-------------------------

Wetting or Drying Curve <W/D>? _

<F1> Help	<Esc> Quit
-----------	------------

(17)

UNSODA 1.0 Code: 4970	--- Lab 0(h) ---	Entry/Append Series:
--------------------------	------------------	-------------------------

Row #	Pressure Head	Water Content
1)	0	0.380
2)	10	0.348
3)	20	0.328
4)	30	0.319
5)	50	0.212
6)	100	0.238
7)	200	0.110
8)	500	0.087
9)	1000	0.069

<F1> Help	<F2> Edit	<F10> Append	<Esc> Quit
-----------	-----------	--------------	------------

(18)

UNSODA 1.0 Code: 4970	--- Lab 0(h) ---	Entry/Append Series:
--------------------------	------------------	-------------------------

Row #	Pressure Head	Water Content
1)	0	0.380
2)	10	0.348
3)	20	0.328
4)	30	0.319
5)	50	0.212
6)	100	0.138
7)	200	0.110
8)	500	0.087
9)	1000	0.069
10)		

<F1> Help	<←>	<Delete>	<Backspace>	<Insert>	<Home>	<End>	<Enter>
-----------	-----	----------	-------------	----------	--------	-------	---------

(19)

UNSODA 1.0	--- Data Entry ---
------------	--------------------

1) Create a New Soil Code and Enter Data
2) Append Tabular Data for an Existing Code
3) Delete Tabular Data for an Existing Code
4) Edit Any Data for an Existing Code
5) Conversion Factors for Dimensions
6) List Codes and Series Names

<F1> Help	<↑↓>	<Enter> or <#> Select	<Esc> Quit
-----------	------	-----------------------	------------

(23)

UNSODA 1.0 Code: 4970	--- Tabular Data Type ---	Entry/Append Series: Troup
--------------------------	---------------------------	-------------------------------

1) Particle Size Distribution 2) Dry Aggregate Size Distribution 3) Mineralogy 4) Field 0(h) 5) Field K(0) 6) Field D(0) 7) Field K(h) 8) Lab 0(h) 9) Lab K(0) a) Lab D(0) b) Lab K(h)
--

<F1> Help	<↑>	<Enter> or <#> Select	<Esc> Quit
-----------	-----	-----------------------	------------

(24)

UNSODA 1.0 Code: 4970	--- Lab 0(h) ---	Entry/Append Series: Troup
--------------------------	------------------	-------------------------------

9 data already exist

Row #	Pressure Head	Water Content
1)	1000	0.069
2)	500	0.09
3)	500	0.095
4)	100	0.140
5)		

Append the data (y/n)? _

(25)

UNSODA 1.0	--- Utilities ---
------------	-------------------

1) DELETE Code 2) CHANGE Code 3) LIST Codes 4) REINDEX Data Tables 5) SORT Tabular Data 6) CHECK Pointer Tables 7) VIEW Text or Data Files
--

<F1> Help	<↑>	<Enter> or <#> Select	<Esc> Quit
-----------	-----	-----------------------	------------

(26)

```
UNSODA 1.0          --- Sort Tabular Data ---          Utilities
```

```
Please input a code number: 4970
```

```
Sort tabular data of code? 4970
Is this correct <y/n>?
```

```
<F1> Help          <Ins> List Codes          <Esc> Quit
```

(27)

```
UNSODA 1.0          --- Sort Tabular Data ---          Utilities
Code: 4970          Series: Troup
```

- 1) Particle Size Distribution
- 2) Dry Aggregate Size Distribution
- 3) Mineralogy
- 4) Field 0(h)
- 5) Field K(0)
- 6) Field D(0)
- 7) Field K(h)
- 8) Lab 0(h)**
- 9) Lab K(0)
- a) Lab D(0)
- b) Lab K(h)

```
<F1> Help          <↑↓>          <Enter> or <#> Select          <Esc> Quit
```

(28)

```
UNSODA 1.0          --- Data Entry ---
```

- 1) Create a New Soil Code and Enter Data
- 2) Append Tabular Data for an Existing Code
- 3) Delete Tabular Data for an Existing Code
- 4) Edit Any Data for an Existing Code**
- 5) Conversion Factors for Dimensions
- 6) List Codes and Series Names

```
<F1> Help          <↑↓>          <Enter> or <#> Select          <Esc> Quit
```

(29)

UNSODA 1.0 --- Select Type of Data --- Entry/Edit

1) General Information Data
 2) Tabular Data
 3) Methodology Comments

<F1> Help <↑↓> <Enter> or <#> Select <Esc> Quit

(30)

UNSODA 1.0 Edit Lab Retention Dataa --- Entry/Edit
 Code: 4970 Drying curve Series: Troup

#	Pressure Head	Water Content
1>	0.00000	0.38000
2>	10.00000	0.34800
3>	20.00000	0.32800
4>	30.00000	0.31900
5>	50.00000	0.21200
6>	100.00000	0.13900
7>	200.00000	0.11000
8>	500.00000	0.09061
9>	1000.00000	0.06900

Enter row number <#>: _

<F1> Help <Esc> Quit

(31)

UNSODA 1.0 --- Utilities ---

1) DELETE Code
 2) CHANGE Code
 3) LIST Codes
 4) REINDEX Data Tables
 5) SORT Tabular Data
 6) CHECK Pointer Tables
 7) VIEW Text or Data Files

<F1> Help <↑↓> <Enter> or <#> Select <Esc> Quit

7.2. Query and Report Generation

The report feature can first be investigated by browsing through the contents of UNSODA without conducting a search. Select QUERY AND REPORT GENERATION of the Main Menu (1) and then press <2>, **All Codes**, on the Data to be Searched screen (2). The screen is the default output device of the Device Settings menu (3). The first screen output appears after the **Compile Report** option <4> is chosen (4). Use the arrow keys <↓> and <↑> to view other screens with information for a code or move to another code by pressing the <PgDn> or <PgUp> keys. The key options are displayed at the bottom of the screen. Press <Esc> to return to the Data to be Searched screen.

