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THE DEVELOPMENT OF THE
COMPUTERIZED GEOTECHNICAL
DATA BANK FOR THE STATE OF
INDIANA

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16. Abstract A computerized, user-oriented, information storage and retrieval system for geological, pedological and geotechnical engineering information has been developed. The computerized data system is flexible so that changes can be made easily as the requirements of users become more clearly defined. A complete instructional User's Manual has been prepared compatible with the present requirements and needs of the Indiana State Highway Commission and the Joint Highway Research Project at Purdue University. The computerized data bank should facilitate efficient and economical handling of geotechnical information from the State of Indiana. The application of statistical methods to the geotechnical data stored to January, 1978 is promising. The grouping of soils by physiographic regions and parent material areas is justified for the prediction of some difficult-to-determine soil parameters from soil properties which are easier to determine. The groups of soils and soil parameters which provide acceptable correlations must be examined on a case by case basis.			
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Interim Report

THE DEVELOPMENT OF THE COMPUTERIZED GEOTECHNICAL
DATA BANK FOR THE STATE OF INDIANA

TO: J. F. McLaughlin, Director
Joint Highway Research Project

FROM: H. L. Michael, Associate Director
Joint Highway Research Project

June 1, 1978

Project: C-36-51T

File: 1-5-20

Attached is an Interim Report on the HPR, Part I Study entitled "A Computerized Information Storage and Retrieval System for the Soils of Indiana". It has been authored by Mr. Gary D. Goldberg, Graduate Instructor in Research on our staff, under the direction of C. W. Lovell and R. D. Miles of our staff.

The report presents the results from the development of the geotechnical data bank for the State of Indiana. A complete instructional User's Manual is included which describes the details of the system. The application of statistical methods to the geotechnical data stored to January, 1978, is promising. The collection of additional soils data is in progress. The application of advanced statistical methods of new input data is expected.

The report is submitted as partial fulfillment of the objectives of the Study. Copies of the report will also be submitted to ISHC and FHWA for their review, comment and similar acceptance.

Respectfully submitted,

Harold L. Michael
Associate Director

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Interim Report

THE DEVELOPMENT OF THE COMPUTERIZED GEOTECHNICAL
DATA BANK FOR THE STATE OF INDIANA

by

Gary D. Goldberg
Graduate Instructor in Research

Joint Highway Research Project

Project No.: C-36-51T

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Prepared as Part of an Investigation

Conducted by

Joint Highway Research Project
Engineering Experiment Station
Purdue University

in cooperation with the

Indiana State Highway Commission
and the
U.S. Department of Transportation
Federal Highway Administration

The contents of this report reflect the views of the author who is responsible for the facts and the accuracy of the data presented herein. The contents do not necessarily reflect the official views or policies of the Federal Highway Administration. This report does not constitute a standard, specification, or regulation.

Purdue University
West Lafayette, Indiana
June 1, 1978

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NOMENCLATURE

AASHTO	American Association of State Highway and Transportation Officials
CBR	California bearing ratio
CBRS01	soaked California bearing ratio at 100 percent of standard Proctor maximum dry density
CBRS02	soaked California bearing ratio at 95 percent of standard Proctor maximum dry density
C_c	coefficient of concavity
C_c	compression index
CDC	Control Data Corporation
C_r	compression ratio
C_u	coefficient of uniformity
DIF	Data Input Form
e_o	initial void ratio
g_1	skewness
g_2	kurtosis
I_p	plasticity index
ISHC	Indiana State Highway Commission
L_I	liquidity index
N	number of samples
p_c	preconsolidation pressure
p_o	overburden pressure
PUCC	Purdue University Computing Center

q_u	unconfined compressive strength
r^2	coefficient of determination
R^2	coefficient of multiple determination
R_a^2	adjusted coefficient of multiple determination
s	standard deviation
s^2	variance
SPSS	Statistical Package for the Social Sciences
SPT	Standard Penetration Test
USCS	Unified Soil Classification System
USDA	United States Department of Agriculture
V	coefficient of variation
w_L	liquid limit
w_n	natural moisture content
w_{opt}	optimum moisture content
w_p	plastic limit
w_s	shrinkage limit
$\bar{x}$	mean
γ_d	natural dry density
$\gamma_{d_{max}}$	standard Proctor maximum dry density
$\gamma_{m_{max}}$	standard Proctor maximum wet density

HIGHLIGHT SUMMARY

A computerized information storage and retrieval system has been developed to include geological, pedological and geotechnical engineering information from the State of Indiana. A User's Manual describes the details of the system and instructs in its use. Data are being collected for inclusion into the system from private consulting firms and private soil testing firms, as well as from tests conducted by the Division of Materials and Tests of the Indiana State Highway Commission (ISHC).

Such information is transmitted to the ISHC in subsurface investigation reports, containing data from both laboratory tests and field surveys. As of January, 1978, a total of 2508 data sets have been stored within the system. It is anticipated that an additional 6000 data sets will be stored by December, 1978, when the ISHC will assume full responsibility for maintenance and operation of the geotechnical data bank.

Various statistical methods have been applied to the data. Results indicate that the range in values to be expected for a given soil parameter depends on the particular physical property and on the population from which the soil has been sampled. Some soil properties appear to be

inherently more variable than others. The grouping of soils by physiographic regions and/or the origin of their parent material suggests that the predicability of some parameters can be improved for certain combinations of parameters and soil groups, but not others.

Specifically, prediction equations have been generated for compression index (C_c) and compression ratio (C_r) from simple-to-determine soil measures for: (a) all test data, (b) for the soils from the Wabash Lowland physiographic unit and (c) for Crawford Upland physiographic unit soils. Additionally, soils derived from outwash and alluvial deposits produced acceptable regression models for C_c .

Valid regression equations have also been developed for the unconfined compressive strength (q_u) for soils from the Calumet Lacustrine Plain and soils derived from lacustrine deposits. It is also possible to predict compaction test values, standard Proctor maximum dry and wet densities and optimum moisture content for (a) soils from the Valparaiso Morainal area and (b) soils derived from residuum of limestone bedrock.

INTRODUCTION

The need for geological, pedological and geotechnical engineering information for use in site selection, planning, design, construction, and maintenance of transportation facilities and of most engineering structures is widely realized. Much of the information initially required by the engineer is used in preliminary construction planning, site selection and for guidance in further soil investigations. Unfortunately, most of these data are necessarily limited in quantity due to economic and time constraints.

The engineer is therefore faced with the problem of determining the location, sequence, thickness, and areal extent of each soil stratum, including a description and classification of the soils and their structure, by extrapolating the data from a few selected sites to an area many times greater than that which has been sampled. Even though large amounts of detailed soils data are available from work performed during planning and construction of adjacent and nearby projects, these data are usually not readily accessible for use, or their existence is unknown.

The accumulation of laboratory and field testing data for characterizing the engineering properties of Indiana soils is extensive. An enormous amount of data, collected

2

and stored from highway projects within the State of Indiana over the last 20 years, has been retained in the form of subsurface investigation reports. These reports have been prepared by private consulting firms and governmental agencies from routine soil investigations. In their bulky, voluminous form, the majority of these data are not very useful.

The need therefore exists to make this information more accessible both for the engineer interested in detailed information of a site and the engineer interested in general soil characteristics over a large area. A computerized geotechnical data bank was judged to be the most efficient, expedient, and economical way to reduce the accumulated data to a form which could readily be made available to interested individuals, such as highway engineers, geotechnical engineers, contractors, land use planners, the Soil Conservation Service, and universities throughout the State.

Purpose

It is the purpose of this study to develop a user-oriented, dynamic information storage and retrieval computer system for geotechnical data. People without a computer programming background should be able to use the system with a minimum amount of instruction. In addition to being user-oriented, the system should also be flexible so that changes can be made easily as the requirements of users become more clearly defined.

The collection of large amounts of soils test data and the fact that most natural soil deposits are highly variable in both horizontal and vertical directions, justifies the use of a statistical approach (31, 32, 33)¹. This study also attempts to evaluate, in a preliminary way, some of the methods by which the engineering properties of the soils of Indiana may be characterized and predicted.

Scope

Data are being collected for inclusion into the geotechnical bank from private consulting firms, private soil testing firms, as well as from tests conducted by the Division of Materials and Tests of the Indiana State Highway Commission (ISHC). Information is reported to the ISHC in subsurface investigation reports, containing data from both laboratory tests and field surveys. Pedologic soils information is also being collected.

Since no standard procedure was required for reporting the results from subsurface investigations before the mid 1960's, the manner of presentation and the information which was reported, are dependent upon the source of such information. A User's Manual has been prepared describing the details of the system and instructions on the use of the computerized geotechnical data bank.

¹ Numerals in parentheses refer to entries in the Bibliography

Over twenty-five hundred sets of data have been collected as of this date (January, 1978). These data sets have subsequently been stored within the data bank and subjected to various methods of statistical analyses. These analyses have included soil characterizations and formulations of correlation and prediction equations. Figure 1 shows the representative counties with the State from which the data have been collected and the soil characterizations, correlations and predictions, generated.

The Concept of a Geotechnical Data Bank

Large amounts of geotechnical information for transportation projects are accumulated each year by highway departments throughout the United States and abroad. Geotechnical investigations are conducted to provide surface and subsurface information relative to soil, rock, and water. This information is used in selecting the proper locations for the project and in making design decisions (17, 64). Subsequent use of this information after the design and construction of a project from which soil samples were taken and geotechnical data generated, has been limited (22, 63).

The State of South Dakota realized the value of extensive soils data which had been accumulated in that state over many years (8). It was recognized that expensive soil testing programs were being conducted on new routes which closely paralleled old routes on which extensive soil testing had been previously undertaken. A study was consequently

FIGURE 1 COUNTY DATA SOURCES

inaugurated in 1965 with the main goal of finding a way of using the large amount of past soil testing experience on new highway locations.

In cooperation with the Soil Conservation Service in South Dakota, the South Dakota Department of Highways began a program to determine the pedological soil series name represented by each highway soil profile. This effort may have been suggested by previous work in Indiana (2) and Michigan (38). Engineering data and the project and location information for each sample site were determined. The project number, stationing, offset, depth, gradation, liquid limit, plasticity index, maximum density, optimum moisture content, and color of each soil sample were then placed on computer punch cards. Each soil sample was then classified according to several methods of soil classification, viz., the American Association of State Highway and Transportation Officials (AASHTO) system, the Unified Soil Classification System (USCS) and a textural classification system.

The data were then sorted and subjected to various methods of statistical analyses. One method of reducing the vast amount of data to a concentrated yet meaningful form was to develop sample distribution curves for each soil series based upon any one of the many engineering characteristics. One such curve has been reproduced and shown in Figure 2. Figure 3 has also been reproduced from the South Dakota report (8) to demonstrate an attempt to use the soil test data to determine the California bearing ratio (CBR)

FIGURE 2 SAMPLE DISTRIBUTION CURVE FOR HOUEK SERIES, C HORIZON
(ADAPTED FROM CRAWFORD et al. (8))

Curve No. 1

Note: Points on curve are the average CBR's for each 5 point increment of liquid limit for the soil classification as listed. A total of 136 CBR tests were used to develop the curve.

CBR and Liquid Limit relationship are not applicable to granular soils (the A1, A2, A3 and sub-groups of these classifications)

FIGURE 3 CALIFORNIA BEARING RATIO - LIQUID LIMIT CURVE (ADAPTED FROM CRAWFORD et al. (8))

from the results of a much easier and more economical liquid limit determination.

In 1976, the Kentucky Department of Transportation published a report that discussed the development of a computerized soils data system for highway projects (56). The purpose of this system was to facilitate the collection, centralized storage, and retrieval of soils data from highway and other engineering projects within Kentucky.

The soils data system in Kentucky is divided into collection, storage, and retrieval subsystems. The type of data being collected can be grouped into four categories: (1) raw data, (2) basic data, (3) derived data, and (4) descriptive data. A brief description of this information follows (56):

"Raw data are measurements such as wet weight, dry weight, temperature, and hydrometer reading that must be recorded to find the basic soil characteristics...

"Basic data are the soil characteristics and properties, such as density, moisture content, specific gravity, and percent of material passing a certain sieve, found by mathematically manipulating the raw data. Some independently meaningful data, such as amount of swell of a sample, are measured directly and could be called either raw or basic data...

"Derived data are deduced from known mathematical and empirical relationships, using the raw and (or) basic data. Examples of derived data include maximum density, optimum moisture, textural classification, liquid limit, and California Bearing Ratio. Derived data could also be called summary data since it (sic) summarizes soil characteristics and properties...

"Descriptive data are not found by laboratory or field tests as are other types of data. They are very important, however, since they directly or indirectly indicate, affect, or locate the soils. They include geographic location, depth, color, bedrock, and soil series name."

Some of the data which were collected were not suitable for direct computer storage. An extensive codification system was consequently devised by the Kentucky Department of Transportation. Due to the completeness of the coding system and its applicability to soils information in general, some of the details of the coding system were adopted in this research (see Appendix C).

Wlaschin (69) reports that the West Virginia Department of Highways has adopted a computerized system whereby boring log information is directly placed onto computer cards in the field. Laboratory data are added to the storage system when the cards are returned to the engineer's office. A complete description of the operation of the system is not available as of this date, and only a rough draft of the preliminary user's manual was reviewed.

Sweden has also developed a system of computer banks for geotechnical data (34). As stated in the English summary of the final report:

"Data deriving from soil surveys is a type of information which never becomes obsolete or out-of-date. Nevertheless, each year vast amounts of the source data disappear through mismanagement of records. This mismanagement takes the form of scattering data throughout the files of Government offices, local authorities, consultants, contractors, and many others to remain in obscurity and often inaccessible."

In Finland and Denmark, computer techniques are to a certain extent used for plotting soil sounding data (34). Spradling (56) states that in France, the Lille Regional Laboratory has prepared a card index system for retrieving boring and soils test data (30). And in Southern Rhodesia (20)

and Algeria (47) large scale mapping programs are under way. The Department of Natural Resources, Province of Quebec, has developed a system for storing and retrieving field information. Canada is also building a national index for all geological data, while making major inventories of existing materials (29, 34).

South Africa has also done extensive work in this area. The objective of their work is to develop a data bank for constructional materials (64). The project is still under way and a final report is not yet available (58).

Benefits of a Geotechnical Data Bank

The benefits which can be obtained from the development of a computerized geotechnical data storage and retrieval system can be divided into two major categories: (a) the direct use of raw data; and (b) the use of statistical methods to reduce the data to a usable form via distribution characterizations, correlations, and predictions. Other uses of the computerized data system can be realized and are mentioned briefly with citations of reference literature.

Direct Use of Raw Data

A computerized geotechnical data bank provides the capability of retrieving an extensive listing of available soil and rock information both quickly and economically. For instance, the location of a selected soil type from a specific geographic location may be used to develop preliminary sources of information for initial site investigations (56).

Rapid inventories and summary tables of soil characteristics for use in town, building, and long range land use planning are also possible (34). With the production of a summary of available soils data, the location of possible sources of granular and select borrow materials could be facilitated, along with route selection studies and right-of-way appraisals. In addition, the compilation of large scale engineering soil maps and profiles based on engineering characteristics is possible (8).

As previously mentioned, the objectives of the South African work include the collection of information about constructional materials for inclusion in a data bank. Specifically, this will help to locate constructional materials more readily, to inform of expected subgrade conditions, to warn of construction hazards and to aid in route location, assisted by soil engineering maps (5, 6).

Deen (10), as referenced by Spradling (56), and Sisiliano (52), Witczak (68), and Roberts (50), studied the regional or physiographic approach to soil characterizations with the objectives of demonstrating the ability to recognize certain areas potentially troublesome with regard to engineering performance of soils. Sisiliano concluded:

"The Physiographic Subdivision Approach outlined in this study can lead to meaningful and worthwhile implications and conclusions for use in the preliminary stages of planning, route location and design of modern highway facilities in the State of Indiana."

However, Sisiliano further concluded that landform or parent material areas would provide the best basis for generalizations of soil behavior in Indiana.

McKittrick (37) showed that subsurface investigation costs were related to physiographic units in Indiana. Kreig (26) described the applicability of the correlation approach to work in Alaska on the Trans-Alaska pipeline. A tremendous amount of data (34,000 samples from 3,500 soil borings) were collected and subsequently stored in a computer-based data bank. Specifically, boring location (by centerline and offset), sample depths and type of sample, water table depth, permafrost encountered, and laboratory test results for each sample (Unified classification, moisture content, dry density, specific gravity, thaw settlement test results, etc.) were stored in the Alyeska data bank (27). The landform type was also included with the sample data. Summaries of the soils information were prepared. Kreig (26) writes:

"Summaries could be prepared for a quantitative picture of the natural variation in critical soil characteristics for each landform.

"Such data bank summaries were useful for many purposes including the comparison of conditions in different landforms and the allocation of exploration expenditures. For example, the number of boreholes made during field programs was usually limited due to high costs and difficult access problems. The drilling program was more efficiently planned using the known variability of different landforms so that few holes were drilled in the uniform landforms and more holes were programmed for highly variable landforms. Had the drilling program been predicted on uniform spacing without regard to landform, exploration expenditures would have been used inefficiently. Once the properties of a landform were fairly well known, preliminary soil studies in new areas such as reroutes were done from airphotos and quantitative estimates of expected soil conditions were made from previously developed data bank summaries."

Statistical Methods of Data Reduction

Statistical methods are used to study the variability of the engineering index properties, to compare one soil type to another, and to group together soil types with similar engineering index properties (31).

Hampton (18) and Hampton, Yoder, and Burr (19) studied the variation in the engineering properties of soils derived from the same parent material and under similar conditions of climate, vegetation, age, and topography. Soil samples were selected from horizons of the Crosby and Brookston soil series within the State of Indiana. Atterberg limit tests, standard AASHTO compaction tests, Hveem stabilometer and swelling pressure tests, California bearing ratio tests, grain size distribution tests, and unconfined compression tests were performed on selected samples and the results were statistically analyzed. It was concluded that soil variability is a function of the property being measured.

Numerous studies at the University of Illinois have attempted to show the relationship between pedological soil types, parent materials, and engineering properties (60, 61, 62). Significant correlations are shown between pedologic soil types and the engineering and physical properties of the soil profiles. Of course, some soil types are more variable than others and the degree of variation within a given soil type appears to be different for the different physical properties being measured. In addition, the parent material from which a soil type has been derived has been

found to be useful for predicting the differences in the engineering properties of the soil.

Various correlations among selected soil properties can be useful to the engineer when the need for extensive laboratory testing is being considered (49, 67). As reported by Ring, Sallberg, and Collins (48), Woods and Litehiser (70) showed the general interrelation of plastic limit, plasticity index, liquid limit, optimum moisture content, and maximum dry density for a large number of soils from Ohio. They reported that increases in the plastic properties of the soils were accompanied by increases in optimum moisture content and decreases in maximum dry density. Rowan and Graham (51) report that the optimum moisture content from the standard Proctor test can be predicted from the shrinkage limit (SL), percentage passing the No. 4 sieve (A), and the percentage passing the No. 40 sieve (B) by the following formula:

Calculated optimum moisture content (percent),

$$w_{\text{opt}} = \text{SL} \left(\frac{B}{A} \right)$$

Rowan and Graham suggested that the calculated optimum moisture content be reduced by three percent, after they compared the predicted values with the results of tests on 10 soils.

Davidson and Gardiner (9) modified the Rowan-Graham formula after comparing the calculated and the laboratory values of optimum

moisture content of 210 soils from different areas in the United States. They reported the greatest deviations between calculated and laboratory values occurred with the more plastic soils. A modified optimum moisture content relation is obtained by adding the correction factor, $\frac{PI}{3} - 4$, to the Rowan-Graham formula, where PI is the plasticity index. Thus:

optimum moisture content (percent) = $w_{opt.}$

$$SL\left(\frac{B}{A}\right) + \frac{PI}{3} - 4$$

Jumikis (24), Ring et al. (48) and James (23) studied the relationships between liquid limit, plastic limit, plasticity index, gradation, optimum moisture content, and maximum dry density. Jumikis examined various glacial soils of New Jersey. Ring et al. used simple and multiple regression analyses to predict optimum moisture content and maximum dry density from simpler classification tests. And finally, James developed families of liquid limit curves to predict the standard Proctor maximum dry density from the plasticity index, and presented relationships between plastic limit and optimum moisture content.

Black (3) and Crawford et al. (8), presented methods of determining the California bearing ratio from the results of index property and moisture content tests. Black used the consistency index, $C_1 = \frac{LL - w}{PI}$, where w is the moisture content, LL is the liquid limit, and PI is the plasticity

index, to predict CBR values. Crawford et al. defined a relationship between liquid limit values and CBR values for use in highway design in South Dakota (see Figure 3).

Relationships have been investigated between unconfined compressive strength, liquidity index, and natural moisture content. Peck (45) examined the relation between natural moisture content and the logarithm of unconfined compressive strength for Chicago clays. He concluded that the relationship was not of much practical value due to a large amount of scatter. A better correlation existed between liquidity index and the logarithm of unconfined compressive strength at various levels of natural moisture content. Similar studies have been reported by Sisiliano (52) for selected soil types of Indiana, and by Fredlund and Dahlman (14) for proglacial Lake Edmonton sediments in Canada. Additional relationships between the values of the standard penetration test (SPT) and the unconfined compressive strength are found in the literature. Since samples for unconfined compressive strength tests are usually taken by methods other than the split spoon (by the ISHC), very few samples for which unconfined strengths tests have been run contain SPT values. Therefore, this relationship has not been investigated here.

Numerous researchers have attempted to predict the compression index (C_c) and compression ratio (C_r) from easier-to-determine soil properties, for example, liquid limit (w_L), natural moisture content (w_n) and the initial void ratio (e_o). Azzouz, Krizek, and Corotis (1) present a summary of different

published equations for prediction of both C_c and C_r including the data base used to establish the relationships. This information has been reproduced as Table 1. Additional regression relationships reported in the literature (25, 28, 52, 66) are similar to those presented in Table 1. Differences which exist between these equations and those of Table 1 are directly attributed to the data base from which the equations have been derived.

TABLE 1. Summary of Published Regression Equations for Prediction of Compression Index, C_c , and Compression Ratio, C_r (Adapted from Azzouz et al. (1))

Regression Equation	Regions of Applicability	Reference
$C_c = 0.007(w_L - 7)$	Remolded clays	Skempton (53)
$C_r = 0.208e_o + 0.0083$	Chicago clays	Peck and Reed (46)
$C_c = 17.66 \times 10^{-5} w_n^2 + 5.93 \times 10^{-3} w_n - 1.35 \times 10^{-1}$	Chicago clays	Peck and Reed (46)
$C_c = 1.15(e_o - 0.35)$	All clays	Nishida (43)
$C_c = 0.30(e_o - 0.27)$	Inorganic, cohesive soil; silt, some clay; silty clay; clay	Hough (21)
$C_c = 1.15 \times 10^{-2} w_n$	Organic soils-meadow mats, peats, and organic silt and clay	Moran, Proctor, Mueser and Rutledge (39)
$C_c = 0.256 + 0.43(e_o - 0.84)$	Brazilian clays	Cozzolino (7)
$C_c = 0.0046(w_L - 9)$	Brazilian clays	Cozzolino (7)
$C_c = 1.21 + 1.055(e_o - 1.87)$	Motley clays from Sao Paulo city	Cozzolino (7)
$C_c = 0.0186(w_L - 30)$	Motley clays from Sao Paulo city	Cozzolino (7)
$C_c = 0.009(w_L - 10)$	Normally consolidated clays	Terzaghi and Peck (59)
$C_c = 0.75(e_o - 0.50)$	Soils of very low plasticity	Sowers (55)
$C_r = 0.156e_o + 0.0107$	All clays	Elnaggar and Krizek (12)
$C_c = 0.01w_n$	Chicago clays	Osterberg (44)

DEVELOPMENT OF THE GEOTECHNICAL DATA BANK

Most of the information being gathered is taken from subsurface investigation reports from highway projects within the state. Pedological soils information is additionally being collected and stored. The latter information is taken from recent agricultural Soil Survey Manuals (54) and General Soil Maps (16) prepared on an individual county basis. Approximately one-third of the counties within the state have completed modern soil surveys (Table 2). Soil surveys developed prior to 1958 are obsolete, since many soil series names have been changed and new methods have been adopted for collecting and reporting pedological information.

Information Collected

Information gathered during a roadway soil investigation is generally limited. Usually, only simple laboratory testing is performed on a few selected soil samples, with more advanced testing reserved for samples taken from sites where special structures are to be constructed or non-typical soil conditions are encountered. Consequently, very small quantities of tests are available for the majority of soil borings from subsurface investigation reports.

