



Development and use of Soilgrasp, the Montana soil pedon database management system
by Zachary Reed Sims

A thesis submitted in partial fulfillment of the requirements for the degree of Master of Science in Soil Science

Montana State University

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Abstract:

Soil characterization data for 838 sites in Montana existed on magnetic tape but were not organized into a usable computerized system. These data (from 31 files) were merged with two smaller data sets into a single database file structure with 1189 sites.

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The Soilgrasp system consists of the data files, their management software, the user interface and the researchers who access the data. A supplementary user manual was written for soil scientists using the System.

The System was used successfully in a classroom situation. Graduate students conducted original research with the database for class projects.

Two scientific studies were completed with the database system. The first was an investigation of the influence parent material has on soil characteristics in Montana. Textural inheritance was evident in soils developed from igneous rock, but not in limestone-derived soils. Sand, silt, clay and coarse fragment contents of 535 soil horizons over these rock types were summarized. Effervescence and CaCO₃ content of limestone-derived soils were consistent with expectations. The second study concerned site and soil properties related to organic carbon content. Organic carbon content of 130 Montana A-horizons was not significantly correlated with clay content, in contrast to soils of the Southern Great Plains, where the correlation was high. In Montana, "organic carbon content is more closely related to elevation and precipitation.

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A thesis submitted in partial fulfillment
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of
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in
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APPROVAL

of a thesis submitted by

Zachary Reed Sims

This thesis has been read by each member of the thesis committee and has been found to be satisfactory regarding content, English usage, format, citations, bibliographic style, and consistency, and is ready for submission to the College of Graduate Studies.

3-7-86
Date

Gerald A. Nielsen
Chairperson, Graduate Committee

Approved for the Major Department

Mar. 7, 1986
Date

Dwaine H. Miller
Head, Major Department

Approved for the College of Graduate Studies

March 11, 1986
Date

Henry P. Parsons
Graduate Dean

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3 Reed Sims

Date

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ABSTRACT

Soil characterization data for 838 sites in Montana existed on magnetic tape but were not organized into a usable computerized system. These data (from 31 files) were merged with two smaller data sets into a single database file structure with 1189 sites.

GRASP (Generalized Rapid Access Software Package) was chosen to manage the database. GRASP is capable of all necessary data manipulation procedures. It also performs most common statistical operations, and can pass data to other software.

A user interface program called SOILGRASP was developed to provide on-line help for researchers, guiding them through database studies. It eliminates much of the complex syntax required by GRASP by converting user responses to SOILGRASP's questions into the proper commands.

The Soilgrasp System consists of the data files, their management software, the user interface and the researchers who access the data. A supplementary user manual was written for soil scientists using the System.

The System was used successfully in a classroom situation. Graduate students conducted original research with the database for class projects.

Two scientific studies were completed with the database system. The first was an investigation of the influence parent material has on soil characteristics in Montana. Textural inheritance was evident in soils developed from igneous rock, but not in limestone-derived soils. Sand, silt, clay and coarse fragment contents of 535 soil horizons over these rock types were summarized. Effervescence and CaCO_3 content of limestone-derived soils were consistent with expectations. The second study concerned site and soil properties related to organic carbon content. Organic carbon content of 130 Montana A-horizons was not significantly correlated with clay content, in contrast to soils of the Southern Great Plains, where the correlation was high. In Montana, organic carbon content is more closely related to elevation and precipitation.

INTRODUCTION

The State of Montana has, since 1960, acquired detailed descriptions of soil pedons from various sources, including Soil Surveys, graduate student projects, SCS Pedon Descriptions including laboratory characterizations performed by the Lincoln, Nebraska and Mandan, N. Dakota Labs, projects in cooperation with the Bureau of Land Management, and ongoing Montana Agricultural Experiment Station research.

The data are useful for research and county extension work, but were not readily accessible to soil scientists. The volume of data presented serious problems for manual access, which required a worker to page through six or more thick volumes of paper copy. Attempts to perform soils studies were limited to small sample sizes and required extensive data sorting by hand. Broad studies were difficult and seldom complete.

Manual data searches introduced errors of omission and accidental inclusion of cases that searches by tested computer software would not be subject to. Data integrity was difficult to improve due to the large number of cases.

There was no "what-if" capability for scientific studies. Changing the sampling criteria amounted to beginning another study. This increased the costs of some studies substantially, while forcing a decision against changing these criteria in other studies for which extra funds were not available.

Soil researchers in Montana have had difficulty finding pedon data collected previously from their study areas or from similar sites. Their only recourse was to recompile the data. This may have meant resampling and analysis of pedons at considerable cost. A complete pedon characterization may cost \$1500.00. Some of these data are used only once and then shelved. Soil Survey teams in Montana routinely discard pedon description data once the Survey of the area is published. These data should be used for research long after the original objectives for their collection were met. This requires a standardized system with as few steps as possible leading to the incorporation of these data into a permanent database.

The objectives of this thesis study can be divided into two major categories. System objectives covered the actual development of computer software and documentation. Applications objectives concerned the various uses that can be made of the database as a part of the Soilgrasp System.

System Objectives

1. Recode and rearrange the existing soils data sets such that all have identical formats and can thereby be joined to form a single database.
2. Standardize the variables and file formats of existing soils data in Montana to be upwardly compatible with the

current Soil Conservation Service national soils databases.

3. Implement a database management system (DBMS) package which would fulfill Montana's needs for soils information delivery.
4. Design the overall System in a way that minimizes user learning time.
5. Provide documentation for the System which describes its configuration and provides examples of its use, written in a style easily understood by university soils faculty and graduate students with a minimum of experience with computer systems.
6. Evaluate the System according to the set of criteria given in objective 3 above; with respect to its user friendliness; and according to its performance as a soil science research tool.

Application Objectives

1. Use the Soilgrasp System to access data for selected A-horizons in Montana, to clarify relationships of soil texture (particularly percent clay) and climatic factors with organic carbon content of soils in Montana.
2. Use the system to quantify the textural and some chemical characteristics of soils over several rock types in Montana, and to compare these properties for evidence of their inheritance from the underlying rock.

3. Use the System in a classroom situation, to enable graduate students to conduct original research with existing soils data for class projects.
4. Use the System to retrieve data for scientific research or extension agency use, according to specific sampling requests.

LITERATURE REVIEW

Database Management

The accumulation of environmental resource information has increased to such a level that manual data searches, though still performed, are impractical and expensive means of access. Heil (1982) stated the problem cogently:

"There is universal agreement among natural resource planners that one of their major problems is finding and organizing data that is relevant, valid and reliable for use in decision-making.

"One method for approaching this problem involves the application of database technology to the development of computerized information systems. Database management technology provides the mechanism through which data can be stored, integrated, and evaluated in many ways so that information can be easily and efficiently delivered to a diverse user community."

The large amounts of soils data already stored on computers are of little value unless they can be used to help us recognize problems and solve them. "The central problem of much data processing is extracting from a mountain of facts an essence of value to human users" (Martin, 1983).

Researchers and administrative decision-makers could gain valuable support from database management tools, but are often unaware of available technology (Priest, 1982). Databases and their management software need a higher profile in the workplace. The key to increased use of information delivery tools is a wider user base, including

the end users of the data. The business field is far ahead of natural resource managers in this respect. Business database software has progressed to the point of using artificial intelligence techniques to make the computer appear to be an assistant. For the most part, resource managers still view the computer as something resembling a calculus quiz. Generalized (or subject) database management software can actually organize natural resource information as readily as that from any other discipline. There is seldom a need to wait for specialized applications software. Applications should be developed around the core database system.

Universities, state and federal agencies are actively exploring ways to organize extensive soils databases so that they can be integrated and shared. Most current efforts are in the experimental or prototype stages.

Montana State University has been involved in the development of soils information delivery systems since 1969, when work began to encode all available soil morphology and laboratory characterization data from the state (Decker, 1972). Decker's thesis work involved the testing of various data encoding techniques and retrieval methods, the actual entry of Montana's existing soil characterization data, and inventory and correlation of those data (Decker, 1972).

Decker envisioned and worked toward an Automated Data Processing (ADP) System for encoding and storing soils data. The objective for the system was to produce tables for land use interpretations based on soils information. Later additions to the system included intermediate data files and programs which could print out standard and popularized pedon descriptions, Soil Survey mapping unit information, and interpretation tables from the Soil Survey data (Decker, Nielsen and Rogers, 1975). They proposed extensions which would determine suitability and capability groupings for woodlands, range sites, windbreaks, and urban development.

The ADP System was difficult to use by anyone but those involved in its development. During the early 1970's, data were primarily entered using mark-sense forms and stored on keypunched cards and magnetic tape. All operations on the data were performed in batch mode on a Xerox Sigma-7 mainframe computer. Interactive (or on-line) access to the data was expensive and seldom possible. FORTRAN IV programs were written for each task, and were completely dependent upon the data file structures. This impaired their applicability and portability to other data sets. Data files were not stored on-line as hard disk files, but were to be loaded for each use from appropriate magnetic tapes. The file names were not recognizable to non-familiar users: program names were difficult to distinguish from raw data file names or those of interpretation table files.

The ADP programs that were developed assumed a data format compatible with a proposed NCSS coding system from 1973, whose format was later changed (Soil Survey Staff, 1979). Data sets encoded during Decker's thesis program were compatible with the 1973 codes. However, after that time, new soils data were not standardized to any specific format. Some data types, record lengths, variable codes and measurement methods were thus incompatible between data sets. An applications program written for one data set was useless for other sets. Expanding the sample size thus required rewriting parts of the applications programs. Few such attempts were made. It was clear that to increase the usage of Montana's soils information, several improvements were necessary. These included faster and easier access to the data, standardized file formats for all data files, the means to update the information, and enough documentation to allow new users to learn the ropes. Martin (1983) noted that if a terminal (or program) is confusing or difficult to use, it simply will not be used. Soils information system designers must make user friendliness a high priority, or even the most powerful systems will be shelved, with potential users opting for old, trusted methods.

Recent advances in database technology have been incorporated by the U. S. Army Corps of Engineers Construction Engineering Research Laboratory. This group has developed an extensive environmental data management

network, one part of which is an interactive system called SIRS (Soils-5 Information Retrieval System) (Goran, 1983). The system accesses SCS-SOI-5 data, maintained by the Soil Conservation Service, and displays land use interpretation tables on the user's screen. The system is housed at the University of Illinois at Champaign, but can be reached through phone lines from any terminal. Sampling and search capabilities are available. The output is designed to present generalized information about soil series and land use recommendations rather than raw data from actual pedons.

Another soils data system is under development by the USDA-SCS Information Management Services (IMS) group in Colorado. This database consists of over 30 computerized Soil Surveys, with a geographical orientation. The database has been managed for many years by System 2000, a hierarchical Database Management System. Recently, the IMS group has replaced that software package with a more versatile relation-style system.

Soils and Parent Material

Extensive areas in southwestern and central Montana contain soils developed from limestone, intrusive igneous and extrusive igneous parent materials, or rock types. The degree to which the properties of these rock types are retained is greatest in young soils with cool and dry climates (Veseth and Montagne, 1980; Birkeland, 1984). Soil

reaction and pH may reflect the composition of the soil's parent material (Ehrlich et al., 1955). Harradine and Jenny (1958) reported that under identical climatic conditions soils derived from basic (extrusive) igneous rock consistently had finer textures than soils derived from acid (intrusive) igneous parent material. Textural variability was higher and moisture equivalents were lower in the acid-igneous soils than in the basic-igneous soils. Soil texture in some Pennsylvania soils is inherited from parent material (Ciolkosz et al., 1979). Parent material texture affected weathering rates and subsequent soil properties in Scotland (Smith, 1962). Kadeba (1978) noted that parent material influences the relationship between percent clay and soil organic matter content in some regions.

Yaalon (1975) discussed the feasibility of separating parent material functions, or lithofunctions, from the other soil-forming factors considered by Jenny (1941). These factors include climate, topography (relief), biological activity, and time. Yaalon concluded that of the five factors, parent material is the most difficult to consider quantitatively as an independent factor because its effects are masked by those of the other, more dynamic pedogenic processes.

Organic Carbon in Montana Soils

Organic matter is an important soil constituent but factors that control the amount of organic matter in soils are not fully understood. Researchers have related accumulation of organic matter to factors influencing soil characteristics such as aspect (Losche, 1967), soil temperature (Anderson and Coleman, 1985; Jenny, 1941), and elevation. Anderson (1979) reported that precipitation and soil moisture regime also influence humus formation in Canadian grassland soils. Cool soil temperatures, anaerobic conditions and high water tables associated with depressions in the landscape can cause increased accumulation of organic matter. Similarly, organic matter in the Nigerian savanna, where precipitation controls plant growth, is closely correlated with the number of rain days per year. Latitude, parent material, soil clay content and human intervention, through cultivation and burning, also influenced the organic matter status in those soils (Kadeba, 1978).

Cannon and Nielsen (1984) reported positive correlations between grass production and both elevation ($r = 0.44$) and mean annual precipitation ($r = 0.53$) in the Northern Great Plains of North America. Organic matter percentage in the mollic epipedon showed even higher correlations with elevation and precipitation, with r -values of 0.62 and 0.71, respectively.

Since fine silt and clay particles combine with organic materials to form stable complexes (Kononova, 1966), soil texture is also expected to influence soil organic matter contents. In some regions, as much as 50 percent of the soil humus is held by clay particles in organo-mineral complexes and is thereby protected from rapid decomposition (Anderson et al., 1981). In the Southern Great Plains states, clay percentage was the major factor correlated with organic carbon content, and precipitation was also related (Nichols, 1984). McDaniel and Munn (1985) grouped 143 Mollisols and Aridisols in Wyoming and Montana into three temperature regimes (cryic, frigid, and mesic), and determined that texture is significantly correlated with organic carbon content only in the mesic soils. McDaniel and Munn used a weighted organic carbon content to a depth of 40 cm in their study, whereas Nichols (1984) used only A1-horizon data.

MATERIALS AND METHODS

Updating the Database

In September of 1983, the decision was made to recode and rearrange the existing soil pedon data files for Montana to conform to the latest national standards released by the Soil Conservation Service. A copy of the revised Pedon Coding System for the National Cooperative Soil Survey (NCSS) (Soil Survey Staff, 1979) was obtained. This publication clearly outlined the sequence and data types of all variables within the system. The exact location and column width for each variable were given. For any variable containing codes instead of real numeric or alphanumeric data, each code or combination of codes was defined.

The state's soil pedon data had been split alphabetically and by year into 31 files and stored on magnetic tape. Two sets of data existed: pedon description files which included site, horizon morphological, and laboratory characterization data for 270 sites; and Official Series Description files that lacked laboratory data but were otherwise similar, for 567 sites. Each case represented a single horizon.

Due to the absence of documentation for these data files, their complete formats were unknown. Four weeks of comparing these huge files to find repeating elements and patterns revealed that each case occupied not one but three

records of a data file. A single column embedded among 3509 repeated the sequence from "1" to "3" down the file. Also, the record lengths were found to be variable, not fixed. Aside from these inconsistencies, the formats matched that of a proposed NCSS pedon coding system released in 1973. A revised version of this format (Soil Survey Staff, 1979), chosen for the updated database, contained a number of column and code changes. An exhaustive comparison of the two formats was made to find every change. FORTRAN 77 programs were written to read in the old data files 3 lines at a time and output new files in which each case occupied a single record. Further programs were written to read each record, change appropriate variable positions and codes, and output new, updated records. At the end of this process, which took approximately two months, the files were standardized and ready for a database management system (DBMS).

The new soils data files were merged to form a single master file. Extensive error-checking was performed on the first 10 cases (by hand, since their record length was too large for access by computer word processors). A single mistake in formatting one of the 1016 variables would have offset data for all variables beyond it. A few errors were indeed found and corrected.

Two smaller data sets at Montana State University contained pedon description information which could be used to expand the database.

The first data set was derived from a Bureau of Land Management study of Montana's native range sites (McDaniel et al., 1982). It contained data for 167 sites (763 horizons, or cases). This data set had been maintained by GRASP (Generalized Rapid Access Software Package), which is discussed in a later section. Many variables concerning ground cover percentage and production of native plant species were extraneous to the NCSS Pedon Coding System. These variables were included in Montana's soil pedon database, which thus became a logical superset of the NCSS Coding System while maintaining compatibility.

The BLM soil variables required recoding and rearrangement into the new database format. Variables without data were blank-filled so that records could be of fixed length. The column width of vegetation cover-presence variables was reduced from 7 to 3 columns to minimize database storage requirements. Approximately 4 Megabytes (million bytes, or characters) of storage space were conserved by this action, which simply eliminated unnecessary blank spaces. Likewise, shrinking vegetation production variables from 7 to 4 columns saved 5 Megabytes of storage space.

A second data set was compiled by Thomas Burke for his thesis study (Burke, 1984). This data set included new variables concerning soil moisture content to several depths, crop type, and crop yield. It contained data for 184 sites. All new variables were added to the main

database and the soils information was recoded and rearranged as described for the BLM data set.

In anticipation of future database needs, new variables for fertilizer application levels of the plant nutrients N, P, K, Ca, B, Fe, Mn, S, and Zn were created within the database.

Three compatible data sets existed after the recoding process. These three sets were merged to form a new master file, "MT_MASTER".

GRASP: The Database Management System

The selection of an appropriate database management system (DBMS) for Montana's soil pedon database was based upon a number of criteria. The DBMS had to:

- a. manipulate soils data of all necessary data types;
- b. handle an unlimited number of cases;
- c. accommodate a large number of variables, in the range from 1000 to 2000;
- d. sort through the data rapidly and at minimum expense to users- certainly faster, cheaper, and more easily than performing the same tasks manually;
- e. be used to update and maintain data, with simple commands for editing and deletion;
- f. be accessible to soil scientists throughout Montana, and elsewhere in the United States if it became necessary; and

- g. communicate with other hardware and software such as geographic information systems, microcomputers and state-of-the-art statistical software.

GRASP was selected as the DBMS because it fulfilled most of the criteria well. GRASP is a set of FORTRAN programs written by the staff of the Center for Data Systems and Analysis (CDSA), a unit of Montana State University in Bozeman. They are housed on campus in the Renne Library building. GRASP is still under development at this writing and is not available for purchase. GRASP runs on MSU's Honeywell Level 66 DPS/C3 mainframe computer and is dependent for certain procedures upon that computer's CP-6 operating system. Inferences in this document to CP-6 refer to the Honeywell computer: "CP-6" is the name used at MSU to mean both the operating system and the hardware.

A full analysis of GRASP's performance according to the above criteria is given in the Results section.

Database Inversion

Preparations began in April of 1984 to set up the database for GRASP use. GRASP required a list of variables for its inversion process, which it would use to flip the two-dimensional database file so that each record contained all the data for a single variable.

The variable list, termed an "invert file", would be used by GRASP as the DBMS built its own "directory file". Each entry in the list contained a unique 12 (or fewer) character variable name; a data type declaration; beginning and ending column numbers which represented the position of that variable in each record of the master (uninverted) data file; and a 40 character variable definition.

It was after completion of the invert file that the column widths of 415 vegetation variables were reduced as described above. A FORTRAN 77 program called "SHRINK_VARIABLES" was written to automatically update all of the invert file entries affected. A similar program, "COLUMNS", corrects column numbers of variable entries after the deletion of a variable, or when a mistake has been found. These programs are listed in the Soilgrasp System User Manual (Appendix) as models for future updates.

The invert file was scanned by GRASP for syntactical or typographical errors prior to data inversion by inserting a "NORUN" command near the end of the invert file. GRASP noted several typographical errors, which were corrected. The inversion was subsequently run with a subset of cases to check for formatting or data type errors. When this step revealed no errors, the database was ready for inversion.

GRASP can only invert 500 variables at a time. The invert file (MTINVERT) was separated into four smaller files, MTINVERT1-4. These files would create four data

files when run in sequence. Site and horizon morphology variables were inverted first. During this run GRASP initiated the directory file, MTDIRECTORY, and created the first of its own data files, MT_SIHZ.

Three subsequent inversions created data files called MT_LAB, MT_VEG, and MT_YIELD. Each time, GRASP added to its directory file the information it needed to locate the data for all new variables.

Database Storage and Backup Procedures

All of the GRASP data files and the database directory were stored together in four different places. One copy was set up permanently on hard disk to allow interactive or batch access to the information at all times. Each backup copy of the complete database occupied two magnetic computer tapes. One of these backups is stored on rented labeled tape at Montana State University's Computing Services Center. A charge of \$1.00 per month is assessed for this service. Another backup set is stored on user-owned tape in MSU's Plant and Soil Science Department. The third backup set is stored in MSU's Statistical Services office.

The file, "MT-DATABASE-BACKUP", was used to perform the backup procedure onto rented magnetic tapes 0819 and 0911.

Its commands are listed below:

```
!JOB ISS005,NIELSEN D(00:05,1/3/86)
!RES MT=1,TIME=3:00:00
!DIRECTORY DP#SOILS.ISS005
```



```
!TAPE(0819/0819/WE)
!PCL
SEVERITY ABORT
MOUNT LT#0819 RING
C DP#SOILS/TAPE0819DIR.ISS005 TO LT#0819/TAPE0819DIR
C DP#SOILS/MTDIRECTORY.ISS005 TO LT#0819/MTDIRECTORY (XTE)
C DP#SOILS/MT_SIHZ.ISS005 TO LT#0819/MT_SIHZ (XTE)
C DP#SOILS/MT_LAB.ISS005 TO LT#0819/MT_LAB (XTE)
REW LT#0819
L(A) LT#0819 TO DP#SOILS/LT0819LIST_BAK.ISS005
REMOVE LT#0819
MOUNT LT#0911 RING
C DP#SOILS/TAPE0911DIR.ISS005 TO LT#0911/TAPE0911DIR
C DP#SOILS/MT_VEG.ISS005 TO LT#0911/MT_VEG (XTE)
C DP#SOILS/MT_YIELD.ISS005 TO LT#0911/MT_YIELD (XTE)
C DP#SOILS/SOILGRPROG.ISS005 TO LT#0911/SOILGRPROG (XTE)
C DP#SOILS/MT_NEWVARS.ISS005 TO LT#0911/MT_NEWVARS (XTE)
REW LT#0911
L(A) LT#0911 TO DP#SOILS/LT0911LIST_BAK.ISS005
REL LT#0911
C DP#SOILS/LT0911LIST_BAK.ISS005 TO LP
C DP#SOILS/LT0819LIST_BAK.ISS005 TO LP
END
```

To subsequently copy the database files onto the user-owned backup magnetic tapes described above, the terms LT#0819 and LT#0911 were changed to reflect the label numbers of each backup set of tapes. The system command,

```
!BATCH MT-DATABASE-BACKUP (SCAN)
```

submitted the file to be run at the deferred time and had the computer scan it for possible errors before execution.

A hard diskpack was rented for storing the database system files. This diskpack is stored permanently in the room that houses the CP-6 computer at Montana State University. It must be mounted each time a user needs to access files stored upon it.

Testing GRASP's Functions

At the time of implementation, GRASP was still under development. Each function or command was tested using the soil pedon database. If a command did not work as documented in the GRASP Users Manual (Allard, 1981) the CDSA was contacted. They quickly reported back with solutions. Notes were written in the GRASP Users Manuals for future documentation changes. We especially wanted to be certain that GRASP could manipulate character (alphanumeric) data such as soil series names. We had to be able to sample by such character strings, eliminating undesirable series or including selected ones in the sample. We also tested GRASP's ability to handle very long string variables (up to 100 or more characters), since site location descriptions were encoded as "notes" which occupied 120 columns of the database.

SOILGRASP: A User Friendly Interface

The CDSA was working on an applications database system for molecular compounds which had a menu-driven front end. A front end is a program that interacts with users, giving them several options rather than a prompt symbol. Work began in December, 1984 to convert a copy of this FORTRAN program to serve as a GRASP front end interface. The new version was given the name SOILGRASP.

SOILGRASP accesses menus stored in another file and shows appropriate menus to the user during a session. The menus were completely rewritten by the author to show choices based on GRASP options. SOILGRASP was designed to build a file of input commands which directs GRASP to perform the series of operations requested by the soil scientist through these menus. The choices offered include most of the common commands used in soils studies.

Improving Data Integrity

Data for the elevations of 65 sites within the database (none of which had elevations recorded) were obtained from topographic maps. With a repeated series of sampling and editing commands these data were entered into the database.

After the Soilgrasp System was built, all cases from the BLM data set were found to be encoded using decimal points where needed for the variable "PH_VALUE". All other cases in the database had been encoded with a single implied decimal place, with no decimal point actually entered. The variable was inverted with the declared data type "REAL(1)". This type indicates an implied decimal point with one decimal place. When GRASP inverted the data for pH, it automatically divided by 10. BLM pH values were thus one tenth of their original value. These cases should have had a "REAL" data type. Since the error was global for BLM

cases it was possible to edit them all with one set of commands:

```
?SELECT: BLM_CASES  
?EDIT PASS=GRRR: PH_VALUE = PH_VALUE*10
```

A special bit variable, "BLM_CASES", had been created which could be used to select for these cases alone. When the editing was finished, a listing of all affected cases was checked for accidental inclusions.

Township and Range location information was not recorded for cases from the original state pedon data set. This information could be valuable if the Soilgrasp System was ever used to provide data to a geographic information system. A file containing locations for these cases was created by work study students from the "location notes" of the original data files. The locations would all be inverted into the database as new variables. At this writing, the latter had not yet been performed.

Soilgrasp System Documentation

The name Soilgrasp was given to the completed System, a name derived from that of the interface program. Common operations performed with the System are described in the Soilgrasp System User Manual (Appendix). This Manual is written in language that users with minimal computer experience can understand. A glossary is included, as well

as an annotated list of references which may be read for a greater understanding of these systems in general.

Using the Soilgrasp System

With the basic components of the database system linked- the full database, the management system, and the user interface- its variety of functions could be addressed.

The first applications were simple attempts to extract data summaries from the database, both to check for data integrity and to answer basic queries about Montana soils. A demonstration was given for representatives of the state Soil Conservation Service office. Sites with crop yield data were selected and sorted by ascending yield. A listing of the site keys, soil series and yields was then printed out as a ranking of series by crop yield. In other example studies, lists of site characteristics, soil chemical properties, and classifications were produced. Soil horizons were chosen using increasingly complex sampling criteria. The sampling procedures used the logical operators AND, OR, EOR, and NOT to combine expressions that defined variable ranges. Relational operators (such as greater-than and less-than) were included, as well as mathematical formulae which transformed the data before case selection.

A listing of soil texture data for A-horizons on cultivated lands in Montana, and basic statistics for each

soil textural class represented in the sample (also output by GRASP), were sent to Dr. Alice Jones at the University of Nebraska for a study on compaction.

The Soilgrasp System was used to provide data for a joint Montana State University and Soil Conservation Service effort to initiate a soils-crop yield database for the state. The feasibility of including the new database in the System was investigated.

The System was used in a classroom situation during the winter of 1985. Graduate students in a Soil Genesis and Morphology course planned inquiries and sampling procedures for original research. The author assisted each of them in using GRASP to select their sample (a function not yet incorporated into SOILGRASP). The students then worked with the Soilgrasp System to obtain pertinent statistics and data summaries. Six studies were completed during a nine week period. Suggestions were solicited from the students for ways to improve the SOILGRASP interface.

Soils and Parent Material

Data for 535 horizons on three different parent materials were extracted from Montana's soil pedon database using the Soilgrasp System. A GRASP input file containing all of the commands for this study was constructed and input in batch mode so that it could be run overnight during hours of low demand, an important consideration on a time-shared mainframe computer system.

The rock types studied included limestone, intrusive (coarse-grained) igneous rock, and extrusive (fine-grained) igneous rock. The sample was stratified by these rock types. The predominant effervescence class and drainage class for soils on each rock type were determined by tallying lists output by GRASP. Soil orders represented on each rock type were recorded. A subset of the total sample, consisting of 156 horizons from 47 pedons which had laboratory data for physical and chemical soil properties, was chosen for further studies. For each rock type, the soils were stratified by horizon, resulting in three groups each of A, B, and C horizons. For each group of horizons (for example, B horizons over limestone) means and ranges were calculated for lab-determined percents sand, silt, clay and coarse fragments; lab pH; cation exchange capacity and percent base saturation. The dominant textural class was determined from lists output by GRASP for each group.

Organic Carbon in Montana Soils

Data from 130 A-horizons at 96 soil pedon sites were extracted from Montana's Soil Pedon Database using the Soilgrasp System.

The site selection procedure was modeled after that used by Nichols (1984) for soils of the Southern Great Plains. All grassland sites were considered for study. From these sites, floodplains or poorly drained sites, Vertisols,

Vertic soils, and soils with a COLE greater than 0.09 (high shrink-swell potential) were eliminated. Soils on terraces and fans, if well drained, were included. This is a slight departure from Nichols' procedure, which included only sites classified as uplands.

Soil orders represented were Mollisols (88 horizons), Alfisols (12), Entisols (18), and Aridisols (12). Of the 130 horizons, 78 were from native grassland sites and 52 were from cultivated sites. All sites in the sample had either cryic or frigid temperature regimes. Like Nichols (1984) and unlike McDaniel and Munn (1985), we sampled only A-horizons from those sites. Because organic carbon content decreased sharply in lower horizons (E,B,C), their inclusion would have masked any relationships which hold for the upper horizons. Some of the high elevation sites had O-horizons, which were excluded from the sample. A-horizons from these sites had been entered into the database as second (lower) horizons, and were included in that subsample.