Next, an example is presented which demonstrates a search for information on C horizons having a silt loam texture and for which the code must be greater than 2000. Select the **Specific Codes** option <1> of the Data to be Searched menu. Move through the Specify Search Fields menu with the arrow keys, press <Enter> or <↔> when a field is reached for which a search value needs to be typed in, and press <Enter> again to set the field. After all three search fields have been set (5), press <F10> to start the query. Select the second option of the Code: screen (6) to specify the range of code numbers (≥ 2000). Information for matching codes can again be written to the screen by pressing <4> of the Device Settings menu. Codes are now being displayed that match the search profile (7). Press <Esc> to initiate another search or to return to the Main Menu.

Finally, to retrieve field-measured water retention data, select the Specific Codes option and go to **Field Wat. Ret. Comment** on the Specify Search Fields menu and press return to obtain comments on the right-hand part of the screen (8). Use the <↓> key until the desired comment is displayed, and then press <Enter> to select the comment (9). Execute the search and write the output to the screen by subsequently typing <F10> and <4>. There are two matching codes as can be seen by moving through the screen output (10). In this case the field water retention data for these codes is to be written to a disk; press <Esc> and repeat the search by using the **Specific Tabular Data** option <3> from the Data to be Searched screen (11). After the methodology comment has been

specified, select the **Field 0(h)** option <4> of the Select Table to Print from (12) and type, for example, the file name a:\fret.dat (13). The contents of the file can be inspected by returning to the Main Menu and selecting the **Utilities** option <4>. From the Utilities menu (14) select <7>, **View Text or Data Files**, and press <F7> to change directory/drive (15). After specifying the directory name (a:), the files currently in the a-directory are displayed on the right-hand side of the screen (16). Use the <↓>, <↑>, <PgDn>, and <PgUp> keys to move through the directory, press <F6> after the desired file is found to enter the file name (17), and view the file in the regular manner (18). Press <Esc> twice to exit the viewing subroutine and return to the Main Menu.

(1)

```
UNSODA 1.0          --- Main Menu ---
```

```
1) Data Entry and Edit
2) Query and Report Generation
3) Models
4) Utilities
```

```
<F1> Help          <↑↓>          <Enter> or <#> Select      <Esc> Quit
```

(2)

```
UNSODA 1.0          --- Data to be Searched ---
```

```
1) Specific Codes
2) All Codes
3) Specific Tabular Data to Disk
4) List Codes
```

```
<F1> Help          <↑↓>          <Enter> or <#> Select      <Esc> Quit
```

(3)

```
UNSODA 1.0          --- Device Settings ---          Query/Report
```

```
1) Screen:<Set>
2)  Disk:<Unset>
3) Printer:<Unset>
4) Compile Report
```

```
<F1> Help          <↑↓>          <Enter> or <#> Select      <Esc> Quit
```

(4)

UNSODA 1.0 Code: 1010	--- Descriptor Data 1 ---	Query/Report Series: Troup
--------------------------	---------------------------	-------------------------------

```

Code: 1010
Family: loamy, siliceous, thermic Grossarenic Paleudult
Series: Troup
Texture: loamy sand
Structure: weak granular
Depth Range: 0 - 24 cm.
Horizon: Ap
Dpt to Grndwtr: 500.00
Location: Union Springs, AL, USA
Site ID: West plot
Annl Rnfall: 140.00
Ave Temp Jan(C): 7.80
Ave Temp Jul(C): 26.70
    
```

<↓> Next Screen	<PgDn> Next Code	<Esc> Quit_
-----------------	------------------	-------------

(5)

UNSODA 1.0	--- Specify Search Fields ---	Query/Report
------------	-------------------------------	--------------

```

Code: 2000
Rating: <Unset>
Family: <Unset>
Series Name: <Unset>
Texture: silt loam
Structure: <Unset>
Horizon: c
Location: <Unset>
Contact: <Unset>
Keyword: <Unset>
Field Wat. Ret. Comment: <Unset>
Lab Wat. Ret. Comment: <Unset>
Field Hydr. Cond. Comment: <Unset>
Lab Hydr. Cond. Comment: <Unset>
Field Ksat. Comment: <Unset>
Lab Ksat. Comment: <Unset>
    
```

<F1> Help	<↑↓>	<Enter> Set/Unset	<F10> Start Query	<Esc> Quit
-----------	------	-------------------	-------------------	------------

(6)

UNSODA 1.0	--- Code: 2000 ---	Query/Report
------------	--------------------	--------------

- | |
|----------------------------|
| 1) Greater |
| 2) Greater or Equal |
| 3) Equal |
| 4) Less or Equal |
| 5) Less |

<F1> Help	<↑↓>	<Enter> or <#> Select	<Esc> Quit
-----------	------	-----------------------	------------

(7)

```

UNSODA 1.0          --- Descriptor Data 1 ---          Query/Report
Code: 2404                                     Series: Gardena lo

```

```

      Code: 2404
      Family: coarse-loamy, mixed, frigid Pachic Haplaboroll
      Series: Gardena loam
      Texture: silt loam
      Structure: NA
      Depth Range: 91 - 122 cm.
      Horizon: C
      Dpt to Grndwtr: NA
      Location: Cass County, ND, USA
      Site ID: Site #5, NE 1/4, S 23, T 137N, R54W
      Annl Rnfall: NA
      Ave Temp Jan(C): NA
      Ave Temp Jul(C): NA

```

```

<↓> Next Screen          <PgDn> Next Code          <Esc> Quit_

```

(8)

```

UNSODA 1.0          --- Specify Search Fields ---          Query/Report

```

```

      Code:<Unset>
      Rating:<Unset>
      Family:<Unset>
      Series Name:<Unset>
      Texture:<Unset>
      Structure:<Unset>
      Horizon:<Unset>
      Location:<Unset>
      Contact:<Unset>
      Keyword:<Unset>
      Field Wat. Ret. Comment:
      Lab Wat. Ret. Comment:<Unset>
      Field Hydr. Cond. Comment:<Unset>
      Lab Hydr. Cond. Comment:<Unset>
      Field Ksat. Comment:<Unset>
      Lab Ksat. Comment:<Unset>