Table 2. Counties with Modern Soil Surveys
Completed Since 1958

1. Allen (1969)	16. Jennings (1976)
2. Bartholomew (1976)	17. Lake (1972)
3. Boone (1975)	18. Madison (1967)
4. Carroll (1958)	19. Owen (1964)
5. Clark (1974)	20. Parke (1967)
6. Crawford (1975)	21. Perry (1969)
7. Daviess (1974)	22. Pulaski (1968)
8. Delaware (1972)	23. Scott (1962)
9. Elkhart (1974)	24. Shelby (1974)
10. Fayette (1960)	25. Spencer (1973)
11. Floyd (1974)	26. Sullivan (1971)
12. Fountain (1966)	27. Tippecanoe (1959)
13. Harrison (1975)	28. Union (1960)
14. Hendricks (1974)	29. Vanderburgh (1976)
15. Howard (1971)	30. Vigo (1974)

The minimum information to be stored for a particular boring (see Appendix B for details) is as follows:

1. gradational characteristics based on standard sieve sizes and hydrometer analysis
2. Atterberg limits
3. visual textural classifications
4. color based on moist condition

A computer program utilizing the above information to classify the samples by the AASHTO (including the group index) and USCS systems has been developed and is presented as Program 3, Appendix E. The following additional test data, are stored, if available:

1. organic content (loss on ignition) as a percent
2. in situ moisture content
3. in situ dry and wet densities, pcf
4. specific gravity
5. compaction test results
6. California bearing ratio (CBR)
7. unconfined compressive strength (tsf) and failure strain (percent)
8. strength data from triaxial and direct shear tests
9. consolidation test results

In addition to laboratory testing data, information will be stored to include:

1. project identification
 - a. project number
 - b. contract number

- c. road number
 - d. data collection agency
- 2. sample location
 - a. county
 - b. district
 - c. township
 - d. range
 - e. section
 - f. line number
 - g. stationing in feet
 - h. offset in feet and the left or right direction from the centerline
- 3. sample identification
 - a. boring number
 - b. laboratory number
 - c. sampling procedure
- 4. date the sample was taken from the hole
- 5. physiographic region
- 6. parent material from which the soil has been derived
- 7. ground surface elevation in feet
- 8. depth from which the sample has been removed in feet
- 9. depth to bedrock in feet
- 10. depth to groundwater in feet
- 11. standard penetration resistance (SPT)
- 12. pedological soils information
 - a. soil association name

- b. soil series name
- c. horizon
- d. slope (topographic) class
- e. erosion class
- f. natural soil drainage class
- g. permeability
- h. flooding potential
- i. frost heave susceptibility
- j. shrink-swell potential
- k. pH

Data Collection Process

The various consulting organizations contracted by the ISHC for subsurface investigation prior to the mid 1960's had unique methods of presenting their results. The information reported by one agency was not necessarily reported by another (for example, some consultants reported the complete range of gradational characteristics, while other consultants reported only a limited range of sieve sizes).

At present, the geotechnical data needs to be transferred to the Data Input Form (DIF) shown in Figure 4.

DATA INPUT FORM

COMPUTERIZED SOIL DATA FOR THE STATE OF INDIANA

RECORDED BY: _____ DATE: _____

CHECKED BY: _____ DATE: _____

SEQUENCE: _____

HOLE NO.		PROJECT NUMBER		CONTRACT NUMBER		ROAD NUMBER		BORING NUMBER		SOIL ASSOC.		STATION		LINE NUMBER		LAB NUMBER		GROUND SURFACE ELEVATION		DEPTH TOP		DEPTH BOTTOM		SPT		SOIL SERIES			
												NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60
61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90
91	92	93	94	95	96	97	98	99	100	101	102	103	104	105	106	107	108	109	110	111	112	113	114	115	116	117	118	119	120
121	122	123	124	125	126	127	128	129	130	131	132	133	134	135	136	137	138	139	140	141	142	143	144	145	146	147	148	149	150
151	152	153	154	155	156	157	158	159	160	161	162	163	164	165	166	167	168	169	170	171	172	173	174	175	176	177	178	179	180
181	182	183	184	185	186	187	188	189	190	191	192	193	194	195	196	197	198	199	200	201	202	203	204	205	206	207	208	209	210
211	212	213	214	215	216	217	218	219	220	221	222	223	224	225	226	227	228	229	230	231	232	233	234	235	236	237	238	239	240
241	242	243	244	245	246	247	248	249	250	251	252	253	254	255	256	257	258	259	260	261	262	263	264	265	266	267	268	269	270
271	272	273	274	275	276	277	278	279	280	281	282	283	284	285	286	287	288	289	290	291	292	293	294	295	296	297	298	299	300
301	302	303	304	305	306	307	308	309	310	311	312	313	314	315	316	317	318	319	320	321	322	323	324	325	326	327	328	329	330
331	332	333	334	335	336	337	338	339	340	341	342	343	344	345	346	347	348	349	350	351	352	353	354	355	356	357	358	359	360
361	362	363	364	365	366	367	368	369	370	371	372	373	374	375	376	377	378	379	380	381	382	383	384	385	386	387	388	389	390
391	392	393	394	395	396	397	398	399	400	401	402	403	404	405	406	407	408	409	410	411	412	413	414	415	416	417	418	419	420
421	422	423	424	425	426	427	428	429	430	431	432	433	434	435	436	437	438	439	440	441	442	443	444	445	446	447	448	449	450
451	452	453	454	455	456	457	458	459	460	461	462	463	464	465	466	467	468	469	470	471	472	473	474	475	476	477	478	479	480
481	482	483	484	485	486	487	488	489	490	491	492	493	494	495	496	497	498	499	500	501	502	503	504	505	506	507	508	509	510
511	512	513	514	515	516	517	518	519	520	521	522	523	524	525	526	527	528	529	530	531	532	533	534	535	536	537	538	539	540
541	542	543	544	545	546	547	548	549	550	551	552	553	554	555	556	557	558	559	560	561	562	563	564	565	566	567	568	569	570
571	572	573	574	575	576	577	578	579	580	581	582	583	584	585	586	587	588	589	590	591	592	593	594	595	596	597	598	599	600
601	602	603	604	605	606	607	608	609	610	611	612	613	614	615	616	617	618	619	620	621	622	623	624	625	626	627	628	629	630
631	632	633	634	635	636	637	638	639	640	641	642	643	644	645	646	647	648	649	650	651	652	653	654	655	656	657	658	659	660
661	662	663	664	665	666	667	668	669	670	671	672	673	674	675	676	677	678	679	680	681	682	683	684	685	686	687	688	689	690
691	692	693	694	695	696	697	698	699	700	701	702	703	704	705	706	707	708	709	710	711	712	713	714	715	716	717	718	719	720
721	722	723	724	725	726	727	728	729	730	731	732	733	734	735	736	737	738	739	740	741	742	743	744	745	746	747	748	749	750
751	752	753	754	755	756	757	758	759	760	761	762	763	764	765	766	767	768	769	770	771	772	773	774	775	776	777	778	779	780
781	782	783	784	785	786	787	788	789	790	791	792	793	794	795	796	797	798	799	800	801	802	803	804	805	806	807	808	809	810
811	812	813	814	815	816	817	818	819	820	821	822	823	824	825	826	827	828	829	830	831	832	833	834	835	836	837	838	839	840
841	842	843	844	845	846	847	848	849	850	851	852	853	854	855	856	857	858	859	860	861	862	863	864	865	866	867	868	869	870
871	872	873	874	875	876	877	878	879	880	881	882	883	884	885	886	887	888	889	890	891	892	893	894	895	896	897	898	899	900
901	902	903	904	905	906	907	908	909	910	911	912	913	914	915	916	917	918	919	920	921	922	923	924	925	926	927	928	929	930
931	932	933	934	935	936	937	938	939	940	941	942	943	944	945	946	947	948	949	950	951	952	953	954	955	956	957	958	959	960
961	962	963	964	965	966	967	968	969	970	971	972	973	974	975	976	977	978	979	980	981	982	983	984	985	986	987	988	989	990
991	992	993	994	995	996	997	998	999	1000	1001	1002	1003	1004	1005	1006	1007	1008	1009	1010	1011	1012	1013	1014	1015	1016	1017	1018	1019	1020

COMMENTS: _____

FIGURE 4 DATA INPUT FORM (DIF)

Information recorded on the DIF can then be directly punched on cards and transferred to magnetic tape for storage. This is Program 1, Appendix E.

Details of the data items to be stored in the computer are described in Appendix B. Some information is not suitable for direct input, and an extensive codification system has been developed and is presented in Appendix C. Since large amounts of data are collected, errors in recording and punching the data are inevitable. An "audit" program has been written to identify those errors which can be detected with the computer and, thereby, allow mistakes to be corrected. Program 2, Appendix E, gives a listing of this program.

Data Management and Manipulation

The Statistical Package for the Social Sciences (SPSS) was selected to provide systematic and effective accessibility for identifying, organizing, storing, retrieving, and cataloging all data. The Purdue University Computing Center (PUCC) operates the Control Data Corporation (CDC) 6500 computer. The SPSS programs presented in Appendix E have been designed for use on this computer system.

The SPSS system is a documented, integrated system of computer programs written in Fortran language. The system provides a unified and comprehensive package designed for data transformation, analysis, and file manipulation. The SPSS text (42) is a complete instructional manuscript for the SPSS programs and data management operation.

For the most part, the programs presented in Appendix E can be run on the IBM 360 computer system available to the ISHC by merely replacing the system control cards. Differences in operating systems, local procedures, and other factors complicate the problem of describing job deck setups. However, the SPSS text (42) describes these differences in detail.

A duplicate magnetic tape containing a listing of the information presently stored within the CDC 6500 geotechnical data bank (2508 soil samples) has been provided to the ISHC for use on the IBM 360. Accordingly, full use and operation of the geotechnical data bank by the ISHC can begin at any time.

To access the data stored on magnetic tape, the SPSS system is activated by means of a sequence of control cards (80-column IBM-card format). The control cards cause the specified operations to be performed in the order in which the control cards are arranged in the program deck. The control cards must be prepared in a manner consistent with the SPSS operation. Over 75 different types of control cards are available and those most useful to the operation of the geotechnical data bank will be discussed.

Data Preparation

Data are card punched onto a series of six cards for each sample. Decimal points are not to be included. Missing information is to be left blank. The order of the data

cards is fixed. A number, from one to six, is sequentially assigned to each card (card number) to identify the card within each data set. Each sample is also assigned a number (sample number) as is each hole (hole number). These numbers are assigned sequentially within each county. Each county name is coded. The card number, the county code, the hole number and the sample number have the purpose of assigning a unique identification number (I.D. number) to each data card. The I.D. number is used for internal bookkeeping.

Details of the formats, card locations, and column locations are presented in Appendix D.

Data Processing

Data are processed in the SPSS system in files. Each file utilized in the data manipulation process contains sixteen control cards. The details of the system are contained in Program 3, Appendix E. The control card identifications are as follows:

1. FILE NAME
2. RUN NAME - identifies the current computer run (the title on the run name card is printed at the top of each page of output generated on that run).
3. VARIABLE LIST
4. INPUT MEDIUM - identifies the source of the data file.
5. INPUT FORMAT

6. VAR LABELS - assigns a name to each variable included on the VARIABLE LIST card.
7. VALUE LABELS - assigns a name to each coded value of each variable defined on the VARIABLE LIST card.
8. MISSING VALUES - excludes missing values from statistical processing. Normally, missing values are treated as zeros in the data manipulation and processed accordingly.
9. IF - creates variable transformations needed to generate the USCS, AASHTO, and group index codes.
10. ASSIGN MISSING - assigns a code (-8) to those variables calculated internally with the SPSS program. This includes the codes assigned to the USCS and AASHTO classifications and the group index. The purpose of this control card is the same as the MISSING VALUES card.
11. RECODE - causes values of existing variables to be altered.
12. N OF CASES - defines the number of samples (cases) contained on the magnetic tape at the time of processing.
13. PRINT FORMATS - defines the formats for data from computer output.
14. READ INPUT DATA
15. SAVE FILE

16. FINISH - terminates processing of the SPSS system.

The control cards identified above, along with the data contained on the magnetic tape, have been combined into a general SPSS system file. This is Program 4, Appendix E, and is stored on a magnetic tape. All data processing and manipulations will access this magnetic tape with the control card GET FILE (Appendix F).

The following control cards include those which are anticipated to be of most use to the operation of the geotechnical data bank. The reader is referred to the SPSS text (42) for a complete description of their application plus a description of those control cards not included below (the name of the control card is punched in columns 1-15; the instructions are punched starting in column 16):

1. COMPUTE - similar to the IF control card.

For example; to generate the new variable, liquidity index (LI), the procedure is:

```
COMPUTE      LI = (NATMC-PL)/PI
ASSIGN MISSING LI (-8)
```

2. SELECT IF - allows the selection of data from specific cases. For example, to select all samples derived from lacustrine deposits (code 1) with plasticity indices greater than 30, the procedure is:

```
SELECT IF      (PARENT EQ 1 AND PI GT 30)
```

3. SORT CASES - permits a reordering of cases according to any one or a specified set of variables. For example, to sort all the data by counties and townships, in ascending order, the procedure is:

```
SORT CASES      COUNTY, TOWN (A)
```

The SORT CASES procedure begins by sorting the file first by county. The file is next sorted by township within each county.

4. TASK NAME - enables the user to identify specific or separate tasks within a given computer run.
5. LIST CASES - enables the user to list the contents of all or a designated set of cases in the file. This control card must be used in conjunction with the SPSS statistical processing procedures, such as CONDESCRIPTIVE (see description of sample procedural cards below). Suppose a user would like a listing of the depths to bedrock which have been encountered within Floyd County (code 22). The following control cards would be used (assuming 100 samples from Floyd County are contained within the data bank):

```
SELECT IF      (COUNTY EQ 22)
```

```
LIST CASES     CASES = 100/VARIABLES = BEDRKB
```

6. CONDESCRIPTIVE - computes descriptive statistics such as mean, mode, standard deviation, kurtosis, etc.
7. FREQUENCIES - computes and presents one-way frequency distribution tables and histograms.
8. CROSSTABS - computes and displays two-way to n-way cross-tabulation tables for any discrete variables. For example, to determine the joint frequency distribution of physiographic regions and parent material areas the control card would be:

CROSSTABS TABLES = PHYSIO BY PARENT
9. SCATTERGRAM - prints a two-dimensional plot.
10. REGRESSION - performs regression analyses.

In addition to the few statistical procedural cards listed above (CONDESCRIPTIVE to REGRESSION), numerous statistics (such as mean, mode, standard deviation, etc.) can be selected with a STATISTICS card, and a variety of options are available for data processing and presentation of results with an OPTIONS card. Examples of the use of the SPSS system with the geotechnical data bank have been included in Appendix F.

ANALYSIS OF DATA

A total of 2508 data sets (cases) were collected and subjected to various methods of statistical analyses, including characterizations of the total data and characterizations on the basis of physiographic units and parent material areas. Figure 5 shows the physiographic regions of the State, and Figure 6 shows the distribution of parent material areas. To further identify the data, Figures 7 and 8 give frequencies within the USCS and AASHTO classification systems, respectively. It should be remembered that the data have been collected throughout the entire state, but no attempt was made to collect equal numbers of samples from all parts of the state. See Figure 1. Therefore, the correlation and prediction equations presented are applicable for only those areas from which data have been collected.

Distributional Characterization of Data

Table 3 presents the results of the statistical analysis of the different soil parameters for all the samples collected and stored in the computer as of January 1978. Liu and Thornburn (31) present a good discussion of the value of many of these statistics and their applicability to the study of natural soil deposits.

FIGURE 5 PHYSIOGRAPHIC UNITS BASED ON PRESENT TOPOGRAPHY. MODIFIED FROM MALOTT (35)

Soil Regions, Their Parent Materials and Representative Soil Series

1. Sandy and loamy lacustrine deposits and eolian sand (Maumee, Rensselaer, Plainfield)
2. Silty and clayey lacustrine deposits (McGary, Patton, Hoytville, Dubois)
3. Alluvial and outwash deposits (Fox, Genesee, Warsaw, Wheeling)
4. Eolian sand deposits (Plainfield, Oshtemo, Bloomfield)
5. Thick loess deposits (Alford, Hosmer, Iva)
6. Loamy glacial till (Riddles, Miami, Crosier, Brookston)
7. Clayey glacial till (Blount, Pewamo, Morley)
8. Thin loess over loamy glacial till (Brookston, Crosby, Miami, Parr)
9. Moderately thick loess over loamy glacial till (Fincastle, Russell, Miami, Brookston)
10. Moderately thick loess over weathered loamy glacial till (Cincinnati, Avonburg, Vigo, Ava)
11. Discontinuous loess over weathered sandstone and shale (Zanesville, Berks, Wellston, Muskingum)
12. Discontinuous loess over weathered limestone (Crider, Frederick, Corydon)
13. Discontinuous loess over weathered limestone and shale (Eden, Switzerland, Pate)

FIGURE 6 SOIL REGIONS OF INDIANA (ADAPTED FROM REFERENCE (36))

FIGURE 7 CLASSIFICATION OF SOIL SAMPLES IN ACCORDANCE WITH UNIFIED SOIL CLASSIFICATION SYSTEM

FIGURE 8 CLASSIFICATION OF SOIL SAMPLES IN ACCORDANCE WITH AASHTO SOIL CLASSIFICATION SYSTEM

TABLE 3. Summary of Statistical Parameters for Different Soil Properties of All Samples Stored as of January 1978.

Soil Property	Units	Mean, $\bar{x}$	Variance, s^2	Standard Deviation, s	Coefficient of Variation, V	Skewness, g_1	Kurtosis, g_2	Minimum Value	Maximum Value	No. of Samples, N
% Passing:										
No. 10 Sieve	%	94.4	120.76	10.99	11.64	-3.47	14.52	2.0	100.0	1929
No. 40 Sieve	%	87.5	264.85	16.27	18.60	-2.27	5.57	1.0	100.0	1928
No. 200 Sieve	%	69.0	642.31	25.34	36.76	-0.88	-0.16	0.0	100.0	1929
No. 270 Sieve	%	66.0	693.55	26.34	39.90	-0.70	-0.49	0.0	100.0	1149
% Sand	%	30.9	611.38	24.73	80.02	0.87	-0.14	0.0	100.0	1928
% Silt	%	38.5	347.43	18.64	48.43	0.11	-0.67	0.0	93.0	1923
% Clay	%	29.6	286.69	16.93	57.28	0.52	-0.18	0.0	86.0	1921
% Colloids	%	17.8	193.53	13.91	78.24	1.29	1.92	0.0	81.0	1173
Liquid Limit, w_L	%	36.9	219.66	14.82	40.11	2.48	16.06	12.0	219.0	1973
Plastic Limit, w_p	%	20.1	38.40	6.20	30.83	4.38	47.96	7.0	120.0	1964
Plasticity Index, I_p	%	17.0	119.11	10.91	64.20	1.80	5.31	1.0	99.0	1958
Shrinkage Limit, w_s	%	16.8	20.54	4.53	27.06	1.21	5.14	0.0	51.0	1602
Natural Water Content, w_n	%	25.6	172.65	13.14	51.25	5.47	55.66	6.0	233.0	1575
Natural Dry Density, γ_d	lb/ft ³	96.2	184.02	13.57	14.10	-1.08	3.29	30.9	130.7	524

TABLE 3. (Continued) Summary of Statistical Parameters for Different Soil Properties of
All Samples Stored as of January 1978.

Soil Property	Units	Mean, $\bar{x}$	Variance, s^2	Standard Deviation, s	Coefficient of Variation, V	Skewness, g_1	Kurtosis, g_2	Minimum Value	Maximum Value	No. of Samples, N
Maximum Dry Density, $\gamma_{d\max}$	lb/ft ³	109.40	66.00	8.12	7.43	0.14	0.49	84.3	130.0	178
Maximum Wet Density, $\gamma_{m\max}$	lb/ft ³	128.20	32.90	5.74	4.48	-0.19	0.73	108.7	142.1	178
Optimum Moisture Content, w_{opt}	%	17.06	17.94	4.24	24.82	0.74	2.31	6.7	35.7	177
CBR at 100% $\gamma_{d\max}$	-	8.79	26.11	5.11	58.14	3.01	14.01	2.4	42.1	148
CBR at 95% $\gamma_{d\max}$	-	5.05	6.66	2.58	51.14	2.01	6.40	0.7	19.2	148
Unconfined Compressive Strength, q_u	tf/ft ²	1.09	0.98	0.99	90.77	4.16	24.92	0.06	8.9	381
Initial Void Ratio, e_o	-	0.941	0.26	0.51	54.64	3.37	11.75	0.429	3.390	116
Coefficient of Consolidation, C_c	-	0.218	0.01	0.11	49.66	1.56	2.91	0.068	0.609	103

The value of maximum, minimum, mean and standard deviation are of obvious interest. The coefficient of variation, V , is useful for comparing the degree of variation within a population or among populations with respect to a given soil property. Accordingly, Table 4 has been prepared containing the coefficients of variation of each parameter for all the physiographic regions and parent material areas under investigation.

Figures A1 through A18, presented in Appendix A, graphically illustrate the range, 95% confidence interval and the mean of the parameters, based upon the soil groupings. These values would help the practicing engineer not familiar with Indiana soils, to obtain an idea of the expected values of the soil parameters. Full illustration of the usefulness of such statistics is deferred to a later report, where the data base has been enlarged.

It is important to note that the statistical results presented within this report are valid only for plastic soils. Some investigators have assigned a zero to the index properties for non-plastic soils, while others have arbitrarily assigned values to the soils based upon the index properties of other soils contained within the populations under study. No method was judged acceptable, and therefore non-plastic soils were excluded from all analyses.

General Method of Analysis

State-wide prediction models for each dependent variable are potentially of value. The dependent variables of major interest are: 1) coefficient of consolidation (C_c) and compression ratio (C_r , which equals $C_c / (1 + e_0)$, where e_0 is the initial void ratio), 2) unconfined compressive strength

TABLE 4. Comparison of the Coefficient of Variation of Soil Properties Among Soil Groupings

Soil Grouping	No. 10 Sieve	No. 40 Sieve	No. 200 Sieve	No. 270 Sieve	% Sand	% Silt	% Clay	% Colloids	w_L	w_p	I_p	w_s	w_n	γ_d
All Samples	11.6	18.6	36.8	39.9	80.0	48.4	57.3	78.2	40.1	30.8	64.2	27.1	51.3	14.1
Physiographic Region:														
Scottsburg Lowland	5.2	11.0	15.5	21.0	75.1	30.0	37.2	47.2	21.4	10.1	49.7	25.8	24.5	5.9
Norman Upland	3.4	4.9	15.6	18.0	82.7	36.5	38.7	52.1	36.0	21.8	57.7	19.6	24.2	7.6
Mitchell Plain	8.6	11.6	19.2	23.3	98.4	43.5	42.9	59.1	37.2	18.2	64.0	23.4	21.6	9.4
Crawford Upland	16.1	19.2	33.8	35.3	97.3	44.0	57.1	68.9	38.8	23.8	68.7	21.0	36.7	10.1
Wabash Lowland	4.5	10.7	32.4	30.3	94.8	39.4	48.1	61.0	31.4	24.5	55.3	21.5	53.8	17.2
Calumet Lacustrine Plain	15.2	22.0	67.8	280.3	90.6	74.2	88.1	--	42.3	28.7	61.6	27.1	55.3	7.7
Valparaiso Morainal Area	6.1	12.5	23.9	--	78.7	47.6	41.0	--	30.5	23.6	45.6	20.2	36.3	--
Kankakee Lacustrine Section	16.1	33.8	76.9	91.9	40.5	95.2	86.8	100.9	40.7	39.0	73.0	29.6	48.1	--
Tipton Till Plain	13.6	22.4	38.7	38.3	56.8	47.0	53.5	73.5	47.1	41.2	65.7	27.6	71.5	19.5

TABLE 4. (Continued) Comparison of the Coefficient of Variation of Soil Properties Among Soil Groupings

Soil Grouping	No. 10 Sieve	No. 40 Sieve	No. 200 Sieve	No. 270 Sieve	% Sand	% Silt	% Clay	% Colloids	w_L	w_p	I_p	w_s	w_n	γ_d
Parent Material Area:														
Lacustrine Deposits	4.5	9.9	26.7	26.5	100.3	46.1	51.6	58.5	37.2	30.0	54.3	28.1	51.0	7.5
Outwash and Alluvial Deposits	16.8	28.4	51.7	53.9	70.8	57.4	63.3	83.3	38.2	32.3	65.4	27.2	54.8	11.2
Thick Loess	5.3	12.5	25.8	31.4	97.4	33.6	40.1	53.3	33.5	27.8	53.7	20.3	71.1	31.4
Clayey Wisconsin Till	8.2	14.0	23.9	32.2	76.5	50.9	46.6	88.4	45.5	42.3	57.1	29.8	54.8	33.6
Thin Loess Over Loamy Wisconsin Till	7.9	13.2	29.6	32.0	52.5	39.0	42.7	62.8	39.9	32.0	57.4	23.3	39.9	12.5
Thick Loess Over Illinoisan Till	2.2	10.0	32.0	22.6	83.2	44.8	36.8	36.5	26.2	18.3	54.6	24.4	15.8	--
Residuum-Siltstone, Shale, Sandstone	11.9	14.8	27.7	29.6	97.8	39.8	48.4	59.2	35.9	19.6	64.0	22.2	21.2	8.2
Residuum-Limestone	6.8	8.6	14.8	18.4	88.2	40.7	38.7	54.7	36.6	17.3	61.5	23.5	21.8	9.3

(q_u), 3) standard Proctor maximum dry ($\gamma_{d_{max}}$) and wet ($\gamma_{m_{max}}$) densities and optimum moisture content (w_{opt}), and 4) soaked California bearing ratios (CBR) at 100 (CBRS01) and 95 (CBRS02) percent of standard Proctor maximum dry densities.