The variables, clay percentage, elevation (in meters), and mean annual precipitation (in cm) were related statistically to laboratory-determined organic carbon content (in g kg⁻¹) for the whole sample and for each of several subsamples. These subsamples included 1) all horizons; 2) horizons of native grassland sites; 3) those of cultivated sites; 4) Mollisols; 5) Entisols; 6) uppermost A-horizons; 7) second A-horizons; and 8) horizons from soils

with a frigid temperature regime. Clay and organic carbon contents were determined by the pipet method (3Al) and acid dichromate digestion (6Al), respectively (Soil Survey Staff, 1967). Means and ranges were calculated for each variable. Correlations were calculated for organic carbon with the other variables for each subsample.

Simple linear regressions were calculated to determine the usefulness of each factor for predicting percent organic carbon content. The first analysis used the clay percentage as the independent variable. A second analysis used elevation and precipitation as independent variables.

RESULTS AND DISCUSSION

Updating the Database

The concatenation and recoding of the many data files which made up the soil pedon database was a process involving a number of soils and computer experts. The updating process lasted six months from initiation to completion, from October, 1983 to April, 1984. The final, polished Master data file was worth the effort, however. Its advantages included a format compatible with current standards, fixed-length records whose structures were identical, and a single file location for all of the information.

The format statement for the updated database file is a superset of the NCSS Pedon Coding System (Soil Survey Staff, 1979). New variables are added at the end of the format statement.

It is desirable to achieve complete independence of raw data management from any specific applications of the information. The design of applications programs around a common data structure or system ensures that all of the data are accessible to every program. This prevents redundancy between discrete sets of data. It also sets the stage for planned, top-down system design as described by Shore (1985). Systems and programs designed this way can more easily incorporate advancements in technology. They do not

become obsolete as fast as do conglomerations consisting of many application-dependent data structures.

GRASP: The Database Management System

The results of the selection criteria for the GRASP DBMS are as follows:

- a. GRASP can manipulate variables of the types Real, Integer, Bit (called "PACK" by GRASP), and Alpha (character). GRASP is unable to effectively manipulate Alpha variable strings of 80 or more characters. This means that data for these variables are not accessible to users. This limitation was not considered important enough to disqualify GRASP because the variables affected are few and would rarely be needed. Some are merely dummy variables set up for future database expansion and would never be accessed as long strings.
- b. GRASP can handle an unlimited number of cases. It has been used successfully to access databases containing over 300,000 cases, 50 times the current case count of Montana's soil pedon database.
- c. GRASP can access an unlimited number of variables, for data contained in ten separate files. If more than ten files are required for a session, files 10 through X may be concatenated, temporarily or permanently.

- d. Because of its use of inverted, machine language data files, GRASP provides sorting and search capabilities that are faster than those available from most DBMS packages that use flat (two-dimensional) ASCII files.
- e. GRASP has a full range of variable editing, creation, deletion, and transformation commands. All of these use fairly simple syntax and have useful options. Passwords are required for sensitive commands, as a measure of database security.
- f. GRASP is maintained on Montana State University's Honeywell Level 66 mainframe computer running the CP-6 operating system, and is available at all times (except during computer maintenance down-time). The computer is accessible through several telephone lines, with 300- or 1200-baud data transfer speeds. Software required for communication is available at no charge from the Computing Services Center on campus.
- g. GRASP enables users to format their own output. Users can transfer data to custom-designed FORTRAN subroutines for analysis. The GRASP command, "SPSS", can be used to generate machine language data files in the proper format used by the Statistical Package for the Social Sciences, a popular statistics package. The "LIST" command can be used to dump data to a file on hard disk for use by other software.

Another reason for choosing GRASP was its integration of some basic statistical procedures with the data management capabilities, so quantitative analysis would be fast and easy. Also, GRASP performed well as the DBMS for the BLM data set which later became a subset of the database. Finally, close contact could be maintained with the Center for Data Systems and Analysis, GRASP's developers.

Before the decision to use GRASP was finalized, a micro-computer-based system was considered. However, at the time of system development, the hardware and software available were not capable of handling such a large database.

DBMS programs for microcomputers were severely limited in file size, number of variables possible per data file, record length, and sorting speed. The complete database for Montana soils occupies over 25 Megabytes. A microcomputer with the usual 8- or 16-bit data bus (data transfer channel within the chip) and slow speed relative to mainframe computers would take hours to perform a single sort of a large number of cases, let alone multiple sorts. All micro-based DBMS's available operated on flat ASCII files, which added tremendous time constraints when performing a complex study. Hard disk memory capacity was limited as well: the usual 20-Megabyte disks were too small, and large-capacity disks were at least as expensive as the rest of the hardware combined. With rapid advancements in microcomputer technology during 1983-1986, some of these problems were solved.

The problem of hardware maintenance falls primarily upon the users with microcomputer systems, whereas mainframe computer charges cover all maintenance support and upgrades.

Database Inversion

It took approximately 120 hours over a 45 day period to construct the four invert files, which had a total of 1026 entries.

Once the invert files were completed and de-bugged, the inversion process essentially ran on its own. The invert files were input into GRASP in the order in which their variables appeared in the database. The directory file was updated by the second through fourth invert files, so that all existing variables could be accessed together: GRASP can only use one directory file during a session.

The file, MT_SIHZ, was unique among the GRASP data files in that it contained a key for each case, developed specifically for database management and without relation to real site numbers. A key contained two parts- a pedon number and a horizon identifier. Further explanation of keys and their use is given in the Soilgrasp System User Manual (Appendix). The keys existed only in this file, so access to MT_SIHZ would be required even if a user was only interested in vegetation or crop yield data for a particular study.

The invert file (MTINVERT1) which GRASP used to create MT_SIHZ contained the following records:

```
INVERT PRINT:
  INPUT(FILE,MT_MASTER) STYLE=CHARACTER CASE=1
  OUTPUT(FILE,MT_SIHZ ISS005 OUT)
  DIRECTORY(FILE,MTDIRECTORY ISS005 OUT)
  RECORD= KEY      ALPHA(8)      1 TO 8
           'Key no. for site and horizon'/
  SERIES      ALPHA(15)      11 TO 25
           '1.Soil series name'/
  FIPS_STATE  ALPHA(2)      29 TO 30
           '2a.FIPS state code'/
  FIPS_COUNTY ALPHA(3)      31 TO 33
           '2b.FIPS county code'/'
```

Many more variable entries were given in the file; only four are presented here. The description for each variable gave the 1979 NCSS Pedon Code number for the corresponding variable in that publication.

A detailed description of each invert file command is given in the GRASP Users Manual (Allard, 1981).

The GRASP data files are created in binary code for increased access speed. This is the key to GRASP's speed. Instead of searching every record of the data file for a variable's value, GRASP can read the single record containing data for that variable. Search time is reduced drastically, and the time savings mount as database size increases.

The actual inversion process was the single most time-consuming and expensive operation performed by GRASP. The inversion took eight hours, including time for correcting typographical errors. Inversion of each of the four invert

files cost from \$65.00 to \$80.00 of computer charges, depending on the file's size.

The problem of multiuser capability was solved by making exact copies of the directory file, each with a different name. This file has the information for all data locations. If several directories contain the same keys, they can each access the data files. Several users can access the data simultaneously by declaring their individual directory files' names. Each user is involved in a different session and is actually using only one directory file. Concurrent requests for the same datum are handled by the time-shared processing feature of the Honeywell Level 66 mainframe.

Database Storage and Backup Procedures

The hard disk storage costs for the database system approached \$800.00 every month during the system's development. This was due in part to the need to have two copies of some files while the variable recoding was being done. Though this cost could be cut by perhaps a third when the file changes were finished, it was clear that long-term disk storage as it existed would be too expensive. Some access trade-offs would be necessary.

The practice of loading files from magnetic tape storage to hard disk before each session was slow and expensive. One loading operation for the entire database took 35 minutes, if only short mounting delays were encountered, and

cost \$ 9.37. The tape drives were often tied up with other users' work for more than an hour during peak daytime use. These machines were prone to failure; data transfers were unreliable or incomplete at times. The job control files to direct such tape transfers were complicated and could be up to 25 lines long.

A solution to these problems was found in user-rented hard diskpacks. These storage devices cost only \$50.00 per month, hold 200 Megabytes of information, and have rapid data transfer rates. Average yearly storage costs could be reduced from about \$9000.00 to \$600.00. A diskpack was rented and put to use. The rented diskpack was named "DP#SOILS". No job control file was needed to access GRASP files. A diskpack mounting request to the machine operators (the simple statement, "Please mount DP#SOILS shared", sent as a message through the user's terminal) and a system directory change sufficed to bring the system on-line. Mounting was usually done within 5 to 10 minutes of the request. It cost \$ 2.00 for an "exclusive" diskpack mount. A "shared" mount was free and allowed multiple users and batch jobs to access the database concurrently. There was still competition for disk drives (also called "spindles"), but the ratio of users:drives was only 4:1 as opposed to nearly 300:1 for magnetic tape drives.

Rented diskpacks were not backed up automatically by the Computing Services Center according to its schedule for the other, permanent diskpacks. The magnetic tapes still played an important role in database backup procedures. The file, "MT-DATABASE-BACKUP", used to back up the entire Soilgrasp System, will not back up any other files resident on the diskpack. However, the procedure would be similar for other files.

Hard diskpack rental did not preclude the use of the more expensive permanent diskpack (called "DP#INOV") which had previously been used. Many operations which did not concern the database system could still be done without loading the rented diskpack. There were essentially two disk drives available.

A database updating form included in the Soilgrasp System User Manual (Appendix) should be used to note changes in the database. Once changes are noted, a run of the backup job ("MT-DATABASE-BACKUP") will safely store the new changes.

Testing GRASP's Functions

Most of the functions available performed as described in the GRASP Users Manual (Allard, 1981). These included all functions which dealt with numeric data, except for COMPUTE. Character data sampling procedures had to be modified.

Statements with the syntax

```
?SAMPLE: KEY(' 9167- 1')
```

can be used to select all cases with that substring included for a certain variable. However, to exclude cases with no data, enclosing a blank string within the quotes does not work. Instead, the following syntax should be used:

```
?SAMPLE: KEY <>
```

GRASP simply cannot manipulate Alpha strings longer than about 40 characters. This is probably an array dimensioning limitation, but may also be due to memory limits or some factor in the sampling procedure.

The COMPUTE and TTEST commands were not functional. `FREQ` (for generating frequency distributions) had intermittent problems with one integer variable (ELEVATION), but not with others. This function is still one of the most useful of GRASP's capabilities. The `PREV` (previous) option for the `PRINT` command did not work.

None of the completed studies required any of the above commands except for `FREQ`, so their faulty operation did not reduce productivity with the database. These findings were reported to CDSA so that the commands could be de-bugged.

SOILGRASP: A User Friendly Interface

Interactive GRASP use was difficult for first-time or infrequent users. The software was command-driven: users were simply prompted with a question mark for the next

command. The combined ideas of a powerful mainframe computer, a large database, and a lack of guidance from the software intimidated some users to the point of keyboard paralysis. To achieve the goal of easy access to the data, some way was needed to provide help on demand.

SOILGRASP's use of menus and questions gives users a measure of guidance. Its help facility works in two ways. First, from the main program menu, users can choose to learn more about its various functions. Several screens of text introduce the main options. Their numerical arrangement in the menu and the organization of the introductory presentation suggest a logical sequence of steps toward completing a research study. Also, from within any of the sub-menus or most of SOILGRASP's questions, users can escape back to a higher, safer level. Thus they are spared the frustration of having to continue when they would rather back up and start over.

To simplify data access, SOILGRASP uses a nested hierarchy of menus. Users are not confronted with every possible option. Instead, each menu choice opens up a small set of options that deal with the same type of function. For example, only when users choose the statistics option on the main program menu will they see which statistics are available. This narrowing of options into groups guides decision-making.

The menu structure converts GRASP's commands, which can be cryptic, into simpler English statements. For instance, the GRASP commands to perform a multiple linear regression are as follows:

```
?MULT BUILD (FILE, CHRIS ISS005 OUT): CEC, PH, BD
?MULT FETCH (FILE, CHRIS ISS005)
?REGRESS: CEC BY PH, BD
```

With these, GRASP constructs a Pearson correlation matrix, copies it to a file, FETCHes the file back into its working space, and finally regresses a dependent variable by any independent variables. These commands must be typed in exact order and syntax to work.

In contrast, using SOILGRASP one need only choose to see the statistics menu, select "Regression", and answer a few questions. SOILGRASP first asks for the dependent variable name, then for the names of up to five independent variables. No special syntax is used. After finishing the statistics step, one can select the output destination. SOILGRASP builds a file of GRASP commands to do the job.

The SOILGRASP interface has several advantages over direct entry of GRASP commands. It reduces the amount of on-line computer costs by accelerating the study design process, especially for new users. Also, the command file serves as a permanent record of the study, so that it may be repeated. This file could serve as a model for similar studies. Often variable names are the only differing elements between studies. Finally, the interface is an

optional tool. Experienced users may bypass it to work interactively with GRASP or build their own input files for batch processing.

There are limitations inherent in using the interface. SOILGRASP does not offer the user every possible GRASP operation. In simplifying, it also reduces the apparent versatility of some commands, such as LIST. Users who need the extra capabilities can delve into the GRASP Users Manual (Allard, 1981) or refer to the command summary presented in the Soilgrasp System User Manual (Appendix).

The SOILGRASP interface was designed primarily for novice or infrequent System users. It represents an attempt to add structure to the database query process and thereby reduce user confusion. SOILGRASP (with some added features) could be a valuable tool for teaching soil science courses, and for welcoming newcomers to the Soilgrasp System.

For security reasons, some of the GRASP functions are not included among the menu options given to users by SOILGRASP. Some of these are variable deletion, creation, editing and inversion, database directory testing and editing. These functions could be used by unqualified personnel to accidentally or intentionally alter the working copy of the database or its directory. Although they were left out of SOILGRASP, these operations can still be performed directly with GRASP, bypassing the interface.

Details of their use are outlined in the GRASP Users Manual (Allard, 1981).

More information on the SOILGRASP interface is given in the Soilgrasp System User Manual (Appendix).

Improving Data Integrity

One advantage of having a DBMS manage the data was that data integrity could be improved. Editing and deletion of erroneous data was possible. Updated information could be immediately incorporated.

Creating the Soilgrasp System enabled us to easily upgrade the database as new information became available. Data encoding errors could be corrected soon after they were detected.

New data could be added using the editing commands. This capability was tested with the elevation data for 65 sites which could be used in the organic carbon study.

An example of the necessary commands for editing elevation values at two sites is given below:

```
?SAMPLE: KEY(' 134-')  
?EDIT PASS=WOOF: ELEVATION = 943  
?SAMPLE: KEY(' 269-')  
?EDIT PASS=ARF: ELEVATION = 778
```

Using the KEY this way samples for all horizons within a certain site, so they all get the new elevation information. The characters " 134-" are a unique substring characteristic of any horizon at site 134. The space is required to

exclude such horizons as "1134- 1" and "9134- 3". The dash is required to eliminate horizon "1342- 1" and the like. Passwords must be given within all commands that can be used to change the database. This provides an important security filter.

This and other editing procedures were performed using input files containing the necessary commands. The files were carefully proofread before their use. This provided a systematic way of checking for errors before the database was changed. Direct (interactive) editing would not have provided this safeguard.

Soilgrasp System Documentation

The documentation provided by CDSA for GRASP was not complete enough to allow a soil scientist to take advantage of all the information available on this specific implementation. There were sections of the GRASP Users Manual (Allard, 1981) which were incomplete, such as the table of contents. It was necessary to write documentation for the Soilgrasp System which could be used as a supplement to the existing documentation.

The Soilgrasp System User Manual covers 1) the basics of performing studies with the aid of the SOILGRASP interface; 2) backing up the database after alterations; 3) some examples of study design; 4) command syntax; and 5) ways to

keep study costs down. Areas which might cause frustration for new users are emphasized.

The GRASP Users Manual (Allard, 1981) provided a good introduction to the sampling options. However, sampling human populations (the subject of examples within that publication) was much less complex than working with natural resource information, where discrete data are rare. A user-oriented example run through the sampling procedures with a soils database was written to serve as a model for other studies.

A description of the database and a complete dictionary of variables are provided in the Soilgrasp System User Manual. The variable dictionary indicates the number of cases with data for each variable. It is in fact a concatenated, modified version of the invert files used to create the GRASP data and directory files.

Detailed descriptions of most commands had been given in the GRASP Users Manual (Allard, 1981), but were spread throughout its pages. A handy reference chart was needed for review. A list of all GRASP commands with their options is included in the new manual for this purpose. The list is especially helpful for interactive GRASP sessions.

Using the Soilgrasp System

Research studies seldom use all of the cases in the database. GRASP provides several sampling commands to help users select certain cases. These can be simple, as shown in the following example:

```
?SAMPLE: PH>7 AND PH<9
```

Sampling procedures can also be quite complex, combining multiple modification steps to hone the sample down to a very similar group of cases. The procedure presented below samples for the cases used in the study of soil organic carbon content:

```
?SAMPLE:HORIZ_LTR('A ')
?MOD SAMPLE:HORIZ_MOD_NO('0','1','11','12')
?MOD SAMPLE:NOT_HORIZON_NUM('3','4','5','6','7','8','9')
?MOD SAMPLE:OC_LAB_PCT>0 AND CLAY>0 AND SILT>0
?MOD SAMPLE:NOT_SUBORDER('AQ') AND NOT ORDER('V')
?MOD SAMPLE:NOT_PHYS_LOCAL('P')
?MOD SAMPLE:NOT_LAND_USE('E','F','W')
?MOD SAMPLE:NOT_SUBGROUP('AQ','AQ02','AQ04','AQ06')
?MOD SAMPLE:NOT_SUBGROUP('VE02','AQ08')
?MOD SAMPLE:NOT_COLE(0.09 TO HI)
?MOD SAMPLE:NOT_SERIES('ONAME?GALLATIN','WISHARD')
?MOD SAMPLE:NOT_SERIES('ONAME?WOLF POIN','PENDROY')
?MOD SAMPLE:ELEVATION>0
```

Once a sample is chosen, the user may proceed to do any of the statistical or data manipulation functions.

An example of the default output listing is given in Table 1. The commands used to generate this table were:

```
?SELECT:BURKE_CASES
?MOD SAMPLE:YLD_CROP>4000
?SORT ASCENDING: YLD_CROP
?LIST:KEY, SERIES, YLD_CROP
```

The entire procedure took approximately 4 minutes and cost

\$ 1.39. The procedure was actually slowed down somewhat by the sorting operation. Listings can also be grouped into blocks of five for easier viewing of long tables.

The use of the Soilgrasp System in a teaching situation was another of its applications. It enabled students to

Table 1- Default GRASP listing of series and ranked yield data for selected sites.

KEY	SERIES	YLD_CROP
9652-00	SCOBEE	4029
9666-00	SCOBEE	4058
9681-00	DANVERS	4069
9598-00	CHAMA	4109
9517-00	CARGILL	4122
9590-00	ABSAROEKEE	4222
9538-00	AMSTERDAM	4388
9550-00	VIDA	4459
9548-00	BOZEMAN	4476
9564-00	KOBAR	4551
9641-00	PARSHALL	4639
9592-00	THURLOW	4654
9677-00	RICHFIELD	4751
9638-00	BOZEMAN	4812
9506-00	ROTHIEMAY	5050
9584-00	SHAAK	5123
9655-00	KEVIN	5401
9547-00	BOZEMAN	5528

test their ideas and questions with real data. Original research projects during the course were chosen by students, often to augment their graduate work.

The studies included an investigation into the possible genetic sources of silt in the upper horizons of silt loam soils such as the Bozeman series. The System was used to separate these horizons from other cases, summarize silt content and compare the average content with that from lower

(B and C) horizons of the same sites. No significant differences were found between horizons.

Another project used the Soilgrasp System to extract data for the two upper horizons of Aridisols. Means and ranges for various soil properties such as cation exchange capacity, bulk density, electrical conductivity and pH were obtained for first and second horizons separately. The values were compared to find distinguishing properties. This study was done in connection with a land reclamation research program. The program's goal was to assess current laws governing the depth of topsoil that can be taken from a site for reclaiming nearby coal spoils. This depth has been roughly the thickness of the A-horizon. The Soilgrasp study was done to reveal soil changes that might be expected to affect plant growth after topsoil removal.

A third project involved argillic and calcic horizons in Montana. CaCO_3 would not be expected in argillic horizons because it is transported downward before clay can disperse and move. This study showed that 40 percent of the argillic horizons in Montana Aridisols and Mollisols had some CaCO_3 in them. Some soils had calcareous horizons above argillic horizons. The Soilgrasp work provided the seed for a more extensive investigation into the possibility that past climatic changes were responsible for this situation.

Two other studies, one of parent materials and soil characteristics and another concerning soil organic carbon

content, were completed by the author using the Soilgrasp System. Their results are presented and discussed in following sections.

Suggestions gleaned from the students for improving classroom use of the system centered around the lack of adequate documentation. A further complaint was that sampling criteria could not be chosen or changed by the SOILGRASP interface. Documentation efforts resulted in the Soilgrasp System User Manual (Appendix). The sampling enhancements to SOILGRASP were planned but not yet implemented at this writing.

Soils and Parent Material

Effervescence and drainage classes for the soils studied are presented in Table 2. None of the 253 horizons developed from intrusive or extrusive igneous rock contained calcium carbonate (CaCO_3). However, limestone-derived soils showed CaCO_3 in every horizon.

Means, ranges and standard errors for percent CaCO_3 on limestone-derived soils are given in Table 3. The amount of CaCO_3 more than doubled from A to C horizons. This indicates that CaCO_3 has been inherited from the limestone parent material, and that the CaCO_3 has subsequently been removed from the A-horizon by pedogenic processes. However,

Table 2- Predominant effervescence and drainage classes for each parent material.

Parent material	No. horizons	Effervescence class	Drainage class
Limestone	282	strongly efferv.	well-drained
Intrusive igneous	170	non-effervescent	mod. well-drained to well-drained
Extrusive igneous	83	non-effervescent	well-drained

Table 3- Amounts of calcium carbonate in the <2mm soil fraction of A, B and C horizons on limestone parent material.

Horizon	CaCO ₃		
	Mean	Standard error	Range
	%		
A	23.2	3.3	8.0-44.0
B	32.0	1.0	31.0-33.0
C	53.1	3.7	41.0-68.0

it is difficult to distinguish between pedogenic carbonates and those inherited from the parent material (Rabenhorst et al., 1984).

The soil orders Alfisol, Entisol, Inceptisol and Mollisol were represented on all three parent materials. Mollisols were predominant in the sample, representing 293 of 535 total horizons.

Means and ranges for textural properties of the soils, stratified by horizon, are shown in Table 4. Soils from intrusive igneous rock had nearly twice the mean sand content of the other soils in every horizon, and the lowest mean percent clay. This particle size distribution parallels that of the parent material and indicates textural inheritance. The soils from extrusive (fine-grained) igneous rock had the lowest sand content in every horizon, while within the solum these soils showed the highest clay content. This may indicate that the extrusive igneous rock type is the most easily weathered of these three in Montana, and also reflects the small size of mineral crystals within the initial, unweathered rock. Variability in particle-size distribution was generally lowest for soils from intrusive igneous rock and highest for soils from extrusive igneous rock, the exception being mean sand content of the A-horizon. In the sola of soils from both limestone and extrusive igneous rock, silt was predominant.

Mean coarse fragment content increased from A to C horizons over all three rock types. The difference was most dramatic in soils from extrusive igneous rock, increasing from 16.5 percent to 65 percent coarse fragments. This lends support to the hypothesis that of the three rock types, this one weathers most rapidly in Montana. Coarse fragment content decreased by only 37 percent over the same interval for limestone-derived soils, indicating that limestone weathers more slowly.

Table 5 shows some chemical characteristics of soils derived from the three parent materials, by horizon. Limestone-derived soils had the highest mean pH values in all horizons, as expected, considering the marine origin of the parent material. Soils from extrusive igneous rock were slightly more acidic than the other soils, and had greater mean cation exchange capacities throughout the profile, probably due to their high clay content. The difference in standard errors for cation exchange capacity between soils of the two igneous parent materials indicates that this property is more predictable for soils derived from intrusive igneous rock. Clay-sized carbonates in limestone-derived soils may have lowered the cation exchange capacity.

The results of this study support and quantify the statements in Table 2 of the Soils of Montana bulletin (Montagne et al., 1982) concerning soil properties on these parent materials.

Table 4- Textural properties of selected soil horizons in Montana.

Parent material	No. hori- zons	Predom- inant texture	Sand		Silt		Clay		Coarse fragments	
			mean	range	mean	range	mean	range	mean	range
			----- % -----							
A-horizon										
limestone	21	l.	36.4	17-68	43.4	8-67	20.2	8-47	29.6	2-64
intrusive igneous	16	l.,sl	62.5	41-80	23.1	9-38	14.3	8-21	16.7	5-45
extrusive igneous	10	l.	29.9	21-41	45.6	26-68	24.5	5-53	16.5	5-30
B-horizon										
limestone	20	cl	33.0	22-53	43.7	16-65	23.3	4-46	35.9	5-68
intrusive igneous	28	sl	60.3	40-76	21.1	9-37	18.6	7-31	23.9	7-40
extrusive igneous	10	l.,cl	31.9	19-42	37.5	22-68	30.6	7-59	40.0	15-70
C-horizon										
limestone	26	l.	38.6	26-57	36.7	26-48	24.7	13-41	47.2	15-95
intrusive igneous	19	sl	71.6	52-94	17.5	4-30	10.8	2-21	42.8	2-95
extrusive igneous	6	l.,col	34.3	21-49	45.3	24-70	20.3	4-55	65.0	35-90

Table 5- Soil chemical properties of selected soil horizons in Montana.

Parent material	No. horizons	pH			CEC			Base saturation		
		mean	st. error	range	mean	st. error	range	mean	st. error	range
					----- meq/100g -----			----- % -----		
					A-horizon					
limestone	21	6.9	0.2	4.6-8.0	23.2	3.3	7-55	85.6	6.7	17-100
intrusive igneous	16	5.9	0.1	4.9-7.1	14.4	1.2	7-22	74.4	3.3	52-100
extrusive igneous	10	5.6	0.1	5.0-6.2	34.6	6.5	15-76	71.5	6.1	36-100
					B-horizon					
limestone	20	6.7	0.21	4.8-7.8	22.7	1.7	10-36	72.9	9.9	5-131
intrusive igneous	28	6.2	0.1	4.8-7.7	15.3	0.9	7-26	85.1	2.7	35-100
extrusive igneous	10	5.9	0.2	5.0-7.0	47.0	8.2	18-94	77.5	4.7	38- 91
					C-horizon					
limestone	26	7.9	0.1	7.2-8.8	14.8	1.2	8-31	103.5	3.5	100-159
intrusive igneous	19	6.4	0.2	5.0-8.1	9.7	1.2	3-24	87.8	2.9	70-100
extrusive igneous	6	6.4	0.1	5.9-6.8	39.4	14.1	9-93	80.0	5.7	62- 97

Organic Carbon in Montana Soils

The organic carbon content of Montana soils varies widely (Table 6). Among our subsamples, the Entisols had the highest mean clay percentage and the lowest mean amounts of organic carbon within A-horizons. Most of these soils have developed on shales in central Montana and have aridic moisture regimes. The amount of clay is high and organic matter contents are low, probably due to low grass production and high decomposition rates under these conditions. Mollisols, on the other hand, had low clay contents and higher organic carbon levels. These soils generally develop in regions with adequate moisture for high grass production, and cool temperatures which reduce the decomposition rate.

Management also affects soil organic matter levels. Cultivated soils showed much lower organic carbon contents than native grassland soils, suggesting that cultivation has decreased the natural organic matter equilibrium levels. This is consistent with the results of previous studies (Dormaer, 1979; Haas et al., 1957; Kononova, 1966; Mamontov, 1975; Newton et al., 1945; Weaver and Forcella, 1979). However, the difference we observed may in part be explained by higher elevations and higher productivity associated with the native grassland sites.

The poor correlation between organic carbon and percent clay is shown in Table 7. The main purpose of subsampling

was to determine whether there were any soils in Montana for which this relationship is as important as it is in the Southern Great Plains (Nichols, 1984). None of the subsampling techniques increased the correlation between organic carbon and percent clay to a significant level: the r values ranged from -0.19 to 0.12. This contrasts with r values of 0.86 to 0.90 reported by Nichols.

The current study provides evidence that organic carbon content of soils in Montana is not significantly influenced by clay content. A simple linear regression between organic carbon and clay for the 130 horizons resulted in an r -squared value of 0.13, indicating that in this region, organic matter accumulation is not strongly related to soil clay content. These results negate, for use in Montana, equations given by Nichols (1984) and Kadeba (1978), which use percent clay to estimate organic matter content, and support the results of McDaniel and Munn (1985). We expect that clayey soils would tend to maintain higher levels of organic matter than sandy soils if elevation, precipitation, and vegetation type were constant.

Elevation correlated well with organic carbon, except in the Entisol subsample. The history of erosional, depositional and fluvial events may be more important than current elevation or climate in determining organic carbon content in Entisols.

Table 6- Organic carbon, clay percentage, elevation and mean annual precipitation in 8 subsamples representing Montana soils.