```

```

This is comment number 1 of 8

```

```

Comment:
Tensiometry and neutron
thermalization

```

```

<↑↓> <Enter> Select <Esc> Quit

```

```

<F1> Help <↑↓> <Enter> Set/Unset <F10> Start Query <Esc> Quit

```

(9)

```

UNSODA 1.0          --- Specify Search Fields ---          Query/Report

```

```

      Code:<Unset>
      Rating:<Unset>
      Family:<Unset>
      Series Name:<Unset>
      Texture:<Unset>
      Structure:<Unset>
      Horizon:<Unset>
      Location:<Unset>
      Contact:<Unset>
      Keyword:<Unset>
      Field Wat. Ret. Comment:8
      Lab Wat. Ret. Comment:<Unset>
      Field Hydr. Cond. Comment:<Unset>
      Lab Hydr. Cond. Comment:<Unset>
      Field Ksat. Comment:<Unset>
      Lab Ksat. Comment:<Unset>

```

```

<F1> Help <↑↓> <Enter> Set/Unset <F10> Start Query <Esc> Quit

```

(10)

```

UNSODA 1.0          --- Methodology ---          Query/Report
Code: 3340                                     Series: Wolfheze
    
```

```

      Field Water Retention: Tensiometry and IDR
      Lab Water Retention: Pressure plate and air drying
Field Hydraulic Conductivity: NA
      Lab Hydraulic Conductivity: Sprinkling infiltrometer
      Field Sat. Hydr. Cond.: NA
      Lab Sat. Hydr. Cond.: NA
    
```

```

<↑↓> Previous/Next Screen   <PgDn> Next Code   <Esc> Quit
    
```

(11)

```

UNSODA 1.0          --- Data to be Searched ---
    
```

```

1) Specific Codes
2) All Codes
3) Specific Tabular Data to Disk
4) List Codes
    
```

```

<F1> Help           <↑↓>           <Enter> or <#> Select   <Esc> Quit
    
```

(12)

```

UNSODA 1.0          --- Select Table to Print from ---  Report/Tab
    
```

```

1) Particle Size Distribution
2) Dry Aggregate Size Distribution
3) Mineralogy
4) Field 0(h)
5) Field K(0)
6) Field D(0)
7) Field K(h)
8) Lab 0(h)
9) Lab K(0)
a) Lab D(0)
b) Lab K(h)
    
```

```

<F1> Help           <↑↓>           <Enter> or <#> Select   <Esc> Quit
    
```

(13)

UNSODA 1.0	--- Filename ---	Report/Tab
------------	------------------	------------

New Filename: a:\fret.dat_

<F1> Help	<↑↓>	<Enter> or <#> Select	<Esc> Quit
-----------	------	-----------------------	------------

(14)

UNSODA 1.0	--- Utilities ---
------------	-------------------

1) DELETE Code 2) CHANGE Code 3) LIST Codes 4) REINDEX Data Tables 5) SORT Tabular Data 6) CHECK Pointer Tables 7) VIEW Text or Data Files

<F1> Help	<↑↓>	<Enter> or <#> Select	<Esc> Quit
-----------	------	-----------------------	------------

(15)

UNSODA.ZIP	HELPTBL.IND	PLHK.IND	PLHT.IND	PLTD.IND
PLTK.IND	GENCODE.IND	SOILPR2.ITB	DASD.ITB	DASDREC.ITB
FHYDRCON.ITB	FITCOEF.ITB	FKSAT.ITB	FLDCOMM.ITB	FRAWHT.ITB
FRAWID.ITB	FRAWK.ITB	FWATRET.ITB	LOCACODE.IND	HELPTBL.ITB
LABCOMM.ITB	LHYDRCON.ITB	LKSAT.ITB	PSD.ITB	LRAWHK.ITB
CLASCODE.IND	LRAWID.ITB	LRAWK.ITB	LWATRET.ITB	CLIMCODE.IND
MINERAL.ITB	MINREC.ITB	MODELS.ITB	MODPARAM.ITB	MODUP.ITB
NEWADD.ITB	METHCODE.IND	PFHT.ITB	PFTD.ITB	PFTK.ITB
PLHK.ITB	PSDCODE.IND	PLTD.ITB	PLTK.ITB	MINCODE.IND
FRAWHK.ITB	RSLTDATA.ITB	RSLTLINK.ITB	DASDCODE.IND	CLASSIF.ITB
SOIL1COD.IND	TEMP.ITB	TEMPLATE.ITB	TXTHVPRM.ITB	SCROLL.EXE
START.EXE	REPORT.EXE	RETC3.EXE	PKUNZIP.EXE	PKZIP.EXE
SOIL2COD.IND	SOIL3COD.IND	MODPARAM.IND	PFHT.IND	PFHK.IND
PFTK.IND	PFTD.IND	GENINFO.ITB	METHODO.ITB	LRAWHT.ITB
TXTHVPRM.IND	PLHT.ITB	SOILPR3.ITB	PRNTEMP	LOCATION.ITB
PSDREC.ITB	RETC.IN	RTEMP.IN	CLIMATE.ITB	PFHK.ITB
SOILPRI.ITB				

Directory name: a:_

(16)