The independent variables included: 1) initial void ratio (e_o), natural moisture content (w_n), natural dry density (γ_d), liquid limit (w_L), plastic limit (w_p), plasticity index (I_p), percent clay, overburden pressure (p_o), and preconsolidation pressure (p_c) for the consolidation test data; 2) w_L , w_p , w_n , γ_d , and liquidity index (L_I) for the unconfined compressive strength data; and 3) w_L , w_p , I_p , and w_s for the compaction and CBR test data.

If a particular dependent variable resisted state-wide regression modelling, or if data were contained in significant quantities to justify modelling on smaller units, that is, physiographic regions, parent material areas, and in some cases on soil types, the data were grouped accordingly to determine if the prediction models could be significantly improved.

The following general approach was applied in the development of the regression models for each dependent variable. The method of least squares was used to find "good" estimates of the regression parameters and to isolate the effects of the independent variables on the chosen dependent variables. Draper and Smith (11) discuss this method in more detail, and the reader is referred to this text for further

explanation of the theory of regression analysis.

Each regression model formulated had random levels of the independent variables. The methods of formulation employed were the regression methods appropriate for fixed levels of the independent variables. The two conditions that justify fixed level methods for random level data are: 1) The conditional distribution of each dependent variable (given the independent variables) is normal with the mean given by the model (dependent on independent variables), also, the measurements of the dependent variable must be mutually independent. 2) The levels of the independent variables for the different data points must be mutually independent, and the distribution of the independent variables must be independent of the model parameters. Both of the above assumptions are reasonable for each set of data modelled, and they have been assumed to be valid.

The regression models developed are linear in the parameters (because no parameter appears as an exponent or is multiplied or divided by another parameter). The potential terms in each model are linear independent variables, squared independent variables, reciprocal transformations of independent variables, and linear interactions of independent variables. Logarithmic transformations of dependent and independent variables were attempted when it was suspected that the model was intrinsically linear by suitable transformation.

Each dependent variable was first plotted against each

independent variable in order to investigate the nature of the dependence. These plots indicate whether linear terms, quadratic terms, or transformations of the variables are appropriate. Additionally, the coefficient of determination, r^2 , was examined to determine the degree of relation between the dependent variable and the single independent variable in each case. The SPSS routine called SCATTERGRAM was applied.

Next, the independent variables and/or transformations suggested by the scatterplots to have some relationship to the dependent variables were selected for an examination of all possible regressions. The Purdue computer program DRRSQU was selected to identify the "best" set of independent variables. Different criteria for selecting the fitted models may be used to determine the "best" equation. The C_p criterion (41), concerned with the total square error (consisting of a random error and bias component) of the n fitted observations, was selected to identify the set of independent variables that leads to the smallest C_p value with a low bias component. The "best" set of independent variables for each dependent variable provided a model for additional examination.

To further select the terms appropriate for each model, stepwise regressions were performed, modelling each dependent variable using the terms indicated by DRRSQU. The REGRESSION routine of the SPSS system was used. The stepwise regression results (see Reference 41 for a discussion of this method) give adjusted coefficients of multiple determination (R_a^2) as each variable is added to or deleted from the model. Usually, only the coefficient of multiple determination,

denoted by R^2 , is used as a measure of the proportionate reduction of the total variation in the dependent variable associated with the use of a set of independent variables. However, since in the step-wise regression procedure used, R^2 can be made large by increasing the independent variables in the model, R_a^2 was used as a criterion for selecting a good model. R_a^2 explicitly recognizes the number of independent variables in the model, as shown below (71),

$$R_a^2 = 1 - \left(\frac{n - 1}{n - p} \right) \frac{\text{sum of squares due to error (or deviation)}}{\text{sum of squares of total}}$$

$$\text{or } R_a^2 = 1 - \frac{\text{mean square due to error}}{\text{mean square of total}}$$

where p = number of independent variables considered

n = number of data sets

The value may actually become smaller when another independent variable is introduced into the model (41). R_a^2 takes on values between 0 and 1. The larger R_a^2 , the better the fitted equation explains the variation in the data.

The regression equations with high R_a^2 values (greater than 0.65) were checked to determine if the relationships were statistically useful. The criteria included: 1) small confidence intervals (at the 95% confidence level) and 2) confidence intervals that did not cross zero. Those equations considered valid, satisfied these two criteria.

After obtaining good prediction models, it is important to examine these models to determine if they are appropriate for the particular

data being examined. Certain assumptions are inherent in formulation of the regression models; an examination of the residuals (differences between the observed and corresponding predicted values) will suggest if any of the usual assumptions are invalid. The usual assumptions are that the errors are independent, have zero mean,

a constant variance, and follow a normal distribution.

An examination of the residuals of the final models were made in each case to investigate possible model deficiencies. The residuals of each model were plotted against each independent variable in the model, in addition to the dependent variable and its predicted value. The residuals were tested for normality by the Purdue Computer Program called NORP. The models with residual plots not displaying systematic tendencies to be positive or negative, but tending to fall within horizontal bands centered around 0, and additionally satisfying the normality criterion at the 90 percent confidence level, were selected as the final models.

Statistical Results

The independent variables selected as possible terms in the regression equations and the associated coefficients of determination, r^2 , are presented in Table 5 for C_c and C_r . Attempting to obtain higher r^2 values, the physiographic regions and parent material areas which contained at least 20 data sets were selected for further investigation. These included the soils of the Crawford Upland, Wabash Lowland, and soils derived from outwash and alluvial deposits. All three groups reduced the total variation in the dependent variables associated with the use of some of the selected independent variables. The r^2 values have been tabulated in Tables 5-A, 5-B, and 5-C for each of the three groups.

Table 6 shows that no adequate r^2 values were obtained

TABLE 5. r^2 Values of All Samples for
Compression Index (C_c) and Compression Ratio (C_r) (N=96)

Independent Variables									
	e_o	w_n	γ_d	w_L	w_p	I_p	% Clay	P_o	P_c
C_c	0.795	0.771	0.639	0.330	0.268	0.243	0.107	0.029	0.013
C_r	0.685	0.674	0.551	0.304	0.206	0.245	0.111	0.030	0.003

TABLE 5-A. r^2 Values for C_c and C_r of Soils
from the Crawford Upland Physiographic Region (N=28)

Independent Variables									
	e_o	w_n	γ_d	w_L	w_p	I_p	% Clay	P_o	P_c
C_c	0.796	0.786	0.700	0.399	0.368	0.220	0.177	0.056	0.029
C_r	0.705	0.704	0.647	0.417	0.317	0.256	0.215	0.057	0.025

TABLE 5-B. r^2 Values for C_c and C_r of Soils
from the Wabash Lowland Physiographic Region (N=29)

Independent Variables									
	e_o	w_n	γ_d	w_L	w_p	I_p	% Clay	P_o	P_c
C_c	0.844	0.818	0.628	0.243	0.364	0.123	0.030	0.026	0.003
C_r	0.758	0.757	0.567	0.203	0.281	0.112	0.024	0.032	0.000

TABLE 5-C. r^2 Values for C_c and C_r of Soils Derived from
Outwash and Alluvial Deposits (N=63)

Independent Variables									
	e_o	w_n	γ_d	w_L	w_p	I_p	% Clay	P_o	P_c
C_c	0.844	0.815	0.716	0.362	0.305	0.297	0.168	0.015	0.006
C_r	0.742	0.722	0.637	0.326	0.234	0.286	0.165	0.015	0.000

TABLE 6. r^2 Values of All Samples for Unconfined Compressive Strength (q_u) (N=356)

Independent Variables						
	w_L	w_p	I_p	w_n	γ_d	L_I
q_u	0.003	0.008	0.020	0.105	0.173	0.134
$\log q_u$	0.001	0.170	0.060	0.179	0.250	0.191

TABLE 6-A. r^2 Values for q_u of Soils Derived from Lacustrine Deposits (N=48)

Independent Variables						
	w_L	w_p	I_p	w_n	γ_d	L_I
q_u	0.209	0.170	0.219	0.607	0.701	0.309
$\log q_u$	0.185	0.171	0.181	0.668	0.692	0.321

TABLE 6-B. r^2 Values for q_u of Soils from the Calumet Lacustrine Plain (N=40)

Independent Variables						
	w_L	w_p	I_p	w_n	γ_d	L_I
q_u	0.100	0.098	0.094	0.560	0.737	0.356
$\log q_u$	0.059	0.088	0.040	0.698	0.745	0.331

when an attempt was made to find a relationship between q_u and $\log q_u$ and the independent variables shown in the Table. Similarly, low r^2 values were obtained for q_u data of the Tipton Till Plain, Scottsburg Lowland, Mitchell Plain, Wabash Lowland, and the Crawford Upland. Additionally, soils derived from residuum of siltstone, shale, and sandstone; residuum of limestone bedrock; thin loess over loamy Wisconsin age glacial till; and outwash and alluvial deposits, did not show any improvement in r^2 . For soils derived from lacustrine deposits as shown in Table 6-A, an improvement in r^2 was achieved, but a significant improvement was observed only for the independent variables of natural moisture content, w_n , and natural dry density, γ_d . As seen in Table 6-B, similarly high r^2 values were observed for soils found in the Calumet Lacustrine Plain. This is expected since most of the soils found within this physiographic region have been derived from lacustrine deposits.

Relatively low r^2 were obtained for the dependent variables of standard Proctor maximum dry and wet densities, optimum moisture content and their logarithmic transformations, for all the compaction test data (Table 7). Soils of the Tipton Till Plain and soils derived from outwash and alluvial deposits; residuum of siltstone, shale, and sandstone; and thin loess deposits over loamy Wisconsin age glacial till, also had low r^2 values. Additionally, those soils classified as CL and CH in the USCS and A-4, A-6, and A-7-6 in the AASHTO System, were also selected to determine

TABLE 7. r^2 Values of All Samples for Maximum Dry Density ($\gamma_{d_{\max}}$), Maximum Wet Density ($\gamma_{m_{\max}}$), and Optimum Moisture Content (w_{opt}) (N=167)

Independent Variables				
	w_L	w_p	I_p	w_s
$\gamma_{d_{\max}}$	0.566	0.489	0.440	0.091
$\log \gamma_{d_{\max}}$	0.589	0.496	0.463	0.086
$\gamma_{m_{\max}}$	0.456	0.436	0.340	0.106
$\log \gamma_{m_{\max}}$	0.466	0.439	0.349	0.103
w_{opt}	0.681	0.503	0.563	0.056
$\log w_{\text{opt}}$	0.613	0.485	0.493	0.065

TABLE 7-A r^2 Values for $\gamma_{d_{\max}}$, $\gamma_{m_{\max}}$, and w_{opt} of Soils from the Valparaíso Morainal Section (N=26)

Independent Variables				
	w_L	w_p	I_p	w_s
$\gamma_{d_{\max}}$	0.823	0.724	0.597	0.237
$\log \gamma_{d_{\max}}$	0.835	0.750	0.591	0.241
$\gamma_{m_{\max}}$	0.788	0.683	0.580	0.199
$\log \gamma_{m_{\max}}$	0.794	0.701	0.574	0.203
w_{opt}	0.755	0.664	0.547	0.256
$\log w_{\text{opt}}$	0.670	0.559	0.512	0.238

if any improvements could be made in r^2 . No significant increases in any of the r^2 values were observed. Coefficients of determination greater than 0.65 were obtained for compaction data of soils found in the Valparaiso Morainal Section and soils derived from residuum of limestone bedrock. The independent variables, along with the improved r^2 values, are included in Tables 7, 7-A and 7-B.

Very low r^2 were observed for CBR test data. Table 8 contains the results for the entire set of data. Relationships for the soil groups which contained 20 or more data sets, that is, those groupings selected for the compaction data, produced similarly poor r^2 values.

Following the application of all possible regressions and stepwise regression modelling for those sets of variables and transformations selected from above, the final acceptable regression models are presented in Tables 9 through 11. These equations satisfy the requirements outlined in the General Method of Analysis, with adjusted coefficients of multiple determination greater than 0.65.

TABLE 7-B. r^2 Values for $\gamma_{d_{max}}$, $\gamma_{m_{max}}$, and w_{opt} of Soils
Derived from Limestone Bedrock (N=22)

Independent Variables				
	w_L	w_p	I_p	w_s
$\gamma_{d_{max}}$	0.802	0.618	0.715	0.035
$\log \gamma_{d_{max}}$	0.815	0.625	0.727	0.039
$\gamma_{m_{max}}$	0.656	0.500	0.586	0.016
$\log \gamma_{m_{max}}$	0.663	0.500	0.595	0.017
w_{opt}	0.823	0.675	0.719	0.101
$\log w_{opt}$	0.814	0.655	0.717	0.075

TABLE 8. r^2 Values of All Samples for Soaked CBR at 100
(CBRS01) and 95 (CBRS02) Percent of Standard Proctor
Maximum Dry Density (N=138)

Independent Variables						
	w_L	w_p	I_p	$\gamma_{d_{max}}$	$\gamma_{m_{max}}$	w_{opt}
CBRS01	.192	.082	.187	.272	.237	.258
CBRS02	.221	.068	.233	.228	.180	.244
$\log$ CBRS01	.321	.143	.310	.328	.271	.353
$\log$ CBRS02	.328	.120	.332	.273	.214	.309

TABLE 9. Summary of Regression Equations for Prediction of Compression Index (C_c) and Compression Ratio (C_r).

Unit	Dependent Variable	R_a^2	Regression Equation	Number of Samples, N
All Samples	C_c	0.856	$C_c = 0.5684(e_o + 0.0033 w_L - 0.0082 w_p + 0.0329 p_c - 0.4322)$	96
		0.800	$C_c = 0.5363(e_o - 0.4110)$	
		0.792	$C_c = 0.0002(w_n^2 - 106.2727)$	
		0.783	$C_c = 0.0129(w_n + 0.1015 w_L - 16.1875)$	
	C_r	0.691	$C_r = 0.2037(e_o - 0.2465)$	
Wabash Lowland	C_c	0.838	$C_c = 0.5673(e_o - 0.4422)$	29
	$\log C_c$	0.831	$\log C_c = 2.7904(e_o - 0.3346 e_o^2 - 0.8449)$	
	C_r	0.750	$C_r = 0.221(e_o - 0.3074)$	
		0.748	$C_r = 0.0065(w_n - 11.6361)$	
		0.735	$C_r = 0.0034((e_o)(w_n) + 8.3647)$	

TABLE 9. Summary of Regression Equations for Prediction of Compression Index (C_c) and Compression Ratio (C_r).

Unit	Dependent Variable	R_a^2	Regression Equation	Number of Samples, N
Crawford Upland	C_c	0.859	$C_c = 0.0101(e_o)(w_L) - 0.5765 w_L + 12.665$	28
		0.833	$C_c = 0.0114(w_n + 0.2491 w_L - 18.8134)$	
		0.788	$C_c = 0.4941(e_o - 0.3507)$	
		0.777	$C_c = 0.0133(w_n - 12.1886)$	
	C_r	0.740	$C_r = 0.0001(w_n^2 + 455.8889)$	
		0.736	$C_r = 0.0033(e_o)(w_n) + 12.5168$	
		0.721	$C_r = 0.1164(e_o^2 + 0.3594)$	
Outwash and Alluvial Deposits	C_c	0.894	$C_c = 0.6076(e_o + 0.003 w_L - 0.0095 w_p + 0.0430 p_c - 0.4186)$	63
		0.842	$C_c = 0.5621(e_o - 0.4215)$	
		0.822	$C_c = 0.0153(w_n + 0.1022 w_L - 0.3104 w_p - 11.6123)$	
	$\log C_c$	0.772	$\log C_c = 2.1389(e_o - 0.2967 e_o^2 - 0.9374)$	

TABLE 10. Summary of Regression Equations for Prediction of Unconfined Compressive Strength (q_u).

Unit	Dependent Variable	R_a^2	Regression Equation	Number of Samples, N
Calumet Lacustrine Plain	q_u	0.756	$q_u = 0.001 (\gamma_d^2 - 9581.2245)$	40
	$\log q_u$	0.750	$\log q_u = 0.0001 (\gamma_d^2 - 10678.5714)$	
Lacustrine Deposits	$\log q_u$	0.699	$\log q_u = -0.0001 (\gamma_d^2 + 10038.5714)$	48

TABLE 11. Summary of Regression Equations for Prediction of Standard Proctor Maximum Dry (γ_d) and Wet (γ_m) Densities and Optimum Moisture Content (w_{opt}).*

Unit	Dependent Variable	R_a^2	Regression Equation	Number of Samples, N
All Samples	w_{opt}	0.894	$w_{opt} = -0.4965 (\gamma_{d_{max}} - 144.3418)$	138
Valparaíso Morainal Area	$\log \gamma_{d_{max}}$	0.816	$\log \gamma_{d_{max}} = -3.6832(1/w_L + 0.1266 \log w_L - 0.7808)$	26
		0.785	$\log \gamma_{d_{max}} = -0.2239(\log w_L - 10.6935)$	
	$\gamma_{m_{max}}$	0.790	$\gamma_{m_{max}} = -114.0835(\log w_L + 9.9623 (1/w_L) - 2.9758)$	
	$\log \gamma_{m_{max}}$	0.694	$\log \gamma_{m_{max}} = -0.1348(\log w_L - 17.2326)$	
Residuum of Limestone Bedrock	w_{opt}	0.972	$w_{opt} = 0.7268 (\gamma_{m_{max}} - 1.2985 \gamma_{d_{max}} + 37.3072)$	22
		0.870	$w_{opt} = 0.4223(\gamma_{d_{max}} - 150.0372)$	
		0.810	$w_{opt} = 23.0357 + 0.002(w_L)(w_p) - 285.9386(1/w_L)$	
	$\gamma_{d_{max}}$ $\log w_{opt}$	0.772 0.781	$\gamma_{d_{max}} = -113.5475 (\log w_L + 14.0953(1/w_L) - 2.9063)$ $\log w_{opt} = 0.0042 (w_L + 259.0381)$	

*Note: The residual plots show minor trends when plotted against the independent variables for all the regression models above. As additional data is collected, the appropriateness of the models can be more accurately assessed.

DISCUSSION OF STATISTICAL ANALYSIS

Soil Variability

The statistical results presented in the preceding Chapter will enable the geotechnical engineer to make certain estimates of soil properties. The resulting data also indicate that the range of values which may be expected for a given soil parameter appears to vary with the particular physical property which is being measured and the population from which the soil has been sampled. Nevertheless, some soil properties are inherently more variable than others.

The grouping of soils by physiographic regions and the origin of their parent materials further suggests that the predicability of some soil properties can be improved for combinations of some independent variables and certain groups of soils, but not others. A specific listing of those combinations of soil parameters and soil groups providing the best reduction in the degree of variability, would show combinations as variable as the data themselves. Expected values must be determined on a case by case basis and Figures A1 through A18 of Appendix A have been prepared for this purpose. The range, 95 percent confidence interval, and mean of each soil parameter under discussion is shown in these Figures.

Predictions and Correlations

Consolidation Test Results

The plasticity chart shown in Figure 9 indicates that the consolidation test results are for soils which are mostly inorganic clays of low to medium plasticity (59 samples) and silts of medium compressibility (25 samples). From Table 9 it can be seen that a very high adjusted coefficient of multiple determination of 0.856 was found to exist between C_c and e_o , w_L , w_p and p_c for all the test data. Since the prediction equation contains p_c , this equation is not of much practical use. The R_a^2 values for the remaining three equations for C_c and the equation for C_r all indicate that the variation in C_c and C_r can be explained with the use of simple and easily determined soil properties.

Figure 9 indicates that the soils collected from the Wabash Lowland are inorganic clays almost all of which are of low to medium plasticity and an equal number of silts of medium compressibility. The R_a^2 values are slightly greater than the R_a^2 values of the equations derived from the total data.

Soils investigated in the Crawford Upland are also medium plastic inorganic clays and medium compressible silts (Figure 9). Prediction equations similar to those of the Wabash Lowland have been generated. Soils derived from outwash and alluvial deposits constitute the largest group of samples collected for the prediction of C_c and C_r , but

FIGURE 9 PLASTICITY CHARTS FOR CONSOLIDATION TEST DATA

FIGURE 9 CONTINUED

no adequate models for C_r were found. Among the models developed, the most useful model explains 84 percent of the variation in C_c and involves only the initial void ratio. The plasticity chart for these soils is also shown in Figure 9.

The majority of the soils investigated above (96 samples) were derived from outwash and alluvial deposits (63 samples). It will be left as an exercise for further researchers to determine if good prediction models can be developed within the other physiographic regions within Indiana and if the grouping of soils by parent material areas would also result in regression equations as good as those developed for outwash and alluvial deposits.

Unconfined and Compressive Strength Test Results

The results from 356 unconfined compressive strength tests were collected and predictions were attempted. An initial attempt was made to develop regression equations for all the soils and selected soil groupings. Later, an attempt was made to develop a series of regression equations for the logarithm of unconfined compressive strength and liquidity index at various levels of natural moisture content (45). No adequate relationships were developed for the total q_u data or for q_u data of soils taken from most of the physiographic regions or parent material areas.

Acceptable regression equations were generated for soils derived from lacustrine deposits using the logarithm

of unconfined compressive strength and the square of the natural dry density (Table 10). Two prediction equations were also developed with R_a^2 values of 0.756 and 0.750 when the lacustrine deposits were limited to the Calumet Lacustrine Plain. Both models also contained only the square of the natural dry density; a higher R_a^2 value was obtained when q_u was applied directly without the logarithmic transformation. The soils taken from the Calumet Lacustrine Plain and derived from lacustrine deposits are identified in the plasticity charts shown in Figure 10.

Compaction and California Bearing Ratio Test Results

A total of 138 sets of data were collected from standard Proctor compaction tests and CBR tests. For the total data, no reliable equations could be generated for the dependent variables of maximum dry or wet densities, optimum moisture content or the CBR value at 100 or 95 percent of maximum dry density and more simple independent variables. A very high correlation, as expected, was found between optimum moisture content and maximum dry density ($R_a^2 = 0.894$).

For the physiographic regions and parent material areas which contained at least 20 sets of compaction test results, only the Valparaiso Morainal Section and those soils derived from residuum of limestone bedrock, displayed any relationship between maximum dry and wet densities, optimum moisture content (and their logarithmic transformations) and simpler independent variables. Reasonably high R_a^2 values

FIGURE 10 PLASTICITY CHARTS FOR UNCONFINED COMPRESSIVE STRENGTH DATA

were obtained for the acceptable prediction models. A remarkably high R_a^2 value of 0.972 was found for the correlation between optimum moisture content and the independent variables of maximum dry and wet densities for soils of the Valparaiso Morainial Section. The plasticity charts for soils from which these models have been formulated, are shown in Figure 11.

No relationships were found to exist with R_a^2 values greater than 0.4 for the CBR test data and the independent variables presented in Table 8. The collection of additional test data representative of soils throughout the entire state will determine if prediction equations can be formulated for CBR test data using the methods utilized and presented within this report. This will also be left as an exercise for future researchers.

FIGURE II PLASTICITY CHARTS FOR COMPACTION TEST DATA

SUMMARY AND CONCLUSIONS

The research results may be summarized as follows:

1. A computerized, user-oriented, information storage and retrieval system for geological, pedological and geotechnical engineering information has been developed. The system is flexible, so that changes can be made easily as the requirements of users become more clearly defined.
2. A complete instructional User's Manual has been prepared, compatible with the present requirements and needs of the Indiana State Highway Commission and the Joint Highway Research Project at Purdue University.
3. Suggestions for standardizing the reporting and collection of new data have been made.

The computerized data bank should facilitate efficient and economical handling of geotechnical information from the State of Indiana. Soils information which was essentially "lost" after a project was completed, can now be utilized for future highway projects and improvements. The data bank should be maintained by the ISHC for all potential users.

The application of statistical methods to the geotechnical data stored to January 1978 is promising. However, no soil group studied can be said to produce better correlation equations than others, overall. The grouping of soils by physiographic regions and parent material areas certainly appears to be justified for some dependent variables and for certain groups of soils. From the statistical analysis to date, the following preliminary conclusions are drawn.