Subsample	No. hori- zons	Organic carbon		Clay		Elevation		Precipitation	
		mean	range	mean	range	mean	range	mean	range
		----- g kg-1 -----		----- % -----		----- m -----		----- cm -----	
All pedons	130	27	8-124	28.8	11-69	1192	670-2666	39	28-102
Native grasslands	78	37	8-124	26.3	11-69	1309	701-2666	41	28-102
Cultivated grasslands	52	14	8- 34	32.6	14-61	1018	670-1463	35	28- 76
Mollisols	88	32	8-124	25.7	11-55	1303	838-2666	41	28-102
Entisols	18	13	8- 30	45.9	18-69	901	670-1067	32	28- 37
1st horizon	93	28	8-100	29.5	11-69	1153	670-1786	37	28-102
2nd horizon	37	27	8-124	27.1	14-57	1291	670-2666	43	28-102
Frigid soils	109	22	8- 69	29.5	11-69	1090	670-1676	36	28-102

The correlation of organic carbon content with elevation was better for the lower A-horizons than for the uppermost A-horizons. This is probably because at the soil-air interface biological, climatic and geomorphological influences fluctuate more erratically. Also, organic carbon content of the upper horizon is partly a function of the depth to its lower boundary, which is sometimes arbitrary. Increasing the depth to this boundary will decrease the horizon's apparent organic carbon content, which generally decreases with depth in the soil profile.

Table 7- Correlation between soil organic carbon content and other soil properties.

Subsample	No. hori- zons	Correlation coefficient (r) with		
		Clay Content	Elevation	Precip.
All pedons	130	-.13	.70 *	.55 *
Native grassland	78	.02	.66 *	.56 *
Cultivated grassland	52	-.13	.23	.54 *
Mollisols	88	.07	.66 *	.50 *
Entisols	18	.12	-.02	-.04
1st horizon	93	-.19	.63 *	.37 *
2nd horizon	37	.001	.85 *	.82 *
Frigid soils	109	-.16	.56 *	.28 *

* - significant at the .01 level.

The correlation of organic carbon content with elevation was significant for native grassland sites, but not for cultivated sites. It appears that cultivation can obscure natural relationships between elevation and organic carbon in soils. However, the narrower range in elevation for the cultivated sites might have reduced the correlation within this subsample.

Mean annual precipitation also correlated significantly with organic carbon, except in the Entisol subsample. On cultivated sites the relationship was stronger than that between organic carbon and elevation. Precipitation seems to affect organic matter accumulation despite disturbance by cultivation.

A multiple linear regression equation of organic carbon content (OC) in g kg^{-1} within the second A-horizon against elevation (elev.) in meters and mean annual precipitation (precip.) in centimeters was calculated:

$$\text{OC} = 0.029(\text{elev.}) + 0.61(\text{precip.}) - 37.5 \quad (1)$$

The multiple linear regression coefficient (r) was 0.88. If all A-horizons are included in the regression, the equation is:

$$\text{OC} = 0.039(\text{elev.}) + 0.30(\text{precip.}) - 31.1 \quad (2)$$

with a multiple linear regression coefficient of 0.72.

Equations (1) and (2) show that organic carbon in Montana soils is related to elevation and precipitation.

Elevation and precipitation are highly correlated with each other within the subsamples ($r = .80$ for lower A-horizons), probably due to orographic effects. As elevation increases, mean annual precipitation will also increase. This results in greater grass production. Soil temperature decreases as elevation increases. Thus for a longer period annually, soils at high elevations are too cold for rapid biological decomposition. The breakdown of roots and other detritus is slowed, causing organic materials to accumulate. The low soil temperatures at high elevations may partially explain the relationship between organic carbon and elevation. We cannot demonstrate this, since on-site soil temperature data were not available for the soils sampled. Farther south in the Great Plains, cold soil temperature ceases to limit biological decomposition, so other factors such as organo-mineral complexing gain importance in determining soil organic matter status.

Evaluation of the Soilgrasp System

The success of the Automated Data Processing System (Decker et al., 1975) was limited by its complexity. This is true for any computer system, whether its function is graphics, data management, decision support, or education. As the level of required computer expertise increases, fewer people will be able to use the system. The best systems are those which appear to manipulate symbols the same way people

do. Speed and economy are important goals, especially for large information systems. However, these goals should not be sought at the expense of user ease. Learning time is not productive in the sense of meeting the user's research objectives. If they perceive the learning time to be too long, they will often decide against using a computer system, even if it might ultimately save them time. There is no guarantee that an untried system will accomplish a user's goals, or even perform as described. The risk element is really equivalent to potential lost time.

The design of the Soilgrasp System centered around the user. The interface program, SOILGRASP, is the key element in making research studies easy. Ideally, as an interface it should insulate the user from ever having to deal directly with the computer operating system or with GRASP's more complex command syntax, unless the user chooses to. SOILGRASP did not completely fulfill that role at this writing. This thesis project produced a model interface. It has the potential for several enhancements to its functions which could allow it to more closely approach the ideal.

The Soilgrasp System provides a core data handling capability with several avenues open to expansion for application development. These applications include furnishing data for sophisticated statistical analysis by other software packages, user-formatted output, interfacing

with geographic information systems, and microcomputer-based study design and preparation.

SUMMARY

Montana's soil pedon data were recoded to conform with the revised Pedon Coding System for the National Cooperative Soil Survey (Soil Survey Staff, 1979). The 31 files containing data were merged to form a contiguous flat file. Within this file, each record held all of the data (for each variable) for a single soil horizon.

Two smaller data sets were merged with the original soils data to increase the sample size and to extend the useful life of their valuable contents. The first of these was from a BLM-MSU joint range vegetation study. The second was a small soils-crop yield data set compiled by Burke (1984). These additions expanded the scope of the database to include variables concerning native vegetation presence and production rates, erosion factors, crop yield and type, and plant nutrient fertilization rates.

GRASP, a database management system developed at Montana State University, was chosen for data manipulation. This package was able to handle unlimited numbers of cases and variables, thus there would be no arbitrary ceiling on the size of the database. GRASP also combined an extensive set of data manipulation commands with many commonly used statistical procedures; it would be a powerful tool for research studies as well as an electronic file clerk.

A mainframe database system was chosen over a micro-computer-based system because the size of the database was unwieldy for the smaller systems. Data files alone would have filled the largest available (and affordable) memory devices. The programs for microcomputers were designed with practical limits to variable ("field") number which Montana's soil pedon database exceeded by an order of magnitude. Finally, access to the database from elsewhere in the state would be more difficult to arrange on a microcomputer than on a mainframe. Even if this could be managed, multiuser capabilities would be severely limited on the smaller systems.

The database was inverted by GRASP into variable-oriented machine language files which it would access during user sessions. This was the key to GRASP's "rapid access" capability.

Database storage problems were solved by renting a large capacity hard diskpack. This brought monthly storage costs from \$800.00 down to \$50.00. Magnetic computer tapes were used to create three complete backup sets of the database. A database update form was developed to assist users in properly saving all database improvements.

SOILGRASP, a user interface program, was developed to provide a friendly environment for researchers designing studies. SOILGRASP takes care of most technical computer commands needed to run the database system.

Complex GRASP command syntax is converted to menu choices and simple answers to SOILGRASP's questions. Help information can be displayed on demand.

The combined data files, management system, user interface, and researchers make up the Soilgrasp System. The Soilgrasp System was used to extract and print out various sorted lists of soils information, both for demonstration purposes and to fill research requests for specific data.

Sampling procedures were tested using increasingly selective criteria. Most criteria were easily applied by consecutive modifications to previous samples, using a process of elimination. It was found that character variables or substrings over 40 characters long could not be manipulated in this way. However, the few variables which were too long contained field notes or unused space, and would rarely need to be accessed for research studies.

The System was used by graduate students in a Soil Genesis and Morphology course. Each student conducted original research for which raw data were obtained with the System.

Two research projects were conducted by the author with the Soilgrasp System. The effect of geologic parent material on texture and chemical properties of 535 soil horizons was investigated. The relationship of organic carbon content with clay, elevation, and precipitation in

130 Montana A-horizons was also studied. Results of the latter project were published in a refereed journal article (Sims and Nielsen, 1986).

From the results of this thesis project, the following conclusions may be drawn:

1. Montana's soil pedon, vegetation, and soil fertility data have been merged to form a single database whose format conforms to current national standards.
2. A database management system, called the Soilgrasp System, has been developed around this database to improve access, updating, and research capabilities, and to expedite distribution of the information for extension purposes.
3. The predominance of sand particles in soils over intrusive rock and finer particles in soils over extrusive rock indicates strong textural inheritance from igneous parent materials in Montana. This is not evident in limestone-derived soils.
4. Cation exchange capacity is higher (and also more variable) in soil horizons developed from extrusive igneous rock than in those from limestone or intrusive igneous rock.
5. Correlations between organic carbon and clay content were not significant in Montana soils formed under grassland vegetation. This contrasts sharply with the close correlation between these properties in soils of the Southern Great Plains.

6. In Montana, organic carbon is most closely related to elevation and precipitation. The significant correlation with elevation is probably explained by higher precipitation, greater production of grasses and forbs, slower organic matter decomposition rates and lower soil temperatures at high elevations.
7. Although beyond the experimental stage, the Soilgrasp System has much room for enhancements. The versatility of GRASP itself will allow soil scientists to develop specific applications software, such as programs to automatically transfer data to statistical graphics packages; user-defined output format libraries to create popular or individualized data output; and improvements for the user interface.
8. The various studies performed to date have demonstrated the usefulness of a computerized, user friendly system to manage Montana's soils and landscape information. The potential for further research into soil relationships is limited only by data availability and integrity. It is evident that users' imaginations are well prepared to furnish the queries. Many more ideas were submitted by soil scientist from all over Montana than could be addressed during this thesis project. This System should help to extend the usefulness of existing data and provide the means to add new information as it becomes available.

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APPENDIX

APPENDIX

Soilgrasp System User Manual

by

Zachary Reed Sims

Montana Agricultural Experiment Station
Bozeman, Montana

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Soilgrasp System User Manual

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INTRODUCTION

The Soilgrasp System is composed of a large soils database, called the Montana Soil Pedon Database, and the computer software needed to manage it. The system was designed to help researchers process soil data quicker and more accurately than they could by hand. It also provides for unlimited expansion of our store of soils information in an organized way. The system can be used to maintain standards for data collection and encoding which conform to those of the National Cooperative Soil Survey. The benefits of this standardization include:

- 1) enabling researchers from other states to use our soils information,
- 2) giving us the chance to increase our sample sizes with data from previous studies, and
- 3) ensuring that information from past research is not shelved in obscure reports and lost in the "information explosion" that is a trademark of this decade.

This manual is intended for use by graduate students, faculty and researchers in a university setting. It is organized as a reference for users of the Soilgrasp System, and as a user oriented supplement to the GRASP Users Manual. Further technical and software-specific information may be obtained from that reference, or from the Center for Data Systems and Analysis at Montana State University.

SOILGRASP SYSTEM OVERVIEW

The Soilgrasp System encompasses three general areas of database management:

- 1) The organization and storage of an unlimited number of soils data sets into a single system with a specific format.
- 2) The retrieval of any part of the data "superset" for use in soil science research projects, accessing cases which correspond to specific queries or qualifications by researchers.
- 3) The generation of a variety of statistics on a sample of cases, with structured output of the results.

The System includes a program which acts as a middleman between the user and the complicated database management software. The program's name, SOILGRASP, was adopted as the name for the System which this manual describes. This program helps users design a sample-selection scheme and choose various statistical procedures to perform on the data in the sample. Users choose operations and output options from menus. They are thereby spared the need to remember specific requirements of the mainframe computer for running GRASP (Generalized Rapid Access Software Package, the database management software used with this System), such as memory allocation and account specifications. Users also need not learn the exact command syntax required by GRASP for its data operations. Since the SOILGRASP program is an optional interface, experienced users may bypass it entirely, working directly with GRASP.

GRASP is an integrated set of FORTRAN programs which together perform all of the operations needed to store and access the soils data. This software was developed by the Center for Data Systems and Analysis (CDSA), a unit of Montana State University, in Bozeman. It is dependent upon the CP-6 operating system, which runs on MSU's Honeywell Level 66 DPS/C3 mainframe computer. The main reason for this dependency is GRASP's use of edit keys which are specific to CP-6. GRASP is not commercially available at this writing, as it is still under development.

GRASP is designed to work efficiently with large, static data sets. A static data set is one which is rarely changed and whose information does not become obsolete. The Montana Soil Pedon Database is such a data set. In contrast, a product catalog from a computer manufacturer would most certainly not contain static data!

As the database grows, GRASP's efficiency edge over most other software increases. This is because GRASP inverts the data files and converts them to binary code, so its i/o (input/output)

access time is minimized. The inversion process is described in Section 1 of this manual.

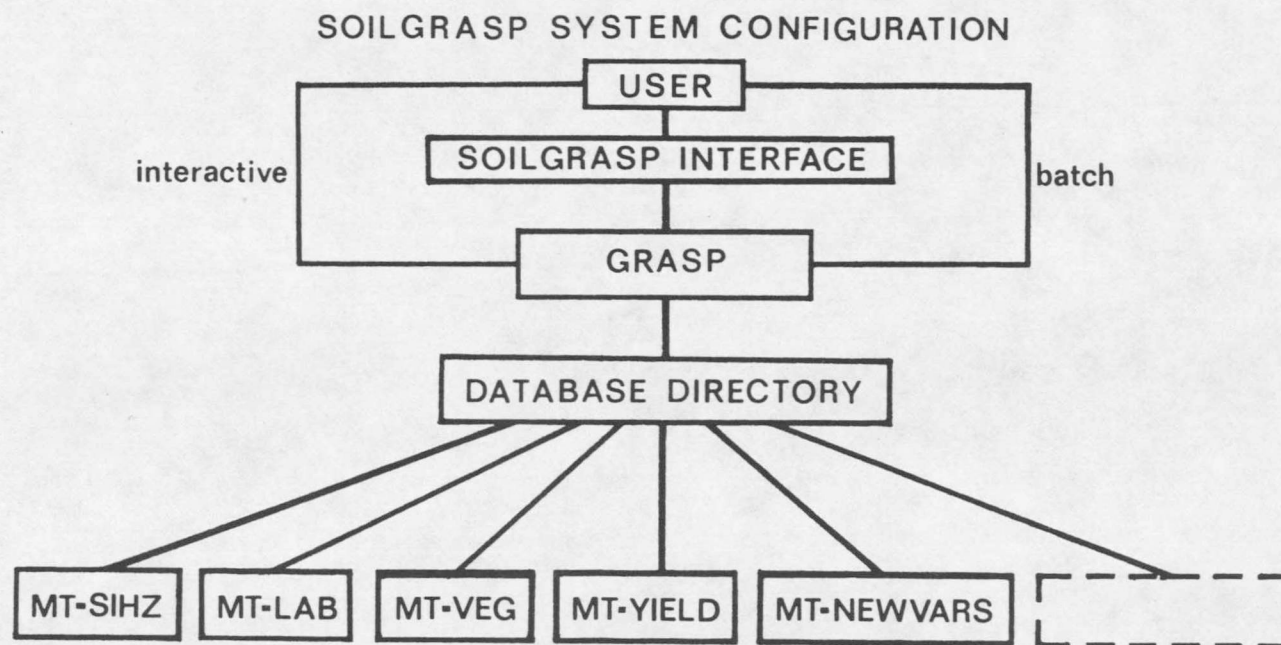
GRASP has routines which can perform some basic statistics on the data. A note of caution: the statistics are easy to perform with GRASP, but may indicate relationships which do not really exist. For instance, a high correlation between two variables does not necessarily indicate a causal relationship. Totally unrelated variables might accidentally be highly correlated. What if a correlation of the thickness of Montana B horizons and the populations of European cities from north to south had an r value of 0.91? Take care in your interpretation of statistical output, from GRASP or any other statistics programs.

The Soilgrasp System enables users with more sophisticated statistical needs to send their sample data out of the system in a format that SPSS, SAS, or other complete statistical packages can read.

An option provided by the Soilgrasp System allows for custom formatting of output. Since GRASP was written in the FORTRAN programming language, it can read standard FORTRAN format statements input by users. This means that output can be directed by the user, although this is not required. GRASP's default output formats are well-organized and easy to read. However, they do not conform to the publishing standards for tables in most agronomic or other scientific journals. A user can build a library of output format statements as separate computer disk files to be used as needed.

For further information about GRASP, consult the GRASP Users Manual (Allard, 1981).

The configuration of the Soilgrasp System is shown below in a flow diagram.



- up to 10 files accessed concurrently

MONTANA SOIL PEDON DATABASE

The Montana Soil Pedon Database contains data collected from soil sites throughout the state. There are over 1000 variables in the database. Some contain laboratory results; others have data for horizon morphology, physical properties, range vegetation, and crop yields. Some of the variables do not contain data at this writing. They have been set up in anticipation of future use. These include most of the fertilizer variables. You can consult the database dictionary (Appendix I) for a list of the number of cases with valid data for each variable.

The Database existed previously in several soils data sets which have since been modified and/or updated. Table 1 gives information on their sources and their organization within the Database structure. The Key number for a site (or pedon) is the number stored in the Database variable, "KEY", and is a unique identifier for the site. The numbers were recorded with the format, SITE-HORIZON NO. (for example, " 172-01" would be site 172, 1st horizon).

Table 1- Data set organization within the Montana Soil Pedon Database. All of these data are accessible by GRASP.

Data Source	Begin Key no.	End Key no.	No. Cases	No. Sites
MT. Benchmark Soils Data	1- 1	271-10	2102	270
MT. Official Series Descr.	1001- 1	1567-10	2967	567
BLM-MT. Range Study	9001- 1	9167- 7	763	149
Master's Thesis Data (Tom Burke, MSU)	9501- 0	9684- 0	184	184

SECTION 1

DATA BASE CREATION

A large soils data set, the Montana Soil Pedon Database, is already accessible to GRASP. Actually, three data sets were merged and entered at once. This section describes the steps needed to enter further data into this Database such that it will be compatible with existing data. A short form of the instructions is also given for researchers choosing to create a smaller, stand-alone database or a non-soils GRASP database.

Setting up a database with standard codes takes some time and expense initially, since many variables probably need to be repositioned and perhaps recoded. Once this work is finished, however, the data set is compatible with a number of others in the United States. The Soil Conservation Service uses the same format for their SCS-SOI-5 database at Ames, Iowa and for other pedon data sets. Uploading of data into this national system and downloading into local computer networks for use by universities or state agencies are among the advantages of having the same soils data formats across state and/or agency boundaries.

The following procedures cover steps to be taken to ensure proper entry of the data.

1.1 Creating a Compatible Data Base

Each new data base (also called a data set) should be organized according to the 1979 National Cooperative Soil Survey Pedon Coding System (Soil Survey Staff, 1979). This serves as a standard for codes and positions of all variables common to both the new data set and the larger Soil Pedon Database.

- A. Encode all data onto computer disk or magnetic tape.
- B. The original data set must be reformatted so that the variables are in the positions specified by the 1979 NCSS Pedon Coding System. Any variables with nonstandard codes must be recoded. The specific codes for each variable are given in that publication. Several programs written by the author and others can be used as models for the recoding process. These generally read in data in its existing format, and output it in a more compatible format. They may be obtained from Dr. G. A. Nielsen, Plant and Soil Science Department, Montana State University. The programs (BLM_RECDE and others) were written in FORTRAN-77.
- C. Once the data set is in the correct format and is coded correctly, it must be "inverted" by GRASP. This process is

described in the System Overview section of this manual. The invert files (MTINVERT1-4) which were originally used to create the Soil Pedon Database may be used on any compatible data sets, since the format and coding system would be identical. The four MTINVERT files can be found on rented magnetic tapes at MSU's Computing Services Center and on tapes stored in Dr. G. A. Nielsen's office.

- D. Variables unique to the new data set can be added to the main GRASP Directory file. This has been done before, with the result that the 1979 Pedon Coding System is now a proper subset of the Montana Soil Pedon Database. Since the large Database does not contain all of your variables in this situation, you will need to treat the new ones differently. The only way to add them to the Database is in an invert file of their own, using the INVERT PRINT ADD VARIABLES command (see section 4.1 for syntax). Don't worry about these variables being inverted separately. It does not matter which data file your new variables will end up in: if information about them is in the database directory, then GRASP can find their data as long as you declare that file in the opening statements for GRASP setup (see DATA command, Section 4.4).

1.2 The Invert File

An invert file tells GRASP the name, data type and columns occupied by each variable. A definition (40 characters or fewer) is added for the benefit of other users: GRASP will print this definition in response to the command, "DIRECTORY LIST INFO: variable name".

The following list describes the parts of each record in an invert file.

A. Variable name

- 12 ASCII characters or fewer, beginning with a letter
- Can include the dash ("-") and underscore ("_")
- Names use all capital letters and may include digits

B. Data types

- ALPHA(x) : GRASP treats any ALPHA variable as a simple alphanumeric character string. Statistical operations cannot be performed on ALPHA variables - their data will have a value of zero if any statistic is requested by a user. The letter "x" is the number of columns the variable occupies in the data set.

- REAL[(d)] : A real variable, where "d" is a fixed decimal point. The [] brackets indicate that (d) is optional. This option is used if no decimal point is included in the data. GRASP will assume that the (d) rightmost digits are decimals. For example, if GRASP accesses a datum for a REAL(2) variable, and finds 9102, it considers the number to be 91.02.

- INTEGER : An integer variable. No column width need be indicated.

- BIT : A bit variable. Codes can only be 0 or 1: think of these as representing "false" and "true". No column width need be indicated, since it always equals 1.

- C. Columns must be specified for every variable after the data type declaration, in the form n1 TO n2, where n1 is the beginning column number and n2 is the ending column number. For variables occupying only one column, n1 may be specified without n2.
- D. Definitions must be specified as 'definition', with not more than 40 characters between the apostrophes. A virgule ("/") is appended to each variable entry.

It is convenient to have one variable per record of the invert file.

Example:

SERIES	ALPHA(15)	11 TO 25	'1.Soil Series Name.'/
SITE_NUMBER	INTEGER	26 TO 28	'2.Site number of pedon.'/
SAND	REAL(1)	29 TO 31	'3.Pct. sand in fines.'/
OM_TYPE	ALPHA(1)	96	'74b.1st o.m. type code.'/

When the invert file has been constructed, including the GRASP commands at the beginning and end of the file (CDSA, 1981), it is time to invert the data set into GRASP. The data set is 'flipped', using the invert file, so that cases (soil horizons) are lined up across the top of the data table, and each record contains all of the data for a single variable. This does not affect how one uses GRASP, but speeds up most data searches, especially in large data sets. During the inversion process, three general operations are performed. GRASP creates its own directory for the data base in machine language, inverts the data set, and converts the data to machine language form. The machine language files are what GRASP uses in its operations. When making tape backups of the data set, the original (case-oriented) file, the invert file used, and the machine language GRASP (variable-oriented) data file should be stored together so that the inversion can be performed again if necessary. A hard copy of the invert file may be referred to by users, when sampling variables,

as a sort of dictionary. The Database Dictionary in Appendix I is an edited (abridged) version of the set of invert files used to enter the Montana Soil Pedon Database files into GRASP. GRASP does not use the invert file after the inversion is complete. Instead, it uses a machine language "directory" file which it creates during inversion. The file, "MTDIRECTORY", is an example.

GRASP will only invert about 500 variables at one time, so the 1057 variables in the Montana Soil Pedon Database were split into four invert files. The inversions were run consecutively. The first file initiated the directory. Subsequent files added variables to the existing directory and created new, separate GRASP data files.

GRASP can access 10 of its data files at one time. Two or more files may be merged if necessary, so the amount of data accessible by any one GRASP directory is limited only by disk space. It is prudent to divide the database into logical subsets (laboratory, site, vegetation and yield data sets, for instance) to permit a user to put only the necessary data files out on disk where they will accrue higher storage costs.

Experience with the many possible bugs in this file manipulation process has shown that a trial run of the inversion should be run with a small subset (the first 10 records) of the data base to check for errors. Common problems include mistakes within the data set itself, typographical errors in the invert file, and errors in one's assumption of the data format. Careful proofreading of the invert file is warranted.

During inversion, GRASP creates its own directory for the data base and one or more (depending on the size of the data base) variable-oriented data files, all in machine language. These are the files that will be used when GRASP is run, and should always be backed up together onto magnetic tape so that the inverted files won't be lost or separated from the software.

1.3 Testing the Invert File

Since formatting and recoding errors are possible, a trial run of the inversion process with a small subset of your data, about 10 records (this is 10 horizons or cases, not 10 variables), should be performed. This small subset will invert quickly and cost much less than inverting the whole data set. You will catch all invert file errors and can correct them before the real inversion. You will also be able to run statistics on some of the variables to check the validity of your data. The sample size will be 10.

To get the subset, copy the first 10 records of the data file into another file with the CP-6 system command, "COPY DATAFILE(1-10) INTO SUBFILE". Declare SUBFILE as the inversion input file, instead of DATAFILE.

1.4 Creating a Stand-Alone Data Base

If your data are unreliable, or are in some other way unacceptable for inclusion in the Montana Soil Pedon Database, you can form an independent data base with its own code system and directory (dictionary) file. A directory file is used by GRASP to access data, and contains such information about a variable as its data type (integer, character, real or bit), which data file to look in for the information for this variable, and which columns of that data file to go to. An independent data base may not have a standard coding system or format for some of its variables. This means that it would be impossible to combine cases with other soils data in the Montana Soil Pedon Database to expand sample sizes. Other researchers could not share the data, as variable names, codes and directories would be incompatible with their own.

To create the database, follow these steps:

- A. Write a FORTRAN format statement describing any single record of the data. All records must be of identical length for GRASP. Data in records of variable length must be converted to fixed-length format, where each variable is in a unique set of columns. Blanks must be entered for any missing data.
- B. After preparing the data base format statement, construct an invert file using this format, according to the procedure described in section 1.2, and then run the inversion.

1.5 Verifying a New Data Base

Whenever a new data set or new case has been entered, it is important to verify that it was entered correctly. One way to do this is to get listings of the new data for your variables, and scan them for unusual values. Also, get basic statistics output for the variables. Check these to be sure they make sense. If the statistics look suspicious, compare a listing for that variable with the raw data as they appeared before being encoded or inverted into the system. For example, data for a new variable, WHEAT_YIELD, have been entered for 100 cases. You want to know if all of the data are in their correct places and were encoded accurately. To do this, sample for those 100 cases. Generate a table of statistics for the variable by entering:

```
STAT:WHEAT_YIELD
```

Check the mean and range given in the output table. These should be the numbers you expect. Get a list for the 100 cases showing

all of the data by typing:

```
LIST:KEY,WHEAT_YIELD
```

Keys are listed so that you can see that the cases are the correct ones, and so that you can spot-check WHEAT_YIELD against the raw data for certain cases. Again, be sure that none of the data are mismatched. If some do not match, you may have had the data in the wrong sequence before inversion. You may also have made some typographical errors in encoding the data.

1.6 Correcting Minor Errors

Isolated mistakes may easily be edited as follows:

- A. Redefine the data files GRASP is accessing to include all necessary files except the file which contains the variable to be edited:

```
DATA REDEFINE: file1, file2, file4, file7
```

- B. Tell GRASP you wish to update data in the file with your variable:

```
DATA FILE: file3 account UPDATE
```

where "account" is the CP-6 account where file3 can be found (e.g. ISS005, RSSES002).

- C. Sample for the case containing erroneous data by using its key number:

```
SAMPLE: KEY(' 9507- 1')
```

For this example, the key number stands for site 9507 (horizon 1).

- D. Edit the variable under consideration:

```
EDIT PASS=password: WHEAT_YIELD:= 1270
```

1.7 Correcting Major Errors

Bigger problems may require that you correct your data and re-invert it into GRASP. Before you can re-invert it, you must delete the variable from the directory (because it already

exists, though the data are incorrect):

```
DELETE PASS=password: WHEAT_YIELD
```

GRASP will erase that variable from its directory, and you can proceed to re-invert it, just as if it were a new variable.

It is sometimes better to avoid this major deletion by sampling case after case and editing each of them separately. This method takes time but involves no major database operation, so it's safer. A good rule of thumb is this: if there are over 200 errors to correct, or if the data seem to be completely scrambled, then re-invert. If there are fewer errors or if it is easy to see what went wrong, correct them one by one. If the errors are very consistent, say 1/10th of what they should be due to an encoding error, you can save a lot of time by editing them all with a single command. This method takes advantage of GRASP's ability to edit a variable using an equation. First, we'll sample for all pertinent cases, let's say all 100 cases of our example. If the data are consistently 1/10th of their true value, we can then enter the command:

```
EDIT PASS=BARK: WHEAT_YIELD:= WHEAT_YIELD*10
```

This command would increase all new data for that variable by the same factor. Addition, subtraction or more complicated operations can also be used.

SECTION 2

SAMPLING THE DATABASE

The process of writing a sampling procedure in a way that GRASP can understand (that is, unambiguously) can be difficult. Computers have no intuition: we are forced to translate our leaps of inference into simple, logical steps that can be performed sequentially to arrive at the same conclusion. To do this, we use symbolic, or Boolean, logic. The language of symbolic logic uses comparators like "and", "or", "either-or", "greater-than", and "less-than". With these, we command GRASP to extract specific cases from the database for a sample.

When conducting a soils study, you usually use some subset of the total number of cases (or horizons) in the database. This subsampling is analogous to setting up the plots for a field experiment. The field researcher must decide which variables should remain constant for all reps in the experiment (for example, soil series or great group, slope), and ensure these conditions. Ranges for other variables must be considered carefully to include all relevant values and exclude inappropriate ones such as those at the low or high extremes.

2.1 Designing a GRASP Study

In designing an adequate sample for a computer study using a large database, you are faced with an enormous quantity of data from which you must select a (usually) small portion. For instance, there are many more soil great groups and a broader range in electrical conductivity than you may wish to consider for, say, a study involving the effects of soil salinity on barley yields.