UNSODA.ZIP	HELPTBL.IND	PLHK.IND	PLHT.IND	FN
PLTK.IND	GENCODE.IND	SOILPR2.ITB	DASD.ITB	FRET.DAT
FHYDRCON.ITB	FITTCOEF.ITB	PKSAT.ITB	FLDCOMM.ITB	
FRAWTD.ITB	FRAWTK.ITB	FWATRET.ITB	LOCACODE.IND	
LABCMM.ITB	LHYDRCON.ITB	LKSAT.ITB	PSD.ITB	
CLASCODE.IND	LRAWTD.ITB	LRAWTK.ITB	LWATRET.ITB	C
MINERAL.ITB	MINREC.ITB	MODELS.ITB	MODPARAM.ITB	
NEWADD.ITB	METHCODE.IND	PFHT.ITB	PFTD.ITB	
PLHK.ITB	PSDCODE.IND	PLTD.ITB	PLTK.ITB	
FRAWHK.ITB	RSLTDATA.ITB	RSLTLINK.ITB	DASDCODE.IND	
SOIL1COD.IND	TEMP.ITB	TEMPLATE.ITB	TXTHYPRM.ITB	
START.EXE	REPORT.EXE	RETC3.EXE	PKUNZIP.EXE	
SOIL2COD.IND	SOIL3COD.IND	MODPARAM.IND	PFHT.IND	
PFTK.IND	PFTD.IND	GENINFO.ITB	METHODO.ITB	L
TXTHYPRM.IND	PLHT.ITB	SOILPR3.ITB	PRNTEMP	
PSDREC.ITB	RETC.IN	RTEMP.IN	CLIMATE.ITB	
SOILPRI.ITB				

<F1>Help <↑↓> <PgDn.,PgUp> <Home> <End>! <F5>DIR <F6>Open <F7>CDIR/DRU <Esc>Qui

(17)

UNSODA.ZIP	HELPTBL.IND	PLHK.IND	PLHT.IND	FN
PLTK.IND	GENCODE.IND	SOILPR2.ITB	DASD.ITB	FRET.DAT
FHYDRCON.ITB	FITTCOEF.ITB	PKSAT.ITB	FLDCOMM.ITB	
FRAWTD.ITB	FRAWTK.ITB	FWATRET.ITB	LOCACODE.IND	
LABCMM.ITB	LHYDRCON.ITB	LKSAT.ITB	PSD.ITB	
CLASCODE.IND	LRAWTD.ITB	LRAWTK.ITB	LWATRET.ITB	C
MINERAL.ITB	MINREC.ITB	MODELS.ITB	MODPARAM.ITB	
NEWADD.ITB	METHCODE.IND	PFHT.ITB	PFTD.ITB	
PLHK.ITB	PSDCODE.IND	PLTD.ITB	PLTK.ITB	
FRAWHK.ITB	RSLTDATA.ITB	RSLTLINK.ITB	DASDCODE.IND	
SOIL1COD.IND	TEMP.ITB	TEMPLATE.ITB	TXTHYPRM.ITB	
START.EXE	REPORT.EXE	RETC3.EXE	PKUNZIP.EXE	
SOIL2COD.IND	SOIL3COD.IND	MODPARAM.IND	PFHT.IND	
PFTK.IND	PFTD.IND	GENINFO.ITB	METHODO.ITB	L
TXTHYPRM.IND	PLHT.ITB	SOILPR3.ITB	PRNTEMP	
PSDREC.ITB	RETC.IN	RTEMP.IN	CLIMATE.ITB	
SOILPRI.ITB				

File name: fret.dat_

(18)

Code: 3340 Series Name: Wolfheze

Field i(h) Drying Curve

h	i
(cm)	(cm ³ /cm ³)
8.0000	0.3210
19.0000	0.1390
19.0000	0.1240
44.0000	0.1240
65.0000	0.1040
65.0000	0.1060
85.0000	0.1040
131.0000	0.0850
131.0000	0.0870
157.0000	0.0850
223.0000	0.0550
223.0000	0.0560
232.0000	0.0500
232.0000	0.0590
270.0000	0.0550
358.0000	0.0500

<F1>Help <↑↓> <PgDn.,PgUp> <Home> <End>! <F5>DIR <F6>Open <F7>CDIR/DRU <Esc>Qui

7.3. Models

In the last example session, the unsaturated hydraulic data with a closed-form parametric model will be described. To do so, the type of data and hydraulic model that will be used must be decided. By fitting the first model of Table 3 to the field retention and conductivity data of code 3090 associated with the drying branch, the hydraulic conductivity, K , is given as a function of the pressure head, h . Select the MODELS option from the Main Menu (1) and then choose the second option — **Execute RETC Optimization** (2). Type 3090 on the Code to be Modeled screen (3) — this number could also be selected from the code list. Specify the **Drying** option for the Hydraulic Curve screen (4). Then select the **Mualem/van Genuchten Model** where m is fitted (5). Based on initial considerations, *i.e.*, to fit both retention and conductivity data, option <1> is specified from the Type of Hydraulic Data screen (6), while also specifying **Field $\theta(h)$** (7) and **Field $K(h)$** (8) data. The next task is to provide initial estimates for the optimization process. Since this is the first optimization, retrieved values cannot be used. Hence, the suggested (<S>) or textural averaged values (9) are used, and l is fixed at 0.5 (10). A somewhat meaningless Summary of Options screen (11) appears. This summary may be useful when alternative models have been implemented in UNSODA. The name of an output file is to be specified on the Output screen (12). After running RETC, the output file can be viewed with the same routine as in the UTILITIES module through the View Model Output (13). The output can be inspected with the customary keys (14) to decide whether additional optimizations are necessary, or if the data is suitable to be stored in UNSODA. After pressing, <Esc> the Store Model Output screen appears. Finally, the option of storing model results is bypassed by pressing <n>.