1. The prediction of compression index (C_c) and compression ratio (C_r) from more simple soil measures is reasonable on a state-wide basis. Soils investigated within the Wabash Lowland and the Crawford Upland physiographic regions also produce regression equations for C_c and C_r with relatively high correlation coefficients. Further, equations generated for soils derived from outwash and alluvial deposits also are statistically significant for the prediction of C_c , but not for the prediction of C_r .
2. Prediction of the unconfined compressive strength (q_u), by the method of regression analysis is not possible for soils found within the Tipton Till Plain, Scottsburg Lowland, Mitchell Plain, Wabash Lowland, Crawford Upland, and soils derived from residuum of siltstone, shale, and sandstone; residuum of

limestone bedrock; thin loess over loamy Wisconsin age glacial till; and outwash and alluvial deposits. Acceptable regression models for q_u of soils from the Calumet Lacustrine Plain and soils derived from lacustrine deposits have been developed.

3. The prediction of maximum dry density ($\gamma_{d_{max}}$), maximum wet density ($\gamma_{m_{max}}$) and optimum moisture content (w_{opt}) is not possible on a statewide basis from the simpler-to-determine independent variables studied and the statistical methods used. Adequate prediction equations for the soils investigated from the Valparaiso Morainal Area have been found to exist for the logarithms of $\gamma_{d_{max}}$, $\gamma_{m_{max}}$ (and their logarithmic transformations), and w_{opt} . Soils derived from residuum of limestone bedrock also produced adequate regression equations, but only for the logarithms of $\gamma_{d_{max}}$ and w_{opt} and the simpler-to-determine independent variables. No acceptable models were found for soils of the Tipton Till Plain and soils derived from residuum of siltstone, shale, and sandstone; thin loess deposits over loamy Wisconsin age glacial till; and soils classified as CL and CH in the Unified Soil Classification System and A-4, A-6, and A-7 in the AASHTO system.

4. The prediction of the soaked CBR is not possible with the methods and data used within this study. The grouping of soils into units similar to those of the compaction test data does not offer any improvement with the set of independent variables investigated.

As sufficient data is collected in the future from all the physiographic and parent material areas, the need to study groups of soils which are more closely related will be determined. These areas should include pedologic soil association areas, soil series, soil horizons, and combinations, thereof.

RECOMMENDATIONS FOR FUTURE RESEARCH

This study has briefly investigated the method of regression analysis to develop meaningful correlations and predictions of difficult to determine soil parameters from more readily attainable soil measures. The following are suggested for future research.

1. Statistical techniques other than regression analysis may prove to be more appropriate to study soil variability, and may lead to better statistical models. Bayesian statistical decision theory has recently been under development and provides mathematical models for making engineering decisions in the face of uncertainty.
2. The analysis of variance (ANOVA) technique should be investigated. The independent variables in ANOVA models may be qualitative (physiographic region, parent material, sampling procedure, etc.) and may provide insight into factors often overlooked in the statistical study of soils.
3. The collection of new soils data should continue from private and public sources. For

those soil properties for which no acceptable models are generated, the need to study groups of soils other than those investigated within this research should be determined. The pedological grouping of soils data appears most promising.

4. The feasibility of contractors using the geotechnical data bank should be studied.
5. The feasibility of incorporating into the data bank the location of bore holes by state plane coordinates should be investigated. This would enable a user of the system to precisely locate the position from which each sample has been taken.

BIBLIOGRAPHY

BIBLIOGRAPHY

1. Azzouz, A.S., Krizek, R.J. and Corotis, R.B. (1976) "Regression Analysis of Soil Compressibility," Soils and Foundations, Vol. 16, No. 2, June, pp. 19-29.
2. ✓ Belcher, D.J., Gregg, L.E. and Woods, K.B. (1943) "The Formation, Distribution and Engineering Characteristics of Soils," Joint Highway Research Project, the State Highway Commission of Indiana - The Engineering Experiment Station - Engineering Bulletin No. 87, Purdue University, January, 389 pp.
3. Black, W.P.M. (1962) "A Method of Estimating the California Bearing Ratio of Cohesive Soils from Plasticity Data," Geotechnique, Vol. 12, No. 4, December, pp. 271-282.
4. Burmister, D.M. (1940) "Practical Methods for the Classification of Soils," Proceedings of the Purdue Conference on Soil Mechanics and Its Applications, Purdue University, September, pp. 129-139.
5. ✓ Clauss, K.A. (1975) "Material or Terrain Data Banking at the National Data Bank for Roads," 3rd Symposium on Terrain Evaluation and Data Storage, Johannesburg, South Africa, February, 9 pp.
6. Clauss, K.A. and Vail, J.W. (1975) "A New Approach to Materials Data Banking for Road Construction," Proceedings of the 6th Regional Conference for Africa, Durban, South Africa, Vol. 1, September, pp. 11-19.
7. Cozzolino, V.M. (1961) "Statistical Forecasting of Compression Index," Proceedings of the 5th International Conference on Soil Mechanics and Foundation Engineering, Paris, Vol. 1, pp. 51-53.
8. Crawford, R.A., Thomas, J.B. and Stout, M.Jr. (1972) "Computerized Soil Test Data for Highway Design," Physical Research Section, South Dakota Department of Highways, Pierre, South Dakota, 24 pp.

9. Davidson, D. T. and Gardiner, W. P. (1949) "Calculation of Standard Proctor Density and Optimum Moisture Content from Mechanical Analysis, Shrinkage Factors, and Plasticity Index," HRB Proceedings, Vol. 29, pp. 477-481.
10. Deen, R. C. (1967) "Highway Construction in Windblown Silts in Western Kentucky," Division of Research, Kentucky Department of Highways, January.
11. Draper, N. and Smith, H. (1966) Applied Regression Analysis, John Wiley and Sons, Inc., 407 pp.
12. Elnaggar, H. A. and Krizek, R. J. (1970) "Statistical Approximation for Consolidation Settlement," Highway Research Board, No. 323, pp. 87-96.
13. Franzmeir, D. P., Sanders, F. W. and Zachary, A. L. (1975) Key to Soils in Indiana, Department of Agronomy, Purdue University and USDA Soil Conservation Service, February, 26 pp.
14. Fredlund, D. G. and Dahlman, A. E. (1971) "Statistical Geotechnical Properties of Glacial Lake Edmonton Sediments," Proceedings of the 1st International Conference on Applications of Statistics and Probability to Soil and Structural Engineering, Peter Lumb, Editor, Hong Kong University Press, September, pp. 203-228.
15. Galloway, H. M., Yahner, J. E., Srinivasan, G. and Franzmeir, D. P. (1975) User's Guide to the General Soil Maps and Interpretative Data for Counties of Indiana, 27 pp.
16. General Soils Maps and Interpretation Tables for the Counties of Indiana (1971), Agricultural Experiment Station/Cooperative Extension Service, Purdue University and Soil Conservation Service, U. S. Department of Agriculture, November.
17. Hagerty, D. J., Schmitt, N. G. and Pfalzer, W. J. (1973) "Retrieval and Use of Geotechnical Information," Ohio River Valley Soil Seminar, Geotechnics in Transportation Engineering, October, pp. 1-9.
18. Hampton, D. (1961) "Statistical Analysis of Soil Variability," Joint Highway Research Project Report No. 12, Purdue University, May, 115 pp.
19. Hampton, D., Yoder, E. J. and Burr, I. W. (1962) "Variability of Engineering Properties of Brookston and Crosby Soils," HRB Proceedings, Vol. 41, pp. 621-649.

20. Holden, A. (1969) "Engineering Soil Mapping from Air-photos," Ministry of Roads and Traffic, Salisbury, South Rhodesia, July.
21. Hough, B.K. (1957) Basic Soils Engineering, The Ronald Press Company, Inc., pp. 114-115.
22. Humphreys, A.P. (1976) "Data Presentation, Preservation and Recovery," Ground Engineering, Vol. 9, No. 8, November, pp. 33-38.
23. James, P.M. (1968) "Atterberg Limit Tests for Quantitative Earthwork Control," Civil Engineering and Public Works Review, Vol. 63, No. 746, September, pp. 1005-1006.
24. Jumikis, A.R. (1958) "Geology and Soils of the Newark (N.J.) Metropolitan Area," Journal of the Soil Mechanics and Foundations Division, ASCE, Vol. 84, No. SM2, Proc. Paper 1646, May, 41 pp.
25. Kogure, K. and Ohira, Y. (1977) "Statistical Forecasting of Compressibility of Peaty Ground," Canadian Geotechnical Journal, Vol. 14, No. 4, November, pp. 562-570.
26. Kreig, R.A. (1977) "Terrain Analysis for the Trans-Alaska Pipeline," Civil Engineering, Vol. 47, No. 7, July, pp. 61-65.
27. Kreig, R.A. (1977) Personal Communication, October.
28. Krizek, R.J., Corotis, R.B. and El-Moursi, H.H. (1977) "Probabilistic Analysis of Predicted and Measured Settlements," Canadian Geotechnical Journal, Vol. 14, No. 1, February, pp. 17-33.
29. Legget, R.F. (1973) Cities and Geology, McGraw-Hill Book Co., Inc., pp. 505-506.
30. Lille Regional Laboratory (1971) "Establishment of a Card Index for Borings and Tests," Ministry Public Works, Paris, January.
31. Liu, T.K. and Thornburn, T.H. (1965) "Engineering Index Properties of Some Surficial Soils in Illinois," Bulletin No. 477, University of Illinois, College of Engineering, Engineering Experiment Station, 111 pp.
32. Lumb, P. (1966) "The Variability of Natural Soils," Canadian Geotechnical Journal, Vol. 3, No. 2, May, pp. 74-97.

33. Lumb, P. (1974) "Application of Statistics in Soil Mechanics," in I.K. Lee (Ed.), Soil Mechanics-New Horizons, American Elsevier Publishing Company, Inc., pp. 44-111.
34. Lundin, S.E., Stephansson, O. and Zetterlund, P. (1973) "Geoteknisk Databank," Rapport R70, National Swedish Building Research Institute, 158 pp.
35. Malott, C.A. (1922) "The Physiography of Indiana," Handbook of Indiana Geology, Indiana Department of Conservation, Pub. 21, part 2.
36. Map of the Soil Associations of Indiana (1977) Cooperative Extension Service, Purdue University in Cooperation with the State Soil and Water Conservation Committee, Indiana Dept. of Natural Resources, and the Soil Conservation Service, U.S.D.A.
37. McKittrick, D.P. (1965) "Subsurface Investigation for Indiana Highways," Joint Highway Research Project Report No. 20, Purdue University, September, 176 pp.
38. Michigan State Highway Department (1952) "Field Manual of Soil Engineering," 3rd Edition, August, 368 pp.
39. Moran, Proctor, Mueser and Rutledge (1958) "Study of Deep Soil Stabilization by Vertical Sand Drains," Bureau of Yards and Docks, Department of the Navy, Contract No. NOY-88812.
40. National Institute for Transport and Road Research (1976) "Geotechnical and Soil Engineering Mapping for Roads and the Storage of Materials Data," Technical Recommendations for Highways, Draft TRH2, Pretoria, South Africa, July, 34 pp.
41. Neter, J. and Wasserman, W. (1974) Applied Linear Statistical Models, Richard D. Irwin, Inc., 842 pp.
42. Nie, N.H., Hull, C.H., Jenkins, J.G., Steinbrenner, K. and Bent, D.H. (1975) Statistical Package for the Social Sciences, 2nd Edition, McGraw-Hill Book Co., 675 pp.
43. Nishida, Y. (1956) "A Brief Note on Compression Index of Soil," Journal of the Soil Mechanics and Foundations Division, ASCE, Vol. 82, No. SM3, Proc. Paper 1027, July, 14 pp.
44. Osterberg, J.O. (1972) Personal Communication between Osterberg and Azzouz et al.

45. Peck, R.B. (1940) "Sampling Methods and Laboratory Tests for Chicago Subway Soils," Proceedings of the Purdue Conference on Soil Mechanics and its Applications, Purdue University, September, pp. 140-150.
46. Peck, R.B. and Reed, W.C. (1954) "Engineering Properties of Chicago Subsoils," Bulletin No. 423, University of Illinois, College of Engineering, Engineering Experiment Station, 62 pp.
47. Redon, J.P. (1972) "Computerized Inventory of Soil Profiles Throughout Algeria," National Laboratory of Public Works and Buildings, Algeria, September.
48. Ring, G.W. III, Sallberg, J.R. and Collins, W.H. (1962) "Correlation of Compaction and Classification Test Data," HRB Bulletin 325, January, pp. 55-75.
49. Rizkallah, V. and El Nimr, E. (1975) "Applicability of Regression Analysis in Soil Mechanics with the Help of Data Banks," Application of Statistics and Probability in Soil and Structural Engineering, 2nd International Conference, Aachen, F.R. Germany, Vol. 2, pp. 423-438.
50. Roberts, W.S. (1976) "Regionalized Feasibility Study of Cold Weather Earthwork," M.S.C.E. Thesis, Purdue University, May 190 pp. (Also, Special Report 76-2, Cold Regions Research and Engineering Laboratory, Hanover, New Hampshire, July, 1976)
51. Rowan, W.H. and Graham, W.W. (1948) "Proper Compaction Eliminates Curing Period in Constructing Fills," Civil Engineering, Vol. 18, No. 7, July, pp. 50-51.
52. Sisiliano, W.J. (1970) "A Regional Approach to Highway Soils Considerations in Indiana," Joint Highway Research Project Report No. 18, Purdue University, September, 223 pp.
53. Skempton, A.W. (1944) "Notes on the Compressibility of Clays," Quarterly Journal of the Geological Society of London, Vol. 100, pp. 119-135.
54. Soil Survey Manuals (1958-present), United States Department of Agriculture, Soil Conservation Service.
55. Sowers, G.B. (1970) Introductory Soil Mechanics and Foundations, 3rd Edition, The Macmillan Company, Collier Macmillan Limited, p. 102.

56. Spradling, D. (1976) "A Soils Data System for Kentucky," Research Report 441, Division of Research, Bureau of Highways, Kentucky Department of Transportation, 58 pp.
57. Stokstad, O.L. (1940) "Soil Type as a Factor in Highway Engineering," Proceedings of the Purdue Conference on Soil Mechanics and its Applications, Purdue University, September, pp. 371-381.
58. Szendrei, M.E. (1977) Personal Communication, February.
59. Terzaghi, K. and Peck, R.B. (1967) Soil Mechanics in Engineering Practice, 2nd Edition, John Wiley and Sons, Inc., p. 73.
60. Thornburn, T.H., Hagerty, D.J. and Liu, T.K. (1970) "Engineering Soil Report: Will County, Illinois," Bulletin 501, University of Illinois, College of Engineering, Engineering Experiment Station, 195 pp.
61. Thornburn, T.H., Liu, T.K. and Misiaszek, E.T. (1970) "Engineering Soil Report: DeWitt County, Illinois," Bulletin 505, University of Illinois, College of Engineering, Engineering Experiment Station, 103 pp.
62. Thornburn, T.H., Morse, R.K. and Liu, T.K. (1966) "Engineering Soil Report: Livingston County, Illinois," Bulletin 482, University of Illinois, College of Engineering, Engineering Experiment Station, 128 pp.
63. Tomlinson, M.J. and Francis, H.W.A. (1973) "Site Investigation for Motorways," The Highway Engineer, Vol. XX, No. 6, June, pp. 23-33.
64. Transportation Research Board (1976) "Acquisition and Use of Geotechnical Information," Synthesis of Highway Practice 33, National Cooperative Highway Research Program, National Research Council, Washington, D.C., 40 pp.
65. United States Department of Agriculture (1971) Guide for Interpreting Engineering Uses of Soils, Soil Conservation Service, November, 87 pp.
66. Valent, P.J. (1978) "Long-Term Stress-Strain Behavior of a Seafloor Soil," Technical Note No. N-1515, Civil Engineering Laboratory, Naval Construction Battalion Center, California, 51 pp.

67. Van Rooyen, M. (1967) "Intercorrelation of Engineering Properties of Soil," Proceedings of the 4th Regional Conference for Africa on Soil Mechanics and Foundation Engineering, Cape Town, pp. 203-208.
68. Witczak, N. W. (1970) "A Generalized Investigation of Selected Highway Design and Construction Factors by Regional Geomorphic Units Within the Continental United States," Ph.D. Thesis, Purdue University, January, 396 pp.
69. Wlaschin, J. B. (1978) "Soils Bore Log Program," Draft presented at 3rd Annual Southwest Geotechnical Engineers Conference, Albuquerque, New Mexico, March.
70. Woods, K. B. and Litehiser, R. R. (1938) "Soil Mechanics Applied to Highway Engineering in Ohio," Bulletin 99, Ohio State University, Engineering Experiment Station.
71. Theil, Henri (1971) "Principles of Econometrics", Wiley and Sons, N. Y. p. 178.

APPENDICES

APPENDIX A

Distributional Characterization of Soil Properties

The following Figures graphically illustrate the range, 95% confidence interval and the mean of the soil parameters, based upon grouping the soils by physiographic regions and parent material areas.

FIGURE A1 DISTRIBUTIONAL CHARACTERIZATION OF PERCENT PASSING NO. 10 SIEVE

FIGURE A2 DISTRIBUTIONAL CHARACTERIZATION OF PERCENT PASSING NO. 40 SIEVE

FIGURE A3 DISTRIBUTIONAL CHARACTERIZATION OF PERCENT PASSING NO. 200 SIEVE

FIGURE A4 DISTRIBUTIONAL CHARACTERIZATION OF PERCENT PASSING NO. 270 SIEVE

FIGURE A5 DISTRIBUTIONAL CHARACTERIZATION OF PERCENT SAND

FIGURE A6 DISTRIBUTIONAL CHARACTERIZATION OF PERCENT SILT

FIGURE A7 DISTRIBUTIONAL CHARACTERIZATION OF PERCENT CLAY

FIGURE A8 DISTRIBUTIONAL CHARACTERIZATION OF PERCENT COLLOIDS

FIGURE A9 DISTRIBUTIONAL CHARACTERIZATION OF LIQUID LIMIT

FIGURE A10 DISTRIBUTIONAL CHARACTERIZATION OF PLASTIC LIMIT

FIGURE A11 DISTRIBUTIONAL CHARACTERIZATION OF PLASTICITY INDEX

FIGURE A12 DISTRIBUTIONAL CHARACTERIZATION OF SHRINKAGE LIMIT

FIGURE A13 DISTRIBUTIONAL CHARACTERIZATION OF NATURAL MOISTURE CONTENT

FIGURE A14 DISTRIBUTIONAL CHARACTERIZATION OF NATURAL DRY DENSITY

FIGURE A15 DISTRIBUTIONAL CHARACTERIZATION OF COMPACTION TEST DATA

FIGURE A15 CONTINUED

FIGURE A16 DISTRIBUTIONAL CHARACTERIZATION OF SOAKED CALIFORNIA BEARING RATIO

FIGURE A17 DISTRIBUTIONAL CHARACTERIZATION OF UNCONFINED COMPRESSIVE STRENGTH

FIGURE A18 DISTRIBUTIONAL CHARACTERIZATION OF CONSOLIDATION TEST DATA

USER'S MANUAL

USER'S MANUAL

Introduction

The User's Manual is presented as Appendices B, C, D, E, and F and is to be used in conjunction with the computerized storage and retrieval system. Appendix B includes a description of the variables included in the data bank. The variable names associated with each data item are used throughout the manual whenever this information is referenced. Appendix C includes a listing of the codes assigned to those variables which cannot directly be recorded from subsurface investigation reports. Appendix D contains the formats, card locations, and column locations for each data item. Appendix E contains the listing of the programs used to add additional data to the data bank; to check data input errors where this is possible; and to use the Statistical Package for the Social Sciences (SPSS) program for data manipulation and management. Appendix F contains examples of the use of the geotechnical data bank.

If the data are available for inclusion into the data system, this information is recorded on the Data Input Form (DIF), Figure 4. Some information will not be available and these spaces will be left blank. For example, for soil

samples taken from counties for which no modern agricultural soil survey reports are available, the soil series name, horizon, slope class, erosion class, depth to bedrock (from the soil survey), depth to seasonal high water table, drainage class, permeability, flood potential, frost-heave susceptibility, shrink-swell potential, and pH data spaces will not be filled.

All numeric data will be right-justified. The F-type format for numeric data is fixed, therefore decimal points are not to be included. It is suggested that leading zeros also be included to minimize punching errors (for example, beginning a string of numbers in the wrong column). Alpha-numeric information, such as boring number, line number, and laboratory number, may be recorded in any columns. However, it is suggested that such alpha-numeric information be left-justified.

APPENDIX B

USER'S MANUAL: PART I

Description of Data Items

Part I of the User's Manual contains a description of the information which is presently being stored in the data bank. Six cards are used, and each card is consecutively numbered from one to six. If no information is available for a particular card (which is usually the case for card 6), the identification number will be recorded, and this card will be maintained in its proper sequence.

Referring to the Data Input Form (DIF), see Figure 4, the variable SEQNUM (located in the upper left corner) refers to the sequence number automatically assigned by the computer to a soil sample. This number ranges from 1 to the total number of samples contained within the data bank. It is recorded on the DIF after a listing of the newly entered data are received for verification. This identification number is automatically present whenever the data are processed, may be accessed by referring to SEQNUM, and may be used as any other variable in the processing of data.

VARIABLE NAMEDESCRIPTION

CARD1

The first column of each card within a data set, containing six cards per data set, contains the card number. The number (1) is always recorded for this variable.

COUNTY

The county from which the soil sample has been taken is recorded here. County names are coded and listed alphabetically in Part II.

HOLENO

A unique number is assigned sequentially to each hole within each county.

SAMPNO

Numbers are assigned sequentially to each sample retrieved from each hole.

The variables COUNTY, HOLENO and SAMPNO, from the identification number (I.D. No.) which is recorded in columns 2-10 of the remaining five cards. Use of the I.D. No., along with the card number, assigns a unique ten digit number to

each data card. This is convenient for internal bookkeeping.

DISTRI

The State of Indiana is divided into six highway districts, which have been coded.

DATEYR

The year in which the sample was taken is recorded here. The two columns show the last two digits of the year. For example, the year 1965 is represented as (65).

DATEMO

The month in which the sample was taken is recorded here in code.

DATEDA

The day of the month on which the sample was taken is recorded here, reported as 01 through 31.

TOWN

The township of the public land survey within the state is recorded here.

TOWNDI

The north-south direction of the township is coded.

RANGE

The range within the State is recorded here.

RANGDI

The east-west direction of the range is coded.

SECTION

The section number is recorded here.

For example, if a soil sample has been taken from township 3 North, range 2 West, section 24 (T3N, R2W, Sec. 24), (03) will be entered for TOWN, (1) will be entered for TOWNDI (see Part II for codes assigned to directions), (02) will be entered for RANGE, (2) will be entered for RANGDI, and (24) will be entered for SECTION.

PROJPR
PROJNO
PROJPA
PROJMI

These four variables make up the project number, consisting of a prefix, number, parenthesis and mileage.

CONTPR
CONTNO

These two variables make up the contract number, consisting of a prefix and a number.

ROADPR
ROADNO
ROADSU

The road number contains a prefix, a number and a suffix.

BORING

A unique alpha-numeric boring number is assigned to each boring within each project.

ASSOC

The soil association name, representing a natural soil landscape with a characteristic topography and repeating pattern of soil types, is coded here. There are 108 soil association types identified within the State of Indiana.

The soil association is taken from the General Soil Maps, contained in Reference (16), prepared for each county.

A user's guide is also available; see Reference (15).

REPEAT

This column is used to indicate the source of the soil index properties (liquid limit, plastic limit and plasticity index) reported. A (1) in Column 80 indicates that original data are reported for the index properties. A (2) indicates that a special test (compaction, strength, or consolidation) was performed on a soil sample but the index

properties were not determined. However, the index properties were reported for a soil sample of the same type (as indicated by a laboratory number) at a different depth within the same hole. If the index properties from a soil sample of the same type taken from a different hole have been reported, a (3) is recorded.

This flag is for statistical analyses purposes, i.e., frequency distributions. A biased estimate of the frequency of the index properties would result if the results of a single test were used more than once. Therefore when a (2) or (3) was recorded the data were not used in a frequency distribution. The number (2) is always recorded for this variable. The identification number (see description on Card 1) is recorded.

CARD2

ID2

STATNO

The station number on the centerline or baseline, used to reference the location of the sample hole, is recorded here to the nearest foot.

EXAMPLE: Station $1954 + 24 =$
0 1 9 5 4 2 4.

OFFSET

The distance from the centerline or baseline to the sample hole is recorded here to the nearest foot. If the sample has been removed from the centerline, the offset is reported as (0000).

OFFDIR

The direction of the offset is coded.

LINE1
LINE2

The alpha-numeric line number description is recorded here. The description is left justified. The line number has been broken up into two variables since the maximum field length allowable is eight, and an appropriate description could contain up to ten characters. The source of the information is coded. The names of the

SOURCE

consulting firms and of the Division of Materials and Tests, ISHC performing the laboratory tests and/or roadway borings are recorded.

SAMPTY

The method of removing the sample from the hole is coded.

LABNO

The laboratory number assigned to the soil sample is left justified.