Before sampling for a GRASP study, you need to decide which soil, site and climatic characteristics are important for the study. In the example of the salinity experiment, electrical conductivity and pH may be important. Sites with rock outcrops or forest vegetation are irrelevant and should be eliminated from the sample. Agricultural lands and a barley crop type are required. You must decide whether all horizons or only those in the plow layer should be used. Sites without data for the crucial variables must be eliminated. If only Natriboroll and Natrargid great groups are being considered, the sampling procedure should reflect this. The entire narrowing and elimination process is performed using only three of GRASP's commands: SAMPLE, MOD SAMPLE, and sometimes SELECT. You rely heavily on the four logical operators AND, OR, EOR, and NOT in choosing appropriate value ranges for the variables under

consideration. You will also use >, <, and = notation.

Another prudent step is to obtain a listing of the sample cases showing all of the important information for each case. A scan through this listing may pick up sites which somehow slipped through the complex logical sampling procedure but must be eliminated from the sample. A unique property or value must be found with which to eliminate it and similar cases. Usually the criterion which disqualified it will suffice. However, the sample modifications are powerful, and you may unwittingly eliminate acceptable cases by confusing your AND's and OR's. You should think carefully through a sampling procedure before performing it. Check for syntax errors. Try to estimate the sample size that should result from each procedure, or use the SIZE option with the sampling commands. The only recourse after an undesirable modification is to start over. GRASP has no "undo" feature for sampling procedures.

Further steps may be necessary in fitting the sample to a researcher's specifications, though each will be similar to those described above. As samples are successively modified, the sample size decreases rapidly and must be monitored. Here the SIZE utility can be useful. For example, if you wish to choose a range in soil pH while maximizing the sample size, you might give GRASP the command, SAMPLE SIZE: PH>7. GRASP will return a count of cases, but will not actually choose the sample. If the sample is large enough, you can take the SIZE option out and go ahead with the sampling: SAMPLE: PH>7. If it would reduce the sample size too much, you might get a count of cases for PH>6.5 and for PH>6. Some variable ranges may be manipulated in this way; others may be inflexible for the purposes of your study, and you are thus limited by the data available.

2.2 An Example Study

Let us consider a small study which you might perform using GRASP with a soils database. In this study, you are interested in finding out the average organic matter content of gleyed soils in Gallatin County, Montana. The first step is consulting the database dictionary. You need two pieces of information from this reference. You first need to know whether the variables you are interested in (organic matter content, county name, and evidence of gleying) exist within the database. There must also be sufficient cases with data for those variables to allow a study.

Problems often arise almost immediately. For instance, there is no variable which directly addresses the question of gleying. There is no data for organic matter as measured in the lab, and the county variable uses FIPS codes, not names. Knowledge of the database is useful in this situation, but these problems can be solved without it. The FIPS code representing

Gallatin County can be found. Organic carbon might be substituted for organic matter if there are enough cases that have that information. The gleying issue is more complex. This property must be defined in terms of other variables which do exist, such as soil color, mottling or soil subgroup classifications. Soil Taxonomy (Soil Survey Staff, 1975) can be a useful reference in finding an adequate definition. At a later time, a new variable, "GLEYED", could be created using this definition. If the new variable would be useful in other studies, it can be saved as a permanent part of the soils database.

When these problems are solved or circumvented, you must translate the qualifications into logical sampling statements that GRASP can perform.

2.2.1 Determining Data Validity

It's important here to note a common problem in using database management systems. We know what the information for certain variables really means. We often assume that the software we are using, since it is working with a soils database, knows as much as we do about the subject. The computer is in fact simply manipulating numbers and symbols. It is totally ignorant of any meaning in the data: that's our domain. We would infer, for example, that a blank or zero value for organic carbon is unlikely, probably representing "no data", and ignore it in our calculations. It is not valid data. Our definition of validity in this case is different from GRASP's.

GRASP's definition of validity for a data item is based solely on the variable's declared data type. If an item for organic carbon is a real number, it fits the declared data type and is therefore valid. GRASP would include cases with zero values in our sample. We have used a rule (or filter) which has nothing to do with data type, so we must tell GRASP that zeros are not to be included in the sample. We must state our rule using symbolic logic:

2.2.2 Assembling the GRASP Commands

We shall continue now with the example study.

A sampling procedure for GRASP can be built once the variables are chosen. The first of several steps in modifying the sample could be to choose the county you want. Using GRASP's SAMPLE command, it would look like this for Gallatin County:

```
SAMPLE: FIPS_COUNTY('13')
```

When you enter this command, GRASP searches every case in the database (a case is a soil horizon) and chooses only those cases with a county code of 13. It will tell you the number of cases it found and wait for the next command.

The next step will be a modification of this set of cases, choosing only those which have a meaningful value for lab-

determined organic carbon. You could enter the command:

```
MOD SAMPLE: OC_LAB_PCT>0
```

To choose gleyed soil horizons may require two or more modifications of the sample. Let's define gleyed horizons as those with a Munsell color chroma less than one (or one if the color value is four or higher), and an aquic moisture regime. Since the database has no specific variable for moisture regime, you must resort to the classification system. The word root, "aqu-" can appear in the suborder (e.g. Aquoll) or in the subgroup (Aquic Haploboroll). GRASP can search for the substring, "AQ", within the classification. The two modifications necessary to choose gleyed horizons would be as follows:

```
MOD SAMPLE: COLR_CHR<1 OR (COLR_CHR<=1 AND COLR_VAL>=4)
MOD SAMPLE: SUBGROUP('AQ') OR SUBORDER('AQ')
```

Each MOD SAMPLE command is ANDed onto the previous sampling commands. It would have been a mistake to use two different MOD SAMPLE commands in searching for an aquic moisture regime, because few soils would have "AQ" in both the suborder and the subgroup.

GRASP can accept these commands one by one as you type them in (interactively, or "on-line"), or as a list of commands read from a file on your account. In the latter procedure, one which I recommend, you can use a text editor to build a command file (let's call it GLEY-SAMPLE), consolidating all of your commands, plus one which tells GRASP where to accept input from after it has read and followed each command:

```
SAMPLE: FIPS_COUNTY('13')
MOD SAMPLE: OC_LAB_PCT<0
MOD SAMPLE: COLR_CHR<1 OR (COLR_CHR <=1 AND COLR_VAL>=4)
MOD SAMPLE: SUBGROUP('AQ') OR SUBORDER('AQ')
INPUT: ME
```

Each time you get into GRASP and need to do work with these cases, you can input a single, simpler command:

```
INPUT: GLEY-SAMPLE
```

You can also use the SOILGRASP program for this procedure, as

described in Section 3.

A useful next step would be to create a new "bit" variable (perhaps called GLEY-STUDY) in the database. GRASP can use this variable to select the cases chosen by your three sampling commands. It is called a bit variable because GRASP assigns a value of 1 ("true") to the cases you have chosen and 0 ("false") to all other cases in the database. 1 and 0 are binary digits (bits). When the new variable exists, the command:

SELECT: GLEY-STUDY

will cause GRASP to find cases for which this variable is "true". This is a much simpler operation than sampling on 5 different variables. Bit variables are useful if you plan to sample a certain way many times, and especially if the sampling procedure is long or complicated.

After the sample is defined and chosen, you may call up statistics and lists for any variable (or expression using variables in the directory). The statistics will apply only to the cases in the current sample. You can also "dump" a set of data to a file on your account, which SPSS or SAS can use to generate more complex statistics or graphics.

The sampling procedure is the most time-consuming portion of a GRASP study. Subsequent statistical operations are easy and quick. The statistics are, however, meaningless if the sample is not correct. A researcher should expect to do a lot of error-checking during the early stages of a study to avoid duplicating them later with a better sample.

SECTION 3

THE SOILGRASP INTERFACE

3.1 WHAT IS SOILGRASP?

SOILGRASP is a program written in FORTRAN and designed to help you put together a GRASP study. It does not do anything unique: you would have to give GRASP the same commands that SOILGRASP does to arrive at your research results. Consider this program to be a tool which makes some GRASP jobs easier.

This program is only one component of The Soilgrasp System. The term, "Soilgrasp System", refers to a broader entity of people, data and software. To distinguish between the two, the name of the program will appear in capital letters in this manual.

SOILGRASP was written for use by newcomers to the system, and for users who access GRASP infrequently. It is menu-driven, whereas GRASP is command-driven. The difference is that GRASP will give you a prompt when it is ready for the next command without telling you what you can or cannot do. SOILGRASP tells you what options are available and then asks you to choose one. Menus free you from memorizing all of GRASP's specific commands, and especially their syntax.

SOILGRASP is not an integral component of the GRASP software. It is a program that has been adapted from a similar database system to take advantage of GRASP's ability to accept commands directly from a disk file, without interactive user input.

The terms, "input" and "output", can easily be confused here. I'll try to explain how they are used in this section. SOILGRASP's output, a file of commands, is what GRASP uses for input. A GRASP input file is a command file; both terms are used synonymously. GRASP has output, too: its output is your research results, the end-product. Think of SOILGRASP output only as an intermediate product which contains GRASP's input or instructions.

This section describes the concepts behind SOILGRASP, and its functions and limitations.

3.2 Menus

The best way to make a system easy to use by a variety of people with different levels of computer knowledge is to give them menu options. Menus in computer systems are similar to those in restaurants. A computer program that is "menu-driven" gives users a list of their options, things the computer will do

for them. Users can enter the letter or number standing for their choice instead of typing in the entire command. Likewise, in some restaurants you can order Combo #1 instead of naming each item you want separately. Based on that choice, the waiter will ask you to choose more specific options such as salad dressing. If wine is included in the dinner, he may offer you a wine menu or simply name your choices.

SOILGRASP is a program which gives you options that GRASP can perform for you. Once you have sampled, you will be given choices of things that can be done with that sample ("and how did you want that cooked?"), such as listing variables or correlating two variables. These sub-choices also appear in menus. Finally based upon your choices, SOILGRASP can build an input file for GRASP. The input file contains the instructions that GRASP will need to do your study, from sampling to statistics to good-bye. All you have to do is start (or enter) GRASP and tell it where to find the instructions (which file to input). SOILGRASP guides you through that process too, but from outside GRASP.

When you enter SOILGRASP, the first thing you see is a menu. The main program menu looks like this:

PROGRAM MENU
1. - Introduction to SOILGRASP.
2. - Set up a command file.
3. - Choose a sample.
4. - Analyze variables.
5. - Scan command file for errors.
6. - Run command file.
7. - Conclude program operations.

Based on your choice from this menu, SOILGRASP will prompt you with questions or give you another menu, such as the statistics and analysis options menu, which lists the statistics that can be accessed through SOILGRASP.

3.3 SOILGRASP's Functions

The purpose for creating SOILGRASP was to help users do research with the database without requiring much learning time.

The services SOILGRASP provides are as follows:

- A. It provides some interactive help. The brief explanations cover the use of this program and the statistics that GRASP can perform.
- B. It shows users many of the options they have in using the Soilgrasp System with a nested hierarchy of menus (main menu, sampling and statistics menus, output menu, etc.). Some options do not appear. Usually the simplest or default forms of lists, statistics and other operations are assumed. This program's output, a GRASP input file, can be edited later to customize output formats. Including all of the complex custom options would defeat SOILGRASP's purpose, which is to keep things simple.
- C. It allows users to choose where the output from their GRASP study will be directed: to the terminal screen, where they can see it immediately; to the line printer (LP) where they can get a paper copy of it; or to a disk file, where it will be saved by the computer for later examination. All three choices have advantages. A fourth option is sometimes useful. By using the DRIBBLE capability of the computer, they can see the output immediately while capturing what appears on the screen into a disk file. See section 6.2 on DRIBBLE files in this manual.
- D. It reminds users of their option to check their study for errors before running it. This is most useful for long or redundant studies because it can save time and money. Once GRASP begins reading and acting from an input file, there is no way to stop it until it finishes, aside from ungracefully exiting GRASP by pressing the BREAK key. In an error-checking mode, GRASP checks each of the keyword commands in the input file for correct syntax. That is all it does. GRASP does not check for variable spelling errors. It does not determine that data for the variables used are indeed resident in the particular data files opened. It does not check that the sample size (after a sampling procedure) is greater than zero. These are all responsibilities of the user. If, during a real run, one of these errors occurs, you should note the error, exit GRASP, edit the input file commands, and run it again. If a sample size is zero, no statistics can be performed; the study will need to be redesigned and tried again. This is a problem of data limitations, not of the software which manages the data.

-
- E. It produces a record (in the form of a command file) of the entire GRASP study procedure so that it can be duplicated and so that errors can be traced more easily. If a command file has errors or misspellings that GRASP didn't catch during an error-checking pass, it doesn't need to be rebuilt from scratch, but simply edited, before re-running.

3.4 Working Without the SOILGRASP Interface

The SOILGRASP interface is an optional one, a tool that you can discard when it is no longer useful. GRASP has some commands which are not given as options within SOILGRASP, either because we did not find them very useful in a soil science study or because of their sensitive nature. Sensitive commands include those which add or delete variables, edit variables, or edit the all-important database directory. The directory is GRASP's only link to the data (it is as essential as the stairs that connect a subway station to the surface). The SOILGRASP program was not developed for users who need to know these commands.

3.4.1 Building New Command Files

Command files built with SOILGRASP can be used as models or templates for users who no longer need menus. Many of the commands contained in GRASP input files are redundant between studies. Several different command files can look identical except for the data files or variables to be accessed. Experienced users can save considerable time by copying a command file template over onto one for a new study. The new file may only need a few editorial changes to be just right for the new study, and can be ready for GRASP much more quickly than a command file begun from scratch.

3.4.2 Interactive GRASP Use

GRASP works well interactively with soil scientists. In an interactive session, GRASP will prompt the user after every operation. This mode is especially useful to the experienced user who needs to explore the data freely. More errors occur this way, but few are serious. The main problem becomes sorting your real results out from large amounts of output which look polished, but are meaningless. A new type of study using

unfamiliar commands is often best performed interactively. Errors can be seen and corrected quickly. The GRASP Users Manual is a useful reference for this type of session. Also useful is the GRASP Command Summary in Section 4 of this manual.

SECTION 4

A GRASP COMMAND SUMMARY

Conventions

[] optional.	"fid"= filename
< > choose only one of the options.	"expression"= a variable, or an equation using variables in the database.
() these parentheses are part of the syntax and should be typed in.	"acct."= account that the file can be found on.
{ } extra information- do not type as part of command.	"etc." is used at times to indicate continuation. It is never part of the syntax.

4.1 Database Creation Commands

ADD (FILE, fid acct. <UPDATE;OUT>)=variable:expression list

CREATE [FILE, fid acct. <UPDATE;OUT>] [type] [EXCMISSING=value]
[MISSING=value]: variable:=expression

{type can be REAL(the default);BIT; INTG; 1;2,3,4,9,12,18}

DELETE PASS=password:variable [,variable,variable,etc.]

DUMP (FILE,fid acct. OUT) FORM=format RECL=number:expression list

DATA FILE: fid acct. UPDATE

{the data file to be updated must exist on the default drive for the account}

EDIT PASS=password: variable:= <value;expression>

{the data file containing the variable to be edited must be set to UPDATE using the DATA FILE command, before editing}

LIST [NOHEADER] [KEY=#] [<FORMAT=FORTRAN format statement;FORMAT,
fid [acct.]>]: expression [,expression]

{up to 5 expressions may be listed on the screen, more if a user-designed format is used}

SORT [<ASCENDING;DESCENDING>]: expression [,expression]

{up to 5 expressions may be sorted on at once, prioritized as listed}

```

INVERT [PRINT] [<ADD VARIABLES;ADD CASES>]:
  INPUT (FILE, fid [acct.]) [STYLE=<CHARACTER;BINARY>]
  [CASE= # records per case]
  OUTPUT (FILE, fid acct. OUT)
  DIRECTORY (FILE,fid acct. <UPDATE;OUT>)
  RECORD= variable name  type  beg.col. [TO end.col.]
          ['description']/
          .
          .      {40-character maximum for description}

<RUN;NORUN>
STOP

```

Example of an INVERT command file:

```

INVERT PRINT ADD VARIABLES:
  INPUT(FILE, NEWVARS ISS005) STYLE=CHARACTER CASE=1
  OUTPUT(FILE, GRASPVARS ISS005 OUT)
  DIRECTORY(FILE, DICTIONARY ISS005 UPDATE)
  RECORD= KEY          ALPHA  1 TO 8  'Key no. for site'/
          PH           REAL   9 TO 11 'Soil pH'/
          EC           REAL  12 TO 15 'Electr. Conduct.'/
          SAL_SEEP     PACK   16      'Saline seep site'/
          YR_SAMPLED   INTG   17 to 18 'Year sampled'/

  NORUN
  STOP

```

4.2 Sampling Commands

[MOD] SAMPLE [SIZE]: [NOT] expression [(code, code [TO
<code;HI>],etc.)) [<AND;OR;EOR>] [NOT] expression,etc.]

Examples:

```

SAMPLE: NOT KEY('1011-1')
MOD SAMPLE SIZE: SERIES<>
SAMPLE SIZE: (PH>6 AND EC=4.0) OR (PH<>5 AND TEXTURE;
('SICL'))
SAMPLE: LAND_USE('C','G') AND NOT SERIES ('HYSHAM')
SAMPLE: SAL_SEEP(1) OR EC(4 TO HI)

```

{Parentheses may be used to direct prioritization in sampling. If you type a semicolon at end of line, GRASP will assume you are continuing on next line, and prompt you}

SELECT [SIZE]: [NOT] bit variable [<AND;OR;EOR> [NOT]] bit variable,etc.]

EXAMPLES:

SELECT SIZE: OM STUDY AND NOT (IDAHO83 OR MONT83)
SELECT: GRASSLANDS
SELECT: SAL_SEEP OR SODIC

CASES: number [,number [TO number], number,etc.]

EXAMPLES:

CASES: 1 TO 999
CASES: 9120,9121,9127,9209

RANDOM [(seed number)]: [<NUMBER=#;PERCENT=pct.>]

SPSS (FILE,fid acct. OUT) [MISSING=any value that means no data]: variable list

{up to 50 variables may be used, with recodes if desired.
Variable names must be 8 characters or less: CREATE
equivalent temporary variables of 8 characters if needed.
More than 50 variables may be used by merging several
GRASP-built files within SPSS}

TRANSFORM [<GROUP;ALL>]: variable list
USERLINK [<GROUP;ALL>]: variable list

{the above two commands are used for custom programming}

4.3 Data Analysis Commands

STORE number: expression [<BY;WITH> expression]
COMPUTE:function (number)

{the above two commands are used together, up to 100 times
per session. For a list of univariate and bivariate
functions, see pg. 5-24 of GRASP USER'S MANUAL.}

CROSS [ROWS= # TO #] [COLS= # TO #]: expression list {for
rows} <BY;WITH> expression list {for columns}

FREQ [GENERAL]: expression [EXC= # [TO HI]]
[recodes] [,expression,expression]

{it is practical to keep the number of expressions in one
frequency command below 10, but limits are not set}

STAT: [FORTRAN fcn] expression list

{fcns= LOG,SQRT,etc.}

TTEST [<COMPARE;NOCOMPARE>] [<EQUAL;UNEQUAL>]: expression list
<BY;WITH> expression list

MULT BUILD [FILE,fid acct,OUT]): variable list

{20 or more variables may be used if desired}

MULT FETCH (FILE,fid [acct.])

REGRESS: variable <BY;WITH> variable list

{A MULT BUILD matrix file must be created first, and MULT
FETCHed immediately prior to issuing the REGRESS command.}

PARTIAL [order]:variable list <BY; WITH> variable list

MATRIX BUILD [(file,fid acct.OUT]): categorical variable
[(MAX=max code)] [(REC=recodes)], categorical variable, etc.
<BY; WITH> continuous variable [(EXC= <LO;#> [TO <#;HI>]]
[(recodes)], continuous variable, etc.

MATRIX FETCH (FILE,fid [account])

MFREQ: variable list [(T:recodes)]

{EXC,LO,and HI may be used in defining recodes}

MCROSS: variable list (rows) <BY;WITH> variable list (columns)
<BY; WITH> variable list (controls)

{any variable may be recoded as:
variable (T:[(EXC= # [TO #])] recodes); LO or HI may
be substituted for all codes beyond a certain limit}

MSTAT: variable list <BY; WITH> variable list

4.4 File Access Commands

DIRECTORY: fid [acct]

DATA [REDEFINE]: fid [acct.], fid [acct.]

{a maximum of 10 files may be declared at once}

INPUT:< fid [acct.]; ME>

OUTPUT: <LP;ME;fid acct. OUT>

TEXT: fid [acct.]

{user may build FORTRAN format statement files to control
format of output}

4.5 Directory Management Commands

DIRECTORY LIST <CASES;VARIABLES;FILES;INFO: variable [TO
variable,variable,etc.]>

DIRECTORY LIST NAMES: variable [,variable,etc.]

DIRECTORY EDIT PASS= password: variable <NAME;KEY;TYPE;PACK;DESC>
=value

{for DESCription, value must be between apostrophes
and 40 characters or less}

DIRECTORY TEST: variable [,variable TO variable,variable,etc.]

DIRECTORY REVIEW <NAMES;TYPE;SHORT;ALL> <variable list,number
list>

4.6 Other Helpful Commands

[DONT] SCAN

{default is to SCAN for errors before executing
commands}

PRINT: [PREV] <SAMPLE;EXPRESSIONS;VARIABLES;CODES;RECODES;ALL;
NONE>

{tells GRASP to list information on current or previous
operations}

PAGE

{tells GRASP to skip a page before next output;
used when output is sent to the line printer}

STOP

{ends a session with GRASP}

SECTION 5

INPUT

5.1 GRASP Input Options

GRASP will accept input from two sources:

A. Interactively- users type in commands:

INPUT: ME

B. From disk files which contain commands:

INPUT: filename account

5.2 Making Your Own Input Files

5.2.1 Using CP-6 Edit

Edit is a text-editing program on the CP-6 computer. Edit creates ASCII files for many purposes. Help is available for most of its functions and should be used to learn some handy editing shortcuts. To build a command file using Edit, just type "BUILD" and your filename at the system prompt. When line numbers appear, type the GRASP commands, each on a separate line. If a command is too long for one line, add a semicolon and continue on the next line. GRASP interprets the semicolon as a continuation symbol. Typing a carriage return twice at a line number will get you to the Edit prompt (an asterisk), and a "Q" will quit and exit you from Edit. Your file is automatically saved.

5.2.2 Using Another Computer

Any text-editing program which can create a plain ASCII file (without control characters) on any other computer can be used to build a GRASP command file. When the file is built, use the file-transfer (communications) program on CP-6 to upload it into CP-6, using the ASCII mode. The file will then be ready to input into GRASP. Most well-known word processors can be used to build the files if "ASCII" or "non-document" mode is used. Consult the manual to be sure yours can create ASCII files.

SECTION 6

OUTPUT

6.1 GRASP Output Options

Three output options are available from GRASP. They are chosen by using the OUTPUT command:

A. Line printer:

OUTPUT:LP

B. Terminal screen:

OUTPUT:ME

C. A disk file:

OUTPUT: filename account no. OUT

A further description of these forms of output is given in Section 3.3 (item C.) of this manual.

6.2 CP-6 DRIBBLE Files

Everything that appears on the screen can be saved to a disk file for later use or editing by using DRIBBLE. This is a program on CP-6 which must be invoked before running GRASP. A simple command at the system prompt (an exclamation mark) begins dribbling to the file:

!DRIBBLE OVER filename

When the GRASP session is finished and you no longer want to capture screen output, type:

!DONT DRIBBLE

Note that there is no apostrophe used in "DONT". Continue with:

!ELBBIRD.X filename OVER filename

This converts it to an ASCII file that can be read or printed easily. The file is now ready to copy to the printer, view with Edit, or keep on disk (it has already been saved). For further

information or updates concerning this screen-capture capability, contact MSU Computing Services.

6.3 Directing Output With SOILGRASP

A discussion of how SOILGRASP helps users direct GRASP's output is given in Section 3.3 of this manual.

SECTION 7

BATCH FILES

7.1 What Is a Batch File?

A batch file is a list of commands that the computer can access sequentially without requiring the user to be connected at the same time. This used to be the only way a program or command could be processed. Now that interactive use is the norm, batch files are optional. They are useful if you do not have time to sit in front of the terminal, but need the computer to do some work for you. On CP-6 a command file, with all necessary computer instructions to get GRASP running, can be input as a batch job for a study.

7.2 When To Use Batch Files

GRASP jobs that are long or very redundant are good candidates for batch processing. This is especially true when you are familiar with the commands to be run and know what kind of output GRASP will give you. In these cases a batch job can save you time and boredom, releasing you for other tasks.

7.3 Batch Files and SOILGRASP

The files that SOILGRASP builds automatically contain all of the system commands which tell CP-6 how much memory GRASP needs to run, which account to find GRASP on (it is in an account of its own), and actually tell it to run GRASP. These are the same as the commands you would type in each time you run GRASP interactively. This set of commands sets up GRASP for what is called on-line batch processing. It is on-line because you can sit at the terminal and watch GRASP obey the commands. Input, however, comes from that command file until the last command is read and performed. You are an observer; you are not prompted for any input until the command file runs out.

A different sort of batch processing can also occur. With this sort, you can turn off your computer terminal and leave, once you have told CP-6 to batch the command file. There are very minor differences between the two types of command file, and the only differences are in the CP-6 system commands, not the GRASP commands. An on-line batch file declares on the first line that it needs extra On-line RESources (ORES), such as extra memory. The user-absent batch files simply declare these as

RESources (RES) instead of on-line resources. This line in a user-absent batch file would read as follows:

!RES MEM=128, TIME=3:00:00

Another difference is that a new first line is added to the user-absent batch file which reads:

!JOB account

This line tells CP-6 that the comand file is to be run off-line, and on which account to search for files. The last difference between on- and off-line batch jobs is in how you tell CP-6 to do the batch job. For on-line batch jobs, you type:

!XEQ filename

This tells CP-6 to perform (execute) the files commands. For off-line batch jobs, type:

!BATCH filename (SCAN)

CP-6 will then execute your commands off-line. You are free to leave. The "(SCAN)" portion requests that the computer scan the file for certain errors before accepting it.

7.4 Time Deferral

Off-line batch files may be delayed until a specified time and date. This means that the batch jobs can be run after peak hours to save substantially on computer costs. To defer your batch job until after midnight when computer rates are lowest, you add a brief statement to the first line of the batch file, such that it reads:

!JOB account D(00:05,9/23/85)

The D stands for Defer. The time and date are given as shown. Any time or date which is already past will be ignored, and the batch job will begin running immediately.

SECTION 8

DATABASE BACKUP PROCEDURES

The files of the Soil Pedon Database are periodically changed, updated, and expanded. If many people use these files regularly, it is important that each change be documented in such a way that all users are notified before a new session begins. A file must be backed up on user-owned storage media and stored in a safe, dry place. It is best to have complete, updated backup sets of the entire database system in at least two different buildings. For convenience, a complete set should also be maintained on rented storage media (Labeled Magnetic Tape) at MSU's Computing Services Center. This will be the working set and is the most important.

For the Honeywell CP-6 computer a series of batch file templates was written to make the backup procedures fast and simple. These files contain a series of commands for the operating system to execute sequentially. The templates may be copied over onto new files and edited as needed.

8.1 Basic Procedures

The basic procedure for database backup is as follows:

- A. Test the data files to make sure that any variable or record changes have been successful (for example, use GRASP to generate descriptive statistics for a new or updated variable).
- B. Use a batch file like the MT_COPY_TAPE-DISK template to read copies of the files to be backed up onto the hard disk so that if an error or system crash occurs, the old copies of the files still exist and may be reinstated. Some parameters in the batch file will need to be changed, such as the time of deferral, the specific files to be read from the tape, and which tape to be accessed.
- C. Put all of the updated database files on the default disk drive. This is the specific drive the system will search for the files when it is ready to copy them to magnetic tape. For CP-6, this will be the diskpack that the account was set up on (DP#INOV for an instructional account). If the files normally reside on a rented user diskpack, the system will fail to find them. You can force CP-6 to search the user diskpack instead of the default drive by typing "!DIRECTORY diskpack-i.d." on a new line after the resource declarations (e.g. "!DIRECTORY

DP#SOILS.ISS005").

- D. Make any necessary changes in the tape directory (a file such as TAPE0123DIR), and be sure to back it up with the other files. The number of granules (1 granule = 4096 bytes), records, or name of a file may have changed; new files added onto the tape should also be added to the directory.
- E. Use a batch file like the MT_COPY_DISK-TAPE template to copy the updated files to magnetic tape.
- F. Make any necessary changes in the TAPE-LISTINGS file, which contains a listing of every magnetic tape owned by the Soils Group.
- G. Notify other database users of the changes.

Ideally, one person would be responsible for all database updates and for contacting database users with update notices. The backup procedure described above should never be done while someone else is using GRASP. A date should be set, with advance notice that the system will be shut down temporarily during the procedure.

8.2 A Worst-Case Scenario

Fred works in the Soils Department. He is a dedicated worker, and has only one hobby. He enjoys breeding exotic plants.

Fred has spent many lonely hours creating a GRASP database for his co-workers. He is under pressure to finish in a minimum of time: one year, tops. Nobody else knows how hard he has worked. Nor, for that matter, do they really even understand what he's doing. Fred has found some dusty tomes full of useful data, and dutifully entered it all into the database. He has even discovered some erroneous data in the past months, and edited certain variables to correct the errors. The database is accessible, up-to-date and error-free. His busy schedule calls for backing up the completed database in early December, so that his files won't be erased by the unreliable computer system.

In October, a bamboo plantation outside of Shanghai offers Fred a competitive salary to be their lab supervisor, with a bonus if he comes within three weeks. Fred decides to take a chance! Unfortunately, his plans won't allow him to finish the database project, or even to back up what he has done so far. In his excitement, Fred forgets to remind his fellows to do so. He tearfully parts with his co-workers and travels to China. He

fits right in, becomes a dedicated bamboo breeder, and decides to adopt the name Sing Wu, which his staff can more easily pronounce.