(1)

UNSODA 1.0 --- Main Menu ---

1) Data Entry and Edit
2) Query and Report Generation
3) Models
4) Utilities

<F1> Help <↑↓> <Enter> or <#> Select <Esc> Quit

(2)

UNSODA 1.0 --- Models ---

1) Add/Delete Model Name
2) Execute REIC Optimization
3) View REIC Results or any other File

<F1> Help <↑↓> <Enter> or <#> Select <Esc> Quit

(3)

UNSODA 1.0 --- Code to be Modeled --- Model

Search for which code? 3090_

<F1> Help <Ins> List Codes <Esc> Quit

(4)

```

UNSODA 1.0          --- Hydraulic Curve ---          Model
Code: 3090                                     Series: Odessa Che

```

```

1) Wetting
2) Drying

```

```

<F1> Help          <↑↓>          <Enter> or <#> Select          <Esc> Quit

```

(5)

```

UNSODA 1.0          --- Select Model for RETC ---          Model
Code: 3090                                     Series: Odessa Che

```

```

1) Mualem/van Genuchten Model <fitted>
2) Burdine/van Genuchten Model <fitted>
3) Mualem/van Genuchten Model <fixed>
4) Burdine/van Genuchten Model <fixed>
5) Mualem/Brooks and Corey Model
6) Burdine/Brooks and Corey Model

```

```

<F1> Help          <↑↓>          <Enter> or <#> Select          <Esc> Quit

```

(6)

```

UNSODA 1.0          --- Type of Hydraulic Data ---          Model
Code: 3090                                     Series: Odessa Che

```

```

1) Retention and Conductivity or Diffusivity Data
2) Retention Data only
3) Conductivity or Diffusivity Data only

```

```

<F1> Help          <↑↓>          <Enter> or <#> Select          <Esc> Quit

```

(7)

```

UNNSODA 1.0          --- Drying Retention Curve ---          Model
Code: 3090                                     Series: Odessa Che
    
```

```

1) Lab  0(h)
2) Field 0(h)
    
```

```

<F1> Help          <↑↓>          <Enter> or <#> Select          <Esc> Quit
    
```

(8)

```

UNNSODA 1.0          --- Drying K/D ---          Model
Code: 3090                                     Series: Odessa Che
    
```

```

1) Lab  K(h)
2) Field K(h)
3) Lab  K(0)
4) Field K(0)
5) Lab  D(0)
6) Field D(0)
    
```

```

<F1> Help          <↑↓>          <Enter> or <#> Select          <Esc> Quit
    
```

(9)

```

UNNSODA 1.0          --- Initial Parameters ---          Model
Code: 3090                                     Series: Odessa Che
    
```

	θ_r	θ_s	α	n	m	l	K_{sat}
Suggested:	0.067	0.45	0.020	1.41	0.29	0.50	10.80
Retrieved:	0.138	0.34	0.003	1.04	0.58	0.00	42.55

```

Use Suggested, Retrieved, User specified values <S/R/U>?
    
```

```

<F1> Help          <↑↓>          <Enter> or <#> Select          <Esc> Quit
    
```

(10)

```

UNSODA 1.0          --- Initial Parameters ---          Model
Code: 3090                                     Series: Odessa Che

```

	θ_r	θ_s	α	n	m	l	Ksat
Suggested:	0.067	0.45	0.020	1.41	0.29	0.50	10.80
Retrieved:	0.138	0.34	0.003	1.04	0.58	0.00	42.55
Fix (y/n)?:	n	n	n	n	n	y	n

```

Are the fixed or variable parameters correct (y/n)? _

```

(11)

```

UNSODA 1.0          --- Summary of Options ---          Model
Code: 3090                                     Series: Odessa Che

```

```

Curve Type : 2
Model Type : 1
Method Type : 4
 $\theta_r$  : 0.067
 $\theta_s$  : 0.45
 $\alpha$  : 0.020
 $n$  : 1.41
 $m$  : 0.29
 $l$  : 0.50 <fixed>
Ksat : 10.80

```

```

Press any key to continue..._

```

(12)

```

UNSODA 1.0          --- Output ---          Model
Code: 3090                                     Series: Odessa Che

```

```

Please enter the output filename for the RETC program: b:\retc.out_

```

```

<F1> Help          <↑↓>          <Enter> or <#> Select          <Esc> Quit

```


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APPENDIX A. Questionnaire for Data

1. Descriptor Data

Family : _____

Series : _____

Texture : _____ (_____)

Structure : _____

Depth range : _____ cm

Horizon : _____

Depth to ground water : _____ cm

Location : _____

Site : _____

Annual rainfall (cm) : _____

Average temperature January (°C) : _____

Average temperature July (°C) : _____

Date : _____

Publication : _____

Contact : _____
_____ phone _____

fax _____

Rating : ___/10 (_____)

Comments

2. Methodology

Retention Field : _____

 Lab : _____

Conductivity Field : _____

 Lab : _____

K_{sat} Field : _____

 Lab : _____

Comments

Laboratory

Field

3. Soil properties

- Bulk Density (g/cm³) : _____
- Particle Density (g/cm³) : _____
- Porosity (cm³/cm³) : _____
- Organic Matter Content (%) : _____
- Saturated Conductivity (cm/d) : _____
- Saturated Water Content (cm³/cm³) : _____
- pH : _____
- CEC (meq/100 g) : _____
- Electrolyte Level (meq/l) : _____
- SAR (mmol^{1/2}/l^{1/2}) : _____
- ESP (%) : _____
- EC (dS/m) : _____
- Free Fe and Al Oxide (%) : _____

Particle-size Distribution		Mineralogy		Dry Aggregate-Size Distribution	
Size (µm)	Cum. Fraction (g/g)	Mineral	Mass fraction (%)	Size (mm)	Cum. Fraction (g/g)

Comments

4. Unsaturated Hydraulic Properties

A. Water Retention (_____)

Laboratory		Field	
h (cm)	θ (cm ³ /cm ³)	h (cm)	θ (cm ³ /cm ³)

B. Hydraulic Conductivity (_____)

Laboratory			Field		
h (cm)	θ (cm ³ /cm ³)	K (cm/d)	h (cm)	θ (cm ³ /cm ³)	K (cm/d)

C. Soil Water Diffusivity (_____)

Laboratory			Field		
h (cm)	θ (cm ³ /cm ³)	D (cm ² /d)	h (cm)	θ (cm ³ /cm ³)	D (cm ² /d)