GRDSUR

The ground surface elevation of the top of the boring is recorded to the nearest tenth of a foot.

DEPTHT

The depth to the top of the sample is entered to the nearest tenth of a foot.

DEPTHB

The depth to the bottom of the sample is entered to the nearest tenth of a foot.

SPT

The value of the Standard Penetration Test for the depth from which the sample has been removed is recorded here.

PHYSIO

The State of Indiana is divided into eleven physiographic units, each being assigned a code. The

Northern Moraine and Lake Region is further subdivided into five areas. See Figure 5.

SERIES

Soils which have been derived from similar parent materials and have horizons of similar origin, character, and arrangement in the soil profile, characterize a soil series.

The location of each sample hole is found on an agricultural soil survey map (54).

The soil series name is subsequently identified and the code is recorded.

The identification of the soil series from a soil survey map requires the determination of the exact position from which the sample has been taken.

This is very difficult since a slight error in scaling can cause an error in the identification of the correct series.

Since the parent material (see PARENT below) is determined

once the soil series is found, the error is compounded if carelessness is not eliminated.

CARD3

The number (3) is always recorded for this variable.

ID3

The identification number is recorded.

PARENT

Twelve parent material areas have been identified within Indiana. The parent material types can be identified once the soil series is found by referring to the booklet, "Key to Soils of Indiana" (13). The soil series formed within each parent material is listed within this booklet for easy identification. The parent material name is coded. If the soil series has been developed in more than one parent material area, the parent material judged to be most characteristic of the area in question is reported.

HORIZO

A simple profile will display each of three horizons,

designated as A, B, and C.

The typical range in depth of each horizon, along with the USDA textural classification, is given within the specific agricultural soil survey report for the county. The depth from which the sample was removed and the textural description provided in the soil profile borings, will help determine the horizon for the sample. If the sample is taken from a depth intermediate between two horizons, the horizon judged to be most representative is reported. The horizon name is coded.

SLOPE

The slope (topographic) class characteristic of the soil series is identified from the soil mapping unit in an agricultural soil survey report. The class intervals have been coded.

EROSIO

The erosion phase of the soil series is identified from the mapping unit located on a soil survey map.

Codes have been assigned to each erosion phase.

BEDRKS

If the depth to bedrock is less than fifteen feet from the ground surface, the value will be reported in the soil survey. If a range of values is reported, the average depth is recorded to the nearest tenth of a foot.

BEDRKB

If bedrock was encountered during drilling or sampling and is noted in the soil profile of the boring log, this information is recorded to the nearest tenth of a foot.

WATERS

The depth to the seasonal high water table is reported in the soil survey if this depth is within six feet from the ground surface. A range of values is normally reported and the average value is recorded to the nearest tenth of a foot.

WATERC WATERF

The depth to water reported in the drill logs at the completion

of drilling is recorded for the variable WATERC. The final or 24 hour reading, whichever is reported in the logs, is recorded for WATERF. Both depths are rounded to the tenth of a foot.

DRAIN

Natural soil drainage classes have been coded. Once the soil series and parent material have been identified, the drainage characteristic of the soil type can be determined from the "Key to Soils of Indiana" (13).

PERMEA

Numerical ranges have been assigned to rate soil permeability and these have been coded. The range in permeability for the soil series is found in the soil survey for the county being considered.

FL00D

Those soils subject to flooding or which have a ponded or perched water condition are indicated in the soil survey. The typical soil condition is coded.

FROST

Three classes of frost potential have been defined, i.e., low, medium and high. These are based on United States Department of Agriculture soil texture classes or the classes in the Unified soil classification system. Further subdivisions have been required and have subsequently been coded.

SHRINK

Qualitative definitions of shrink-swell behavior are reported in the soil surveys and these have been assigned ranges which have subsequently been coded.

PH

The pH reaction range typical for the soil series is given in the soil survey. Each range has been assigned a code. If a wide range of pH values have been reported, overlapping the coded ranges, no information will be recorded.

GRAD

The percent soil by weight passing the following sieve sizes is reported to the nearest

tenth of a percent:

GRAD01
GRAD02
GRAD03
GRAD04
GRAD05

1 1/2 inch
1 inch
3/4 inch
1/2 inch
3/8 inch

CARD4
ID4

Between GRAD05 and GRAD06, the number (4) is reported for CARD4 and the identification number for ID4.

GRAD06
GRAD07
GRAD08
GRAD09
GRAD10

No. 4
No. 10
No. 40
No. 200
No. 270

SAND
SILT
CLAY
COLLOIDS

The percent sand, silt, clay and colloids by weight are recorded to the nearest tenth of a percent. Percent sand has presented some problems due to inconsistencies in reporting by the numerous consulting firms. Accordingly, a sub-program was written to calculate the percent sand based upon percent passing No. 10 sieve minus percent passing No. 200 sieve (SAND = GRAD07 - GRAD09). Liquid limits and plastic limits are reported in addition to the plasticity index.

LL
PL
PI

Non-plastic soils have been assigned a code (-010). The percentages are rounded to the nearest tenth.

SL

The shrinkage limit is recorded to the nearest tenth of a percent. If a special test has been performed on a soil and a sieve analysis and/or index property test has not been run, the results from the sieve analysis and/or index property determination of the soil sample with the same laboratory number will be reported for this sample. See discussion under REPEAT.

LOSSIG

The percent weight loss for the determination of organic content (loss on ignition test) is reported to the nearest tenth of a percent.

CARD5

The number (5) is always entered.

ID5

The identification number is recorded.

NATMC

The natural moisture content is

rounded to the nearest tenth of a percent.

NATWD
NATDD

The natural wet density and natural dry density are recorded to the nearest tenth. The units are pounds per cubic foot.

SPECGR

If the results from a triaxial or consolidation test are reported for a soil sample, the specific gravity is usually given. This is rounded to the thousand place.

TEXTUR

The textural classification as reported in the soil profile survey has been coded.

ORGANI

The relative amount of organic matter (as determined from a loss on ignition test or visual identification) is coded.

COLOR

The color of the soil sample based on the moist condition is coded.

TESTEF

The type of compaction test and compactive effort applied to the sample are recorded in code.

If the compactive effort is

not typical, the value is recorded under the comments section of the data input form, Figure 4.

MAXDD
MAXWD

Both the maximum dry density (MAXDD) and the maximum wet density (MAXWD) are recorded to the nearest tenth of a pound per cubic foot.

OPTIMC

The optimum moisture content to the nearest tenth of a percent is recorded.

CBRUN1
CBRUN2
CBRS01
CBRS02

The value of the CBR number is recorded to the nearest tenth of a percent. CBRUN1 and CBRUN2 represent the unsoaked values at 100 percent and 95 percent maximum dry density, respectively. CBRS01 and CBRS02 represent the soaked values at 100 percent and 95 percent maximum dry density, respectively.

QUSTR

The unconfined compressive strength to the nearest hundredth of a ton per square foot is entered here.

AASHTO1
UNIF1
GI

A program to calculate both the AASHTO (including group index, GI) and Unified classifications has been written and included in Part IV of the User's Manual. The names have been coded. The variable names are AASHTO, GI and UNIF.

If one of the variables used to classify the soil type was not reported (i.e., liquid limit, plastic limit, percent passing No. 4, No. 10, No. 40, or No. 200 sieve), it is not possible to classify the soil with the computer. But if the soil sample had been visually classified in the laboratory and reported within the soil profile survey, a provision has been incorporated to include this information in the data system. The two variables, AASHTO1 and UNIF1, have been created for this purpose, and the appropriate code is entered (see

Part II for codes). If it is not possible for the computer to generate the soil classification name and this information has not been reported in the laboratory, these two items will be left blank and a (-8) will automatically be assigned to these variables to indicate that they are unknown.

CARD6

The number (6) is entered.

ID6

The identification number is recorded.

QUSTA

The failure strain reported to the nearest hundredth of a percent is entered if an unconfined compressive strength test has been run.

TYPE

Codes have been assigned to the various types of strength tests.

STRENGTH

The failure strength reported to the nearest hundredth of a ton per square foot is entered.

STRAIN

The failure strain reported to the nearest hundredth of a percent is recorded.

CONFPRES

The confining pressure is entered to the nearest hundredth of a pound per square inch.

COHESION
ANGLE

If a Mohr failure envelope is included in the strength test results, the intercept to the nearest hundredth of a ton per square foot, and the strength angle to the nearest tenth of a degree, is recorded.

Strength parameters from total-stress circles will be reported.

POREPRES

When a saturated strength test with pore pressure measurements is presented in a subsurface investigation report, the pore pressure at failure will be recorded to the nearest hundredth of a pound per square inch.

MAJOR

The major principal stress at failure will be recorded to the nearest hundredth of a ton per square foot.

E0
EF

The initial (E0) and final (EF) void ratio is reported to the nearest thousandth.

SO
SF

The initial (SO) and final (SF) degree of saturation is entered to the nearest tenth of a percent.

PO
PC

The overburden pressure (PO) and preconsolidation pressure (PC) is entered to the nearest tenth of a ton per square foot. Total stresses will be reported.

CC
CR

The compression index (CC) and recompression index (CR) is rounded to the nearest thousandth.

CV

The coefficient of consolidation in square feet per month is rounded to the nearest hundredth.

APPENDIX C

USER'S MANUAL: PART II

Coding System

Information which cannot be directly recorded has been codified to make the system compatible with computerized storage and retrieval. Whenever the data are accessed, the code will be used. The printed output will contain the code and the description (value label). Such labels are particularly helpful in documenting output and have therefore been included in the SPSS programs listed in Part IV.

As additional codes are required (in particular, for SOURCE and SAMPTY), they can be added to the system.

VARIABLE NAME COUNTY

<u>CODE</u>	<u>DESCRIPTION</u>	<u>CODE</u>	<u>DESCRIPTION</u>
1.	Adams	17.	Dekalb
2.	Allen	18.	Delaware
3.	Bartholomew	19.	Dubois
4.	Benton	20.	Elkhart
5.	Blackford	21.	Fayette
6.	Boone	22.	Floyd
7.	Brown	23.	Fountain
8.	Carroll	24.	Franklin
9.	Cass	25.	Fulton
10.	Clark	26.	Gibson
11.	Clay	27.	Grant
12.	Clinton	28.	Greene
13.	Crawford	29.	Hamilton
14.	Daviess	30.	Hancock
15.	Dearborn	31.	Harrison
16.	Decatur	32.	Hendricks

VARIABLE NAME COUNTY (Continued)

<u>CODE</u>	<u>DESCRIPTION</u>	<u>CODE</u>	<u>DESCRIPTION</u>
33.	Henry	63.	Pike
34.	Howard	64.	Porter
35.	Huntington	65.	Posey
36.	Jackson	66.	Pulaski
37.	Jasper	67.	Putnam
38.	Jay	68.	Randolph
39.	Jefferson	69.	Ripley
40.	Jennings	70.	Rush
41.	Johnson	71.	St. Joseph
42.	Knox	72.	Scott
43.	Kosciusko	73.	Shelby
44.	Lagrange	74.	Spencer
45.	Lake	75.	Starke
46.	LaPorte	76.	Steuben
47.	Lawrence	77.	Sullivan
48.	Madison	78.	Switzerland
49.	Marion	79.	Tippecanoe
50.	Marshall	80.	Tipton
51.	Martin	81.	Union
52.	Miami	82.	Vanderburgh
53.	Monroe	83.	Vermillion
54.	Montgomery	84.	Vigo
55.	Morgan	85.	Wabash
56.	Newton	86.	Warren
57.	Noble	87.	Warrick
58.	Ohio	88.	Washington
59.	Orange	89.	Wayne
60.	Owen	90.	Wells
61.	Parke	91.	White
62.	Perry	92.	Whitley
		93.	State of Kentucky

VARIABLE NAME DISTRI

<u>CODE</u>	<u>DESCRIPTION</u>
1.	Crawfordsville
2.	Fort Wayne
3.	Greenfield
4.	LaPorte
5.	Seymour
6.	Vincennes

<u>VARIABLE NAME</u>	<u>DATEMO</u>
<u>CODE</u>	<u>DESCRIPTION</u>
1.	January
2.	February
3.	March
4.	April
5.	May
6.	June
7.	July
8.	August
9.	September
10.	October
11.	November
12.	December

<u>VARIABLE NAME</u>	<u>TOWNDI</u>
<u>CODE</u>	<u>DESCRIPTION</u>
1.	North
2.	South

<u>VARIABLE NAME</u>	<u>RANGDI</u>
<u>CODE</u>	<u>DESCRIPTION</u>
1.	East
2.	West

<u>VARIABLE NAME</u>	<u>SECTIO</u>
<u>CODE</u>	<u>DESCRIPTION</u>
99.	Special Land Grant - refer to map of area

<u>VARIABLE NAME</u>	<u>ASSOC</u>
<u>CODE</u>	<u>DESCRIPTION</u>
1.	Eel-Martinsville-Genesee
2.	Genesee-Ross-Shoals
3.	Wakeland-Stendal-Haymond
4.	Genesee-Shoals-Eel
5.	Haymond-Nolin-Petrolia
6.	Genesee-Eel-Stendal-Pope
7.	Huntington-Wheeling-Markham
8.	Huntington-Lindsay
9.	Haymond-Wakeland
10.	Alida-Delrey-Whitaker

<u>VARIABLE NAME</u>	<u>ASSOC (continued)</u>
<u>CODE</u>	<u>DESCRIPTION</u>
11.	Bono-Maumee-Warners
12.	Chelsea-Hillsdale-Oshtemo
13.	Conrad-Wooten-Weiss
14.	Door-Tracy-Quinn
15.	Door-Lydick
16.	Elston-Wea
17.	Dubois-Otwell
18.	Fox-Martinsville-Aluvi
19.	Fox-Nineveh-Ockley
20.	Fox-Rodman
21.	Fulton-Rimer-Milford-Rensselaer
22.	Homer-Sebewa-Gilford
23.	Maumee-Gilford-Rensselaer
24.	Maumee-Newton
26.	Martinsville-Belmore-Fox
27.	Martinsville-Whitaker
28.	Mahalasville-Whitaker
30.	Milford-Montgomery-Rensselaer
31.	McGary
32.	Negley-Parke
33.	Oshtemo-Bronson
34.	Oakville-Plainfield-Tawas
35.	Oshtemo-Fox
36.	Ockley-Westland
37.	Ockley-Wea
38.	Ockley-Fox
39.	Plainfield-Brems-Morrocco
40.	Plainfield-Tyner-Oshtemo
41.	Plainfield-Watseka
42.	Plainfield-Chelsea
43.	Patton-Henshaw
44.	Patton-Lyles-Henshaw
45.	Peoga-Bartle-Hosmer
46.	Parke-Miami-Negley
47.	Rensselaer-Montgomery
48.	Rensselaer-Darroch
49.	Rensselaer-Whitaker
50.	Vincennes-Zipp-Ross
51.	Volinia-Dickinson
53.	Wea-Crane
54.	Warsaw-Elston-Fox
55.	Westland-Sleeth
56.	Weinbach-Sciotoville
57.	Weinbach-Wheeling
58.	Crosier-Brookston
59.	Brookston-Odell-Corwin
61.	Blount-Morley-Pewamo
62.	Blount-Pewamo
63.	Riddles-Miami-Crosby

<u>VARIABLE NAME</u>	<u>ASSOC (Continued)</u>
<u>CODE</u>	<u>DESCRIPTION</u>
64.	Crosby-Brookston
65.	Elliott-Markham-Pewamo
66.	Fincastle-Ragsdale
67.	Hoytsville-Nappanee
69.	Parr-Miami
70.	Parr-Corwin
71.	Randolph-Hillsdale
72.	Reesville-Ragsdale
73.	Raub-Ragsdale
74.	Ragsdale-Sidell
76.	Russell-Hennepin
77.	Russell-Zenia
78.	Miami-Metea-Celina
79.	Miami-Ososso-Riddles
80.	Miami-Crosby-Metea
81.	Miami-Russell-Fincastle
82.	Miami-Fox-Milton
83.	Miami-Crosby
84.	Miami-Hennepin
85.	Miami-Fox-Martinsville
86.	Morley-Blount
87.	Muskingum-Shadeland-Highgap
88.	Odell-Chalmers
89.	Sidell-Parr
90.	Hennepin-Rodman
91.	Avonburg-Clermont
92.	Cincinnati-Hickory
93.	Cincinnati-Rossmoyne-Hickory
95.	Cincinnati-Ava
96.	Cincinnati-Ava-Alford
98.	Crider-Hagerstown-Frederick
99.	Crider-Frederick
100.	Corydon-Weikert-Berks
101.	Fairmount-Switzerland
102.	Grayford
103.	Lawrence-Bedford-Crider
104.	Tilsit-Johnsburg
105.	Wellston-Zanesville-Berks
106.	Berks-Gilpin-Weikert
107.	Zanesville-Wellston
108.	Mucks-Peats
109.	Alford
110.	Bloomfield-Princeton-Ayrshire
111.	Hosmer
112.	Iva-Ava
113.	Hosmer-Cincinnati-Iva
114.	Lyles-Ayrshire-Princeton
115.	Princeton-Ayrshire-Bloomfield
116.	Princeton-Fox

<u>VARIABLE NAME</u>	REPEAT
<u>CODE</u>	<u>DESCRIPTION</u>
1.	Original Index Properties
2.	Index Properties Repeated from Same Hole
3.	Index Properties Repeated from Different Hole

<u>VARIABLE NAME</u>	OFFDIR
<u>CODE</u>	<u>DESCRIPTION</u>
1.	Left
2.	Right
3.	Centerline

<u>VARIABLE NAME</u>	SOURCE
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NOTE: OEA is an open end agreement:
CONSULTANT is a consultants report

<u>CODE</u>	<u>DESCRIPTION</u>
1.	Indiana State Highway Commission
2.	American Testing and Engineering Company (OEA)
3.	American Testing and Engineering Company (Consultant)
4.	The H. C. Nutting Company (OEA)
5.	The H. C. Nutting Company (Consultant)
6.	Pittsburg Testing Laboratory (OEA)
7.	Pittsburg Testing Laboratory (Consultant)
8.	Westenhoff and Novick, Inc. (OEA)
9.	Westenhoff and Novick, Inc. (Consultant)
10.	Stokely and Associates (OEA)
11.	Stokely and Associates (Consultant)
12.	Soil Testing Services, Inc. (OEA)
13.	Soil Testing Services, Inc. (Consultant)
14.	Geo-Surveys (OEA)
15.	Geo-Surveys (Consultant)
16.	Testing Service Corporation (OEA)
17.	Testing Service Corporation (Consultant)
18.	Hurst-Rosche Engineers of Indiana, Inc. (OEA)
19.	Hurst-Rosche Engineers of Indiana, Inc. (Consultant)
20.	Homer L. Chastain and Associates (OEA)
21.	Homer L. Chastain and Associates (Consultant)
22.	L. E. Gregg and Associates (OEA)
23.	L. E. Gregg and Associates (Consultant)
24.	Harold S. Shaffer (OEA)
25.	Harold S. Shaffer (Consultant)

VARIABLE NAME SAMPTY

<u>CODE</u>	<u>DESCRIPTION</u>
1.	Shelby Tube
2.	Split Spoon
3.	Denison Sampler
4.	Continuous Flight Auger
5.	Hand Auger
6.	Jar
7.	Bag
8.	Rock Core
9.	Piston Sampler
10.	Hollow Stem Auger
11.	Power Auger

VARIABLE NAME PHYSIO

<u>CODE</u>	<u>DESCRIPTION</u>
1.	Tipton Till Plain
2.	Dearborn Upland
3.	Muscatatuck Regional Slope
4.	Scottsburg Lowland
5.	Norman Upland
6.	Mitchell Plain
7.	Crawford Upland
8.	Wabash Lowland
9.	Calumet Lacustrine Section
10.	Valparaiso Moraine
11.	Kankakee Lacustrine Section
12.	Maumee Lacustrine Section
13.	Steuben Morainal Section

VARIABLE NAME SERIES

<u>CODE</u>	<u>DESCRIPTION</u>	<u>CODE</u>	<u>DESCRIPTION</u>
10.	Ade	150.	Bedford
20.	Adrian	160.	Bellmore
30.	Alford	170.	Berks
40.	Algiers	180.	Birds
50.	Alida	190.	Bloomfield
60.	Allison	200.	Blount
70.	Armiesburg	210.	Bonnie
80.	Aubbeenaubbee	220.	Bono
90.	Ava	230.	Boonesboro
100.	Avonburg	240.	Boyer
110.	Ayr	250.	Brady
120.	Ayrshire	260.	Brems
130.	Bartle	270.	Bronson
140.	Baxter	280.	Brookston

VARIABLE NAME SERIES (Continued)

<u>CODE</u>	<u>DESCRIPTION</u>	<u>CODE</u>	<u>DESCRIPTION</u>
290.	Burgin	760.	Fulton
300.	Burnside	770.	Genesee-
310.	Camden		Silt Loam
320.	Carlisle	771.	Genessee-
330.	Casco		Urban Land
340.	Catlin	780.	Gilford
350.	Celina	790.	Gilpin
360.	Chalmers	800.	Ginat
370.	Chelsea	810.	Glenhall
380.	Cincinnati	820.	Granby
390.	Clarence	830.	Grayford
400.	Clermont	840.	Guthrie
410.	Colyer	850.	Hagerstown
420.	Conover	860.	Hanna
430.	Conrad	870.	Haskins
440.	Corwin	880.	Haubstadt
450.	Cory	890.	Haymond
460.	Corydon	900.	Hennepin
470.	Coupee	910.	Henshaw
480.	Crane	920.	Hickory
490.	Crider	930.	High Gap
500.	Crosby	940.	Hillsdale
510.	Crosier	950.	Homer
520.	Cuba	960.	Hoopeston
530.	Dana	970.	Hosmer
540.	Darroch	980.	Houghton
550.	Del Rey	990.	Hoytville
560.	Dickinson	1000.	Huntington
570.	Door	1010.	Huntsville
580.	Dowagiac	1020.	Iona
590.	Dubois	1030.	Ipava
600.	Dunning	1040.	Iva
610.	Eden	1050.	Jasper
620.	Edenton	1060.	Jennings
630.	Edwards	1070.	Johnsburg
640.	Eel	1080.	Jules
650.	Elkinsonville	1090.	Kalamazoo
660.	Elliott	1100.	Kerston
670.	Elston	1110.	Kings
680.	Evansville	1120.	Kokomo
690.	Fabius	1130.	Landes
700.	Fairmount	1140.	Lawrence
710.	Fincastle	1150.	Lenawee
720.	Flanagan	1160.	Lindside
730.	Foresman	1170.	Linkville
740.	Fox-Silt Loam	1180.	Longlois
741.	Fox-Loam	1190.	Lorenzo
742.	Fox-Urban Land	1200.	Lowell
750.	Frederick	1210.	Lucas

VARIABLE NAME SERIES (Continued)

<u>CODE</u>	<u>DESCRIPTION</u>	<u>CODE</u>	<u>DESCRIPTION</u>
1220.	Lydick	1700.	Petrolia
1230.	Lyles	1710.	Pewamo
1240.	Mahalasville	1720.	Pike
1250.	Markham	1730.	Pinhook
1260.	Markland	1740.	Plainfield
1270.	Martinsville	1750.	Plano
1280.	Martisco	1760.	Pope
1290.	Massie	1770.	Princeton
1300.	Matherton	1780.	Proctor
1310.	Maumee	1790.	Quinn
1320.	McGary	1800.	Ragsdale
1330.	Medway	1810.	Rahm
1340.	Mellott	1820.	Randolph
1350.	Mermill	1830.	Rarden
1360.	Metamora	1840.	Raub
1370.	Metea	1850.	Rawson
1380.	Miami-Silt Loam	1860.	Reesville
1381.	Miami-Urban Land	1870.	Rensselaer
1390.	Milford	1880.	Riddles
1400.	Millsdale	1890.	Rimer
1410.	Milton	1900.	Robinson
1420.	Monitor	1910.	Rockcastle
1430.	Montgomery	1920.	Rodman
1440.	Montmorenci	1930.	Ross
1450.	Morley	1940.	Rossmoyne
1460.	Morocco	1950.	Runnymede
1470.	Muren	1960.	Rush
1480.	Muskingum	1970.	Russell
1490.	Mussey	1980.	St. Clair
1500.	Nappanee	1990.	Saranac
1510.	Negley	2000.	Saugatuck
1520.	Newark	2010.	Sciotoville
1530.	Newton	2020.	Sebewa
1540.	Nicholson	2030.	Seward
1550.	Nineveh	2040.	Shadeland
1560.	Nolin	2050.	Shipshe
1570.	Oakville	2060.	Shoals
1580.	Ockley	2070.	Sidell
1590.	Octagon	2080.	Sleeth
1600.	Odell	2090.	Sloan
1610.	Oshtemo	2100.	Sparta
1620.	Otwell	2110.	Starks
1630.	Owosso	2120.	Steff
1640.	Palms	2130.	Stendal
1650.	Parke	2140.	Stonelick
1660.	Parr	2150.	Stoy
1670.	Patton	2160.	Strole
1680.	Pekin	2170.	Sunbury
1690.	Peoga	2180.	Switzerland