Back at the University, the computer system crashes once again. A memo is sent out to all departments, apologizing for the failure and advising them that all files were lost...

GLOSSARY

Some of the definitions given in this section were adapted from Darcy and Boston (1983). The definitions herein refer primarily to the use of the terms in this manual and in the Soilgrasp System.

ALPHA (n). Alphabetic or character data. GRASP's name for such data.

ASCII (acronym). Any character in the set called the American Standard Code for Information Interchange. There are 128; most are represented on a computer keyboard.

batch file (n). A group of instructions or commands that the computer or program processes in a single run; no interaction with a user takes place.

bit (n). A Binary digIT. In base-2 counting, 0 and 1 are the only two possible digits. Computers use this counting in all of their operations, where (effectively) 0 is off and 1 is on.

bit variable (n). A GRASP variable whose only codes are 0 and 1. GRASP interprets these codes as "false" and "true", respectively.

character (n). An alphabetic or other symbol which is a member of the ASCII set.

command (n). A word or keyword which GRASP recognizes as one of its instructions.

command file (n). A file of instructions which GRASP can input and follow, resident in computer disk memory.

compatible (adj). Having identical formats, data types, commands, or other characteristics, such that a computer or program can use both entities interchangeably.

control character (n). Any unprintable character which a program inserts into a document or file.

CP-6 (acronym). Montana State University's mainframe computer, manufactured by the Honeywell Corp.

data (n). Numbers or symbols which represent information and which have meaning for specific cases or variables.

database (n). A complete system of information management, including the data and the software which organizes it and makes it accessible to users. This contrasts with the term, "data base", which is used to refer only to the data set itself.

data file (n). A structured group of data or records manipulated as a single unit.

data type (n). Classification of a data item, as to whether it contains integer, real number, logical or ASCII character information.

DBMS (acronym). Data Base Management System software. GRASP is an example of a DBMS, as are System 2000, DBase II, and RIM.

default (adj). A value, format or code that is automatically chosen if the user does not specify another choice.

directory (n). An index file which GRASP constructs as it inverts or modifies a data file. GRASP then uses this file to access specific data items when it is called to do so. Certain elements of the directory file should never be edited, since they are GRASP's sole link to the information in the data files.

disk file (n). A computer file, organized into records (lines) and residing on a hard or floppy random access memory (RAM) disk.

download (v). To transfer files from a large computer to a smaller one.

encode (v). To type the data from field sheets or notebooks into a computer random access file.

expression (n). A variable, or an equation using variables in the database (e.g. $2(\text{pH}) - \frac{3}{4}(\text{precipitation})$).

fid (acronym). File Identifier, or filename.

file (n). A set of records which are joined together in computer memory under one title, the filename.

format (n). The exact arrangement of one representative record

of data in a computer file, or in a table of data. For the FORTRAN language, this is explicitly specified, along with data types for each variable.

FORTRAN (acronym). The FORMula TRANslation computer language, one of the earliest such languages designed for use in programming scientific applications. The language that GRASP and SOILGRASP are written in.

GRASP (acronym). The Generalized Rapid Access Software Package, the database management system software used to maintain the Montana Soil Pedon Database. GRASP was developed at Montana State University by the Center for Data Systems and Analysis, and is being maintained by that organization.

improper subset (n). A subset of a larger set (or list) of variables or functions, which also contains some unique members that are not represented in the larger set.

interactive (adj). Real-time use of a computer system, where each of the user's commands is acted on as it is sent from the terminal. This contrasts with batch processing of a file of commands with no user input.

interface (n). A shared boundary between two computers, or between a user and a computer. A device or program which facilitates communication across this boundary.

inversion (n). The process whereby GRASP converts a set of data into a file it can access in database operations.

keyword (n). A significant word which GRASP recognizes as a member of its exclusive command set.

library (n). A collection of computer disk files which can be used by a program, and which represent oft-used utilities.

menu (n). A list of optional functions a user can have the program perform.

numeric (adj). Integer, bit, or real number data. A variable whose data are represented by one of these data types.

package (n). A group of programs which work together to perform a related set of tasks, such as statistics or database management. GRASP is a software package.

password (n). A user's secret name attached to a file or function which limits its use to those who know the password. It is generally used for sensitive data files or powerful functions (such as delete or edit) which should not be available to all users.

pedon (n). A set of soil horizons which characterize the soil of a single location. In The Soilgrasp System, each pedon has a unique site number (the first number in a KEY). Horizons within that pedon are numbered in sequence from the top down (the second, two-digit number after the dash in the KEY).

program (n). A set of statements in a computer language which directs the computer to perform distinct functions. As a verb, it can refer to the activity of writing such statements.

prompt (n). A symbol that the computer sends to the screen to let a user know that it is ready for the next command.

proper subset (n). A subset of a larger set (or list) of variables or functions, every member of which is represented in the larger set.

queue (n). A "stack" of computer programs or batch jobs awaiting the computer's attention for execution in a first in, first out arrangement.

random access file (n). A disk file which the computer can read from or write into.

record (n). One line from a data file, program or other disk file. This corresponds to a single "IBM" card used before computer terminals with displays were available. In data files a record would be a row of data.

relational (n). A type of database management system which organizes and works with data in a two-dimensional table format.

SOILGRASP (acronym). A FORTRAN program which uses menus to help researchers build a set of GRASP commands for their database projects.

Soilgrasp System (n). The system composed of soil scientists, the Montana Soil Pedon Database, GRASP, the SOILGRASP interface program, MSU's Honeywell CP-6 computer, and the 1979 Pedon Coding System for the National Cooperative Soil Survey.

stand-alone (adj). Unique in some one or more characteristics, non-standard.

statement (n). An executable group of words and symbols in (or for) a computer program.

syntax (n). The exact spelling and arrangement of words and punctuation in a computer command or program statement.

system (n). A group of people, software, data, computer hardware, combined with a set of conventions or rules and organized to perform a specified set of functions. The software that manages a computer's time, memory, and operations (also called "operating system").

upload (v). To transfer files or programs from a small computer to a larger one.

validity (n). The acceptability of the format of a datum in a database.

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APPENDICES

APPENDIX I

MONTANA SOILS DATA BASE DICTIONARY

The variables resident in the database are listed on the following pages. There are several files, and variables are listed alphabetically within each file. A listing consists of the GRASP variable name, the type of data that variable represents, a 40 (or fewer) character description of it, and the number of cases in the database which have valid data for the variable.

The data files MT_SIHZ (site/horizon), MT_LAB (laboratory characterization), MT_VEG (native vegetation), MT_YIELD (data from Burke (1984)), and MT_NEWVARS (new variables created by the author) are kept on the Soils Group's Hard Diskpack and on rented labeled magnetic tape at the Montana State University Computing Services Center. These data files are the inverted machine language files which GRASP creates. The original two-dimensional ASCII files are also kept on labeled tape.

Some of the data types listed include a number in parentheses. For ALPHA (character data) variables, this number is the number of columns the variable occupies in the original uninverted file. It also indicates the maximum number of characters the variable can contain for a single case. For REAL numeric variables, this number signifies the number of implied decimal places (for cases where the encoder did not include a decimal point).

For information regarding the positions and sequence of variables as they exist in the original, uninverted data files, consult the 1979 Pedon Coding System for the National Cooperative Soil Survey (Soil Survey Staff, 1979).

Site & Horizon Variables: Data are in the file MT_SIHZ.

VARIABLE	DATA TYPE	BRIEF DATA DESCRIPTION	CASES W/DATA
AIRTEMP_AVE	INTEGER	17.Avg. annual air temp.(C).	1027
AIRTEMP_SUM	INTEGER	17.Avg. summer air temp.(C).	902
AIRTEMP_WIN	INTEGER	17.Avg. winter air temp.(C).	596
BOUND_DESCR	ALPHA(2)	72.Bound. distinctness and topogr.	4543
CEMENT_AGENT	ALPHA(1)	64.Cementing agent code.	5
CF2_ABUN	ALPHA(2)	69b.2nd coarse fragm.,abundance.	246
CF2_KIND	ALPHA(1)	69a.2nd coarse fragments,kind.	85
CF2_SIZE	ALPHA(1)	69c.2nd coarse fragments,size.	283
CF3_ABUN	ALPHA(2)	169b.3rd coarse fragm.,abundance.	3
CF3_KIND	ALPHA(1)	69a.3rd coarse fragments,kind.	0
CF3_SIZE	ALPHA(1)	69c.3rd coarse fragments,size.	3
CF_ABUN	ALPHA(2)	69b.1st coarse fragm.,abundance.	1447

VARIABLE	DATA TYPE	BRIEF DATA DESCRIPTION	CASES W/DATA
CF_KIND	ALPHA(1)	69a.1st coarse fragments,kind.	377
CF_SIZE	ALPHA(1)	69c.1st coarse fragments,size.	1410
COLOR2_CHR	REAL(1)	57d.2nd chroma to half units.	5264
COLOR2_HUE	ALPHA(2)	57d.2nd hue on 100 scale.	5316
COLOR2_LOC	ALPHA(1)	57b.2nd color location or treatmt.	1330
COLOR2_MOIS	ALPHA(1)	57c.2nd color moisture cond.	5328
COLOR2_PCT	INTEGER	57a.2nd color percent of matrix.	5832
COLOR2_VAL	REAL(1)	57d.2nd value to nearest half unit.	5315
COLOR3_CHR	REAL(1)	57d.3rd chroma to half units.	1016
COLOR3_HUE	ALPHA(2)	57d.3rd hue on 100 scale.	1023
COLOR3_LOC	ALPHA(1)	57b.3rd color location or treatmt.	608
COLOR3_MOIS	ALPHA(1)	57c.3rd color moisture cond.	1022
COLOR3_PCT	INTEGER	57a.3rd color percent of matrix.	5069
COLOR3_VAL	REAL(1)	57d.3rd value to nearest half unit.	1021
COLOR4_CHR	REAL(1)	57d.4th chroma to half units.	614
COLOR4_HUE	ALPHA(2)	57d.4th hue on 100 scale.	597
COLOR4_LOC	ALPHA(1)	57b.4th color location or treatmt.	451
COLOR4_MOIS	ALPHA(1)	57c.4th color moisture cond.	617
COLOR4_PCT	INTEGER	57a.4th color percent of matrix.	5069
COLOR4_VAL	REAL(1)	57d.4th value to nearest half unit.	615
COLOR5_CHR	REAL(1)	57d.5th chroma to half units.	31
COLOR5_HUE	ALPHA(2)	57d.5th hue on 100 scale.	31
COLOR5_LOC	ALPHA(1)	57b.5th color location or treatmt.	31
COLOR5_MOIS	ALPHA(1)	57c.5th color moisture cond.	31
COLOR5_PCT	INTEGER	57a.5th color percent of matrix.	5069
COLOR5_VAL	REAL(1)	57d.5th value to nearest half unit.	31
COLOR6_CHR	REAL(1)	57d.6th chroma to half units.	18
COLOR6_HUE	ALPHA(2)	57d.6th hue on 100 scale.	18
COLOR6_LOC	ALPHA(1)	57b.6th color location or treatmt.	18
COLOR6_MOIS	ALPHA(1)	57c.6th color moisture cond.	18
COLOR6_PCT	INTEGER	57a.6th color percent of matrix.	5069
COLOR6_VAL	REAL(1)	57d.6th value to nearest half unit.	18
COLOR_CHR	REAL(1)	57d.1st chroma to half units.	5447
COLOR_HUE	ALPHA(2)	57d.1st hue on 100 scale.	5510
COLOR_LOC	ALPHA(1)	57b.1st color location or treatmt.	1308
COLOR_MOIS	ALPHA(1)	57c.1st color moisture cond.	5528
COLOR_PCT	INTEGER	57a.1st color percent of matrix.	1505
COLOR_VAL	REAL(1)	57d.1st value to nearest half unit.	5459
CONSISTENCE	ALPHA(2)	63.1st consistence code.	5386
CONSISTENCE2	ALPHA(2)	63.2nd consistence code.	5160
CONSISTENCE3	ALPHA(2)	63.3rd consistence code.	4607
CONSISTENCE4	ALPHA(2)	63.4th consistence code.	4411
CONSISTENCE5	ALPHA(2)	63.5th consistence code.	767
CONSISTENCE6	ALPHA(2)	63.6th consistence code.	763
CONTROL_LO	INTEGER	25b.Ctrl. sec. lower bound in cm.	3858
CONTROL_UP	INTEGER	25a.Ctrl. sec. upper bound in cm.	3803
CUTAN2_ABUN	ALPHA(2)	67b.2nd cutan,abund. and contin.	304
CUTAN2_CHR	INTEGER	67g.2nd cutan,1st chroma.	62
CUTAN2_CHR2	INTEGER	67g.2nd cutan,2nd chroma.	0
CUTAN2_DIST	ALPHA(1)	67c.2nd cutan,distinct. or thick.	215

VARIABLE	DATA TYPE	BRIEF DATA DESCRIPTION	CASES W/DATA
CUTAN2_HUE	ALPHA(2)	67g.2nd cutan,1st hue code.	59
CUTAN2_HUE2	ALPHA(2)	67g.2nd cutan,2nd hue code.	1
CUTAN2_KIND	ALPHA(1)	67a.2nd cutan,kind.	558
CUTAN2_LOC	ALPHA(1)	67d.2nd cutan,location code.	459
CUTAN2_MOIS	ALPHA(1)	67f.2nd cutan,1st moisture cond.	55
CUTAN2_MOIS2	ALPHA(1)	67g.2nd cutan,2nd moisture cond.	1
CUTAN2_STRUC	ALPHA(1)	67e.2nd cutan,structure units.	55
CUTAN2_VAL	INTEGER	67g.2nd cutan,1st value.	62
CUTAN2_VAL2	INTEGER	67g.2nd cutan,2nd value.	0
CUTAN3_ABUN	ALPHA(2)	67b.3rd cutan,abund. and contin.	67
CUTAN3_CHR	INTEGER	67g.3rd cutan,1st chroma.	18
CUTAN3_CHR2	INTEGER	67g.3rd cutan,2nd chroma.	0
CUTAN3_DIST	ALPHA(1)	67c.3rd cutan,distinct. or thick.	47
CUTAN3_HUE	ALPHA(2)	67g.3rd cutan,1st hue code.	16
CUTAN3_HUE2	ALPHA(2)	67g.3rd cutan,2nd hue code.	1
CUTAN3_KIND	ALPHA(1)	67a.3rd cutan,kind.	142
CUTAN3_LOC	ALPHA(1)	67d.3rd cutan,location code.	115
CUTAN3_MOIS	ALPHA(1)	67f.3rd cutan,1st moisture cond.	16
CUTAN3_MOIS2	ALPHA(1)	67g.3rd cutan,2nd moisture cond.	1
CUTAN3_STRUC	ALPHA(1)	67e.3rd cutan,structure units.	16
CUTAN3_VAL	INTEGER	67g.3rd cutan,1st value.	18
CUTAN3_VAL2	INTEGER	67g.3rd cutan,2nd value.	0
CUTAN_ABUN	ALPHA(2)	67b.1st cutan,abund. and contin.	1022
CUTAN_CHR	INTEGER	67g.1st cutan,1st chroma.	203
CUTAN_CHR2	INTEGER	67g.1st cutan,2nd chroma.	0
CUTAN_DIST	ALPHA(1)	67c.1st cutan,distinct. or thick.	875
CUTAN_HUE	ALPHA(2)	67g.1st cutan,1st hue code.	208
CUTAN_HUE2	ALPHA(2)	67g.1st cutan,2nd hue code.	1
CUTAN_KIND	ALPHA(1)	67a.1st cutan,kind.	1790
CUTAN_LOC	ALPHA(1)	67d.1st cutan,location code.	1348
CUTAN_MOIS	ALPHA(1)	67f.1st cutan,1st moisture cond.	198
CUTAN_MOIS2	ALPHA(1)	67g.1st cutan,2nd moisture cond.	1
CUTAN_STRUC	ALPHA(1)	67e.1st cutan,structure units.	198
CUTAN_VAL	INTEGER	67g.1st cutan,1st value.	203
CUTAN_VAL2	INTEGER	67g.1st cutan,2nd value.	0
DATA_AVAIL	ALPHA(4)	26.Data available on this site.	5069
DIAGNOSTIC	ALPHA(1)	76.1st diagnostic horizon.	382
DIAGNOSTIC2	ALPHA(1)	76.2nd diagnostic horizon.	70
DIAGNOSTIC3	ALPHA(1)	76.3rd diagnostic horizon.	2
DIAGNOSTIC4	ALPHA(1)	76.4th diagnostic horizon.	0
DIAGNOSTICS	ALPHA(4)	76.All recorded diagn. horizons.	382
DRAINAGE	ALPHA(1)	24. Soil drainage class: code 0-9.	5832
EFFER_AGENT	ALPHA(1)	71b.Effervescence agent code.	2429
EFFER_CLASS	ALPHA(1)	71a.Effervescence class code.	3706
EFFER_EXTEN	ALPHA(1)	71c.Effervescence,extension.	98
ELEVATION	INTEGER	11.Elevation in meters.	6016
FAM_MINERAL	ALPHA(2)	15b.Family-mineralogy.	5986
FAM_OTHER	ALPHA(2)	15b.Family-other properties.	5986
FAM_PARTICLE	ALPHA(3)	15b.Family-particle size.	5957
FAM_REACTION	ALPHA(2)	15b.Family-reaction.	5986

VARIABLE	DATA TYPE	BRIEF DATA DESCRIPTION	CASES W/DATA
FAM_TEMP	ALPHA(2)	15b.Family-soil temperature.	5986
FIELD2_KIND	ALPHA(1)	75b.2nd kind of field analysis.	0
FIELD2_METH	ALPHA(3)	75a.2nd field data method code.	0
FIELD2_RESUL	INTEGER	75c.2nd field data result.	0
FIELD3_KIND	ALPHA(1)	75b.3rd kind of field analysis.	0
FIELD3_METH	ALPHA(3)	75a.3rd field data method code.	0
FIELD3_RESUL	INTEGER	75c.3rd field data result.	0
FIELD4_KIND	ALPHA(1)	75b.4th kind of field analysis.	0
FIELD4_METH	ALPHA(3)	75a.4th field data method code.	0
FIELD4_RESUL	INTEGER	75c.4th field data result.	0
FIELD5_KIND	ALPHA(1)	75b.5th kind of field analysis.	0
FIELD5_METH	ALPHA(3)	75a.5th field data method code.	0
FIELD5_RESUL	INTEGER	75c.5th field data result.	0
FIELD_KIND	ALPHA(1)	75b.1st kind of field analysis.	0
FIELD_METH	ALPHA(3)	75a.1st field data method code.	0
FIELD_RESUL	INTEGER	75c.1st field data result.	0
FIPS_COUNTY	ALPHA(3)	2b.FIPS county code.	6016
FIPS_STATE	ALPHA(2)	2a.FIPS state code.	6016
GRTGROUP	ALPHA(2)	15a.Soil classif.-great group.	5979
HORIZON	ALPHA(16)	55a-d.Combined horizon variable.	2980
HORIZON_NUM	ALPHA(2)	54.Horizon number.	5825
HORZ_LIMITLO	INTEGER	56b.Lower horizon limit in cm.	5601
HORZ_LIMITUP	INTEGER	56a.Upper horizon limit in cm.	4791
HORZ_LTR	ALPHA(3)	55b.Horizon letter or letters.	5823
HORZ_MOD_LTR	ALPHA(10)	55d.Small letter horz. modifiers.	803
HORZ_MOD_NO	ALPHA(2)	55c.Arab numeral horizon modifier.	5069
HZ_AV_EXTENT	INTEGER	73d.Ave. spacing of cyclic horz.,m.	0
HZ_COMMENTS	ALPHA(80)	77.Free form notes.	1395
HZ_THICK_AVE	INTEGER	73a.Ave. thickness of horizon.	676
HZ_THICK_MAX	INTEGER	73c.Thickest part of horizon,cm.	1791
HZ_THICK_MIN	INTEGER	73b.Thinnest part of horizon,cm.	1614
KEY	ALPHA(8)	Key no. for site and horizon.	5955
LAB	ALPHA(1)	30a. Lab where analyses were done.	2102
LAB_METHODS	ALPHA(80)	32.Soil lab method codes.	590
LAB_STATE	ALPHA(2)	30b.St. FIPS code of analyzing lab.	2102
LAM2_ABUN	ALPHA(2)	61e.2nd lamellae-abundance.	3
LAM2_AVTHICK	INTEGER	61g.2nd lamellae-ave. thickness.	1
LAM2_CHR	INTEGER	61k.2nd lamellae-chroma, 1 digit.	6
LAM2_CONSIST	ALPHA(2)	61d.2nd lamellae-consistence.	0
LAM2_HUE	ALPHA(2)	61k.2nd lamellae-hue on 100 scale.	6
LAM2_KIND	ALPHA(1)	61a.2nd lamellae- kind.	8
LAM2_LOC	ALPHA(1)	61i.2nd lamellae-location.	0
LAM2_MOIS	ALPHA(1)	61j.2nd lamellae-moisture cond.	0
LAM2_NOTE	ALPHA(1)	61f.2nd lamellae-note(F,N,P).	2
LAM2_TEXT	ALPHA(5)	61b.2nd lamellae- texture.	2
LAM2_TEXTMOD	ALPHA(3)	61c.2nd lamellae-text. modifier.	1
LAM2_TOTHICK	INTEGER	61h.2nd lamellae-total thickness.	0
LAM2_VAL	INTEGER	61k.2nd lamellae-value, 1 digit.	6
LAM3_ABUN	ALPHA(2)	61e.3rd lamellae-abundance.	1
LAM3_AVTHICK	INTEGER	61g.3rd lamellae-ave. thickness.	0

VARIABLE	DATA TYPE	BRIEF DATA DESCRIPTION	CASES W/DATA
LAM3_CHR	INTEGER	6lk.3rd lamellae-chroma, 1 digit.	1
LAM3_CONSIST	ALPHA(2)	6ld.3rd lamellae-consistence.	0
LAM3_HUE	ALPHA(2)	6lk.3rd lamellae-hue on 100 scale.	1
LAM3_KIND	ALPHA(1)	6la.3rd lamellae- kind.	1
LAM3_LOC	ALPHA(1)	6li.3rd lamellae-location.	0
LAM3_MOIS	ALPHA(1)	6lj.3rd lamellae-moisture cond.	0
LAM3_NOTE	ALPHA(1)	6lf.3rd lamellae-note(F,N,P).	0
LAM3_TEXT	ALPHA(5)	6lb.3rd lamellae- texture.	1
LAM3_TEXTMOD	ALPHA(3)	6lc.3rd lamellae-text. modifier.	0
LAM3_TOThICK	INTEGER	6lh.3rd lamellae-total thickness.	0
LAM3_VAL	INTEGER	6lk.3rd lamellae-value, 1 digit.	1
LAM_ABUN	ALPHA(2)	6le.1st lamellae-abundance.	67
LAM_AVTHICK	INTEGER	6lg.1st lamellae-ave. thickness.	52
LAM_CHR	INTEGER	6lk.1st lamellae-chroma, 1 digit.	63
LAM_CONSIST	ALPHA(2)	6ld.1st lamellae-consistence.	5
LAM_HUE	ALPHA(2)	6lk.1st lamellae-hue on 100 scale.	63
LAM_KIND	ALPHA(1)	6la.1st lamellae- kind.	217
LAM_LOC	ALPHA(1)	6li.1st lamellae-location.	0
LAM_MOIS	ALPHA(1)	6lj.1st lamellae-moisture cond.	46
LAM_NOTE	ALPHA(1)	6lf.1st lamellae-note(F,N,P).	9
LAM_TEXT	ALPHA(5)	6lb.1st lamellae- texture.	83
LAM_TEXTMOD	ALPHA(3)	6lc.1st lamellae-text. modifier.	8
LAM_TOThICK	INTEGER	6lh.1st lamellae-total thickness.	6
LAM_VAL	INTEGER	6lk.1st lamellae-value, 1 digit.	63
LAND_USE	ALPHA(1)	2l.Current land use at site.	5789
LATITUDE	ALPHA(6)	8a.Latitude-deg,min,sec.	0
LAT_DEGREES	INTEGER	8a.Latitude-degrees.	0
LAT_DIR	ALPHA(1)	8a.Latitude-direction.	947
LAT_MINUTES	INTEGER	8a.Latitude-minutes.	0
LAT_SECONDS	INTEGER	8a.Latitude-secondconditions.	0
LITHOLOGIC	ALPHA(1)	55a.Roman num. lithol. discontin.	659
LONGITUDE	ALPHA(8)	8b.Longitude-deg,min,sec,direction.	347
LON_DEGREES	INTEGER	8b.Longitude-degrees.	184
LON_DIR	ALPHA(1)	8b.Longitude-direction.	947
LON_MINUTES	INTEGER	8b.Longitude-minutes.	184
LON_SECONDS	INTEGER	8b.Longitude-secondconditions.	0
MISC_VALUES	ALPHA(30)	33.Misc. pedon values.	0
MLRA_CODE	ALPHA(3)	7a.Major Land Resource Area.	1171
MONTH	ALPHA(2)	9.Month pedon was described.	5069
MOTL2_ABUN	ALPHA(2)	58a.2nd mottle- abundance.	73
MOTL2_CHR	INTEGER	58f.2nd mottle-chroma,single digit.	118
MOTL2_CONTR	ALPHA(1)	58c.2nd mottle- contrast.	73
MOTL2_HUE	ALPHA(2)	58f.2nd mottle-hue on 100 scale.	119
MOTL2_LOC	ALPHA(1)	58d.2nd mottle-location or treatmt.	32
MOTL2_MOIS	ALPHA(1)	58e.2nd mottle-moisture cond.	109
MOTL2_SIZE	ALPHA(2)	58b.2nd mottle- size.	59
MOTL2_VAL	INTEGER	58f.2nd mottle-value, single digit.	119
MOTL3_ABUN	ALPHA(2)	58a.3rd mottle- abundance.	3
MOTL3_CHR	INTEGER	58f.3rd mottle-chroma,single digit.	13
MOTL3_CONTR	ALPHA(1)	58c.3rd mottle- contrast.	0

VARIABLE	DATA TYPE	BRIEF DATA DESCRIPTION	CASES W/DATA
MOTL3_HUE	ALPHA(2)	58f.3rd mottle-hue on 100 scale.	13
MOTL3_LOC	ALPHA(1)	58d.3rd mottle-location or treatmt.	13
MOTL3_MOIS	ALPHA(1)	58e.3rd mottle-moisture cond.	13
MOTL3_SIZE	ALPHA(2)	58b.3rd mottle- size.	1
MOTL3_VAL	INTEGER	58f.3rd mottle-value, single digit.	13
MOTL4_ABUN	ALPHA(2)	58a.4th mottle- abundance.	1
MOTL4_CHR	INTEGER	58f.4th mottle-chroma, single digit.	5
MOTL4_CONTR	ALPHA(1)	58c.4th mottle- contrast.	0
MOTL4_HUE	ALPHA(2)	58f.4th mottle-hue on 100 scale.	5
MOTL4_LOC	ALPHA(1)	58d.4th mottle-location or treatmt.	5
MOTL4_MOIS	ALPHA(1)	58e.4th mottle-moisture cond.	5
MOTL4_SIZE	ALPHA(2)	58b.4th mottle- size.	1
MOTL4_VAL	INTEGER	58f.4th mottle-value, single digit.	5
MOTL_ABUN	ALPHA(2)	58a.1st mottle- abundance.	219
MOTL_CHR	INTEGER	58f.1st mottle-chroma, single digit.	276
MOTL_CONTR	ALPHA(1)	58c.1st mottle- contrast.	188
MOTL_HUE	ALPHA(2)	58f.1st mottle-hue on 100 scale.	276
MOTL_LOC	ALPHA(1)	58d.1st mottle-location or treatmt.	82
MOTL_MOIS	ALPHA(1)	58e.1st mottle-moisture cond.	251
MOTL_SIZE	ALPHA(2)	58b.1st mottle- size.	178
MOTL_VAL	INTEGER	58f.1st mottle-value, single digit.	276
NODULE2_ABUN	ALPHA(2)	68b.2nd nodule, abundance.	189
NODULE2_CHR	INTEGER	68e.2nd nodule, chroma: 1 digit.	0
NODULE2_HUE	ALPHA(2)	68e.2nd nodule, hue on 100 scale.	0
NODULE2_KIND	ALPHA(2)	68a.2nd nodule, kind.	226
NODULE2_SHAP	ALPHA(1)	68c.2nd nodule, shape code.	0
NODULE2_SIZE	ALPHA(2)	68d.2nd nodule, size code.	119
NODULE2_VAL	INTEGER	68e.2nd nodule, value: 1 digit.	0
NODULE_ABUN	ALPHA(2)	68b.1st nodule, abundance.	1070
NODULE_CHR	INTEGER	68e.1st nodule, chroma: 1 digit.	0
NODULE_HUE	ALPHA(2)	68e.1st nodule, hue on 100 scale.	0
NODULE_KIND	ALPHA(2)	68a.1st nodule, kind.	1228
NODULE_SHAPE	ALPHA(1)	68c.1st nodule, shape code.	0
NODULE_SIZE	ALPHA(2)	68d.1st nodule, size code.	527
NODULE_VAL	INTEGER	68e.1st nodule, value: 1 digit.	0
NO_HORIZONS	INTEGER	27.No. of horz. described-max.15.	6005
OM2_KIND	ALPHA(1)	74a.2nd kind of organic matter.	0
OM2_PCT	INTEGER	74b.2nd o.m., 1st type percent.	0
OM2_PCT2	INTEGER	74b.2nd o.m., 2nd type percent.	0
OM2_TYPE	ALPHA(1)	74b.2nd o.m., 1st type code.	0
OM2_TYPE2	ALPHA(1)	74b.2nd o.m., 2nd type code.	0
OM3_KIND	ALPHA(1)	74a.3rd kind of organic matter.	0
OM3_PCT	INTEGER	74b.3rd o.m., 1st type percent.	0
OM3_PCT2	INTEGER	74b.3rd o.m., 2nd type percent.	0
OM3_TYPE	ALPHA(1)	74b.3rd o.m., 1st type code.	0
OM3_TYPE2	ALPHA(1)	74b.3rd o.m., 2nd type code.	0
OM_KIND	ALPHA(1)	74a.1st kind of organic matter.	0
OM_PCT	INTEGER	74b.1st o.m., 1st type percent.	0
OM_PCT2	INTEGER	74b.1st o.m., 2nd type percent.	0
OM_TYPE	ALPHA(1)	74b.1st o.m., 1st type code.	0