APPENDIX B. Sample of Form for Code with Database Information

SAMPLE

1. Descriptor Data

Code : 1010
Family : Loamy, siliceous, thermic Grossarenic Paleudults
Series : Troup
Texture : loamy sand
Structure : weak granular
Depth Range : 0-24 cm
Horizon : Ap
Depth to Ground water :
Location : Union Springs, Ala, USA
Site : West plot
Annual Rainfall (cm) :
Average Temperature January (°C) :
Average Temperature July (°C) :
Date : 1979
Publication : Southern Cooperative Series Bulletin 262, 1983, Alabama
Agricultural Experiment Station, Auburn University, Alabama
Contact : Dr. J. H. Dane, Dept. of Agronomy and Soils, Auburn University, AL
36849-5412. tel. 205-844-3974; fax 205-844-3945.
Rating :

Comments

The site was a pecan orchard with grass cover

2. Methodology

Water Retention Field : Tensiometry and neutron thermalization
Lab : Tempe cell, pressure membrane
Hydraulic Conductivity Field : Instantaneous profile
Lab : -
Sat. Hydr. Cond. (K_{sat}) Field : -
Lab : Constant head

Comments

Laboratory Undisturbed samples were obtained with a drop hammer type sampler. Sample size: I.D.=5.35 cm and height=3 cm for retention and 6 cm for saturated conductivity. Water retention was obtained with Tempe pressure cells, pressure cookers, and pressure membranes. Water outflow volumes between successive pressures were determined gravimetrically. The saturated hydraulic conductivity was determined with the constant head method using vertical samples.
Average temperature during experiment was 25 °C. Drying curve.

Field 2 by 2 m square plots were bounded by 28-cm high boards placed 12 cm above and 16 cm below the surface. A neutron probe access tube was installed at the center of each plot to determine water contents. Soil water pressure head values were obtained using three parallel jet-fill tensiometers, with cups installed at the same depth for which undisturbed samples were taken. The hydraulic conductivity was derived by solving the Richards equation using measured head and water content profiles during drainage after flood irrigation with a zero flux condition at the surface. The data are for the first drainage cycle.

3. Soil properties

Bulk Density (g/cm ³)	:	1.640
Particle Density (g/cm ³)	:	2.64
Porosity (cm ³ /cm ³)	:	0.394
Organic Matter Content (%)	:	0.01
Saturated Conductivity (cm/d)	:	171.1
Saturated Water Content (cm ³ /cm ³)	:	0.384
CEC (meq/100 g)	:	-
pH	:	-
Electrolyte Level (meq/l)	:	-
SAR (mmol ^{1/2} /l ^{1/2})	:	-
ESP (%)	:	-
EC (dS/m)	:	-
Free Fe and Al Oxide (%)	:	-

Particle-Size Distribution		Mineralogy		Dry Aggregate-Size Distribution	
Size (µm)	Cum. Fraction (g/g)	Mineral	Mass fraction (%)	Size (µm)	Cum. Fraction (g/g)
<2	0.030				
<50	0.170				
<106	0.279				
<250	0.735				
<500	0.921				
<1000	0.994				
<2000	1.002				

Comments

Undisturbed samples for bulk density. Disturbed samples for particle density and soil textural analysis. Vertical saturated conductivity. The particle-size distribution was determined with dry sieving while the particle density was determined with the pycnometer method.

4. Unsaturated Hydraulic Properties

A. Water Retention (main drying)

Laboratory		Field	
h (cm)	θ (cm ³ /cm ³)	h (cm)	θ (cm ³ /cm ³)
0	0.380	13	0.292
10	0.348	23	0.273
20	0.328	31	0.257
30	0.319	37	0.245
50	0.212	41	0.235
100	0.138	44	0.227
200	0.110	51	0.193
500	0.087	53	0.181
1000	0.069	56	0.176
		71	0.153
		86	0.136
		89	0.132
		91	0.131
		92	0.128
		96	0.123
		103	0.115
		109	0.110

B. Hydraulic Conductivity (main drying)

Field		
h (cm)	θ (cm ³ /cm ³)	K (cm/d)
18	0.282	45.6
27	0.265	36.96
34	0.251	30.0
39	0.240	24.24
42	0.231	19.75
47	0.215	11.18
51	0.197	3.05
79	0.145	0.432
88	0.134	0.089
90	0.132	0.022
110	0.110	0.002

APPENDIX C. Model Dependent Parts of RETC4.FOR

```
C*****  
DATA BI(8) ' WCR ',BI(9) ' WCS ',BI(10) 'ALPHA',BI(11) ' N '  
DATA BI(12) ' M ',BI(13) 'EXPO ',BI(14) 'CONDS'
```

```
C*****
```

```
C
```

The names for the elements of the vector $\mathbf{b}=\{\theta_r, \theta_s, \alpha, n, m, \ell, K_s\}$ are contained in the array BI. They can be declared in the main program. Note that the choice of parameter names will not affect the optimization procedure as they are only used for identification in the output; they can be modified for convenience. There is no reason to change the names for the six default models from RETC (i.e., $MTYPE \leq 6$ in UNSODA) but changes for other models may help interpreting the program output. The names correspond to the parameter values contained in the array B; obviously, it is important that consistent use is made of the array subscripts when programming additional hydraulic functions.

```
C
```

```
C -----  
SUBROUTINE MODEL(B, Y, X, NWC, NOB, MTYPE, METHOD, INDEX, IOR)
```

```
C
```

The subroutine MODEL contains the formulations of the default hydraulic functions from RETC. Use this subroutine also for implementing additional hydraulic models.

```
C
```

```
C DEFINE ALTERNATIVE NAMES FOR VARIABLES
```

```
C
```

```
IF(MTYPE.GT.6) THEN
```

```
C
```

```
C*****
```

```
WCR=B(8)  
WCS=B(9)  
ALPHA=B(10)  
A1=B(11)  
A2=B(12)  
EXPO=B(13)  
CONDS=B(14)
```

```
C*****
```

```
C
```