VARIABLE NAME SERIES (continued)

<u>CODE</u>	<u>DESCRIPTION</u>	<u>CODE</u>	<u>DESCRIPTION</u>
2190.	Swygert	2440.	Wea
2200.	Sylvan	2450.	Weikert
2210.	Taggart	2460.	Weinbach
2220.	Tama	2470.	Wellston
2230.	Tedrow	2480.	Westland
2240.	Tilsit	2490.	Wheeling
2250.	Tippecanoe	2500.	Whitaker
2260.	Toledo	2510.	Whitson
2270.	Toronto	2520.	Wilbur
2280.	Tracy	2530.	Willette
2290.	Trappist	2540.	Wingate
2300.	Troxel	2550.	Woodmere
2310.	Tyner	2560.	Woolper
2320.	Uniontown	2570.	Wynn
2330.	Vigo	2580.	Xenia
2340.	Vincennes	2590.	Zanesville
2350.	Volinia	2600.	Zipp
2360.	Wakeland	2700.	Borrow Pit
2370.	Wallkill	2800.	Urban Land
2380.	Warners	2900.	Alluvial Land
2390.	Warsaw	3000.	Gravel Pit
2400.	Wasepi	3100.	Gullied Land
2410.	Washtenaw	3200.	Strip Mine
2420.	Watseka	3300.	Cut and Fill
2430.	Wauseon	3400.	Made Land

VARIABLE NAME PARENT

<u>CODE</u>	<u>DESCRIPTION</u>
1.	Soils formed in lacustrine deposits
2.	Soils formed in outwash and alluvial deposits
3.	Soils formed in eolian sand deposits
4.	Soils formed in thick loess deposits
5.	Soils formed in loamy Wisconsin age glacial till
6.	Soils formed in clayey Wisconsin age glacial till
7.	Soils formed in thin loess deposits over loamy Wisconsin age glacial till
8.	Soils formed in moderately thick loess deposits over loamy Wisconsin age glacial till
9.	Soils formed in moderately thick loess deposits over Illinoian till or clayey paleosols
10.	Soils formed in residuum from siltstone, shale and sandstone bedrock
11.	Soils formed in residuum from limestone bedrock
12.	Soils formed in residuum from soft calcareous shale and limestone

VARIABLE NAME HORIZO

CODE DESCRIPTION

1.	A
2.	B
3.	C
4.	ROCK

VARIABLE NAME SLOPE

CODE DESCRIPTION

1.	Level or nearly level
2.	0-2 percent slopes
3.	2-6 percent slopes
4.	6-12 percent slopes
5.	12-18 percent slopes
6.	18-25 percent slopes
7.	25-35 percent slopes
8.	Greater than 35 percent slopes

VARIABLE NAME EROSIO

CODE DESCRIPTION

1.	None-slight
2.	Eroded (Moderate)
3.	Severe

VARIABLE NAME WATERC, WATERF

-010 Dry

VARIABLE NAME DRAIN

CODE DESCRIPTION

1.	Well, Somewhat Excessive, Excessive
2.	Moderately Well
3.	Somewhat Poorly
4.	Poorly and Very Poorly

VARIABLE NAME PERMEA

CODE DESCRIPTION NUMERICAL RANGE (inches per hour)

1.	Very slow	(less than 0.06)
2.	Slow	(0.06-0.2)
3.	Moderately slow	(0.2-0.63)
4.	Moderate	(0.63-2.0)
5.	Moderately Rapid	(2.0-6.0)
6.	Rapid	(6.0-20.0)
7.	Very Rapid	(More than 20.0)

VARIABLE NAME FLOODCODE DESCRIPTION

1. None
2. Perched, Poned, Hazard, or Common

VARIABLE NAME FROST OR SHRINKCODE DESCRIPTION

1. Very Low
2. Very Low-Low
3. Low
4. Low-Moderate
5. Moderate (subject to)
6. Moderate-High
7. High (severe)
8. High-Very High
9. Very High

VARIABLE NAME PH

<u>CODE</u>	<u>DESCRIPTION</u>	(pH range)
1.	Extremely acid	(Below 4.5)
2.	Very strongly acid	(4.5-5.0)
3.	Strongly acid	(5.1-5.5)
4.	Medium acid	(5.6-6.0)
5.	Slightly acid	(6.1-6.5)
6.	Neutral	(6.6-7.3)
7.	Mildly alkaline	(7.4-7.8)
8.	Moderately alkaline	(7.9-8.4)
9.	Strongly alkaline	(8.5-9.0)
10.	Very strongly alkaline	(Above 9.0)

VARIABLE NAME LL, PL AND PICODE DESCRIPTION

-010 Non-plastic soils

VARIABLE NAME SLCODE DESCRIPTION

-10 Non-plastic soils

VARIABLE NAME TEXTUR

<u>CODE</u>	<u>DESCRIPTION</u>
1.	Sand
2.	Sand-Trace Gravel
3.	Sand-Little Gravel
4.	Sand-Some Gravel
5.	Sand and Gravel
6.	Sandy Loam
7.	Sandy Loam-Trace Gravel
8.	Sandy Loam-Little Gravel
9.	Sandy Loam-Some Gravel
10.	Sandy Loam and Gravel
11.	Loam
12.	Loam-Trace Gravel
13.	Loam-Little Gravel
14.	Loam-Some Gravel
15.	Loam and Gravel
16.	Silty Loam
17.	Silty Loam-Trace Gravel
18.	Silty Loam-Little Gravel
19.	Silty Loam-Some Gravel
20.	Silty Loam and Gravel
21.	Silt
22.	Silt-Trace Gravel
23.	Silt-Little Gravel
24.	Silt-Some Gravel
25.	Silt and Gravel
26.	Sandy Clay Loam
27.	Sandy Clay Loam-Trace Gravel
28.	Sandy Clay Loam-Little Gravel
29.	Sandy Clay Loam-Some Gravel
30.	Sandy Clay Loam and Gravel
31.	Clay Loam
32.	Clay Loam-Trace Gravel
33.	Clay Loam-Little Gravel
34.	Clay Loam-Some Gravel
35.	Clay Loam and Gravel
36.	Silty Clay Loam
37.	Silty Clay Loam-Trace Gravel
38.	Silty Clay Loam-Little Gravel
39.	Silty Clay Loam-Some Gravel
40.	Silty Clay Loam and Gravel
41.	Sandy Clay
42.	Sandy Clay-Trace Gravel
43.	Sandy Clay-Little Gravel
44.	Sandy Clay-Some Gravel
45.	Sandy Clay and Gravel
46.	Silty Clay
47.	Silty Clay-Trace Gravel
48.	Silty Clay-Little Gravel
49.	Silty Clay-Some Gravel

VARIABLE NAME TEXTUR (Continued)

<u>CODE</u>	<u>DESCRIPTION</u>
50.	Silty Clay and Gravel
51.	Clay
52.	Clay-Trace Gravel
53.	Clay-Little Gravel
54.	Clay-Some Gravel
55.	Clay and Gravel
56.	Gravel
57.	Sandy Gravel
58.	Gravelly Sand
59.	Sand and Gravel
60.	Coprogenous Earth
61.	Diatomaceous Earth
62.	Fibric Material
63.	Fragmental Material
64.	Hemic Material
65.	Ice or Frozen Soil
66.	Marl
67.	Muck
68.	Mucky Peat
69.	Oxide-Protected Weathered Bedrock
70.	Partially Decomposed Organic Matter
71.	Peat
72.	Sapric Material
73.	Undecomposed Organic Matter
74.	Unweathered Bedrock
75.	Weathered Bedrock, Saprolite, or Grus
76.	Complex
77.	Inapplicable

VARIABLE NAME ORGANI

<u>CODE</u>	<u>DESCRIPTION</u>
1.	No Organic Material
2.	Trace (1-10% Organic Matter)
3.	Little (11-20% Organic Matter)
4.	Some (21-35% Organic Matter)
5.	And (36-50% Organic Matter)

VARIABLE NAME COLOR

<u>CODE</u>	<u>DESCRIPTION</u>
1.	Bluish Gray
2.	Black
3.	Brown
4.	Brownish Yellow
5.	Dark Brown
6.	Dark Bluish Gray

VARIABLE NAME COLOR (Continued)

<u>CODE</u>	<u>DESCRIPTION</u>
7.	Dark Gray
8.	Dark Grayish Brown
9.	Dark Greenish Gray
10.	Dark Olive
11.	Dark Olive Gray
12.	Dark Red
13.	Dark Reddish Brown
14.	Dark Reddish Gray
15.	Dusky Red
16.	Dark Yellowish Brown
17.	Grayish Brown
18.	Greenish Gray
19.	Grayish Green
20.	Green
21.	Gray
22.	Light Bluish Gray
23.	Light Brown
24.	Light Brownish Gray
25.	Light Greenish Gray
26.	Light Gray
27.	Light Olive Brown
28.	Light Olive Gray
29.	Light Red
30.	Light Reddish Brown
31.	Light Yellowish Brown
32.	Olive Brown
33.	Olive
34.	Olive Gray
35.	Olive Yellow
36.	Pale Brown
37.	Pale Green
38.	Pale Olive
39.	Pale Red
40.	Pale Yellow
41.	Pinkish Gray
42.	Pink
43.	Pinkish White
44.	Reddish Black
45.	Reddish Brown
46.	Red
47.	Reddish Gray
48.	Reddish Yellow
49.	Strong Brown
50.	Very Dark Brown
51.	Very Dark Gray
52.	Very Dark Grayish Brown
53.	Very Dark Red
54.	Very Pale Brown
55.	Very Dusky Red

VARIABLE NAME COLOR (Continued)

<u>CODE</u>	<u>DESCRIPTION</u>
56.	Weak Red
57.	White
58.	Yellowish Brown
59.	Yellowish Red
60.	Yellow

VARIABLE NAME TESTEF

<u>CODE</u>	<u>DESCRIPTION</u>
1.	Standard Proctor: 12400 ft-lb/cu.ft.
2.	Standard Proctor: See DIF for Compactive Energy
3.	Standard Proctor: Compactive Energy Not Given
4.	Modified Proctor: 12400 ft-lb/cu.ft.
5.	Modified Proctor: 56000 ft-lb/cu.ft.
6.	Modified Proctor: 56300 ft-lb/cu.ft.
7.	Modified Proctor: See DIF for Compactive Energy
8.	Modified Proctor: Compactive Energy Not Given
9.	15-Blow Compaction: 7400 ft-lb/cu.ft.
10.	15-Blow Compaction: 7800 ft-lb/cu.ft.
11.	15-Blow Compaction: See DIF for Compactive Energy
12.	15-Blow Compaction: Compactive Energy Not Given
13.	Mechanical Kneading Compactor: See DIF For Compactive Energy
14.	Mechanical Kneading Compactor: Compactive Energy Not Given
15.	Harvard Miniature Apparatus: See DIF For Compactive Energy
16.	Harvard Miniature Apparatus: Compactive Energy Not Given
17.	Hveem Method: See DIF for Compactive Energy
18.	Hveem Method: Compactive Energy Not Given
19.	Vibratory Table: See DIF for Compactive Energy
20.	Vibratory Table: Compactive Energy Not Given
21.	Compression Machine: See DIF for Compactive Energy
22.	Compression Machine: Compactive Energy Not Given

VARIABLE NAME AASHTO (AASHTO1)CODE DESCRIPTION

1.	A-1-A
2.	A-1-B
3.	A-2-4
4.	A-2-5
5.	A-2-6
6.	A-2-7
7.	A-3
8.	A-4
9.	A-5
10.	A-6
11.	A-7-5
12.	A-7-6
13.	A-8

VARIABLE NAME UNIF (UNIF1)CODE DESCRIPTION

1.	CL
2.	CH
3.	CL-CH
4.	ML
5.	OL
6.	ML-OL
7.	ML-CL
8.	CL-OL
9.	ML-OL OR CL
10.	MH
11.	OH
12.	MH-OH
13.	MH-CH
14.	CH-OH
15.	MH-OH OR CH
16.	ML-MH
17.	OL-OH
18.	MH-OH OR ML-OL
19.	Any combination of fine-grained soil
20.	CL-ML
21.	GM
22.	GC
23.	GM-GC
24.	SM
25.	SC
26.	SM-SC
27.	GW OR GP*=G
28.	SW OR SP*=S
29.	G*-GM
30.	G*-GC

VARIABLE NAME UNIF (UNIF1) (Continued)

<u>CODE</u>	<u>DESCRIPTION</u>
31.	G*-GM OR G*-GC
32.	S*-SM
33.	S*-SC
34.	S*-SM OR S*-SC
35.	PT

*GW and GP, and SW and SP have been combined and coded as G and S, respectively. This has been necessary since grain-size curves are rarely presented within subsurface investigation reports and the gradational characteristics cannot be determined, that is, the uniformity coefficient, C_u , and the coefficients of curvature, C_c .

VARIABLE NAME TYPE

<u>CODE</u>	<u>DESCRIPTION</u>
1.	Unconsolidated Undrained Triaxial Test
2.	Consolidated Undrained Triaxial Test - Not Saturated
3.	Consolidated Undrained Triaxial Test - Saturated
4.	Direct Shear
5.	Consolidated Drained Triaxial Test

APPENDIX D

USER'S MANUAL: PART III

Formats, Card and Column Locations

<u>VARIABLE NAME</u>	<u>FORMAT</u>	<u>CARD LOCATION</u>	<u>COLUMN LOCATION</u>
CARD1	F1.0	1	1
COUNTY	F2.0	1	2-3
HOLENO	F5.0	1	4-8
SAMPNO	F2.0	1	9-10
DISTR1	F1.0	1	12
DATEYR	F2.0	1	14-15
DATEMO	F2.0	1	17-18
DATEDA	F2.0	1	20-21
TOWN	F2.0	1	23-24
TOWNDI	F1.0	1	26
RANGE	F2.0	1	28-29
RANGDI	F1.0	1	31
SECT10	F2.0	1	33-34
PROJPR	A3	1	36-38
PROJNO	F5.0	1	39-43
PROJPA	A3	1	44-46
PROJMI	F3.0	1	47-49
CONTPR	A3	1	51-53

<u>VARIABLE NAME</u>	<u>FORMAT</u>	<u>CARD LOCATION</u>	<u>COLUMN LOCATION</u>
CONTNO	F5.0	1	54-58
ROADPR	A2	1	60-61
ROADNO	F3.0	1	62-64
ROADSU	A1	1	65
BORING	A8	1	67-74
ASSOC	F3.0	1	76-78
REPEAT	F1.0	1	80
CARD2	F1.0	2	1
ID2	F9.0	2	2-10
STATNO	F7.0	2	12-18
OFFSET	F4.0	2	20-23
OFFDIR	F1.0	2	25
LINE1	A8	2	27-34
LINE2	A2	2	35-36
SOURCE	F2.0	2	38-39
SAMPTY	F2.0	2	41-42
LABNO	A8	2	44-51
GRDSUR	F5.1	2	53-57
DEPTH1	F4.1	2	59-62
DEPTHB	F4.1	2	64-67
SPT	F2.0	2	69-70
PHYSIO	F2.0	2	72-73
SERIES	F4.0	2	75-78
CARD3	F1.0	3	1
ID3	F9.0	3	2-10
PARENT	F2.0	3	12-13

<u>VARIABLE NAME</u>	<u>FORMAT</u>	<u>CARD LOCATION</u>	<u>COLUMN LOCATION</u>
HORIZO	F1.0	3	15
SLOPE	F1.0	3	17
EROSIO	F1.0	3	19
BEDRKS	F3.1	3	21-23
BEDRKB	F4.1	3	25-28
WATERS	F2.1	3	30-31
WATERC	F4.1	3	33-36
WATERF	F4.1	3	38-41
DRAIN	F1.0	3	43
PERMEA	F1.0	3	45
FLOOD	F1.0	3	47
FROST	F1.0	3	49
SHRINK	F1.0	3	51
PH	F2.0	3	53-54
GRAD01	F4.1	3	56-59
GRAD02	F4.1	3	61-64
GRAD03	F4.1	3	66-69
GRAD04	F4.1	3	71-74
GRAD05	F4.1	3	76-79
CARD4	F1.0	4	1
ID4	F9.0	4	2-10
GRAD06	F4.1	4	12-15
GRAD07	F4.1	4	17-20
GRAD08	F4.1	4	22-25
GRAD09	F4.1	4	27-30
GRAD10	F4.1	4	32-35

<u>VARIABLE NAME</u>	<u>FORMAT</u>	<u>CARD LOCATION</u>	<u>COLUMN LOCATION</u>
SAND	F4.1	4	37-40
SILT	F4.1	4	42-45
CLAY	F4.1	4	47-50
COLL	F4.1	4	52-55
LL	F4.1	4	57-60
PL	F4.1	4	62-65
PI	F4.1	4	67-70
SL	F3.1	4	72-74
LOSSIG	F3.1	4	76-78
CARD5	F1.0	5	1
ID5	F9.0	5	2-10
NATMC	F4.1	5	12-15
NATWD	F4.1	5	17-20
NATDD	F4.1	5	22-25
SPECGR	F4.3	5	27-30
TEXTUR	F2.0	5	32-33
ORGANI	F1.0	5	35
COLOR	F2.0	5	37-38
TESTEF	F2.0	5	40-41
MAXDD	F4.1	5	43-46
MAXWD	F4.1	5	48-51
OPTIMC	F3.1	5	53-55
CBRUN1	F3.1	5	57-59
CBRUN2	F3.1	5	61-63
CBRS01	F3.1	5	65-67
CBRS02	F3.1	5	69-71

<u>VARIABLE NAME</u>	<u>FORMAT</u>	<u>CARD LOCATION</u>	<u>COLUMN LOCATION</u>
QUSTR	F3.1	5	73-76
AASHTO1	F2.0	5	77-78
UNIF1	F2.0	5	79-80
CARD6	F1.0	6	1
ID6	F9.0	6	2-10
QUSTA	F4.2	6	12-15
TYPE	F1.0	6	17
STRENGTH	F4.2	6	18-21
STRAIN	F4.2	6	22-25
CONFPRES	F4.2	6	26-29
COHESION	F3.2	6	30-32
ANGLE	F3.1	6	33-35
POREPRES	F4.2	6	36-39
MAJOR	F4.2	6	40-43
EO	F4.3	6	45-48
EF	F4.3	6	49-52
SO	F4.1	6	53-56
SF	F4.1	6	57-60
PO	F4.2	6	61-64
PC	F4.2	6	65-68
CC	F4.3	6	69-72
CR	F4.3	6	73-76
CV	F4.2	6	77-80

APPENDIX E

USER'S MANUAL: PART IV

Computer Programs

The computer programs are used for data management and manipulation. All programs are written for use on the CDC 6500 system at Purdue University.

PROGRAM NUMBER 1

THE FOLLOWING PROGRAM WILL ADD NEW DATA TO THE
EXISTING DATA FILE.

12345,ABC,CM15000,L10000,T25,P20,TU8000,TC200,TP1.

PASS=

REQUEST(SOILDAT,1414,UP=***,WRITE)

REWIND(SOILDAT)

SKIPF,SOILDAT,1.

BKSPR,SOILDAT,1.

COPYBF,,SOILDAT.

7/8/9

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DATA CARDS

.

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6/7/8/9

PROGRAM NUMBER 2

 THE PURPOSE OF THIS PROGRAM IS TO CHECK NEW INPUT DATA FOR CARD PUNCHING
 ERRORS. ONLY THOSE ERRORS WHICH CAN BE DETECTED WITH THE FOLLOWING ~AUDIT~
 PROGRAM WILL BE REPORTED.

12345,ABC,CM77000,L10000,T25,P20,TU4000.

PASS=

DAYBAN. *SOIL DATA FOR THE STATE OF INDIANA*

COMMON(SPSS)

SPSS.

7/8/9

RUN NAME

VARIABLE LIST

***** SOIL DATA CHECK *****

CARD1,COUNTY,HOLENO,SAMPNO,DISTRI,DATEYR,DATEMO,DATEDA,TOWN,
 TOWNDI,RANGE,RANGDI,SECTIO,PROJPR,PROJNO,PROJPA,PROJMI,CONTPR,
 CONTNO,ROADPR,ROADNO,ROADSU,BORING,ASSOC,REPEAT,CARD2,ID2,
 STATNO,OFFSET,OFFDIR,LINE1,LINE2,SOURCE,SAMPTY,LABNO,GRDSUR,
 DEPTHT,DEPTHB,SPT,PHYSIO,SERIES,CARD3,ID3,
 PARENT,HORIZO,SLOPE,EROSIO,BEDRKS,
 BEDRKB,WATERS,WATERC,WATERF,DRAIN,PERMEA,FLOOD,FROST,SHRINK,PH,
 GRAD01 TO GRAD05,CARD4,ID4,GRAD06 TO GRAD10,SAND,SILT,CLAY,
 COLL,LL,PL,PI,SL,LOSSIG,CARD5,IDS,NATMC,NATWD,NATDD,SPECGR,
 TEXTUR,ORGANI,COLOR,TESTEF,MAXDD,MAXWD,OPTIMC,CBRUN1,CBRUN2,
 CBR01,CBR02,QUSTR,AASHTO1,UNIF1,CARD6,ID6,
 QUSTA,TYPE,STRENGTH,STRAIN,CONFPRES,COHESION,
 ANGLE,POREPRES,MAJOR,EO,EF,SO,SF,PO,PC,CC,CR,CU

INPUT FORMAT

(F1.0,F2.0,F5.0,F2.0,1X,F1.0,1X,F2.0,1X,F2.0,1X,F2.0,1X,F2.0,
 1X,F1.0,1X,F2.0,1X,F1.0,1X,F2.0,1X,A3,F5.0,A3,F3.0,1X,A3,
 F5.0,1X,A2,F3.0,A1,1X,AB,1X,F3.0,1X,F1.0/F1.0,1F9.0,1X,
 F7.0,1X,F4.0,1X,F1.0,1X,AB,A2,1X,F2.0,1X,F2.0,1X,AB,
 1X,F5.1,1X,F4.1,1X,F4.1,1X,F2.0,1X,F2.0,1X,F4.0/F1.0,F9.0,1X,
 F2.0,1X,F1.0,1X,F1.0,1X,F1.0,1X,F3.1,1X,F4.1,1X,F2.1,
 1X,F4.1,1X,F4.1,1X,F1.0,1X,F1.0,1X,F1.0,1X,F1.0,1X,F1.0,
 1X,F2.0,1X,F4.1,1X,F4.1,1X,F4.1,1X,F4.1,1X,F4.1/F1.0,F9.0,1X,
 F4.1,1X,F4.1,1X,F4.1,1X,F4.1,1X,F4.1,1X,F4.1,1X,F4.1,
 1X,F4.1,1X,F4.1,1X,F4.1,1X,F4.1,1X,F4.1,1X,F3.1,1X,F3.1/
 F1.0,F9.0,1X,F4.1,1X,F4.1,1X,F4.1,1X,F4.3,1X,F2.0,1X,F1.0,1X,
 F2.0,1X,F2.0,1X,F4.1,1X,F4.1,1X,F3.1,1X,F3.1,1X,F3.1,1X,F3.1,
 1X,F3.1,1X,F4.2,F2.0,F2.0/F1.0,F9.0,1X,
 F4.2,1X,F1.0,3F4.2,F3.2,F3.1,2F4.2,1X,
 2F4.3,2F4.1,2F4.2,2F4.3,F4.2)

COMMENT

THE NUMBER OF CASES (N OF CASES) WILL COINCIDE WITH
 THE NUMBER OF SAMPLES BEING VERIFIED IN A PARTICULAR RUN

N OF CASES

IF

70
 (CARD1 NE 1 OR CARD2 NE 2 OR CARD3 NE 3 OR CARD4 NE 4
 OR CARD5 NE 5 OR CARD6 NE 6) REPORT.=1

IF

(ID2 NE ID3 OR ID3 NE ID4 OR ID4 NE ID5 OR ID5 NE ID6) REPORT.=2

IF

(DISTRI GT 6 OR (DATEYR GT 78 OR LT 60) OR DATEMO GT 12
 OR DATEDA GT 31 OR TOWN GT 38 OR TOWNDI GT 2 OR RANGE GT 15
 OR RANGDI GT 2 OR ASSOC GT 116 OR REPEAT GT 3) REPORT.=10

IF

(OFFDIR GT 3 OR SOURCE GT 25 OR SAMPTY GT 11 OR PHYSIO GT 13


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OR SERIES GT 3400) REPORT.=20
IF (OFFDIR EQ 3 AND OFFSET NE 0) REPORT.=21
IF (LOSSIG GT 0 AND LE 10 AND ORGANI NE 2) REPORT.=22
IF (LOSSIG GT 10 AND LE 20 AND ORGANI NE 3) REPORT.=23
IF (LOSSIG GT 20 AND LT 35 AND ORGANI NE 4) REPORT.=24
IF (LOSSIG GT 35 AND ORGANI NE 5) REPORT.=25
IF (PARENT GT 12 OR HORIZO GT 3 OR SLOPE GT 8 OR EROSIO GT 3
OR DRAIN GT 4 OR PERMEA GT 7 OR FLOOD GT 2 OR FROST GT 9
OR SHRINK GT 9 OR PH GT 10) REPORT.=30
IF (GRAD01 GT 100 OR GRAD02 GT 100 OR GRAD03 GT 100 OR GRAD04 GT 100
OR GRAD05 GT 100 OR GRAD06 GT 100 OR GRAD07 GT 100
OR GRAD08 GT 100 OR GRAD09 GT 100 OR GRAD10 GT 100 OR
SAND GT 100 OR SILT GT 100 OR CLAY GT 100 OR COLL GT 100)
REPORT.=35
IF (LL GT 130 OR PL GT 100 OR PI GT 85 OR SL GT 55 OR LOSSIG GT 60)
REPORT.=40
IF (NATMC GT 125 OR NATWD GT 140 OR NATDD GT 135 OR SPECGR GT 2.79
OR TEXTUR GT 77 OR ORGANI GT 5 OR COLOR GT 60 OR TESTEF GT 22
OR MAXDD GT 135 OR MAXWD GT 150 OR OPTIMC GT 40 OR CBRUN1 GT 25
OR CBRUN2 GT 25 OR CBR01 GT 45 OR CBR02 GT 25 OR OUSTR GT 4.5
OR AASHTO1 GT 13 OR UNIF1 GT 35) REPORT.=50
IF (QUSTA GT 20 OR TYPE GT 4 OR STRENGTH GT 11 OR STRAIN GT 20 OR
COHESION GT 1.5 OR ANGLE GT 40) REPORT.=55
IF (EO GT 1.5 OR EF GT 1.0 OR SO GT 100 OR SF GT 110 OR PO GT 2 OR
PC GT 7.0 OR CC GT .61 OR CR GT .5) REPORT.=60
IF (DEPHTH GT DEPTHB) REPORT.=70
IF (GRAD01 LT GRAD02 OR GRAD02 LT GRAD03 OR GRAD03 LT GRAD04 OR
GRAD04 LT GRAD05 OR GRAD05 LT GRAD06 OR GRAD06 LT GRAD07 OR
GRAD07 LT GRAD08 OR GRAD08 LT GRAD09 OR GRAD09 LT GRAD10)
REPORT.=80
IF (LL NE -1 AND PL NE -1 AND PI NE -1 AND ((PI NE (LL-PL)) OR
(PL GT LL))) REPORT.=90
IF (MAXDD GT MAXWD) REPORT.=100
IF (CBRUN1 LT CBRUN2 OR CBR01 LT CBR02) REPORT.=200
IF (EO LT EF OR SO GT SF OR PO GT PC OR CC LT CR) REPORT.=300
READ INPUT DATA

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DATA CARDS
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FINISH
6/7/8/9

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PROGRAM NUMBER 3

 THE FOLLOWING IS A LISTING OF THE SPSS PROGRAM BEING USED IN CONJUNCTION
 WITH THE SPSS SYSTEM FOR DATA MANIPULATIONS-INCLUDING A LISTING OF RAW
 DATA AND THE PROCESSING OF DATA WITH ANY OF THE SPSS PROCEDURES.