VARIABLE	DATA TYPE	BRIEF DATA DESCRIPTION	CASES W/DATA
OM_TYPE2	ALPHA(1)	74b.1st o.m.,2nd type code.	0
ORDER	ALPHA(1)	15a.Soil classification-order.	5982
PERMEABILITY	ALPHA(1)	23. Perm. class: codes 0 thru 7.	5832
PHYSIOGRAPHY	ALPHA(2)	14. Physiography-regional & local.	5785
PHYS_LOCAL	ALPHA(1)	14b. Physiography-local.	3471
PHYS_REGION	ALPHA(1)	14a. Physiography-regional.	3062
PH_METHOD	ALPHA(1)	70a. Field-pH determining method.	41
PH_VALUE	REAL(1)	670b. Field-pH value, nearest 10th.	2331
PM2_2NDARY	ALPHA(2)	16c. 2nd par. material-sec. source.	196
PM2_ACCUM	ALPHA(1)	16b. 2nd par. material-accum.	1039
PM2_FRACTURE	ALPHA(1)	16d. 2nd par. mat. bedrock fract.	0
PM2_PRIMARY	ALPHA(2)	16c. 2nd par. mat.-prim. source.	899
PM2_WEATHER	ALPHA(1)	16a. 2nd p.m.-weath. or bed inclin.	18
PM3_2NDARY	ALPHA(2)	16c. 3rd par. material-sec. source.	0
PM3_ACCUM	ALPHA(1)	16b. 3rd par. material-accum.	23
PM3_FRACTURE	ALPHA(1)	16d. 3rd par. mat. bedrock fract.	0
PM3_PRIMARY	ALPHA(2)	16c. 3rd par. mat.-prim. source.	16
PM3_WEATHER	ALPHA(1)	16a. 3rd p.m.-weath. or bed inclin.	0
PM4_2NDARY	ALPHA(2)	16c. 4th par. material-sec. source.	0
PM4_ACCUM	ALPHA(1)	16b. 4th par. material-accumulation.	0
PM4_FRACTURE	ALPHA(1)	16d. 4th p. mat. bedrock fract.	0
PM4_PRIMARY	ALPHA(2)	16c. 4th par. material-prim. source.	0
PM4_WEATHER	ALPHA(1)	16a. 4th p.m.-weath. or bed inclin.	0
PM_2NDARY	ALPHA(2)	16c. 1st par. material-sec. source.	800
PM_ACCUM	ALPHA(1)	16b. 1st par. material-accum.	5803
PM_FRACTURE	ALPHA(1)	16d. 1st p. m. bedrock fracturing.	0
PM_PRIMARY	ALPHA(2)	16c. 1st par. mat.-source.	5643
PM_WEATHER	ALPHA(1)	16a. 1st p.m.-weath. or bed inclin.	94
PORE2_ABUN	ALPHA(2)	66b. 2nd pore abundance code.	346
PORE2_KIND	ALPHA(2)	66a. 2nd pore kind code.	161
PORE2_SIZE	ALPHA(2)	66c. 2nd pore size code.	340
PORE_ABUN	ALPHA(2)	66b. 1st pore abundance code.	2696
PORE_KIND	ALPHA(2)	66a. 1st pore kind code.	1592
PORE_SIZE	ALPHA(2)	66c. 1st pore size code.	2647
PRECIP_AVE	INTEGER	19. Avg. annual precip. in cm.	2633
ROOTRESTRICT	ALPHA(1)	65A. Root restricting layer? R=yes.	0
ROOTS2_ABUN	ALPHA(2)	65a. 2nd roots abundance code.	0
ROOTS2_LOC	ALPHA(1)	65c. 2nd roots location code.	0
ROOTS2_SIZE	ALPHA(2)	65b. 2nd roots size code.	0
ROOTS_ABUN	ALPHA(2)	65a. 1st roots abundance code.	3415
ROOTS_LOC	ALPHA(1)	65c. 1st roots location code.	1243
ROOTS_SIZE	ALPHA(2)	65b. 1st roots size code.	2763
SERIES	ALPHA(15)	1. Soil series name.	3095
SITE_DESCR1	ALPHA(120)	29. Unassigned site descr. 1st part	0
SITE_DESCR2	ALPHA(30)	29. Unassigned site descr. 2nd part	0
SITE_LOC	ALPHA(100)	34. Site location description.	3556
SITE_NO	ALPHA(6)	3. Site number.	5685
SITE_SUBUNIT	ALPHA(1)	3c. Site no.: subunit.	0
SITE_UNIT	INTEGER	3b. Site no.: unit no.	5253
SITE_YEAR	INTEGER	3a. Site no.: year sampled.	6016

VARIABLE	DATA TYPE	BRIEF DATA DESCRIPTION	CASES W/DATA
SLPMIC_AMT	ALPHA(1)	12e.Slope-microrelief amount.	0
SLPMIC_KIND	ALPHA(1)	12e.Slope-microrelief kind.	18
SLPMIC_PAT	ALPHA(1)	12e.Slope-microrelief pattern.	5069
SLP_ASPECT	ALPHA(1)	12d.Slope-aspect.	6016
SLP_GEOMOR	ALPHA(2)	12c.Slope-geomorphic component.	5831
SLP_PCT	INTEGER	12a.Slope-percent.	2966
SLP_POSITION	ALPHA(1)	12f.Slope-pedon position.	832
SLP_SHAPE	ALPHA(1)	12b.Slope-shape.	5831
SOILTEMP_AVE	INTEGER	18.Avg. annual soil temp.(C).	164
SOILTEMP_SUM	INTEGER	18.Avg. summer soil temp.(C).	596
SOILTEMP_WIN	INTEGER	18.Avg. winter soil temp.(C).	0
SSSN	ALPHA(12)	6a-f.Soil Survey Sample No.	5618
STONINESS	ALPHA(1)	22. St. class:codes 1 through 6.	5029
STRUC2_GRADE	ALPHA(1)	62a.2nd structure-grade.	1416
STRUC2_MOIS	ALPHA(1)	62d.2nd structure-moisture cond.	53
STRUC2_RELAT	ALPHA(1)	62e.2nd structure-relationship.	27
STRUC2_SIZE	ALPHA(2)	62b.2nd structure-size.	1441
STRUC2_TYPE	ALPHA(3)	62c.2nd structure-type.	1564
STRUC3_GRADE	ALPHA(1)	62a.3rd structure-grade.	93
STRUC3_MOIS	ALPHA(1)	62d.3rd structure-moisture cond.	13
STRUC3_RELAT	ALPHA(1)	62e.3rd structure-relationship.	0
STRUC3_SIZE	ALPHA(2)	62b.3rd structure-size.	93
STRUC3_TYPE	ALPHA(3)	62c.3rd structure-type.	116
STRUC4_GRADE	ALPHA(1)	62a.4th structure-grade.	2
STRUC4_MOIS	ALPHA(1)	62d.4th structure-moisture cond.	0
STRUC4_RELAT	ALPHA(1)	62e.4th structure-relationship.	0
STRUC4_SIZE	ALPHA(2)	62b.4th structure-size.	2
STRUC4_TYPE	ALPHA(3)	62c.4th structure-type.	2
STRUC_GRADE	ALPHA(1)	62a.1st structure-grade.	3972
STRUC_MOIS	ALPHA(1)	62d.1st structure-moisture cond.	49
STRUC_RELAT	ALPHA(1)	62e.1st structure-relationship.	970
STRUC_SIZE	ALPHA(2)	62b.1st structure-size.	3848
STRUC_TYPE	ALPHA(3)	62c.1st structure-type.	5287
SUBDIVISION	ALPHA(1)	7b.MLRA subdivision.	0
SUBGROUP	ALPHA(4)	15a.Soil classification-subgroup.	5979
SUBORDER	ALPHA(2)	15a.Soil classification-suborder.	5979
SURFACE	ALPHA(3)	13.Soil surface features.	0
TAXONOMY	ALPHA(20)	15a-b.Complete soil classification.	6016
TEXTURE	ALPHA(5)	59.Horizon texture-1st recording.	3071
TEXTURE2	ALPHA(5)	59.Horizon texture-2nd recording.	265
TEXTURE_MOD	ALPHA(3)	60.Horizon text. modifier,1st.	1056
TEXTURE_MOD2	ALPHA(3)	60.Horizon text. modifier,2nd.	46
WATERSHED	ALPHA(10)	28.Watershed code-presently blank.	0
WTABLE_DEPTH	INTEGER	20a.Depth to water table in cm.	581
WTABLE_KIND	ALPHA(1)	20c.Kind of water table observed.	5069
WTABLE_MONTH	ALPHA(2)	20b.Month water table observed.	5029
YEAR_ANALYZE	ALPHA(2)	31. Year lab analyses were done.	911
YR_CODED	INTEGER	10.Year pedon info was encoded.	5253

 Lab Data Variables: Data are contained in the file MT_LAB.

VARIABLE	DATA TYPE	BRIEF DATA DESCRIPTION	CASES W/DATA
ATT_LIQUID	INTEGER	128a.Atterberg limits,liquid limit.	0
ATT_PL_INDEX	INTEGER	128b.Atterberg limits,plast. ind.	0
BASE_SAT	INTEGER	124d.1st Base Saturation result.	1219
BASE_SAT2	INTEGER	124d.2nd Base Saturation result.	352
BASE_SAT3	INTEGER	124d.3rd Base Saturation result.	0
BASE_SAT4	INTEGER	124d.4th Base Saturation result.	0
BD	REAL(1)	115c.1st bulk density, result.	1562
BD2	REAL(1)	115c.2nd bulk density, result.	688
BD2_DBASE	ALPHA(1)	115a.2nd bulk density, code.	491
BD2_MOIS	ALPHA(1)	115b.2nd bulk density, moisture.	688
BD2_NOTE	ALPHA(1)	115d.2nd bulk density, note code.	0
BD3	REAL(1)	115c.3rd bulk density, result.	72
BD3_DBASE	ALPHA(1)	115a.3rd bulk density, code.	0
BD3_MOIS	ALPHA(1)	115b.3rd bulk density, moisture.	72
BD3_NOTE	ALPHA(1)	115d.3rd bulk density, note code.	0
BD4	REAL(1)	115c.4th bulk density, result.	0
BD4_DBASE	ALPHA(1)	115a.4th bulk density, code.	0
BD4_MOIS	ALPHA(1)	115b.4th bulk density, moisture.	0
BD4_NOTE	ALPHA(1)	115d.4th bulk density, note code.	0
BD_DBASE	ALPHA(1)	115a.1st bulk density, code.	1416
BD_MOIS	ALPHA(1)	115b.1st bulk density, moisture.	1661
BD_NOTE	ALPHA(1)	115d.1st bulk density, note code.	158
CACO3_2_KIND	ALPHA(1)	114b.2nd Carb. as CaCO3,kind code.	630
CACO3_2_NOTE	ALPHA(1)	114a.2nd Carb. as CaCO3,note code.	367
CACO3_2_PCT	INTEGER	114c.2nd Carbonate as CaCO3,pct..	263
CACO3_KIND	ALPHA(1)	114b.1st Carb. as CaCO3,kind code.	1481
CACO3_NOTE	ALPHA(1)	114a.1st Carb. as CaCO3,note code.	337
CACO3_PCT	INTEGER	114c.1st Carbonate as CaCO3,pct..	1144
CEC	REAL(1)	124c.1st CEC result.	2183
CEC2	REAL(1)	124c.2nd CEC result.	364
CEC2_METH	ALPHA(1)	124b.2nd CEC and BS method.	374
CEC2_NOTE	ALPHA(1)	124a.2nd CEC and BS note.	0
CEC3	REAL(1)	124c.3rd CEC result.	0
CEC3_METH	ALPHA(1)	124b.3rd CEC and BS method.	0
CEC3_NOTE	ALPHA(1)	124a.3rd CEC and BS note.	0
CEC4	REAL(1)	124c.4th CEC result.	0
CEC4_METH	ALPHA(1)	124b.4th CEC and BS method.	0
CEC4_NOTE	ALPHA(1)	124a.4th CEC and BS note.	0
CEC_ADDITION	ALPHA(1)	125.Additional CECand BS results.	0
CEC_METH	ALPHA(1)	124b.1st CEC and BS method.	2301
CEC_NOTE	ALPHA(1)	124a.1st CEC and BS note.	0
CF_LAB2_KIND	ALPHA(1)	109a.2nd lab coarse frag., kind.	790
CF_LAB2_NOTE	ALPHA(1)	109b.2nd lab coarse frag., note.	455
CF_LAB2_PCT	INTEGER	109c.2nd lab coarse frag., pct..	335
CF_LAB3_KIND	ALPHA(1)	109a.3rd lab coarse frag., kind.	662
CF_LAB3_NOTE	ALPHA(1)	109b.3rd lab coarse frag., note.	320
CF_LAB3_PCT	INTEGER	109c.3rd lab coarse frag., pct..	343
CF_LAB4_KIND	ALPHA(1)	109a.4th lab coarse frag., kind.	528

VARIABLE	DATA TYPE	BRIEF DATA DESCRIPTION	CASES W/DATA
CF_LAB4_NOTE	ALPHA(1)	109b.4th lab coarse frag., note.	309
CF_LAB4_PCT	INTEGER	109c.4th lab coarse frag., pct..	219
CF_LAB5_KIND	ALPHA(1)	109a.5th lab coarse frag., kind.	128
CF_LAB5_NOTE	ALPHA(1)	109b.5th lab coarse frag., note.	108
CF_LAB5_PCT	INTEGER	109c.5th lab coarse frag., pct..	20
CF_LAB_KIND	ALPHA(1)	109a.1st lab coarse frag., kind.	1765
CF_LAB_NOTE	ALPHA(1)	109b.1st lab coarse frag., note.	1011
CF_LAB_PCT	INTEGER	109c.1st lab coarse frag., pct..	1199
CLAY	REAL(1)	107b.Percent clay in sample.	2502
CLAY_NOTE	ALPHA(1)	107a.Explanation note for clay.	0
CM	REAL(2)	116.Coarse fragment conv. factor.	81
COLE	REAL(3)	117.Coefficient of linear extens.	607
COLE_F	REAL(3)	118.COLE for fine earth fabric.	36
CSAND	REAL(1)	107b.Percent csand in sample.	1673
CSAND_NOTE	ALPHA(1)	107a.Explanation note for csand.	122
CSILT	REAL(1)	107b.Percent csilt in sample.	1785
SILT_NOTE	ALPHA(1)	107a.Explanation note for csilt.	0
CU	REAL	BLM.PPM Copper.	525
DATA_BASE	ALPHA(1)	106b.Soil size-fraction tested.	1899
EC	REAL	BLM.Electr. conductivity,mmhos/cm.	707
ENGR_SILT	REAL(1)	107b.Percent engr. silt in sample.	713
ENGR_SI_NOTE	ALPHA(1)	107a.Explan. note for engr. silt.	0
FE	REAL	BLM.PPM Iron.	525
FSAND	REAL(1)	107b.Percent fsand in sample.	1773
FSAND_NOTE	ALPHA(1)	107a.Explanation note for fsand.	23
FSILT	REAL(1)	107b.Percent fsilt in sample.	1791
FSILT_NOTE	ALPHA(1)	107a.Explanation note for fsilt.	0
INT_II	REAL(1)	107b.Percent INT II in sample.	1786
INT_II_NOTE	ALPHA(1)	107a.Explanation note for INT II.	1
LAB_COMMENT1	ALPHA(60)	129.Lab notes, 1st part.	254
LAB_COMMENT2	ALPHA(15)	129.Lab notes, 2nd part.	72
LAB_NUMBER1	ALPHA(4)	106a.First part of lab number.	1899
LAB_NUMBER2	ALPHA(3)	106a.Second part of lab number.	1899
LEGAL_DESCR	ALPHA(10)	Legal descr. for site,to section.	409
MISC10_KIND	ALPHA(1)	127b.10th misc. results kind code.	0
MISC10_NOTE	ALPHA(1)	127a.10th misc. results note code.	0
MISC10_RESUL	REAL	127c.10th misc.result.	0
MISC2_KIND	ALPHA(1)	127b.2nd misc. results kind code.	99
MISC2_NOTE	ALPHA(1)	127a.2nd misc. results note code.	31
MISC2_RESUL	REAL	127c.2nd misc.result.	69
MISC3_KIND	ALPHA(1)	127b.3rd misc. results kind code.	0
MISC3_NOTE	ALPHA(1)	127a.3rd misc. results note code.	0
MISC3_RESUL	REAL	127c.3rd misc.result.	0
MISC4_KIND	ALPHA(1)	127b.4th misc. results kind code.	0
MISC4_NOTE	ALPHA(1)	127a.4th misc. results note code.	0
MISC4_RESUL	REAL	127c.4th misc.result.	0
MISC5_KIND	ALPHA(1)	127b.5th misc. results kind code.	0
MISC5_NOTE	ALPHA(1)	127a.5th misc. results note code.	0
MISC5_RESUL	REAL	127c.5th misc.result.	0
MISC6_KIND	ALPHA(1)	127b.6th misc. results kind code.	0

VARIABLE	DATA TYPE	BRIEF DATA DESCRIPTION	CASES W/DATA
MISC6_NOTE	ALPHA(1)	127a.6th misc. results note code.	0
MISC6_RESUL	REAL	127c.6th misc.result.	0
MISC7_KIND	ALPHA(1)	127b.7th misc. results kind code.	0
MISC7_NOTE	ALPHA(1)	127a.7th misc. results note code.	0
MISC7_RESUL	REAL	127c.7th misc.result.	0
MISC8_KIND	ALPHA(1)	127b.8th misc. results kind code.	0
MISC8_NOTE	ALPHA(1)	127a.8th misc. results note code.	0
MISC8_RESUL	REAL	127c.8th misc.result.	0
MISC9_KIND	ALPHA(1)	127b.9th misc. results kind code.	0
MISC9_NOTE	ALPHA(1)	127a.9th misc. results note code.	0
MISC9_RESUL	REAL	127c.9th misc.result.	0
MISC_KIND	ALPHA(1)	127b.1st misc. results kind code.	661
MISC_NOTE	ALPHA(1)	127a.1st misc. results note code.	353
MISC_RESUL	REAL	127c.1st misc.result.	314
MN	REAL	BLM.PPM Manganese.	525
MSAND	REAL(1)	107b.Percent msand in sample.	1729
MSAND_NOTE	ALPHA(1)	107a.Explanation note for msand.	67
NITROGEN_PPM	REAL	BLM.PPM Total Nitrogen.	532
NITRO_NOTE	ALPHA(1)	112a.Nitrogen notecode.	0
NITRO_PCT	REAL(3)	112b.Nitrogen percent in sample.	776
OC_LAB_NOTE	ALPHA(1)	111a.Lab-determined o.c. note.	28
OC_LAB_PCT	REAL(2)	111b.Lab-determined o.c. percent.	1578
OM_LAB_NOTE	ALPHA(1)	110a.Lab-determined o.m. note.	0
OM_LAB_PCT	REAL(2)	110b.Lab-determined o.m. percent.	714
PARTCL2_KIND	ALPHA(1)	108a.2nd misc. particles,kind.	235
PARTCL2_NOTE	ALPHA(1)	108b.2nd misc. particles,note.	0
PARTCL2_PCT	REAL(1)	108c.2nd misc. particles, percent.	235
PARTCL3_KIND	ALPHA(1)	108a.3rd misc. particles,kind.	82
PARTCL3_NOTE	ALPHA(1)	108b.3rd misc. particles,note.	0
PARTCL3_PCT	REAL(1)	108c.3rd misc. particles, percent.	81
PARTCL4_KIND	ALPHA(1)	108a.4th misc. particles,kind.	0
PARTCL4_NOTE	ALPHA(1)	108b.4th misc. particles,note.	0
PARTCL4_PCT	REAL(1)	108c.4th misc. particles, percent.	0
PARTCL5_KIND	ALPHA(1)	108a.5th misc. particles,kind.	0
PARTCL5_NOTE	ALPHA(1)	108b.5th misc. particles,note.	0
PARTCL5_PCT	REAL(1)	108c.5th misc. particles, percent.	0
PARTCL_KIND	ALPHA(1)	108a.1st misc. particles,kind.	587
PARTCL_NOTE	ALPHA(1)	108b.1st misc. particles,note.	0
PARTCL_PCT	REAL(1)	108c.1st misc. particles, percent.	580
PHOSPHOR_PPM	REAL	BLM.PPM Bragg Phosphorus.	645
PH_LAB2METH	ALPHA(1)	120a.2nd Lab pH meas. method code.	1186
PH_LAB2RESUL	REAL(1)	120b.2nd Lab pH meas. result.	1186
PH_LAB3METH	ALPHA(1)	120a.3rd Lab pH meas. method code.	699
PH_LAB3RESUL	REAL(1)	120b.3rd Lab pH meas. result.	699
PH_LAB4METH	ALPHA(1)	120a.4th Lab pH meas. method code.	0
PH_LAB4RESUL	REAL(1)	120b.4th Lab pH meas. result.	0
PH_LAB5METH	ALPHA(1)	120a.5th Lab pH meas. method code.	0
PH_LAB5RESUL	REAL(1)	120b.5th Lab pH meas. result.	0
PH_LABMETH	ALPHA(1)	120a.Lab pH meas. method code.	2654
PH_LABRESUL	REAL(1)	120b.Lab pH determination result.	2602

VARIABLE	DATA TYPE	BRIEF DATA DESCRIPTION	CASES W/DATA
QUARTERS	ALPHA(8)	4th,3rd,2nd,and 1st qtr. sections.	258
RANGE	ALPHA(4)	Range for site.	946
RSCOND	INTEGER	BLM. Rangesite Condition (%).	630
RSPHAS	ALPHA(2)	BLM. Rangesite Soil Phase.	40
RSPREC	INTEGER	BLM. Rangesite Precip.	678
RSREG	ALPHA(2)	BLM. Rangesite Region.	762
RSSOIL	ALPHA(4)	BLM. Rangesite Soil type.	756
SAND	REAL(1)	107b.Percent sand in sample.	2501
SAND_NOTE	ALPHA(1)	107a.Explanation note for sand.	42
SAR	REAL	BLM.Sodium absorption ratio.	436
SCA	REAL	BLM.Soluble Calcium,meq per 100g.	708
SECTION	INTEGER	Section for site.	942
SILT	REAL(1)	107b.Percent silt in sample.	2502
SILT_NOTE	ALPHA(1)	107a.Explanation note for silt.	0
SITE	INTEGER	BLM.See BLM report for locations.	736
SK	REAL	BLM.Soluble Potassium,meq per 100g.	697
SMG	REAL	BLM.Soluble Magnesium,meq per 100g.	707
SNA	REAL	BLM.Soluble Sodium,meq per 100g.	684
SUBSITE	ALPHA(1)	BLM.A=inside,B=outside enclosure.	9
TOWNSHIP	ALPHA(4)	Township for site.	946
VCSAND	REAL(1)	107b.Percent vcsand in sample.	1421
VCSAND_NOTE	ALPHA(1)	107a.Explanation note for vcsand.	372
VFSAND	REAL(1)	107b.Percent vfsand in sample.	1789
VFSAND_NOTE	ALPHA(1)	107a.Explanation note for vfsand.	7
WC2_KIND	ALPHA(1)	119b.2nd water content, kind.	1418
WC2_NOTE	ALPHA(1)	119a.2nd water content, note.	0
WC2_PCT	REAL(1)	119c.2nd water content, percent.	1366
WC3_KIND	ALPHA(1)	119b.3rd water content, kind.	994
WC3_NOTE	ALPHA(1)	119a.3rd water content, note.	0
WC3_PCT	REAL(1)	119c.3rd water content, percent.	942
WC4_KIND	ALPHA(1)	119b.4th water content, kind.	9
WC4_NOTE	ALPHA(1)	119a.4th water content, note.	0
WC4_PCT	REAL(1)	119c.4th water content, percent.	9
WC5_KIND	ALPHA(1)	119b.5th water content, kind.	0
WC5_NOTE	ALPHA(1)	119a.5th water content, note.	0
WC5_PCT	REAL(1)	119c.5th water content, percent.	0
WC6_KIND	ALPHA(1)	119b.6th water content, kind.	0
WC6_NOTE	ALPHA(1)	119a.6th water content, note.	0
WC6_PCT	REAL(1)	119c.6th water content, percent.	0
WC7_KIND	ALPHA(1)	119b.7th water content, kind.	0
WC7_NOTE	ALPHA(1)	119a.7th water content, note.	0
WC7_PCT	REAL(1)	119c.7th water content, percent.	0
WC_AVAIL	REAL	BLM.Percent available water.	712
WC_KIND	ALPHA(1)	119b.1st water content, kind.	2411
WC_NOTE	ALPHA(1)	119a.1st water content, note.	0
WC_PCT	REAL(1)	119c.1st water content, percent.	2334
WX10_KIND	ALPHA(1)	126b.10th water extract kind code.	179
WX10_NOTE	ALPHA(1)	126a.10th water extract note.	30
WX10_RESUL	REAL	126c.10th water extract result.	179
WX2_KIND	ALPHA(1)	126b.2nd water extract kind code.	781

VARIABLE	DATA TYPE	BRIEF DATA DESCRIPTION	CASES W/DATA
WX2_NOTE	ALPHA(1)	126a.2nd water extract note.	11
WX2_RESUL	REAL	126c.2nd water extract result.	775
WX3_KIND	ALPHA(1)	126b.3rd water extract kind code.	751
WX3_NOTE	ALPHA(1)	126a.3rd water extract note.	66
WX3_RESUL	REAL	126c.3rd water extract result.	685
WX4_KIND	ALPHA(1)	126b.4th water extract kind code.	708
WX4_NOTE	ALPHA(1)	126a.4th water extract note.	23
WX4_RESUL	REAL	126c.4th water extract result.	701
WX5_KIND	ALPHA(1)	126b.5th water extract kind code.	300
WX5_NOTE	ALPHA(1)	126a.5th water extract note.	2
WX5_RESUL	REAL	126c.5th water extract result.	298
WX6_KIND	ALPHA(1)	126b.6th water extract kind code.	231
WX6_NOTE	ALPHA(1)	126a.6th water extract note.	204
WX6_RESUL	REAL	126c.6th water extract result.	51
WX7_KIND	ALPHA(1)	126b.7th water extract kind code.	203
WX7_NOTE	ALPHA(1)	126a.7th water extract note.	0
WX7_RESUL	REAL	126c.7th water extract result.	203
WX8_KIND	ALPHA(1)	126b.8th water extract kind code.	187
WX8_NOTE	ALPHA(1)	126a.8th water extract note.	21
WX8_RESUL	REAL	126c.8th water extract result.	171
WX9_KIND	ALPHA(1)	126b.9th water extract kind code.	179
WX9_NOTE	ALPHA(1)	126a.9th water extract note.	20
WX9_RESUL	REAL	126c.9th water extract result.	159
WX_KIND	ALPHA(1)	126b.1st water extract kind code.	781
WX_NOTE	ALPHA(1)	126a.1st water extract note.	0
WX_RESUL	REAL	126c.1st water extract result.	781
XACID_NOTE	ALPHA(1)	122a.Extract. acidity note code.	11
XACID_RESUL	REAL(1)	122b.Extractable acidity result.	474
XAL_NOTE	ALPHA(1)	123a.KCl extr. aluminum note code.	0
XAL_RESUL	REAL(1)	123b.KCl extr. aluminum result.	37
XBASE2_NOTE	ALPHA(1)	121a.2nd extr. bases note code.	143
XBASE2_RESUL	REAL(1)	121b.2nd extr. bases result.	1190
XBASE3_NOTE	ALPHA(1)	121a.3rd extr. bases note code.	153
XBASE3_RESUL	REAL(1)	121b.3rd extr. bases result.	1385
XBASE4_NOTE	ALPHA(1)	121a.4th extr. bases note code.	5
XBASE4_RESUL	REAL(1)	121b.4th extr. bases result.	1533
XBASE5_NOTE	ALPHA(1)	121a.5th extr. bases note code.	0
XBASE5_RESUL	REAL(1)	121b.5th extr. bases result.	0
XBASE_NOTE	ALPHA(1)	121a.1st extr. bases note code.	137
XBASE_RESUL	REAL(1)	121b.1st extr. bases result.	1057
XCA	REAL	BLM.Exch. calcium,meq per 100g.	715
XFE_NOTE	ALPHA(1)	113a.Extractable iron as Fe, note.	0
XFE_PCT	REAL(1)	113b.Extractable iron as Fe, pct.	348
XK	REAL	BLM.Exchangeable Kin meq per 100g.	715
XMG	REAL	BLM.Exch. Magnesium,meq per 100g.	715
XNA	REAL	BLM.Exch. Sodium,meq per 100g.	690
ZN	REAL	BLM.PPM Zinc.	525

 BLM Vegetation Variables: Data are in the file MT_VEG.