The array elements of the optimization vector can be renamed to help programming additional hydraulic models ($MTYPE > 6$). Above is an example of this renaming, the names do not appear in the output and are only for internal use in the subroutine MODEL.

```
C
```

```
C Specify additional retention models
```

```
C
```

```
SELECT CASE(MTYPE)  
CASE(7)
```

```
C
```

```
C*****
```

```

      Y(I)=WCS*(ALPHA*X(I)**(-A1)
C*****
C
      CASE(8)
C
C*****
      Y(I)=WCS*(1+(ALPHA*X(I)**A1)**(-A2)
C*****
C
C   CASE(9)
C   :
C   :
      END SELECT

```

Above is an example of the implementation of two additional retention functions, $\theta(h)$. Expressions for the retention function, i.e., the water content Y as a function of the pressure head X , need to be programmed by the user in RETC4.FOR using the CASE statement. Only one function can be used during each run. The function to be fitted to the data is specified through the variable MTYPE in the MODEL section of UNSODA.

```

C
C   Specify additional conductivity/diffusivity models
C   METHOD = 2 : CONDUCTIVITY BASED ON WATER CONTENT
C   METHOD = 4 : CONDUCTIVITY BASED ON HEAD
C   METHOD = 6 : DIFFUSIVITY BASED ON WATER CONTENT
C
      SELECT CASE(MTYPE)
      CASE(7)
        IF(METHOD.EQ.2) THEN
C
C*****
          DLGC=0
C*****
C
          ELSE IF (METHOD.EQ.4) THEN
C
C*****
          DLGC=DLOG10(CONDS/(1+ALPHA*X(I)**EXPO)
C*****
C
          ELSE IF (METHOD.EQ.6) THEN
C
C*****
          DLGD=0
C*****
C
          ENDIF
      CASE(8)

```

```

      IF(METHOD.EQ.2) THEN
C
C*****
      DLGC=0
C*****
C
      ELSE IF (METHOD.EQ.4) THEN
C
C*****
      DLGC=DLOG10(CONDS*DEXP(-EXPO*X(I)))
C*****
C
      ELSE IF (METHOD.EQ.6) THEN
C
C*****
      DLGD=0
C*****
C
      ENDIF
C   :
C   :
      END SELECT

```

Expressions for the hydraulic conductivity $K(\theta)$ and $K(h)$ as well as the soil water diffusivity $D(\theta)$ can be provided in a similar manner as for the water retention curve. Note that the optimization takes place on log transformed conductivity or diffusivity data. Again, only one function can be used during each run. This function is selected in the MODEL section of UNSODA based on the type of data (METHOD) and the selected model number (MTYPE). The expressions for the $^{10}\log K$ or $^{10}\log D$ functions also need to be programmed by the user in RETC4.FOR using the CASE statement. In the above example two functions are provided for $\log K(h)$ (i.e., METHOD=4) for models 7 and 8. If $K(\theta)$ and $D(\theta)$ data are to be optimized, corresponding expressions for $\log K(\theta)$ and $\log D(\theta)$ need to be provided.

APPENDIX D: Menu Structure

Opening screen

Main Menu

1 Data Entry and Edit

 Data Entry

 1 CREATE

 Specify New Code#

 Descriptor Data 1

 Descriptor Data 2

 Soil Properties

 Add to Database and Continue

 Methodology

 1 Field $\theta(h)$

 2 Lab $\theta(h)$

 3 Field K/D

 4 Lab K/D

 5 Field Ksat

 6 Lab Ksat

 7 Field Comment

 8 Lab Comment

 Tabular Data Type

 1 Particle Size Distribution

 2 Dry Aggregate Size Distribution

 3 Mineralogy

 4 Field $\theta(h)$

 5 Field K(θ)

 6 Field D(θ)

 7 Field K(h)

 8 Lab $\theta(h)$

 9 Lab K(θ)

 10 Lab D(θ)

 11 Lab K(h)

 2 APPEND

 Code # for Appending Tabular Data

 Tabular Data Type

 1 Particle Size Distribution

 2 Dry Aggregate Size Distribution

 3 Mineralogy

 4 Field $\theta(h)$

 5 Field K(θ)

 6 Field D(θ)

 7 Field K(h)

 8 Lab $\theta(h)$

 9 Lab K(θ)

 10 Lab D(θ)

 11 Lab K(h)

3 DELETE

Code # for Deleting Tabular Data

Tabular Data to be Deleted

1 Particle Size Distribution

2 Mineralogy

3 Dry Aggregate Size Dist.

4 Field $\theta(h)$

5 Field $K(\theta)$

6 Field $D(\theta)$

7 Field $K(h)$

8 Lab $\theta(h)$

9 Lab $K(\theta)$

10 Lab $D(\theta)$

11 Lab $K(h)$

4 EDIT

Select Type of Data

1 General Information Data

Enter Code # To Edit

Descriptor Data 1

Descriptor Data 2

Soil Properties

Add to Database and Return to Select Screen

2 Tabular Data

Enter Code # To Edit

Edit Tabular Data

1 Particle Size Distribution

2 Mineralogy

3 Dry Aggregate Size Dist.

4 Field $\theta(h)$

5 Field $K(\theta)$

6 Field $D(\theta)$

7 Field $K(h)$

8 Lab $\theta(h)$

9 Lab $K(\theta)$

10 Lab $D(\theta)$

11 Lab $K(h)$

3 Methodology Comments

Enter Code # To Edit

Methodology

1 Field $\theta(h)$

2 Lab $\theta(h)$

3 Field K/D

4 Lab K/D

5 Field K_{sat}

6 Lab K_{sat}

7 Field Comment

8 Lab Comment

5 CONVERSION

Conversion Factors for Dimensions

1 Initialize Conversion Factors to 1.0

2 Edit Conversion Factors

6 LIST

2 Query and Report Generation

Codes to be Searched

1 Select Specific Codes

Specify Search Fields

(Code:)

(Rating:)

Search

Device Settings

1 Screen

2 Disk

3 Printer

4 Compile

(Filename:)

2 Select All Codes

Device Settings

1 Screen

2 Disk

3 Printer

4 Compile

(Filename:)

3 Write Tabular Data to Disk

Specify Search Fields

(Code:)

(Rating:)

Search

Select Table to Print From

1 Particle Size Distribution

2 Mineralogy

3 Dry Aggregate Size Distribution

4 Field $\theta(h)$

5 Field $K(\theta)$

6 Field $D(\theta)$

7 Field $K(h)$

8 Lab $\theta(h)$

9 Lab $K(\theta)$

10 Lab $D(\theta)$

11 Lab $K(h)$

File Name

4 List of Codes to Screen

3 Models

1 Add/Delete Model Name

Existing Models

- 1 Mualem/van Genuchten Model (fitted)
- 2 Burdine/van Genuchten Model (fitted)
- 3 Mualem/van Genuchten Model (fixed)
- 4 Burdine/van Genuchten Model (fixed)
- 5 Mualem/Brooks and Corey Model
- 6 Burdine/Brooks and Corey Model
- 7 etc.