FILE NAME	PROG
RUN NAME	***** SOIL DATA FOR THE STATE OF INDIANA *****
VARIABLE LIST	COUNTY,HOLENO,SAMPNO,DISTRI,DATEYR,DATEMO,DATEDA,TOWN,TOWNDI, RANGE,RANGDI,SECTIO,PROJPR,PROJNO,PROJPA,PROJMI,CONTPR, CONTNO,ROADPR,ROADNO,ROADSU,BORING,ASSOC,REPEAT,STATNO,OFFSET, OFFDIR,LINE1,LINE2,SOURCE,SAMPTY,LABNO,GRDSUR,DEPTHT, DEPTHB,SPT,PHYSIO,SERIES,PARENT,HORIZO,SLOPE,EROSIO,BEDRKS, BEDRKB,WATERS,WATERC,WATERF,DRAIN,PERMEA,FLOOD,FROST,SHRINK,PH, GRAD01 TO GRAD10,SAND,SILT,CLAY,COLL,LL,PL,PI,SL,LOSSIG, NATMC,NATWD,NATDD,SPECGR,TEXTUR,ORGANI,COLOR,TESTEF,MAXDD, MAXWD,OPTIMC,CBRUN1,CBRUN2,CBRSO1,CBRSO2,QUSTR,AASHTO1,UNIF1, QUSTA,TYPE,STRENGTH,STRAIN,CONFPRES,COHESION,ANGLE,POREPRES, MAJOR,EQ,EF,SO,SF,PO,PC,CC,CR,CU
INPUT MEDIUM	SOIL1
INPUT FORMAT	(1X,F2.0,F5.0,F2.0,1X,F1.0,1X,F2.0,1X,F2.0, 1X,F2.0, 1X,F2.0, 1X,F1.0, 1X,F2.0, 1X,F1.0,1X,F2.0, 1X,A3,F5.0,A3,F3.0, 1X,A3, F5.0, 1X,A2,F3.0,A1, 1X,A8, 1X,F3.0, 1X,F1.0/ 11X,F7.0, 1X,F4.0, 1X,F1.0, 1X, A8,A2, 1X,F2.0, 1X,F2.0, 1X, A8, 1X,F5.1, 1X,F4.1, 1X,F4.1, 1X,F2.0, 1X,F2.0, 1X,F4.0/ 11X,F2.0, 1X,F1.0, 1X,F1.0, 1X,F1.0, 1X,F3.1, 1X,F4.1, 1X,F2.1, 1X,F4.1, 1X,F4.1, 1X,F1.0, 1X,F1.0, 1X,F1.0, 1X,F1.0, 1X,F1.0, 1X,F2.0, 1X,F4.1, 1X,F4.1, 1X,F4.1, 1X,F4.1, 1X,F4.1, 1X,F4.1/ 11X,F4.1, 1X,F4.1, 1X,F4.1, 1X,F4.1, 1X,F4.1, 1X,F4.1, 1X,F4.1, 1X,F4.1, 1X,F4.1, 1X,F4.1, 1X,F4.1, 1X,F4.1, 1X,F3.1, 1X,F3.1/ 11X,F4.1, 1X,F4.1, 1X,F4.1, 1X,F4.3, 1X,F2.0, 1X,F1.0, 1X,F2.0, 1X,F2.0, 1X,F4.1, 1X,F4.1, 1X,F3.1, 1X,F3.1, 1X,F3.1, 1X,F3.1, 1X,F3.1, 1X,F4.2,F2.0,F2.0/ 11X F4.2,1X,F1.0,3F4.2,F3.2, F3.1,2F4.2,1X,2F4.3,2F4.1,2F4.2,2F4.3,F4.2)
VAR LABELS	COUNTY COUNTY/HOLENO HOLE NUMBER/SAMPNO SAMPLE NUMBER/DATEYR YEAR TAKEN FROM HOLE/DATEMO MONTH TAKEN FROM HOLE/DATEDA DAY TAKEN FR OM HOLE/TOWN TOWNSHIP/TOWNDI TOWNSHIP-DIRECTION/RANGE RANGE/ RANGDI RANGE-DIRECTION/SECTIO SECTION/ PROJPR PROJECT NUMBER-PREFIX/PROJNO PROJECT NUMBER/ PROJPA PROJECT NUMBER-PARENTHESIS/PROJMI PROJECT NUMBER-MILE/ CONTPR CONTRACT NUMBER-PREFIX/ CONTNO CONTRACT NUMBER/ DISTRI DISTRICT/ ROADPR ROAD NUMBER-PREFIX/ROADNO ROAD NUMBER/ ROADSU ROAD NUMBER-SUFFIX/BORING BORING NUMBER/ASSOC SOIL ASSOCIA TION/REPEAT DATA REPEAT/ STATNO STATION NUMBER/OFFSET OFFSET/OFFDIR OFFSET-DIRECTION/ LINE1 TO LINE2=LINE NUMBER/SOURCE SOURCE OF INFORMATION/ SAMPTY SAMPLE TYPE/LABNO LAB NUMBER/ GRDSUR GROUND SURFACE ELEVATION/DEPTHT DEPTH TO TOP OF SAMPLE/ DEPTHB DEPTH TO BOTTOM OF SAMPLE/PHYSIO PHYSIOGRAPHIC UNIT/ SPT N VALUE OF SPT/ SERIES SOIL SERIES NAME/ PARENT PARENT MATERIAL/

HORIZO HORIZON/ SLOPE SLOPE CLASS/ EROSIO EROSION CLASS/
 BEDRKS DEPTH TO BEDROCK-SOIL SURVEY/ BEDRKB DEPTH TO BEDROCK-BO
 RING LOG/WATERS DEPTH-SEASONAL HIGH WATER TABLE-SOIL SURVEY/
 WATERC WATER DEPTH AT COMPLETION/WATERF WATER DEPTH FINAL OR 24 H
 OURS/DRAIN NATURAL SOIL DRAINAGE/PERMEA PERMEABILITY/
 FLOOD FLOODING POTENTIAL/ FROST POTENTIAL FROST ACTION/
 SHRINK SHRINK-SWELL POTENTIAL/ PH REACTION-PH/
 GRAD01 PERCENT PASSING 1 1-2~~≠~~ SIEVE/
 GRAD02 PERCENT PASSING 1~~≠~~ SIEVE/
 GRAD03 PERCENT PASSING 3-4~~≠~~ SIEVE/
 GRAD04 PERCENT PASSING 1-2~~≠~~ SIEVE/
 GRAD05 PERCENT PASSING 3-8~~≠~~ SIEVE/
 GRAD06 PERCENT PASSING NO. 4 SIEVE/
 GRAD07 PERCENT PASSING NO. 10 SIEVE/
 GRAD08 PERCENT PASSING NO. 40 SIEVE/
 GRAD09 PERCENT PASSING NO. 200 SIEVE/
 GRAD10 PERCENT PASSING NO. 270 SIEVE/
 SAND PERCENT SAND/
 SILT PERCENT SILT/CLAY PERCENT CLAY/COLL PERCENT COLLOIDS/
 LL LIQUID LIMIT/ PL PLASTIC LIMIT/ PI PLASTICITY INDEX/
 SL SHRINKAGE LIMIT/ LOSSIG LOSS ON IGNITION/
 NATMC NATURAL MOISTURE CONTENT/ NATWD NATURAL WET DENSITY/
 NATDD NATURAL DRY DENSITY/ SPECGR SPECIFIC GRAVITY/
 TEXTUR TEXTURAL CLASSIFICATION/ ORGANI ORGANIC CONTENT/
 COLOR COLOR/
 TESTEF TEST-EFFORT IDENTIFIER/ MAXDD MAXIMUM DRY DENSITY/
 MAXWD MAXIMUM WET DENSITY/ OPTIMC OPTIMUM MOISTURE CONTENT/
 CBRUN1 UNSOAKED CBR-100 MAXDD/ CBRUN2 UNSOAKED CBR-95 MAXDD/
 CBR501 SOAKED CBR-100 MAXDD/CBR502 SOAKED CBR-95 MAXDD/
 QUSTR UNCONFINED COMPRESSIVE STRENGTH-TSF/
 QUSTA FAILURE STRAIN-PERCENT/
 TYPE TYPE OF STRENGTH TEST/STRENGTH FAILURE STRENGTH/
 STRAIN FAILURE STRAIN/CONFRES CONFINING PRESSURE/
 ANGLE FAILURE ANGLE/POREPRES PORE PRESSURE AT FAILURE/MAJOR MAJOR
 PRINCIPAL STRESS/EO INITIAL VOID RATIO/EF FINAL VOID RATIO/SO IN
 ITIAL DEGREE OF SATURATION/SF FINAL DEGREE OF SATURATION/PO OVERB
 URDEN STRESS/PC PRECONSOLIDATION PRESSURE/CC COMPRESSION INDEX/
 CR RECOMPRESSION INDEX/CV COEFFICIENT OF CONSOLIDATION
 AASHTO1,UNIF1 (BLANK=9999)/ SAND (BLANK=999)
 COUNTY (-0)UNKNOWN (01)ADAMS (02)ALLEN (03)BARTHOLOMEW (4)BENTON
 (05)BLACKFORD (06)BOONE (07)BROWN (08)CARROLL (09)CASS (10)CLARK
 (11)CLAY (12)CLINTON (13)CRAWFORD (14)DAVISS (15)DEARBORN
 (16)DECATUR (17)DEKALB (18)DELAWARE (19)DUBOIS (20)ELKHART
 (21)FAYETTE (22)FLOYD (23)FOUNTAIN (24)FRANKLIN (25)FULTON
 (26)GIBSON (27)GRANT (28)GREENE (29)HAMILTON (30)HANCOCK
 (31)HARRISON (32)HENDRICKS (33)HENRY (34)HOWARD (35)HUNTINGTON
 (36)JACKSON (37)JASPER (38)JAY (39)JEFFERSON (40)JENNINGS
 (41)JOHNSON (42)KNOX (43)KOSCIUSKO (44)LAGRANGE (45)LAKE
 (46)LAPORTE (47)LAWRENCE (48)MADISON (49)MARION (50)MARSHALL
 (51)MARTIN (52)MIAMI (53)MONROE (54)MONTGOMERY (55)MORGAN
 (56)NEWTON (57)NOBLE (58)OHIO (59)ORANGE (60)OWEN (61)PARKE
 (62)PERRY (63)PIKE (64)PORTER (65)POSEY (66)PULASKI (67)PUTNAM
 (68)RANDOLPH (69)RIPLEY (70)RUSH (71)ST. JOSEPH (72)SCOTT
 (73)SHELBY (74)SPENCER (75)STARKE (76)STEBEN (77)SULLIVAN
 (78)SWITZERLAND (79)TIPPECANOE (80)TIPTON (81)UNION
 (82)VANDERBURGH (83)VERMILLION (84)VIGO (85)WABASH (86)WARREN
 (87)WARRICK (88)WASHINGTON (89)WAYNE (90)WELLS (91)WHITE
 (92)WHITLEY (93)STATE OF KENTUCKY/

RECODE
 VALUE LABELS

DISTRI (-0)UNKNOWN (1)CRAWFORDSVILLE
 (2)FORT WAYNE (3)GREENFIELD (4)LAPORTE (5)SEYMOUR (6)VINCENNES/
 DATEMO (-0)UNKNOWN (01)JANUARY (02)FEBRUARY (03)MARCH (04)APRIL
 (05)MAY (06)JUNE (07)JULY (08)AUGUST (09)SEPTEMBER (10)OCTOBER
 (11)NOVEMBER (12)DECEMBER/
 TOWNDI (-0)UNKNOWN (1)NORTH (2)SOUTH/
 RANGDI (-0)UNKNOWN (1)EAST (2)WEST/
 ASSOC (-0)UNKNOWN
 (1) EEL-MARTINSU-GENESSE (2) GENESEE-ROSS-SHOALS (3) WAKELAN-STEM
 DA-HAYMO (4) GENESEE-SHOALS-EEL (5) HAYMON-NOLIN-PETROLI
 (6) GENESE-EEL-STEND-POPE
 (7) HUNTING-WHEELI-MARKH (8) HUNTINGTON-LINDSIDE
 (9) HAYMOND-WAKELAND (10) ALIDA-DELREY-WHITAKE (11) BONO-MAUMEE
 -WARNERS (12) CHELS-HILLSDAL-OSHT (13) CONRAD-WOOTEN-WEISS (14)
 DOOR-TRACY-QUINN (15) DOOR-LYDICK (16) ELSTON-WEA (17) DUBOIS-QTW
 ELL (18) FOX-MARTINSVILL-ALUV (19) FOX-NINEVEH-OCKLEY (20) FOX-RO
 DMAN (21) FULT-RIM-MILF-RENSSEL (22) HOMER-SEBEWA-GILFORD (23) MA
 UME-GILFOR-RENSSEL (24) MAUMEE-NEWTON (26) MARTINSVIL-BELMO-FOX
 (27) MARTINSVILLE-WHITAKE (28) MAHALASVILL-WHITAKER (30)MILF-MONT
 COM-RENSSEL (31) MCGARY (32) NEGLEY-PARKE (33) OSHTMO-BRONSON
 (34) OAKVIL-PLAINFIE-TAWA (35) OSHTMO-FOX (36) OCKLEY-WESTLAND
 (37) OCKLEY-WEA (38) OCKLEY-FOX (39) PAILNFIE-BREM-MORROC (40) P
 LAINFIE-TYNER-OSHT (41) PLAINFIELD-WATSEKA (42) PLAINFIELD-CHELS
 EA (43) PATTON-HENSHAW (44) PATTON-LYLES-HENSHAW (45) PEOGA-BARTL
 E-HOSMER (46) PARKE-MIAMI-NEGLEY (47) RENSSELAER-MONTGOMER (48)
 RENSSELAER-DARROCH (49) RENSSELAER-WHITAKER (50) VINCENNES-ZIPP-R
 OSS (51) VOLINIA-DICKINSON (53) WEA-CRANE (54) WARSAW-ELSTON-FOX
 (55) WESTLAND-SLEETH (56) WEINBACH-SCIOTOVILLE (57) WEINBACH-WHEE
 LING (58) CROSIER-BROOKSTON (59) BROOKSTO-ODELL-CORWI (61) BLOUNT
 -MORLEY-PEWAMO (62) BLOUNT-PEWAMO (63) RIDDLES-MIAMI-CROSBY (64)
 CROSBY-BROOKSTON (65) ELLIOT-MARKHAM-PEWAM (66) FINCASTLE-RAGSDAL
 E (67) HOYTSVILLE-NAPPANEE (69) PARR-MIAMI (70) PARR-CORWIN (71)
 RANDOLPH-HILLSDALE (72) REESVILLE-RAGSDALE (73) RAUB-RAGSDALE
 (74) RAGSDALE-SIDELL (76) RUSSELL-HENNEPIN (77) RUSSELL-XENIA
 (78) MIAMI-METEA-CELINA (79) MIAMI-OSOSSO-RIDDLES (80) MIAMI-C
 ROSBY-METEA (81) MIA-RUSSEL-FINCASTLE (82) MIAMI-FOX-MILTON (83)
 MIAMI-COSBY (84) MIAMI-HENNEPIN (85) MIAMI-FOX-MARTINSVIL (86) MO
 RLEY-BLOUNT (87) MUSKIN-SHADELA-HIGHG (88) ODELL-CHALMERS (89) SI
 DELL-PARR (90) HENNEPIN-RODMAN (91) AVONBURG-CLERMONT (92) CINCIN
 NATI-HICKORY (93) CINCINNA-ROSSMO-HICK (95) CINCINNATI-AVA (96) C
 INCINNAT-AVA-ALFORD (98) CRID-HAGERSTO-FREDER (99) CRIDER-FREDERI
 CK (100) CORYDON-WEIKERT-BERK (101) FAIRMOUNT-SWITZERLAN (102) GR
 AYFORD (103) LAWRENC-BEDFORD-CRID (104) TILSIT-JOHNSBURG (105) WE
 LLST-ZANESVIL-BERK (106) BERKS-GILPIN-WEIKERT (107) ZANESVILLE-WE
 LLSTON (108) MUCKS-PEATS (109) ALFORD (110) BLOOMFI-PRINCE-AYRSH
 (111) HOSMER (112) IVA-AVA (113) HOSMER-CINCINNAT-IVA (114) LYLE
 -AYRSHIR-PRINCET (115) PRINCET-AYRSH-BLOOMF (116) PRINCETON-FOX/
 REPEAT (1)ORIGINAL DATA (2)DATA FROM SAME HOLE
 (3)DATA-DIFFERENT HOLE/
 OFFDIR (-0)UNKNOWN (1)LEFT (2)RIGHT (3)CENTERLINE/
 SOURCE (-0)UNKNOWN (01)STATE (02)ATEC-OEA
 (03)ATEC-CONSULTANT (04)NUTTING-OEA (05)NUTTING-CONSULTANT
 (06)PITTSBURG TEST-OEA (07)PITTSBURG TEST-CONS
 (08)WESTENHOFF-NOV-OEA (09)WESTENHOFF-NOV-CONS (10)STOKLEY-OEA
 (11)STOKLEY-CONSULTANT (12)STS-OEA (13)STS-CONSULTANT
 (14)GEO SURVEYS-OEA (15)GEO SURVEYS-CONSULT. (16)TESTING SERVICE-
 OEA (17)TESTING SERVICE-CONSULT. (18)HURST-ROSHE-OEA (19)HURST-RO
 SHE-CONSULT. (20)CHASTAIN-OEA (21)CHASTAIN-CONSULTANT

(22)GREGG-DEA (23)GREGG-CONSULTANT (24)SHAFFER-DEA (25)SHAFFER-CONSULTANT/
 SAMPTY (-0)UNKNOWN (01)SHELBY TUBE (02)SPLIT SPOON
 (03)DENISON SAMPLER (04)CONT. FLIGHT AUGER (05)HAND AUGER
 (06)JAR (07)BAG (08)ROCK CORE (09)PISTON SAMPLER (10)HOLLOW STEM
 AUGER (11)POWER AUGER-MACHINE/
 PHYSIO (-0)UNKNOWN (1)TIPTON TILL PLAIN (2)DEARBORN UPLAND
 (3)MUSCATATUCK REGIONAL SLOPE (4)SCOTTSBURG LOWLAND
 (5)NORMAN UPLAND (6)MITCHELL PLAIN (7)CRAWFORD UPLAND
 (8)WABASH LOWLAND (9)CALUMET LACUSTRINE (10)VALPARAISO MORaine
 (11)KANKAKEE LACUSTRINE (12)MAUMEE LACUSTRINE (13)STEBEN MORAINA
 L/
 SERIES (-0)UNKNOWN (10)ADE (20)ADRIAN (30)ALFORD (40)ALGIERS
 (50)ALIDA (60)ALLISON (70)ARMIESBURG (80)AUBBEENAUBBEE
 (90)AVA (100)AVONBURG (110)AYR (120)AYRSHIRE (130)BARTLE
 (140)BAXTER (150)BEDFORD (160)BELLMORE (170)BERKS
 (180)BIRDS (190)BLOOMFIELD (200)BLOUNT (210)BONNIE
 (220)BONO (230)BOONESBORO (240)BOYER (250)BRADY
 (260)BREMS (270)BRONSON (280)BROOKSTON (290)BURGIN
 (300)BURNSIDE (310)CAMDEN (320)CARLISLE (330)CASCO
 (340)CATLIN (350)CELINA (360)CHALMERS (370)CHELSEA
 (380)CINCINNATI (390)CLARENCE (400)CLERMONT (410)COLYER
 (420)CONOVER (430)CONRAD (440)CORWIN (450)CORY (460)CORYD
 ON (470)COUPEE (480)CRANE (490)CRIDER (500)CROSBY
 (510)CROSIER (520)CUBA (530)DAMA (540)DARROCH (550)DEL RAY
 (560)DICKINSON (570)DOOR (580)DOWAGIAC (590)DUBOIS (600)D
 UNNING (610)EDEN (620)EDENTON (630)EDWARDS (640)EEL
 (650)ELKINSONVILLE (660)ELLIOTT (670)ELSTON (680)EVANSVILLE
 (690)FABIUS (700)FAIRMOUNT (710)FINCASTLE (720)FLANAGAN
 (730)FRESMAN (740)FOX-SILT LOAM (741)FOX-LOAM (742)FOX-URBAN LAN
 D (750)FREDERICK (760)FULTON (770)GENESEE-SILT LOAM (771)GENESEE-
 URBAN LAND (780)GILFORD (790)GILPIN (800)GINAT (810)GLENHALL
 (820)GRANBY (830)GRAYFORD (840)GUTHRIE (850)HAGERSTOWN
 (860)HANNA (870)HASKINS (880)HAUBSTADT (890)HAYMOND (900)
 HENNEPIN (910)HENSHAW (920)HICKORY (930)HIGH GAP (940)HIL
 LSDALE (950)HOMER (960)HOOPESTON (970)HOSMER (980)HOUGHTO
 N (990)HOYTVILLE (1000)HUNTINGTON (1010)HUNTSVILLE (1020)
 IONA (1030)IPAUA (1040)IVA (1050)JASPER (1060)JENNINGS
 (1070)JOHNSBURG (1080)JULES (1090)KALAMAZOO (1100)KERSTON
 (1110)KINGS (1120)KOKOMO (1130)LANDES (1140)LAWRENCE
 (1150)LENAWEE (1160)LINDSIDE (1170)LINKVILLE (1180)LONGLOIS
 (1190)LORENZO (1200)LOWELL (1210)LUCAS (1220)LYDICK (1230)
 LYLES (1240)MAHALASVILLE (1250)MARKHAM (1260)MARKLAND
 (1270)MARTINSVILLE (1280)MARTISCO (1290)MASSIE (1300)MATHER
 TON (1310)MAUMEE (1320)MCGARY (1330)MEDWAY (1340)MELLOTT
 (1350)MERMILL (1360)METAMORA (1370)METEA (1380)MIAMI-SILT L
 OAM (1381)MIAMI-URBAN LAND
 (1390)MILFORD (1400)MILLSDALE (1410)MILTON (1420)MONITOR
 (1430)MONTGOMERY (1440)MONTMORENCI (1450)MORLEY (1460)MOROC
 CO (1470)MUREN (1480)MUSKINGUM (1490)MUSSEY (1500)NAPPANE
 E (1510)NEGLEY (1520)NEWARK (1530)NEWTON (1540)NICHOLSON
 (1550)NINEVEH (1560)NOLIN (1570)OAKVILLE (1580)OCKLEY
 (1590)OCTAGON (1600)ODELL (1610)OSHTENO (1620)OTWELL
 (1630)OWOSSO (1640)PALMS (1650)PARKE (1660)PARR (1670)PATT
 ON (1680)PEKIN (1690)PEOGA (1700)PETROLIA (1710)PEWAMO
 (1720)PIKE (1730)PINHOOK (1740)PLAINFIELD (1750)PLANO
 (1760)POPE (1770)PRINCETON (1780)PROCTOR (1790)QUINN
 (1800)RAGSDALE (1810)RAHM (1820)RANDOLPH (1830)RARDEN