VARIABLE	DATA TYPE	BRIEF DATA DESCRIPTION	CASES W/DATA
AAFF	REAL	304 Unknown Annual Forb.	167
AAFF_PROD	REAL	304 Unknown Annual Forb Prod.	167
AAGG	REAL	301 Unknown Annual Grass.	167
AAGG_PROD	REAL	301 Unknown Annual Grass Prod.	167
ACMI2	REAL	100 Achillea millefolium.	167
ACMI2_PROD	REAL	100 Achillea millefolium Prod.	167
AGCA	REAL	050 Agropyron caninum.	167
AGCA_PROD	REAL	050 Agropyron caninum Production.	167
AGCR_PROD	REAL	Agropyron cristatum Production.	167
AGDA	REAL	051 Agropyron dasystachyum.	167
AGDA_PROD	REAL	051 Agropyron dasystachyum Prod.	167
AGROP2	REAL	054 Agropyron spp.	167
AGROP2_PROD	REAL	054 Agropyron spp Production.	167
AGSC5	REAL	055 Agrostis scabra.	167
AGSM	REAL	052 Agropyron smithii.	167
AGSM_PROD	REAL	052 Agropyron smithii Production.	167
AGSP	REAL	053 Agropyron spicatum.	167
AGSP_PROD	REAL	053 Agropyron spicatum Production.	167
ALCE2	REAL	102 Allium cernuum.	167
ALCE2_PROD	REAL	102 Allium cernuum Production.	167
ALLIU	REAL	104 Allium spp.	167
ALLIU_PROD	REAL	104 Allium spp Production.	167
AMAL2	REAL	006 Amalanchier alnifolia.	167
AMRE	REAL	106 Amaranthus retroflexus.	167
ANGE	REAL	056 Andropogon gerardii.	167
ANGE_PROD	REAL	056 Andropogon gerardii Prod.	167
ANRA	REAL	107 Antennaria racemosa.	167
ANRA_PROD	REAL	107 Antennaria racemosa Prod.	167
ANSC2	REAL	057 Andropogon scoparius.	167
ANSC2_PROD	REAL	057 Andropogon scoparius Prod.	167
ANTEN	REAL	108 Antennaria spp.	167
ANTEN_PROD	REAL	108 Antennaria spp Production.	167
ARAL4	REAL	113 Arnica alpina.	167
ARAR8	REAL	010 Artemisia arbuscula arbuscula.	167
ARAR8_PROD	REAL	010 A. arbuscula arbuscula Prod.	167
ARARN	REAL	011 Artemisia arbuscula nova.	167
ARARN_PROD	REAL	011 Artemisia arbuscula nova Prod.	167
ARCA12	REAL	034 Artemisia campestris.	167
ARCA12_PROD	REAL	034 Artemisia campestris Prod.	167
ARCA13	REAL	012 Artemisia cana cana.	167
ARCA13_PROD	REAL	012 Artemisia cana cana Production.	167
ARCO5	REAL	111 Arenaria congesta.	167
ARCO5_PROD	REAL	111 Arenaria congesta Production.	167
ARCO9	REAL	114 Arnica cordifolia.	167
ARCO9_PROD	REAL	114 Arnica cordifolia Production.	167
ARDR	REAL	110 Arabis drummondii.	167
ARDR_PROD	REAL	110 Arabis drummondii Production.	167
ARFR4	REAL	036 Artemisia frigida.	167

VARIABLE	DATA TYPE	BRIEF DATA DESCRIPTION	CASES W/DATA
ARFR4_PROD	REAL	036 Artemisia frigida Production.	167
ARLO3	REAL	058 Aristida longiseta.	167
ARLO3_PROD	REAL	058 Aristida longiseta Production.	167
ARLO7	REAL	037 Artemisia longifolia.	167
ARLO7_PROD	REAL	037 Artemisia longifolia Prod.	167
ARLU	REAL	115 Artemisia ludoviciana ludovic.	167
ARLU_PROD	REAL	115 A.ludoviciana ludoviciana Prod.	167
ARPE6	REAL	038 Artemisia pedatifida.	167
ARPE6_PROD	REAL	038 Artemisia pedatifida Prod.	167
ARSA	REAL	109 Arabidopsis salsuginea.	167
ARSA_PROD	REAL	109 Arabidopsis salsuginea Prod.	167
ARSP5	REAL	014 Artemisia tripartita.	167
ARSP5_PROD	REAL	014 Artemisia tripartita Prod.	167
ARTR2	REAL	039 Artemisia spinescens.	167
ARTR2_PROD	REAL	039 Artemisia spinescens Prod.	167
ARTR4	REAL	013 Artemisia tridentata.	167
ARTR4_PROD	REAL	013 Artemisia tridentata Prod.	167
ASGIL	REAL	124 Astragalus gilviflorus.	167
ASSC3	REAL	119 Aster scopulorum.	167
ASSC3_PROD	REAL	119 Aster scopulorum Production.	167
ASTER	REAL	120 Aster spp.	167
ASTER_PROD	REAL	120 Aster spp Production.	167
ASTRA	REAL	127 Astragalus spp.	167
ASTRA_PROD	REAL	127 Astragalus spp Production.	167
ATCA2	REAL	015 Atriplex canescens.	167
ATCA2_PROD	REAL	015 Atriplex canescens Production.	167
ATCO	REAL	016 Atriplex confertifolia.	167
ATNU2	REAL	040 Atriplex nuttallii.	167
ATNU2_PROD	REAL	040 Atriplex nuttallii Production.	167
BASA	REAL	131 Balsamorhiza sagittata.	167
BERE	REAL	041 Berberis repens.	167
BERE_PROD	REAL	041 Berberis repens Production.	167
BGROUND	REAL	No vegetative OR rock cover.	167
BOCU	REAL	059 Bouteloua curtipendula.	167
BOCU_PROD	REAL	059 Bouteloua curtipendula Prod.	167
BOGR2	REAL	060 Bouteloua gracilis.	167
BOGR2_PROD	REAL	060 Bouteloua gracilis Production.	167
BRASS2	REAL	303 Brassicaceae species.	167
BRASS2_PROD	REAL	303 Brassicaceae species Prod.	167
BRCA5	REAL	061 Bromus carinatus.	167
BRCA5_PROD	REAL	061 Bromus carinatus Production.	167
BRIN2	REAL	062 Bromus inermis.	167
BRJA	REAL	063 Bromus japonicus.	167
BRJA_PROD	REAL	063 Bromus japonicus Production.	167
BRTE	REAL	064 Bromus tectorum.	167
BRTE_PROD	REAL	064 Bromus tectorum Production.	167
BUDA	REAL	065 Buchloe dactyloides.	167
BUDA_PROD	REAL	065 Buchloe dactyloides Production.	167
CAEL	REAL	132 Calochortus elegans.	167
CAFI	REAL	069 Carex filifolia.	167

VARIABLE	DATA TYPE	BRIEF DATA DESCRIPTION	CASES W/DATA
CAFI_PROD	REAL	069 Carex filifolia Production.	167
CAGE2	REAL	070 Carex geyeri.	167
CAGE2_PROD	REAL	070 Carex geyeri Production.	167
CALO	REAL	068 Calamovilfa longifolia.	167
CALO_PROD	REAL	068 Calamovilfa longifolia Prod.	167
CAMI12	REAL	136 Castilleja miniata.	167
CAMI12_PROD	REAL	136 Castilleja miniata Production.	167
CAMO	REAL	066 Calamagrostis montanensis.	167
CAMO_PROD	REAL	066 Calamagrostis montanensis Prod.	167
CANU3	REAL	133 Calochortus nuttallii.	167
CANU3_PROD	REAL	133 Calochortus nuttallii Prod.	167
CARO2	REAL	135 Campanula rotundifolia.	167
CARO2_PROD	REAL	135 Campanula rotundifolia Prod.	167
CARU	REAL	067 Calamagrostis rubescens.	167
CAST12	REAL	137 Castilleja spp.	167
CAST12_PROD	REAL	137 Castilleja spp Production.	167
CAST4	REAL	071 Carex stenophylla C eleocharis.	167
CAST4_PROD	REAL	071 C. stenophylla/eleocharis Prod.	167
CEAR4	REAL	139 Cerastium arvense.	167
CEAR4_PROD	REAL	139 Cerastium arvense Production.	167
CELE3	REAL	007 Cercocarpus ledifolius.	167
CEMA4	REAL	138 Centauria maculosa.	167
CHNA2	REAL	017 Chrysothamnus nauseosus.	167
CHNA2_PROD	REAL	017 Chrysothamnus nauseosus Prod.	167
CHVI6	REAL	141 Chrysopsis villosa.	167
CHVI6_PROD	REAL	141 Chrysopsis villosa Production.	167
CHVI8	REAL	018 Chrysothamnus viscidiflorus.	167
CHVI8_PROD	REAL	018 Chrysoth. viscidiflorus Prod.	167
CIAR4	REAL	142 Cirsium arvense.	167
CICA6	REAL	143 Cirsium canovirens.	167
CICA6_PROD	REAL	143 Cirsium canovirens Production.	167
CIRSI	REAL	146 Cirsium spp.	167
CIUN	REAL	144 Cirsium undulatum.	167
CIUN_PROD	REAL	144 Cirsium undulatum Production.	167
CIVU	REAL	145 Cirsium vulgare.	167
CIVU_PROD	REAL	145 Cirsium vulgare Production.	167
CLCO2	REAL	042 Clematis columbiana.	167
CLCO2_PROD	REAL	042 Clematis columbiana Production.	167
COBBLE	REAL	Pct. cobble cover.	167
CORA5	REAL	148 Cordylanthus ramosus.	167
CORA5_PROD	REAL	148 Cordylanthus ramosus Prod.	167
COUM	REAL	147 Comandra umbellata.	167
COUM_PROD	REAL	147 Comandra umbellata Production.	167
CRAC2	REAL	150 Crepis acuminata.	167
CRAC2_PROD	REAL	150 Crepis acuminata Production.	167
CRCE	REAL	153 Cryptantha celosioides.	167
CRCE_PROD	REAL	153 Cryptantha celosioides Prod.	167
CRIN9	REAL	152 Cryptantha interrupta.	167
CRIN9_PROD	REAL	152 Cryptantha interrupta Prod.	167
CRMO4	REAL	151 Crepis modocensis.	167

VARIABLE	DATA TYPE	BRIEF DATA DESCRIPTION	CASES W/DATA
CRMO4_PROD	REAL	151 Crepis modocensis Production.	167
DAIN	REAL	072 Danthonia intermedia.	167
DAIN_PROD	REAL	072 Danthonia intermedia Prod.	167
DAUN	REAL	073 Danthonia uniflora.	167
DEBI	REAL	154 Delphinium bicolor.	167
DIST	REAL	074 Distichlis stricta.	167
DIST_PROD	REAL	074 Distichlis stricta Production.	167
DOMO	REAL	156 Douglasia montana.	167
DOMO_PROD	REAL	156 Douglasia montana Production.	167
ECPA	REAL	157 Echinacea pallida.	167
ECPA_PROD	REAL	157 Echinacea pallida Production.	167
EPILO	REAL	158 Epilobium spp.	167
EPILO_PROD	REAL	158 Epilobium spp Production.	167
ERAS2	REAL	176 Erysimum asperum.	167
ERAS2_PROD	REAL	176 Erysimum asperum Production.	167
ERCA2	REAL	159 Erigeron caespitosus.	167
ERCA2_PROD	REAL	159 Erigeron caespitosus Prod.	167
ERCO4	REAL	160 Erigeron compositus.	167
ERCO4_PROD	REAL	160 Erigeron compositus Production.	167
ERFI2	REAL	161 Erigeron filifolius.	167
ERFI2_PROD	REAL	161 Erigeron filifolius Production.	167
ERHE2	REAL	168 Eriogonum heracleoides.	167
ERIGE2	REAL	166 Erigeron spp.	167
ERIGE2_PROD	REAL	166 Erigeron spp Production.	167
ERIN7	REAL	177 Erisimum inconspicuum.	167
ERIOG	REAL	175 Eriogonum spp.	167
ERIOG_PROD	REAL	175 Eriogonum spp Production.	167
ERLI	REAL	162 Erigeron linearis.	167
ERLI_PROD	REAL	162 Erigeron linearis Production.	167
ERMA3	REAL	169 Eriogonum mancum.	167
ERMA3_PROD	REAL	169 Eriogonum mancum Production.	167
ERMI4	REAL	170 Eriogonum microthecum.	167
ERMI4_PROD	REAL	170 Eriogonum microthecum Prod.	167
EROV	REAL	171 Eriogonum ovalifolium.	167
EROV_PROD	REAL	171 Eriogonum ovalifolium Prod.	167
ERPA9	REAL	172 Eriogonum pauciflorum.	167
ERPA9_PROD	REAL	172 Eriogonum pauciflorum Prod.	167
ERPU2	REAL	164 Erigeron pumilus.	167
ERPU2_PROD	REAL	164 Erigeron pumilus Production.	167
ERST4	REAL	173 Eriogonum strictum.	167
ERST4_PROD	REAL	173 Eriogonum strictum Production.	167
ERTW	REAL	165 Erigeron tweedyi.	167
ERTW_PROD	REAL	165 Erigeron tweedyi Production.	167
ERUM	REAL	174 Eriogonum umbellatum.	167
ERUM_PROD	REAL	174 Eriogonum umbellatum Prod.	167
EULA5	REAL	043 Eurotia lanata.	167
EULA5_PROD	REAL	043 Eurotia lanata Production.	167
EUSE4	REAL	178 Euphorbia serpyllifolia.	167
EUSE5_PROD	REAL	178 Euphorbia serpyllifolia Prod.	167
FEID	REAL	075 Festuca idahoensis.	167

VARIABLE	DATA TYPE	BRIEF DATA DESCRIPTION	CASES W/DATA
FEID_PROD	REAL	075 Festuca idahoensis Production.	167
FEOC2	REAL	076 Festuca octoflora.	167
FEOC2_PROD	REAL	076 Festuca octoflora Production.	167
FESC	REAL	077 Festuca scabrella.	167
FESC_PROD	REAL	077 Festuca scabrella Production.	167
FEVI	REAL	078 Festuca viridula.	167
FEVI_PROD	REAL	078 Festuca viridula Production.	167
FRVI	REAL	179 Fragaria virginiana.	167
FRVI_PROD	REAL	179 Fragaria virginiana Production.	167
GAAR	REAL	180 Gaillardia aristata.	167
GABO2	REAL	181 Galium boreale.	167
GACO5	REAL	182 Gaura coccinea.	167
GARA2	REAL	183 Gayophytum ramosissimum.	167
GARA2_PROD	REAL	183 Gayophytum ramosissimum Prod.	167
GEAF	REAL	184 Gentiana affinis.	167
GETR	REAL	185 Geum triflorum.	167
GETR_PROD	REAL	185 Geum triflorum Production.	167
GLLE3	REAL	006 Glycerrhiza lepidota.	167
GRAVEL	REAL	Pct. gravel cover.	167
GRSQ	REAL	187 Gridelia squarrosa.	167
GRSQ_PROD	REAL	187 Gridelia squarrosa Production.	167
GUSA2	REAL	188 Gutierrezia sarothrae.	167
GUSA2_PROD	REAL	188 Gutierrezia sarothrae Prod.	167
HAAC	REAL	190 Haplopapus acaulis.	167
HAAC_PROD	REAL	190 Haplopapus acaulis Production.	167
HACKE	REAL	189 Hackelia spp.	167
HACKE_PROD	REAL	189 Hackelia spp Production.	167
HEHI	REAL	197 Hedioma hispida.	167
HEHI_PROD	REAL	197 Hedioma hispida Production.	167
HELIA3	REAL	005 Helianthus spp.	167
HELIA3_PROD	REAL	195 Helianthus spp Production.	167
HEUCH	REAL	196 Heuchera spp.	167
HEUCH_PROD	REAL	196 Heuchera spp Production.	167
HOJU	REAL	079 Hordeum jubatum.	167
HOJU_PROD	REAL	079 Hordeum jubatum Production.	167
JUBA	REAL	080 Juncus balticus.	167
JUBA_PROD	REAL	080 Juncus balticus Production.	167
JUCO6	REAL	019 Juniperus communis.	167
JUCO6_PROD	REAL	019 Juniperus communis Production.	167
JUHO2	REAL	044 Juniperus horizontalis.	167
JUHO2_PROD	REAL	044 Juniperus horizontalis Prod.	167
JUSC2	REAL	001 Juniperus scopulorum.	167
KOCR	REAL	081 Koeleria cristata.	167
KOCR_PROD	REAL	081 Koeleria cristata Production.	167
KOSC	REAL	001 Kochia scoparia.	167
KOSC_PROD	REAL	201 Kochia scoparia Production.	167
LAPU	REAL	Lactuca pulchella.	167
LEAL	REAL	006 Lesquerella alpina.	167
LEAL_PROD	REAL	006 Lesquerella alpina Production.	167
LEDE	REAL	004 Lepidium densiflorum.	167

VARIABLE	DATA TYPE	BRIEF DATA DESCRIPTION	CASES W/DATA
LEDE_PROD	REAL	204 <i>Lepidium densiflorum</i> Prod.	167
LEGUM	REAL	306 Unknown Legume.	167
LEGUM_PROD	REAL	306 Unknown Legume Production.	167
LEPE2	REAL	005 <i>Lepidium perfoliatum</i> .	167
LEPE2_PROD	REAL	05 <i>Lepidium perfoliatum</i> Production.	167
LEPU	REAL	045 <i>Leptodactylon pungens</i> .	167
LEPU_PROD	REAL	045 <i>Leptodactylon pungens</i> Prod.	167
LERE7	REAL	007 <i>Lewisia rediviva</i> .	167
LERE7_PROD	REAL	207 <i>Lewisia rediviva</i> Production.	167
LICHEN	REAL	307 Lichens.	167
LIDA	REAL	010 <i>Linaria dalmatica</i> .	167
LIDA_PROD	REAL	210 <i>Linaria dalmatica</i> Production.	167
LIPE2	REAL	009 <i>Linum perenne lewisii</i> .	167
LIPE2_PROD	REAL	209 <i>Linum perenne lewisii</i> Prod.	167
LIPU	REAL	008 <i>Liatrus punctata</i> .	167
LIPU_PROD	REAL	208 <i>Liatrus punctata</i> Production.	167
LIVER	REAL	308 Liverworts.	167
LOMAT	REAL	011 <i>Lomatium</i> spp.	167
LOMAT_PROD	REAL	211 <i>Lomatium</i> spp Production.	167
LUPIN	REAL	014 <i>Lupinus</i> spp.	167
LUPIN_PROD	REAL	214 <i>Lupinus</i> spp Production.	167
LYJU	REAL	015 <i>Lygodesmia juncea</i> .	167
LYJU_PROD	REAL	215 <i>Lygodesmia juncea</i> Production.	167
MACA2	REAL	016 <i>Machaeranthera canescens</i> .	167
MACA2_PROD	REAL	216 <i>Machaeranthera canescens</i> Prod.	167
MAMI3	REAL	017 <i>Mammillaria missouriensis</i> .	167
MAMI3_PROD	REAL	217 <i>Mammillaria missouriensis</i> Prod.	167
MEOF	REAL	0 <i>Melilotus officinalis</i> .	167
MEOF_PROD	REAL	0 <i>Melilotus officinalis</i> Prod.	167
MOSS	REAL	309 Mosses.	167
MUCU3	REAL	082 <i>Muhlenbergia cuspidata</i> .	167
MUCU3_PROD	REAL	082 <i>Muhlenbergia cuspidata</i> Prod.	167
NLITTER	REAL	Non persistent Litter.	167
OECA	REAL	1 <i>Oenothera caespitosa</i> .	167
OESE	REAL	046 <i>Oenothera serrulata</i> .	167
OPPO	REAL	047 <i>Opuntia polycantha</i> .	167
OPPO_PROD	REAL	047 <i>Opuntia polycantha</i> Production.	167
ORFA	REAL	<i>Orobanche fasciculata</i> .	167
ORFA_PROD	REAL	222 <i>Orobanche fasciculata</i> Prod.	167
ORHY	REAL	83 <i>Oryzopsis hymenoides</i> .	167
ORHY_PROD	REAL	083 <i>Oryzopsis hymenoides</i> Prod.	167
OXSE	REAL	4 <i>Oxytropis sericea</i> .	167
OXSE_PROD	REAL	224 <i>Oxytropis sericea</i> Prod.	167
OXYTR	REAL	5 <i>Oxytropis</i> spp.	167
OXYTR_PROD	REAL	225 <i>Oxytropis</i> spp Production.	167
PAVI_PROD	REAL	Production.	167
PEAL8	REAL	8 <i>Penstemon albertinus</i> .	167
PEAL8_PROD	REAL	228 <i>Penstemon albertinus</i> Prod.	167
PECO	REAL	7 <i>Pedicularis contorta</i> .	167
PEFR3	REAL	048 <i>Penstemon fruticosus</i> .	167

VARIABLE	DATA TYPE	BRIEF DATA DESCRIPTION	CASES W/DATA
PEFR3_PROD	REAL	048 Penstemon fruticosus Prod.	167
PELA9	REAL	9 Penstemon laricifolius.	167
PELA9_PROD	REAL	229 Penstemon laricifolius Prod.	167
PELY	REAL	30 Penstemon lyallii.	167
PELY_PROD	REAL	230 Penstemon lyallii Production.	167
PEPU6	REAL	34 Petalostemon purpureum.	167
PEPU6_PROD	REAL	234 Petalostemon purpureum Prod.	167
PERA2	REAL	3 Penstemon radicosus.	167
PHHO	REAL	36 Phlox hoodii.	167
PHHO_PROD	REAL	36 Phlox hoodii Production.	167
PHLOX	REAL	37 Phlox spp.	167
PHLOX_PROD	REAL	237 Phlox spp Production.	167
PHMU4	REAL	35 Phlox multiflora.	167
PHMU4_PROD	REAL	35 Phlox multiflora Production.	167
PHPR3	REAL	084 Phleum pratense.	167
PHYSA2	REAL	38 Physaria spp.	167
PICO	REAL	002 Pinus contorta latifolia.	167
PIFL2	REAL	003 Pinus flexilis.	167
PIPO	REAL	004 Pinus ponderosa.	167
PIPO_PROD	REAL	004 Pinus ponderosa Production.	167
PLITTER	REAL	Persistent Litter.	167
PLPA2	REAL	39 Plantago patagonica.	167
PLPA2_PROD	REAL	239 Plantago patagonica Prod.	167
POCU	REAL	085 Poa curta.	167
POCU3	REAL	086 Poa cusickii.	167
POCU3_PROD	REAL	086 Poa cusickii Production.	167
POFE	REAL	087 Poa fendleriana.	167
POFE_PROD	REAL	087 Poa fendleriana Production.	167
POGR9	REAL	43 Potentilla gracilis.	167
POJU	REAL	085 Poa juncifolia.	167
POPR	REAL	089 Poa pratensis.	167
POPR_PROD	REAL	089 Poa pratensis Production.	167
POSA12	REAL	090 Poa sandbergii.	167
POSA12_PROD	REAL	090 Poa sandbergii Production.	167
POTEN	REAL	44 Potentilla spp.	167
POTEN_PROD	REAL	244 Potentilla spp Production.	167
PPFF	REAL	305 Unknown Perennial Forb.	167
PPFF_PROD	REAL	305 Unknown Perennial Forb Prod.	167
PPGG	REAL	302 Unknown Perennial Grass.	167
PPGG_PROD	REAL	302 Unknown Perennial Grass Prod.	167
PPSS_PROD	REAL	Perennial Shrub Production.	167
PRVI	REAL	008 Prunus virginiana.	167
PSME	REAL	005 Pseudotsuga menziesii.	167
PSME_PROD	REAL	005 Pseudotsuga menziesii Prod.	167
PSORA	REAL	47 Psoralea spp.	167
PSORA_PROD	REAL	247 Psoralea spp Production.	167
PUTR2	REAL	021 Purshia tridentata.	167
RACO3	REAL	48 Ratibida columnifera.	167
RACO3_PROD	REAL	248 Ratibida columnifera Prod.	167
RHTR	REAL	Rhus trilobata.	167

VARIABLE	DATA TYPE	BRIEF DATA DESCRIPTION	CASES W/DATA
RHTR_PROD	REAL	022 Rhus trilobata Production.	167
RIBES	REAL	04 Ribes spp.	167
RICE	REAL	03 Ribes cereum.	167
ROAR3	REAL	025 Rosa arkansana.	167
ROAR3_PROD	REAL	025 Rosa arkansana Production.	167
ROWO	REAL	026 Rosa woodsii.	167
ROWO_PROD	REAL	026 Rosa woodsii Production.	167
RUMEX	REAL	50 Rumex spp.	167
SAKA	REAL	5 Salsola kali.	167
SAKA_PROD	REAL	252 Salsola kali Production.	167
SAVE4	REAL	027 Sarcobatus vermiculatus.	167
SAVE4_PROD	REAL	027 Sarcobatus vermiculatus Prod.	167
SCPA	REAL	091 Schedonnardus paniculatus.	167
SCPA_PROD	REAL	091 Schedonnardus paniculatus Prod.	167
SECA2	REAL	57 Senecio canus.	167
SECA2_PROD	REAL	57 Senecio canus Production.	167
SEDE2	REAL	56 Selaginella densa.	167
SEDUM	REAL	55 Sedum spp.	167
SEDUM_PROD	REAL	55 Sedum spp Production.	167
SELA	REAL	53 Sedum lanceolatum.	167
SELA_PROD	REAL	53 Sedum lanceolatum Production.	167
SENEC	REAL	58 Senecio spp.	167
SENEC_PROD	REAL	58 Senecio spp Production.	167
SEST2	REAL	54 Sedum stenopetalum.	167
SEST2_PROD	REAL	54 Sedum stenopetalum Production.	167
SHAR	REAL	009 Shepherdia argentia.	167
SHCA	REAL	08 Shepherdia canadensis.	167
SIHY	REAL	092 Sitanion hystrix.	167
SIHY_PROD	REAL	09 Sitanion hystrix Production.	167
SOAS	REAL	61 Sonchus asper.	167
SOMI2	REAL	59 Solidago missouriensis.	167
SOUL3	REAL	62 Sonchus uliginosus.	167
SOUL3_PROD	REAL	6 Sonchus uliginosus Production.	167
SPAR	REAL	63 Spargula arvensis.	167
SPBE2	REAL	029 Spirea betulifolia.	167
SPBE2_PROD	REAL	029 Spirea betulifolia Production.	167
SPCO	REAL	64 Sphaeralcea coccinea.	167
SPCO_PROD	REAL	64 Sphaeralcea coccinea Production.	167
SPCR	REAL	093 Sporobolus criptandrus.	167
SPCR_PROD	REAL	093 Sporobolus criptandrus Prod.	167
SPHE	REAL	094 Sporobolus heterolepis.	167
STCO3	REAL	095 Stipa columbiana.	167
STCO3_PROD	REAL	095 Stipa columbiana Production.	167
STCO4	REAL	096 Stipa comata.	167
STCO4_PROD	REAL	096 Stipa comata Production.	167
STONE	REAL	Pct. stone oover.	167
STVI4	REAL	097 Stipa viridula.	167
STVI4_PROD	REAL	097 Stipa viridula Production.	167
SYOC	REAL	030 Symphoricarpos occidentalis.	167
SYOC_PROD	REAL	030 Symphor. occidentalis Prod.	167

VARIABLE	DATA TYPE	BRIEF DATA DESCRIPTION	CASES W/DATA
TAOF	REAL	67 Taraxacum officinale.	167
TAOF_PROD	REAL	67 Taraxacum officinale Production.	167
TBARE	REAL	No vegetative cover.	167
TECA2	REAL	031 Tetradymia canescens.	167
TECA2_PROD	REAL	031 Tetradymia canescens Prod.	167
TESP2	REAL	03 Tetradymia spinosa.	167
THERM	REAL	7 Thermopsis spp.	167
THMO3	REAL	70 Thermopsis montana.	167
THMO3_PROD	REAL	70 Thermopsis montana Production.	167
THOC	REAL	68 Thalictrum occidentale.	167
THOC_PROD	REAL	68 Thalictrum occidentale Prod.	167
THRH	REAL	71 Thermopsis rhombifolia.	167
THRH_PROD	REAL	71 Thermopsis rhombifolia Prod.	167
TOTAL_PROD	REAL	Total Production (Lbs/Acre).	167
TOTPTS	REAL	Total pts in determ. Basal Cover.	167
TRDU	REAL	74 Tragopogon dubius.	167
TRDU_PROD	REAL	74 Tragopogon dubius Production.	167
TRSP2	REAL	098 Trisetum spicatum.	167
TRSP2_PROD	REAL	098 Trisetum spicatum Production.	167
VIAM	REAL	76 Vicia americana.	167
VIAM_PROD	REAL	76 Vicia americana Production.	167
YUGL	REAL	033 Yucca glauca.	167
YUGL_PROD	REAL	033 Yucca glauca Production.	167
ZYGAD	REAL	77 Zygadenus spp.	167
ZYGAD_PROD	REAL	77 Zygadenus spp Production.	167

Tom Burke's Thesis Variables and Yield Variables: Data are in file MT_YIELD.