2 Specify RETC parameters

Code to be Modeled

Hydraulic Curve

- 1 Wetting
- 2 Drying

Existing Models

- Mualem/van Genuchten Model (fitted)
- Burdine/van Genuchten Model (fitted)
- Mualem/van Genuchten Model (fixed)
- Burdine/van Genuchten Model (fixed)
- Mualem/Brooks and Corey Model
- Burdine/Brooks and Corey Model
- etc.

Type of Hydraulic Data

1 Retention and Conductivity/Diffusivity Data

Drying/Wetting Retention

- 1 Lab $\theta(h)$
- 2 Field $\theta(h)$

Drying/Wetting K/D

- 1 Lab K(h)
- 2 Field K(h)
- 3 Lab K(θ)
- 4 Field K(θ)
- 5 Lab D(θ)
- 6 Field D(θ)

2 Retention Data Only

Drying/Wetting Retention

- 1 Lab $\theta(h)$
- 2 Field $\theta(h)$

- 3 Conductivity/Diffusivity Data Only
 - Drying/Wetting K/D
 - 1 Lab K(h)
 - 2 Field K(h)
 - 3 Lab K(θ)
 - 4 Field K(θ)
 - 5 Lab D(θ)
 - 6 Field D(θ)
 - Initial Parameters for RETC
 - Fix parameters
 - Summary of Options
 - Output
 - View Model Output
 - Store Model Output
- 3 View RETC (model) results
- 4 Utilities
 - 1 Delete Code
 - 1 List Codes and Series Names
 - 2 Delete Record and Exit
 - Code Number to be Deleted
 - 2 Change Code
 - 1 List Codes and Series Names
 - 2 Change Code and Exit
 - Old Code Number
 - New Code Number
 - 3 List Codes
 - 4 Reindex Data Tables
 - 5 Sort Tabular Data
 - Code Number to be Sorted
 - 1 Particle Size Distribution
 - 2 Mineralogy
 - 3 Dry Aggregate Size Distribution
 - 4 Field θ (h)
 - 5 Field K(θ)
 - 6 Field D(θ)
 - 7 Field K(h)
 - 8 Lab θ (h)
 - 9 Lab K(θ)
 - 10 Lab D(θ)
 - 11 Lab K(h)
 - 6 Check Pointer Table
 - 7 View Text or Data Files

APPENDIX E: List of Short Methodology Comments

Field Water Retention

- 1 Tensiometry and neutron thermalization
- 2 Tensiometry and neutronprobe
- 3 Tensiometry and gravimetric sampling
- 4 No comment
- 5 NA
- 6 Infiltration under suction and gravimetry
- 7 Tensiometry and neutron thermalization/gravimetry
- 8 Tensiometry and TDR

Laboratory Water Retention

- 1 Tempe cell
- 2 Buchner cell and pressure plate
- 3 Tensiometry and gamma attenuation
- 4 Haines' apparatus and pressure plate
- 5 Hanging water column
- 6 Pressure plate
- 7 Pressure plate and thermocouple psychrometry
- 8 Pressure outflow
- 9 Tensiometry and volumetry
- 10 Tensiometry and TDR
- 11 Tempe cell and pressure plate
- 12 Tensiometry and gravimetry
- 13 Tensiometry and neutron thermalization
- 14 Tensiometry, pressure plate, and gamma attenuation
- 15 Vacuum suction
- 16 Temple cell, pressure membrane
- 17 No Comment
- 18 NA
- 19 Hanging water column and pressure outflow
- 20 Infiltration under suction and gravimetry
- 21 Tensiometry/Buchner funnel and pressure outflow
- 22 Pressure outflow and gravimetry
- 23 Pressure outflow, gravimetry, and salt solutions
- 24 Tensiometry and neutron thermalization/TDR
- 25 Pressure outflow and air drying

Field Hydraulic Conductivity

- 1 Disc permeameter
- 2 Guelph permeameter
- 3 Instantaneous profile
- 4 Drainage
- 5 No Comment
- 6 NA
- 7 Vacuum on tensiometer

Laboratory Hydraulic Conductivity

- 1 Double plate
- 2 Soil water diffusivity
- 3 Evaporation
- 4 Hot air method
- 5 Instantaneous profile
- 6 Bruce & Klute
- 7 Short column
- 8 Long column
- 9 Sorptivity
- 10 Short column, falling head
- 11 Short column, multistep
- 12 Centrifugation
- 13 Inverse method
- 14 No Comment
- 15 NA
- 16 Steady state
- 17 Outflow-inflow (Bruce & Klute)
- 18 Sprinkling infiltrometer
- 19 Crust method
- 20 Crust and hot air methods

Field saturated conductivity

- 1 Constant head
- 2 Instantaneous profile
- 3 Ring infiltrometer
- 4 Double ring infiltrometer
- 5 Steady infiltration
- 6 No comment
- 7 NA
- 8 Ponding
- 9 Falling head permeameter

Laboratory saturated conductivity

- 1 Constant head
- 2 Inverse method
- 3 Falling head
- 4 Steady infiltration
- 5 Falling head, short column
- 6 Steady flow
- 7 None
- 8 NA