VARIABLE	DATA TYPE	BRIEF DATA DESCRIPTION	CASES W/DATA
BD_AP_HORZ	REAL(2)	Bulk density, Ap horz., g/cm3.	184
BD_B_HORZ	REAL(2)	Bulk density, B horz., g/cm3.	184
BD_CCA_HORZ	REAL(2)	Bulk density, Cca horz., g/cm3.	182
CONSISTD_AP	REAL(1)	Dry consistence, Ap horz., kg/cm2.	184
CONSISTD_B	REAL(1)	Dry consistence, B horz., kg/cm2.	168
CONSISTD_CCA	REAL(1)	Dry consistence, C horz., kg/cm2.	182
CROP_TYPE	INTEGER	1-w.wh., 2-s.wh., 3-barley, 4-oats.	184
DEPTH_TO_CCA	INTEGER	Burke. Depth to Cca horizon, cm.	182
EXPERIMT_NO	INTEGER	Burke. Site expt. number (1-3).	179
FERT_B	INTEGER	Boron fertilizer rate, kg/ha.	0
FERT_FE	INTEGER	Iron fertilizer rate, kg/ha.	0
FERT_K	INTEGER	Potassium fertilizer rate, kg/ha.	0
FERT_MN	INTEGER	Manganese fertilizer rate, kg/ha.	0
FERT_N	INTEGER	Nitrogen fertilizer rate, kg/ha.	0
FERT_P	INTEGER	Phosphorus fertilizer rate, kg/ha.	0
FERT_S	INTEGER	Sulfur fertilizer rate, kg/ha.	0
FERT_ZN	INTEGER	Zinc fertilizer rate, kg/ha.	0

VARIABLE	DATA TYPE	BRIEF DATA DESCRIPTION	CASES W/DATA
FROST_FREE	INTEGER	Length of frost-free season, days.	184
GEOGRAPHIC	INTEGER	Burke.Geogr. location (1-4).	184
HZ_THICK_B	INTEGER	Burke.Thickness of B horizon.	169
MOIS_REGIME	INTEGER	Soil moisture regime code.	160
PE	INTEGER	Potential evapotranspiration,cm.	184
PRECIP_GROW	REAL(1)	Burke.Growing season precip.,cm.	117
SOILTEMP_APR	INTEGER	Burke.April soil temperature.	23
SOILTEMP_JUL	INTEGER	Burke. July soil temperature.	42
SOILTEMP_JUN	INTEGER	Burke. June soil temperature.	43
SOILTEMP_MAY	INTEGER	Burke. May soil temperature.	40
SOIL_THICK	INTEGER	Burke.Soil thickness code.	130
STRU_GR_AP	INTEGER	Burke.Structure grade,Ap horizon.	176
STRU_GR_B	INTEGER	Burke.Structure grade, B horizon.	152
STRU_GR_CCA	INTEGER	Burke.Structure grade,Cca horizon.	143
STRU_SZ_AP	INTEGER	Burke.Structure size,Ap horizon.	176
STRU_SZ_B	INTEGER	Burke.Structure size, B horizon.	152
STRU_SZ_CCA	INTEGER	Burke.Structure size, Cca horizon.	143
STRU_TY_AP	ALPHA(3)	Burke.Structure type,Ap horizon.	176
STRU_TY_B	ALPHA(3)	Burke.Structure type, B horizon.	152
STRU_TY_CCA	ALPHA(3)	Burke.Structure type, Cca horizon.	152
TAX_FAMTEMP	ALPHA(2)	Temp. textural family code,Burke.	0
TEMP_REGIME	INTEGER	Soil temperature regime code.	184
WC_AVAL_CODE	INTEGER	Burke. Avail. water-hold capac.	158
WC_SPR_TOT	REAL(1)	Burke.Total spring soil water,cm.	131
WC_SPR_V41	REAL(1)	Burke.Spring soil water,0-30 cm.	113
WC_SPR_V42	REAL(1)	Burke.Spring soil water,30-60 cm.	113
WC_SPR_V43	REAL(1)	Burke.Spring soil water,60-90 cm.	112
WC_SPR_V44	REAL(1)	Burke.Spring soil water,90-122 cm.	100
WC_SPR_V45	REAL(1)	Burke.Spring soil water,122-152 cm	67
WC_SPR_V46	REAL(1)	Burke.Spring soil water,152-183 cm	40
WC_SPR_V48	REAL(1)	Burke.Spring soil water,0-60 cm.	114
WC_SPR_V49	REAL(1)	Burke.Spring soil water,00-90 cm.	112
WC_SPR_V50	REAL(1)	Burke.Spring soil water,0-122 cm.	103
WC_SPR_V51	REAL(1)	Burke.Spring soil water,00-152 cm.	64
WC_SPR_V52	REAL(1)	Burke.Spring soil water,00-183 cm.	39
YLD_CROP	INTEGER	Crop yield data, in kg/ha.	184
YLD_PROTEIN	REAL(1)	Crop protein content (percent).	0
YLD_SEEDS	REAL(1)	Yield data,seeds per tiller.	0
YLD_TEST_WT	REAL(1)	Crop yield test wt.(wt/bushel).	0
YLD_TILLERS	REAL(1)	Yield data, tillers per meter.	0

Reed Sims' Thesis Variables (Data are contained in MT_NEWVARS.)

VARIABLE	DATA TYPE	BRIEF DATA DESCRIPTION	CASES W/DATA
BURKE_CASES	PACK	Bit var. 184 Burke thesis cases.	184
CA_MB	PACK	Bit variable for CaCO3 study cases.	52
CA_MB2	PACK	Bit variable for CaCO3 study cases.	489

VARIABLE	DATA TYPE	BRIEF DATA DESCRIPTION	CASES W/DATA
CA_STUDY	PACK	Bit variable for CaCO ₃ study cases.	135
DRAIN_INTG	INTEGER	Integer var. for drainage class.	5087
EFV_INTG	INTEGER	Integer var. for effervescence cl.	2898
JDN_CASES	PACK	O.M. study -sampled like Nichols'.	130
OM_STUDY	PACK	Bit variable for O.M. study cases.	195
ORD_INTG	INTEGER	Integer var. for soil order.	5978
SI_STUDY	PACK	Bit var.-chooses silty A-horizons.	2442

Appendix II

Useful Programs

The following programs may be useful for various Soilgrasp System operations. Each program listing identifies its purpose and is annotated to make adaptation to the user's specific needs easier. The programs are stored on rented magnetic tapes at MSU's Computing Services Center. A complete tape directory is maintained by the Soils Group, Plant and Soil Science Dept., MSU.

```

*****
*
*          PROGRAM COLUMNS
*
*  Program to edit column numbers in a GRASP invert file.
*  This program will successively increment the beginning and
*  ending column numbers of variables listed in the invert
*  file by a specified amount. Used to correct an invert
*  file or to make room between variables in an existing file
*  for new variables. Product is a new, updated invert file.
*
*  Author: R.Sims. 5 July 1984. Language: FORTRAN 77.
*
*****
*
*          Variables and their Definitions
*
*  A,B,C      Character variables for transferring parts of
*              updated lines to updated file.
*  DUMMY      Character variable which is used for transfer-
*              ring unneeded records to the updated file.
*  FIRST      Variable which holds the beginning column
*              number of a directory variable to be moved.
*  INCREMENT  Parameter defining the constant used to
*              increment the columns.
*  I,J        Do loop variables.
*  LAST       Variable which holds the ending column number
*              of a directory variable to be moved.
*  NUMREC     Parameter defining the number of records to
*              be updated.
*  SKIP       Parameter defining the number of records to
*              transfer before updating column numbers.
*
*****
*
CHARACTER DUMMY*91,A*34,B*4,C*50
INTEGER SKIP,NUMREC,INCREMENT,I,J
INTEGER FIRST, LAST

```

```

*   The parameters which can be changed:
*
*   PARAMETER(SKIP=104,NUMREC=283,INCREMENT=14)
*
*   Open the input and output files:
*
*   OPEN(UNIT=1,FILE='MTINVERT1',STATUS='OLD')
*   OPEN(UNIT=2,FILE='MTINVERT1_UPDATED',STATUS='NEW')
*
*   Transfer unneeded lines to updated file:
*
*   DO 10, I=1,SKIP
*       READ(1,5) DUMMY
*       WRITE(2,5) DUMMY
*   .5  FORMAT(A100)
* 10  CONTINUE
*
*   Read the records to update into variables:
*
*   DO 40,J=1,NUMREC
*       READ(1,20) A,FIRST,B,LAST,C
* 20  FORMAT(A34,I4,A4,I4,A50)
*
*   Add the constant to beginning and ending columns
*   for each record:
*
*       FIRST = FIRST + INCREMENT
*       LAST = LAST + INCREMENT
*
*   Check to see if there was anything in LAST before it
*   was incremented (that is, whether LAST equals the
*   increment value). If LAST was empty,do not transfer it
*   to the new, updated file:
*
*       IF(LAST .EQ. INCREMENT) THEN
*           WRITE(2,29) A,FIRST,B,C
* 29  FORMAT(A34,I4,A4,4X,A50)
*
*   If LAST had a value in it before incrementing, transfer it
*   along with the other variables into the new, updated file:
*
*       ELSE IF(LAST .GT. INCREMENT) THEN
*           WRITE(2,30) A,FIRST,B,LAST,C
* 30  FORMAT(A34,I4,A4,I4,A50)
*       END IF
* 40  CONTINUE
*
*   Close the files:
*
*   CLOSE(UNIT=1,STATUS='KEEP')
*   CLOSE(UNIT=2,STATUS='KEEP')
*
*   END

```

```

*****
*
*          PROGRAM SHRINK_VARIABLES
*
*   Program to shrink the column-width of any number of simi-
*   lar and consecutive variables in a GRASP invert file. A
*   limitation is that the program requires variables to be
*   of identical column widths within a single block.
*
*   Author: R. Sims.   Language: FORTRAN 77   August, 1984
*
*****
*
*   Variables and their Descriptions:
*
*   BEGIN,END   Beginning and ending column numbers.
*   I,J,K       Increment variables in loops.
*   REPEATS     Number of records to be changed.
*   SKIP        Number of records to transfer as-is to output
*               file, before working on the block needing
*               changes.
*   WIDTH       Width of each variable in columns, minus one
*               for the starting column.
*   A,B         Variables used for data to be transferred as-
*               is to output file within records to be
*               changed.
*   LINE        Length of each record of data.
*   LEFTOVERS   Number of records, after all column changes
*               have been made, to end of file. These
*               records are transferred as-is to output file.*
*
*****
*
*   CHARACTER A*34,B*47,LINE*95
*   INTEGER BEGIN,END,REPEATS,SKIP,LEFTOVERS,I,J,K,WIDTH
*   PARAMETER(WIDTH=3,SKIP=847,REPEATS=183,LEFTOVERS=15)
*
*   Open input and output files:
*
*   OPEN(UNIT=1,FILE='MTINVERT1',STATUS='OLD')
*   OPEN(UNIT=2,FILE='MTINVERT_CORRECTED',STATUS='NEW')
*
*   Transfer unchanged data to output file:
*
*   DO 30 I=1,SKIP
*       READ(1,10) LINE
*       WRITE(2,10) LINE
*   10  FORMAT(A95)
*   30  CONTINUE

```

```
*      Read the first record to get the beginning column no. and
*      write it to output file:
*
      READ(1,40) A,BEGIN,B
40  FORMAT(A34,I4,8X,A47)
*
      END = BEGIN + WIDTH
*
      WRITE(2,50) A,BEGIN,END,B
50  FORMAT(A34,I4,' TO ',I4,A47)
*
      Now correct the column no's of all other variables to be
      changed and write the corrected records to output file:
*
      DO 80 J=2,REPEATS
*
          READ(1,60) A,B
60  FORMAT(A34,12X,A47)
*
          BEGIN = END + 1
          END = BEGIN + WIDTH
*
          WRITE(2,70) A,BEGIN,END,B
70  FORMAT(A34,I4,' TO ',I4,A47)
*
80  CONTINUE
*
      Transfer remaining lines in file to output file:
*
      DO 90 K=1,LEFTOVERS
          READ(1,10) LINE
          WRITE(2,10) LINE
90  CONTINUE
*
      Close input and output files:
*
      CLOSE(UNIT=1,STATUS='KEEP')
      CLOSE(UNIT=2,STATUS='KEEP')
      CLOSE(UNIT=3,STATUS='KEEP')
      CLOSE(UNIT=4,STATUS='KEEP')
*
      END
```



```

*****
*
*                               PROGRAM SETTY5B_RECODE
*
*   Program to recode the structure, textural class and
*   textural family variables in Tom Burke's thesis data.
*
*   Author: R.Sims  Language: FORTRAN 77  June,1984
*
*****
*
*   Variables and their descriptions:
*
* A,B,C,D      Filler variables to transfer data to new file.
* REPEATS      Parameter:no. of times do-loop is to be repeated.
* V14,V17,V20   Structure - grade variables.
* V15,V18,V21   Structure - size variables.
* V16,V19,V22   Structure - type variables.
* V23          Ap texture variable.
* V24          Textural family of B or Cca horizon.
* V??A         Output variable corresponding to original
*              input variable.
*****
*
*   CHARACTER A*60,B*7,C*80,D*80
*   CHARACTER*1 V14,V15,V16,V17,V18,V19,V20,V21,V22,V23,V24
*   CHARACTER*1 V14A,V17A,V20A,V15A*2,V18A*2,V21A*2
*   CHARACTER*3 V16A,V19A,V22A,V23A*5,V24A*5
*   INTEGER REPEATS,I
*   PARAMETER (REPEATS=184)
*
*   Open the input and output files:
*
*   OPEN(UNIT=1,FILE='SETTY5B',STATUS='OLD')
*   OPEN(UNIT=2,FILE='SETTY5B_VERSION2',STATUS='NEW')
*
*   Loop to successively read,recode, and transfer 3 lines
*   at a time
*   DO 30 I=1,REPEATS
*       READ(1,10) A,V14,V15,V16,V17,V18,V19,V20,V21,V22,V23,V24,
*       & B,C,D
*   10  FORMAT(A60,9A1,X,A1,X,A1,A7/A80/A80)
*
*       IF(V14 .EQ. '1') V14A='3'
*       IF(V14 .EQ. '2') V14A='5'
*       IF(V14 .EQ. '3') V14A='7'
*       IF(V14 .EQ. ' ') V14A=' '
*       IF(V17 .EQ. '1') V17A='3'
*       IF(V17 .EQ. '2') V17A='5'
*       IF(V17 .EQ. '3') V17A='7'
*       IF(V17 .EQ. ' ') V17A=' '
*       IF(V20 .EQ. '1') V20A='3'

```

```

IF(V20 .EQ. '2') V20A='5'
IF(V20 .EQ. '3') V20A='7'
IF(V20 .EQ. ' ') V20A=' '
IF(V15 .EQ. '1') V15A='14'
IF(V15 .EQ. '2') V15A='19'
IF(V15 .EQ. '3') V15A='23'
IF(V15 .EQ. ' ') V15A=' '
IF(V18 .EQ. '1') V18A='14'
IF(V18 .EQ. '2') V18A='19'
IF(V18 .EQ. '3') V18A='23'
IF(V18 .EQ. ' ') V18A=' '
IF(V21 .EQ. '1') V21A='14'
IF(V21 .EQ. '2') V21A='19'
IF(V21 .EQ. '3') V21A='23'
IF(V21 .EQ. ' ') V21A=' '
IF(V16 .EQ. '1') V16A='PL'
IF(V16 .EQ. '2') V16A='PR'
IF(V16 .EQ. '3') V16A='COL'
IF(V16 .EQ. '4') V16A='ABK'
IF(V16 .EQ. '5') V16A='SBK'
IF(V16 .EQ. '6') V16A='GR'
IF(V16 .EQ. '7') V16A='MA'
IF(V16 .EQ. '8') V16A='SGR'
IF(V16 .EQ. ' ') V16A=' '
IF(V19 .EQ. '1') V19A='PL'
IF(V19 .EQ. '2') V19A='PR'
IF(V19 .EQ. '3') V19A='COL'
IF(V19 .EQ. '4') V19A='ABK'
IF(V19 .EQ. '5') V19A='SBK'
IF(V19 .EQ. '6') V19A='GR'
IF(V19 .EQ. '7') V19A='MA'
IF(V19 .EQ. '8') V19A='SGR'
IF(V19 .EQ. ' ') V19A=' '
IF(V22 .EQ. '1') V22A='PL'
IF(V22 .EQ. '2') V22A='PR'
IF(V22 .EQ. '3') V22A='COL'
IF(V22 .EQ. '4') V22A='ABK'
IF(V22 .EQ. '5') V22A='SBK'
IF(V22 .EQ. '6') V22A='GR'
IF(V22 .EQ. '7') V22A='MA'
IF(V22 .EQ. '8') V22A='SGR'
IF(V22 .EQ. ' ') V22A=' '
IF(V23 .EQ. '1') V23A='FSL'
IF(V23 .EQ. '2') V23A='L'
IF(V23 .EQ. '3') V23A='SIL'
IF(V23 .EQ. '4') V23A='SICL'
IF(V23 .EQ. '5') V23A='CL'
IF(V23 .EQ. '6') V23A='C'
IF(V23 .EQ. ' ') V23A=' '
IF(V24 .EQ. '1') V24A='080'
IF(V24 .EQ. '2') V24A='096'
IF(V24 .EQ. '3') V24A='106'

```

```
      IF(V24 .EQ. '4') V24A='12637'  
      WRITE(2,20) A,V14A,V15A,V16A,V17A,V18A,V19A,V20A,V21A,  
      &          V22A,V23A,V24A,B,C,D  
20    FORMAT(A60,A1,A2,A3,A1,A2,A3,A1,A2,A3,X,A5,X,A5,  
      &          A7/A80/A80)
```

```
*  
30 CONTINUE  
*  
*    Close the input and output files:  
*  
      CLOSE(UNIT=1,STATUS='KEEP')  
      CLOSE(UNIT=2,STATUS='KEEP')  
*  
      END
```

```

*****
*
*          PROGRAM BURKE_SETTY5B_MERGE
*
*   Program to concatenate two data files of Tom Burke's
*   thesis, line by line, into a new file, and add a key no.
*   The variables will be output in a format compatible with
*   that of the Montana Pedon Data as shown in MTINVERT.
*
*   Author: R.Sims. 15 July, 1984. Language: FORTRAN.
*
*****
*          Variables and their descriptions
*
*   V1,V2,V3      Character string variables to be used in trans-
*                  ferring data from input to output files.
*   V23           Textural class.
*   VO6TO22       Block of variables in SETTY5B_NEW to be trans-
*                  ferred to output file (variables not included
*                  in MTINVERT).
*   V33TO56       Block of more new variables to be transferred to
*                  output file.
*   ELEV          Elevation-will be moved.
*   SLOPE         Pct. slope in old format.
*   SLPPCT        Pct. slope in new format.
*   SLPASPECT     Aspect of site.
*   TEMP          Soil temperature in old format.
*   SOILTEMPAVE   Soil temperature in new format.
*   NOHORIZONS    Number of horizons delineated.
*   QUARTERS      Quarter sections for site description.
*   LEGALDESCR    Legal description for the site to section.
*   EXP           Experiment number-will be moved.
*   I             Do loop variable.
*   REPEATS       Parameter indicating the number of loop repeats.
*   KEY           Key no. to be output in the first 5 columns of
*                  the new file.
*   PREVKEY       Used to store the former record's key no. for
*                  incrementing purposes within the loop.
*
*****
*
*   CHARACTER V1*28,EXP*1,V2*35,V3*20,V23*5,QUARTERS*8
*   CHARACTER LEGALDESCR*10,VO6TO22*68,V25TO27*7,V33TO56*86
*   INTEGER KEY,ELEV,SLPPCT,SLPASPECT,SOILTEMPAVE,NOHORIZONS
*   REAL SLOPE,TEMP
*   INTEGER I,REPEATS,V03
*   PARAMETER(REPEATS=184)
*
*   Open the input and output files:
*
*   OPEN(UNIT=1,FILE='BURKE_SITEDATA',RECL=300,STATUS='OLD')
*   OPEN(UNIT=2,FILE='SETTY5B_VERSION3',RECL=350,STATUS='OLD')

```



```
-----
      OPEN(UNIT=3,FILE='BURKE_MASTER',RECL=4000,STATUS='NEW')
*
*   Initialize the key variables:
*
      PREVKEY=09500
      KEY=0
*
      DO 40 I=1,REPEATS
*
*   Increment the output key variable:
*
      KEY = PREVKEY + 1
      PREVKEY = KEY
*
      READ(1,10) V1,EXP,V2,V3,NOHORIZONS,QUARTERS,LEGALDESCR
10  FORMAT(10X,A28,A1,3X,A35,19X,A20,63X,I2,18X,A8,A10)
*
      READ(2,20) V03,V06TO22,V23,V25TO27,ELEV,SLOPE,SLPASPECT,
&              TEMP,V33TO56
20  FORMAT(4X,I1,4X,A68,X,A5,6X,A7,X,I4,X,F2.1,X,I1,5X,
&              F3.1,X,A86)
*
*   Recode variables "SLOPE" and "TEMP" to the MTINVERT format,
*   and make two new output variables with correct format:
*
      SLPPCT = NINT(SLOPE)
      SOILTEMPAVE = NINT(TEMP)
*
*   Write all vars. except those in "old" format to output file
*
      WRITE(3,30) KEY,V1,V2,ELEV,SLPPCT,SLPASPECT,V3,SOILTEMPAVE,
&              NOHORIZONS,V23,QUARTERS,LEGALDESCR,EXP,V03,
&              V06TO22,V25TO27,V33TO56
*
30  FORMAT(I5,'-00',2X,A28,4X,A35,I4,I2,3X,I1,9X,A20,34X,I2,
&              27X,I2,573X,A5,980X,A8,A10,1589X,A1,I1,A68,A7,A86)
40  CONTINUE
*
*   Close input and output files:
*
      CLOSE(UNIT=1,STATUS='KEEP')
      CLOSE(UNIT=2,STATUS='KEEP')
      CLOSE(UNIT=3,STATUS='KEEP')
      END
```

Appendix III

How To Start Using the System

This appendix gives steps you will need to begin using the Soilgrasp System.

1. You must have access to a terminal with a phone modem. Through the modem you will dial one of several phone numbers to gain access to MSU's Honeywell Level 66 ("CP-6") mainframe. These numbers may be obtained from the MSU Computing Services Center. Most terminals can communicate with this computer. Some terminals on the MSU campus are hard-wired into the computer. With these, no modem or phone is necessary.
2. You must set up an account on CP-6. The Computing Services Center will work with you to open the account and can provide information about logging onto (entering) the computer. The log-on procedures appear to be complicated, but are essential for CP-6 to determine certain parameters of your terminal, such as how fast it can send and receive data. You also give CP-6 the "profile" of your terminal, from which CP-6 assumes even more about how to communicate with it. The proper profile can be obtained from the Center.

When you set up the account, you need to tell the Center that you will be accessing GRASP, and therefore will require 128 Kilobytes of online memory (the normal limit is 100 K). Without this extra memory, GRASP will not run.

Your CP-6 account is independent of any particular terminal profile. In other words, you can use any terminal to get into your account.

3. Once you have logged onto CP-6, you are free to use many of the programs available. CP-6 prompts you for new commands with a symbol. The "!" symbol is its operating system prompt. Other programs use different symbols for their prompts. You will start from this prompt whenever you wish to enter the Soilgrasp System. Several steps are taken when you are ready to use the Soilgrasp System.

First, you must exit your own account's directory to enter the one containing all Soilgrasp System files. This takes two commands. Since these files are stored on a rented hard diskpack, this diskpack must be mounted on a disk drive. From your terminal, type:

```
!M PLEASE MOUNT DP#SOILS, SHARED
```

You would not type the exclamation point, since the computer gives you that as the prompt. This statement sends a message to the computer operators. They will mount DP#SOILS (the SOILS diskpack) when they can, usually within 10-15 minutes.

The diskpack directory can then be accessed by typing:

```
!DIRECTORY DP#SOILS.ISS005
```

You know that the diskpack has been mounted when your command,

```
!LIST
```

brings up a listing of files instead of the statement, "DP#SOILS is not ready for use."

4. The next step is to access the Soilgrasp System. If you wish to use SOILGRASP, the user interface program, type:

```
!SOILGRASP.
```

The dot (period) at the end is necessary. SOILGRASP is a compiled and linked FORTRAN 77 program, and typing the dot indicates this to CP-6.

From this point, SOILGRASP will guide you.

5. Sampling can only be done directly with GRASP at this writing. Therefore, you need to know how to access GRASP interactively. A series of commands gets you into GRASP and declares which directory and data files to use. Those commands are as follows:

```
!ORES MEM=128
!GRASP.USDGRASP
?DATA:MT_SIHZ,MT_LAB,MT_VEG,MT_YIELD,MT_NEWVARS
?DIRECTORY:MTDIRECTORY
?SAMPLE:ALL
```

This puts you into the database. Your sampling commands may then be entered. Sampling is described in Section 2 of this manual, and in the GRASP Users Manual (Allard,1981).

6. If you plan to use the SOILGRASP interface after choosing your sample, you can create a bit variable which will select for the sites in your sample. You name the variable and it is created out on disk in a file of its own. The command,

```
?CREATE (FILE, REED ISS005 OUT) BIT: REED:=1
```

will create the variable REED, in a data file of the same name, which can then be used to select for a specific sample. Cases in the sample have a "1" for this variable, but all other cases have a "0".

When you use SOILGRASP later on, you will tell it to select the sample using the new variable. Your first name or initials are a good choice for the file's name. Note that before you can use such a file, it must be declared, or

opened, as one of the data files to be accessed. Typing the statement,

!DATA: MT_SIHZ,MT_LAB,REED

would open the file REED as well as two of the other Soilgrasp System data files. This type of statement can be given at any time in a session to change the data files that are accessed.

7. For information on what commands are available after the sample is chosen, consult the GRASP Command Summary (Section 4 of this manual). At the end of a session, the command,

?STOP

will allow you to exit from GRASP.

Appendix IV

Record of Database Updates

Adequate records of changes to the Database must be maintained to ensure that users are informed of the updates. This record will help us track down any problems in the system, and will allow users to take advantage of corrections and new data. The record is organized into forms, with two forms per page. A new form should be used for each change in the database.

Several types of database changes should be entered into this record. Some of these are:

- 1) A variable's name is changed permanently.
- 2) A data or directory file's name is changed permanently.
- 3) The number of cases with valid data for a certain variable has been increased or decreased.
- 4) A new, permanent variable has been created from existing ones.
- 5) A new variable has been added from outside the database.
- 6) A variable has been deleted from the database.
- 7) New cases have been added to the database.
- 8) The tapes storing backup copies of the database have been replaced by others with different numbers and/or densities.

Description of Entries on the Update Record Form

Effective date: the date from which changes, deletions or additions are effective.

Name: the name of the person or persons who made the changes.

Files affected:

Directory: the database directory file which contains the updated variable information.

Data: the file containing new data, changed data, or the data for a deleted variable.

Variable affected: the variable which has been added from outside the database, deleted from the database, or created using other variables already existing in the database.

Define: enter a short definition or description of the variable.
This should be 40 characters or less and should be the same as the definition in the database directory.

Cases affected: if all cases in the database have been affected, check "all". If only a few (e.g. A-horizons; BLM cases) are affected, check "some" and describe which ones, using the KEY (KEY is a variable; it is a unique identifier for a case).

Description of update: enter here a description of the changes that were made in this database update. Mention its implications to the user.

GRASP commands used: mention only the GRASP keywords used. This is necessary for tracking down errors or recovering from a faulty update.

Changes backed up?: check here only if the directory, data files and user dictionary have all been backed up onto magnetic tape and old copies are no longer accessible (either deleted or archived).

B.date: enter here the date you were satisfied that all back-up procedures were successfully completed.

Tape no.: the number (e.g. LT#0789) of the Labeled Tape upon which the database has been backed up. Include all tapes, if more than one.

Density: enter here the recording density used when making the backup tapes.

Rented;User-owned: check rented if the backup tape is rented from MSU's Computing Center. Check user-owned if the tape has been purchased, and is stored somewhere besides the Computing Center.

Location: where the backup tape is stored.

DATABASE UPDATE RECORD

Effective date _____ Name _____

Files affected: _____
 Directory Data

Variable affected: _____ define _____
 __added __deleted __created from other variables

Cases affected: __all __some:define _____

Description of update: _____

GRASP commands used: _____

____Changes backed up? B.date _____ Tape no. _____ density _____
Tape: __Rented __User-owned Location _____

Note: Be sure to adjust the user-dictionary to reflect changes.

DATABASE UPDATE RECORD

Effective date _____ Name _____

Files affected: _____
 Directory Data

Variable affected: _____ define _____
 __added __deleted __created from other variables

Cases affected: __all __some:define _____

Description of update: _____

GRASP commands used: _____

____Changes backed up? B.date _____ Tape no. _____ density _____
Tape: __Rented __User-owned Location _____

Note: Be sure to adjust the user-dictionary to reflect changes.

DATABASE UPDATE RECORD

Effective date _____ Name _____

Files affected: _____
 Directory Data

Variable affected: _____ define _____
__added __deleted __created from other variables

Cases affected: __all __some:define _____

Description of update: _____

GRASP commands used: _____

__Changes backed up? B.date _____ Tape no. _____ density _____
Tape: __Rented __User-owned Location _____

Note: Be sure to adjust the user-dictionary to reflect changes.

DATABASE UPDATE RECORD

Effective date _____ Name _____

Files affected: _____
 Directory Data

Variable affected: _____ define _____
__added __deleted __created from other variables

Cases affected: __all __some:define _____

Description of update: _____

GRASP commands used: _____

__Changes backed up? B.date _____ Tape no. _____ density _____
Tape: __Rented __User-owned Location _____

Note: Be sure to adjust the user-dictionary to reflect changes.



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S158 Development and use of
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