(1840)RAUB (1850)RAWSON (1860)REESVILLE (1870)RENSSELAER
 (1880)RIDDLES (1890)RIMER (1900)ROBINSON (1910)ROCKCASTLE
 (1920)RODMAN (1930)ROSS (1940)ROSSMOYNE (1950)RUNNYMEDE
 (1960)RUSH (1970)RUSSELL (1980)ST. CLAIR (1990)SARANAC
 (2000)SAUGATUCK (2010)SCIOTOVILLE (2020)SEBEWA (2030)SEWARD
 (2040)SHADELAND (2050)SHIPSHE (2060)SHOALS (2070)SIDELL
 (2080)SLEETH (2090)SLOAN (2100)SPARTA (2110)STARKS
 (2120)STEFF (2130)STENDAL (2140)STONELICK (2150)STOY
 (2160)STROLE (2170)SUNBURY (2180)SWITZERLAND (2190)SWYGERT
 (2200)SYLVAN (2210)TAGGART (2220)TAMA (2230)TEDROW (2240)
 TILSIT (2250)TIPPECANOE (2260)TOLEDO (2270)TORONTO (2280)
 TRACY (2290)TRAPPIST (2300)TROXEL (2310)TYNER (2320)UNION
 TOWN (2330)UIGO (2340)UINCENNES (2350)VOLINIA (2360)WAKEL
 AND (2370)WALLKILL (2380)WARNERS (2390)WARSAW (2400)WASEP
 I (2410)WASHTEAW (2420)WATSEKA (2430)WAUSEON (2440)WEA
 (2450)WEIKERT (2460)WEINBACH (2470)WELLSTON (2480)WESTLAND
 (2490)WHEELING (2500)WHITAKER (2510)WHITSON (2520)WILBUR
 (2530)WILLETTE (2540)WINGATE (2550)WOODMERE (2560)WOOLPER
 (2570)WYNN (2580)XENIA (2590)ZANESVILLE (2600)ZIPP
 (2700)BORROW PIT (2800)URBAN LAND (2900)ALLUVIAL LAND
 (3000)GRAVEL PIT (3100)GULLIED LAND (3200)STRIP MINE
 (3300)CUT AND FILL (3400)MADE LAND/
 PARENT (-0)UNKNOWN (1)LACUSTRINE DEPOSITS (2)OUTWASH AND ALLUVIAL
 DEPOSITS (3)EOLIAN SAND DEPOSITS (4)THICK LOESS DEPOSITS (5)LOAMY
 WISCONSIN TILL (6)CLAYEY WIS. TILL (7)THIN LOESS-LOAMY WIS TILL
 (8)THICK LOESS-LOAM WIS TILL (9)THICK LOESS-ILL TILL
 (10)RESIDUUM-SI. ST SH SS (11)RESIDUUM-LS BEDROCK
 (12)RES-CALCAREOUS SH LS/
 HORIZO (-0)UNKNOWN (1)A HORIZON (2)B HORIZON (3)C HORIZON
 (4)D HORIZON/
 SLOPE (-0)UNKNOWN (1)LEVEL-NEARLY LEVEL (2)0-2 (3)2-6 (4)6-12
 (5)12-18 (6) 18-25 (7)25-35 (8)35+/
 EROSIO (-0)UNKNOWN (1)NONE-SLIGHT (2)MODERATE-ERODED (3)SEVERE/
 WATERC (-0)UNKNOWN (-1)DRY/
 WATERF (-0)UNKNOWN (-1)DRY/
 DRAIN (-0)UNKNOWN (1)WELL-EXCESSIVE (2)MODERATELY WELL
 (3)SOMEWHAT POORLY (4)POORLY-VERY POORLY/
 PERMEA (-0)UNKNOWN (1)LESS THAN .06 (2).06-.2 (3).2-.63 (4).63-2.
 0 (5)2.0-6.0 (6)6.0-20 (7)GREATER THAN 20/
 FLOOD (-0)UNKNOWN (1)NONE (2)PERCHED-PONDED-HAZARD/
 FROST (-0)UNKNOWN (1)VERY LOW (2)VERY LOW-LOW (3)LOW (4)LOW-MODE
 RATE (5)MODERATE (6)MODERATE-HIGH (7)HIGH (8)HIGH-VERY HIGH
 (9)VERY HIGH/
 SHRINK (-0)UNKNOWN (1)VERY LOW (2)VERY LOW-LOW (3)LOW (4)LOW-MODE
 RATE (5)MODERATE (6)MODERATE-HIGH (7)HIGH (8)HIGH-VERY HIGH
 (9)VERY HIGH/
 PH (-0)UNKNOWN (01)BELOW 4.5 (02)4.5-5.0 (03)5.1-5.5 (04)5.6-6.
 0 (05)6.1-6.5 (06)6.6-7.3 (07)7.4-7.8 (08)7.9-8.4 (09)8.5-9.0
 (10)ABOVE 9.0/
 LL, PL, PI, SL (-0)UNKNOWN (-1)NOT PLASTIC/
 TEXTUR (-0)UNKNOWN (1)SAND (2)SAND-TRACE GRAVEL (3)SAND-LITTLE GR
 AVEL (4)SAND-SOME GRAVEL (5)SAND AND GRAVEL (6)SANDY LOAM
 (7)SANDY LOAM-TRACE GRAVEL (8)SANDY LOAM-LITTLE GRAVEL
 (9)SANDY LOAM-SOME GRAVEL (10)SANDY LOAM AND GRAVEL
 (11)LOAM (12)LOAM-TRACE GRAVEL (13)LOAM-LITTLE GRAVEL
 (14)LOAM-SOME GRAVEL (15)LOAM AND GRAVEL (16)SILTY LOAM
 (17)SILTY LOAM-TRACE GRAVEL (18)SILTY LOAM-LITTLE GRAVEL
 (19)SILTY LOAM-SOME GRAVEL (20)SILTY LOAM AND GRAVEL

(21)SILT (22)SILT-TRACE GRAVEL (23)SILT-LITTLE GRAVEL
 (24)SILT-SOME GRAVEL (25)SILT AND GRAVEL (26)SANDY CLAY LOAM
 (27)SANDY CLAY LOAM-TRACE GRAVEL (28)SANDY CLAY LOAM-LITTLE GRAVE
 L (29)SANDY CLAY LOAM-SOME GRAVEL (30)SANDY CLAY LOAM AND GRAVEL
 (31)CLAY LOAM (32)CLAY LOAM-TRACE GRAVEL (33)CLAY LOAM-LITTLE GRA
 VEL (34)CLAY LOAM-SOME GRAVEL (35)CLAY LOAM AND GRAVEL
 (36)SILTY CLAY LOAM (37)SILTY CLAY LOAM-TRACE GRAVEL
 (38)SILTY CLAY LOAM-LITTLE GRAVEL (39)SILTY CLAY LOAM-SOME GRAVEL
 (40)SILTY CLAY LOAM AND GRAVEL (41)SANDY CLAY
 (42)SANDY CLAY-TRACE GRAVEL (43)SANDY CLAY-LITTLE GRAVEL
 (44)SANDY CLAY-SOME GRAVEL (45)SANDY CLAY AND GRAVEL
 (46)SILTY CLAY (47)SILTY CLAY-TRACE GRAVEL (48)SILTY CLAY-LITTLE
 GRAVEL (49)SILTY CLAY-SOME GRAVEL (50)SILTY CLAY AND GRAVEL
 (51)CLAY (52)CLAY-TRACE GRAVEL (53)CLAY-LITTLE GRAVEL
 (54)CLAY-SOME GRAVEL (55)CLAY AND GRAVEL
 (56)GRAVEL (57)SANDY GRAVEL (58)GRAVELLY SAND
 (59)SAND AND GRAVEL
 (60)COPROGENOUS EARTH (61)DIATOMACEOUS EARTH (62)FIBRIC MATERIAL
 (63)FRAGMENTAL MATERIAL (64)HEMIC MATERIAL (65)ICE OR FROZEN SOIL
 (66)MARL (67)MUCK (68)MUCKY PEAT (69)OXIDE-PROTECT. WX BR
 (70)PART. DECOM ORG MATL (71)PEAT (72)SAPRIC MATERIAL
 (73)UNDECOM ORG MATL (74)UNWEATHERED BEDROCK
 (75)WX BR,SAPROLITE,GRUS (76)COMPLEX (77)INAPPLICABLE/
 ORGANI (-0)UNKNOWN (1)NO ORGANIC MATL (2)TRACE (3)LITTLE (4)SOME
 (5)AND/
 COLOR (-0)UNKNOWN (01)BLUISH GRAY (02)BLACK
 (03)BROWN (04)BROWNISH YELLOW (05)DARK BROWN (06)DARK BLUISH GRAY
 (07)DARK GRAY (08)DARK GRAYISH BROWN (09)DARK GREENISH GRAY
 (10)DARK OLIVE (11)DARK OLIVE GRAY (12)DARK RED
 (13)DARK REDDISH BROWN (14)DARK REDDISH GRAY (15)DUSKY RED
 (16)DARK YELLOWISH BROWN (17)GRAYISH BROWN (18)GREENISH GRAY
 (19)GRAYISH GREEN (20)GREEN (21)GRAY (22)LIGHT BLUISH GRAY
 (23)LIGHT BROWN (24)LIGHT BROWNISH GRAY (25)LIGHT GREENISH GRAY
 (26)LIGHT GRAY (27)LIGHT OLIVE BROWN (28)LIGHT OLIVE GRAY
 (29)LIGHT RED (30)LIGHT REDDISH BROWN (31)LIGHT YELLOWISH BR.
 (32)OLIVE BROWN (33)OLIVE (34)OLIVE GRAY (35)OLIVE YELLOW
 (36)PALE BROWN (37)PALE GREEN (38)PALE OLIVE (39)PALE RED
 (40)PALE YELLOW (41)PINKISH GRAY (42)PINK (43)PINKISH WHITE
 (44)REDDISH BLACK (45)REDDISH BROWN (46)RED (47)REDDISH GRAY
 (48)REDDISH YELLOW (49)STRONG BROWN (50)VERY DARK BROWN
 (51)VERY DARK GRAY (52)U. DK. GRAYISH BROWN (53)VERY DARK RED
 (54)VERY PALE BROWN (55)VERY DUSKY RED (56)WEAK RED (57)WHITE
 (58)YELLOWISH BROWN (59)YELLOWISH RED (60)YELLOW/
 TESTEF (-0)UNKNOWN (01)STANDARD-12400
 (02)STANDARD-SEE DIF (03)STANDARD-NOT GIVEN (04)MODIFIED-12400
 (05)MODIFIED-56000 (06)MODIFIED-56300 (07)MODIFIED-SEE DIF
 (08)MODIFIED-NOT GIVEN (09)15 BLOW-7400 (10)15 BLOW-7800
 (11)15 BLOW-SEE DIF (12)15 BLOW-NOT GIVEN (13)KNEADING-SEE DIF
 (14)KNEADING-NOT GIVEN (15)HARVARD MIN-SEE DIF
 (16)HARVARD MIN-NOT GIVEN (17)HUEEM-SEE DIF (18)HUEEM-NOT GIVEN
 (19)VIBRATORY-SEE DIF (20)VIBRATORY-NOT GIVEN (21)COMPRESSION-SEE
 DIF (22)COMPRESSION-NOT GIVEN/
 TYPE (-0)UNKNOWN (1)UU TEST (2)CU TEST-UNSATURATED
 (3)CU TEST-SATURATED (4)DIRECT SHEAR (5)CD TEST/
 HOLENO, SAMPNO, DATEYR, DATEDA, TOWN, RANGE, SECTIO TO BORING, STATNO,
 OFFSET, LINE1, LINE2, LABNO TO SPT, BEDRKS TO WATERS, GRAD01 TO COLL,
 LOSSIG TO SPECGR, MAXDD TO QUSTR, QUSTA, STRENGTH TO CU
 (-0)UNKNOWN

MISSING VALUES COUNTY TO QUSTR, QUSTA TO CU (-0)/

COMMENT THE FOLLOWING SERIES OF ~IF~ STATEMENTS COMPUTE BOTH THE AASHTO AND UNIFIED CLASSIFICATION CODES-FOR THOSE PROGRAMS NOT REQUIRING EITHER OF THESE TWO CLASSIFICATIONS, THESE STATEMENTS SHOULD BE OMITTED

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IF (TEXTUR EQ 67 OR 68 OR 70 OR 71 OR 73 OR 60 OR 62) AASHTO=13
IF (GRAD09 GE 35.5 AND LL GE 40.5 AND PI GE 10.5 AND PI GT (LL-30))
  AASHTO=12
IF (GRAD09 GE 35.5 AND LL GE 40.5 AND PI GE 10.5 AND PI LE (LL-30))
  AASHTO=11
IF (GRAD09 GE 35.5 AND LL LT 40.5 AND PI GE 10.5) AASHTO=10
IF (GRAD09 GE 35.5 AND (LL GE 40.5 OR EQ -1) AND PI LT 10.5)
  AASHTO=09
IF (GRAD09 GE 35.5 AND LL LT 40.5 AND PI LT 10.5) AASHTO=08
IF (GRAD09 LT 35.5 AND LL GE 40.5 AND PI GE 10.5) AASHTO=06
IF (GRAD09 LT 35.5 AND LL LT 40.5 AND PI GE 10.5) AASHTO=05
IF (GRAD09 LT 35.5 AND (LL GE 40.5 OR EQ -1) AND PI LT 10.5)
  AASHTO=04
IF (GRAD09 LT 35.5 AND LL LT 40.5 AND PI LT 10.5) AASHTO=03
IF (GRAD08 GE 50.5 AND GRAD09 LT 10.5 AND (LL EQ -1 OR PL EQ -1
  OR PI EQ -1)) AASHTO=07
IF (GRAD08 LT 50.5 AND GRAD09 LT 25.5 AND PI LT 6.5) AASHTO=02
IF (GRAD07 LT 50.5 AND GRAD08 LT 30.5 AND GRAD09 LT 15.5
  AND PI LT 6.5) AASHTO=01
IF (TEXTUR EQ 67 OR 68 OR 70 OR 71 OR 73 OR 60 OR 62) AASHTO=13
IF (AASHTO NE 05 OR 06)
  GI=RND((GRAD09-35)*(.2+.005*(LL-40))+.01*(GRAD09-15)*(PI-10))
IF (AASHTO EQ 05 OR 06) GI=RND(.01*(GRAD09-15)*(PI-10))
IF (PL EQ -1 OR LL EQ -1 OR GI LT 0) GI=0
ASSIGN MISSING GI (-8)
IF (TEXTUR EQ 67 OR 68 OR 70 OR 71 OR 73 OR 60 OR 62) UNIF=35
IF (GRAD09 GE 50 AND (PI GT (.73*(LL-20)) AND 7) AND LL LT 50)
  UNIF=01
IF (GRAD09 GE 50 AND PI GT (.73*(LL-20)) AND LL GT 50) UNIF=02
IF (GRAD09 GE 50 AND PI GT (.73*(LL-20)) AND LL EQ 50) UNIF=03
IF (GRAD09 GE 50 AND (PI LT (.73*(LL-20)) OR 4) AND LL LT 50 AND
  (ORGANI EQ 1 OR 2)) UNIF=04
IF (GRAD09 GE 50 AND (PI LT (.73*(LL-20)) OR 4) AND LL LT 50 AND
  (ORGANI EQ 4 OR 5)) UNIF=05
IF (GRAD09 GE 50 AND (PI LT (.73*(LL-20)) OR 4) AND LL LT 50 AND
  ORGANI EQ 3) UNIF=06
IF (GRAD09 GE 50 AND (PI EQ (.73*(LL-20)) AND GT 7) AND LL LT 50 AND
  (ORGANI EQ 1 OR 2)) UNIF=07
IF (GRAD09 GE 50 AND (PI EQ (.73*(LL-20)) AND GT 7) AND LL LT 50 AND
  (ORGANI EQ 4 OR 5)) UNIF=08
IF (GRAD09 GE 50 AND (PI EQ (.73*(LL-20)) AND GT 7) AND LL LT 50 AND
  ORGANI EQ 3) UNIF=09
IF (GRAD09 GE 50 AND PI LT (.73*(LL-20)) AND LL GT 50 AND
  (ORGANI EQ 1 OR 2)) UNIF=10
IF (GRAD09 GE 50 AND PI LT (.73*(LL-20)) AND LL GT 50 AND
  (ORGANI EQ 4 OR 5)) UNIF=11
IF (GRAD09 GE 50 AND PI LT (.73*(LL-20)) AND LL GT 50 AND ORGANI EQ
  3) UNIF=12
IF (GRAD09 GE 50 AND PI EQ (.73*(LL-20)) AND LL GT 50 AND
  (ORGANI EQ 1 OR 2)) UNIF=13
IF (GRAD09 GE 50 AND PI EQ (.73*(LL-20)) AND LL GT 50 AND
  (ORGANI EQ 4 OR 5)) UNIF=14
IF (GRAD09 GE 50 AND PI EQ (.73*(LL-20)) AND LL GT 50 AND ORGANI EQ

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3) UNIF=15
IF (GRAD09 GE 50 AND PI LT (.73*(LL-20)) AND LL EQ 50 AND
   (ORGANI EQ 1 OR 2)) UNIF=16
IF (GRAD09 GE 50 AND PI LT (.73*(LL-20)) AND LL EQ 50 AND
   (ORGANI EQ 4 OR 5)) UNIF=17
IF (GRAD09 GE 50 AND PI LT (.73*(LL-20)) AND LL EQ 50 AND ORGANI EQ
   3) UNIF=18
IF (GRAD09 GE 50 AND PI EQ (.73*(LL-20)) AND LL EQ 50) UNIF=19
IF (GRAD09 GE 50 AND (PI GE (.73*(LL-20)) AND LE 7 AND GE 4))
   UNIF=20
IF (GRAD09 LT 50 AND GRAD06 LE 50 AND GRAD09 GT 12 AND (PI LT
   (.73*(LL-20)) OR 4)) UNIF=21
IF (GRAD09 LT 50 AND GRAD06 GT 50 AND GRAD09 GT 12 AND (PI LT
   (.73*(LL-20)) OR 4)) UNIF=24
IF (GRAD09 LT 50 AND GRAD06 LE 50 AND GRAD09 GT 12 AND (PI GT
   (.73*(LL-20)) AND 7)) UNIF=22
IF (GRAD09 LT 50 AND GRAD06 GT 50 AND GRAD09 GT 12 AND (PI GT
   (.73*(LL-20)) AND 7)) UNIF=25
IF (GRAD09 LT 50 AND GRAD06 LE 50 AND GRAD09 GT 12 AND ((PI EQ
   (.73*(LL-20))) OR (PI GT (.73*(LL-20)) AND LE 7 AND GE 4)))
   UNIF=23
IF (GRAD09 LT 50 AND GRAD06 GT 50 AND GRAD09 GT 12 AND ((PI EQ
   (.73*(LL-20))) OR (PI GT (.73*(LL-20)) AND LE 7 AND GE 4)))
   UNIF=26
IF (GRAD09 LT 50 AND GRAD06 LE 50 AND GRAD09 LT 5) UNIF=27
IF (GRAD09 LT 50 AND GRAD06 GT 50 AND GRAD09 LT 5) UNIF=28
IF (GRAD09 LT 50 AND GRAD06 LE 50 AND (GRAD09 GE 5 AND LE 12) AND
   (PI LT (.73*(LL-20)) OR 4)) UNIF=29
IF (GRAD09 LT 50 AND GRAD06 LE 50 AND (GRAD09 GE 5 AND LE 12) AND
   (PI GT (.73*(LL-20)) AND 7)) UNIF=30
IF (GRAD09 LT 50 AND GRAD06 LE 50 AND (GRAD09 GE 5 AND LE 12) AND
   ((PI EQ (.73*(LL-20))) OR (PI GT (.73*(LL-20)) AND LE 7 AND
   GE 4))) UNIF=31
IF (GRAD09 LT 50 AND GRAD06 GT 50 AND (GRAD09 GE 5 AND LE 12) AND
   (PI LT (.73*(LL-20)) OR 4)) UNIF=32
IF (GRAD09 LT 50 AND GRAD06 GT 50 AND (GRAD09 GE 5 AND LE 12) AND
   (PI GT (.73*(LL-20)) AND 7)) UNIF=33
IF (GRAD09 LT 50 AND GRAD06 GT 50 AND (GRAD09 GE 5 AND LE 12) AND
   ((PI EQ (.73*(LL-20))) OR (PI GT (.73*(LL-20)) AND LE 7 AND
   GE 4))) UNIF=34
IF (TEXTUR EQ 67 OR 68 OR 70 OR 71 OR 73 OR 60 OR 62) UNIF=35
IF (AASHTO1 NE 9999) AASHTO=AASHTO1
IF (UNIF1 NE 9999) UNIF=UNIF1
IF (SAND EQ 999) SAND=-0
IF (SAND NE 999) SAND=GRAD07-GRAD09
ASSIGN MISSING AASHTO,UNIF (-8)
VAR LABELS GI GROUP INDEX/AASHTO AASHTO CLASSIFICATION/UNIF UNIFIED CLASSIFI
CATION
VALUE LABELS GI (-8)MISSING DATA/
AASHTO (-0)UNKNOWN (1)A-1-A (2)A-1-B (3)A-2-4 (4)A-2-5 (5)A-2-6
(6)A-2-7 (7)A-3 (8)A-4 (9)A-5 (10)A-6 (11)A-7-5 (12)A-7-6
(13)A-8/
UNIF (-0)UNKNOWN (01)CL (02)CH (03)CL-CH (04)ML (05)OL (06)ML-OL
(07)ML-CL (08)CL-OL (09)ML-OL OR CL (10)MH (11)OH (12)MH-OH
(13)MH-CH (14)CH-OH (15)MH-OH OR CH (16)ML-MH (17)OL-OH
(18)MH-OH OR ML-OL (19)ANY COMBINATION (20)CL-ML
(21)GM (22)GC (23)GM-GC (24)SM (25)SC (26)SM-SC (27)GW OR GP*=G
(28)SW OR SP*=S (29)G-GM (30)G-GC (31)G-GM OR G-GC (32)S-SM

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(33)S-SC (34)S-SM OR S-SC (35)PT
COMMENT THE ABOVE STATEMENT IS THE LAST STATEMENT WHICH
SHOULD BE OMITTED IF THE AASHTO AND UNIFIED
CLASSIFICATIONS ARE NOT REQUIRED
COMMENT THE NUMBER OF CASES (N OF CASES) WILL COINCIDE WITH
THE NUMBER OF SAMPLES CONTAINED WITHIN THE DATA BANK
AT THE TIME OF PROCESSING
N OF CASES 2508
PRINT FORMATS SPECGR,EO,EF,CC,CR (3)/ QUSTR,QUSTA,STRENGTH TO COHESION,
POREPRESS,MAJOR,PO,PC,CU (2)/ GRDSUR TO DEPTHB,
BEDRKS TO WATERF,
GRADO1 TO NATDD,MAXDD TO CBR502,ANGLE,SO,SF (1)/PROJPR,
PROJPA,CONTPR,ROADPR,ROADSU TO BORING,LINE1,LINE2,LABNO (A)
READ INPUT DATA
SAVE FILE PROG
FINISH
6/7/8/9

PROGRAM NUMBER 4

THIS PROGRAM WILL ACCESS THE MAGNETIC TAPE ONTO WHICH DATA IS STORED FROM PROG1 AND THE SPSS PROGRAM CREATED IN PROG3 AND PLACE THE NEW SPSS FILE ONTO A NEW MAGNETIC TAPE. THIS SPSS FILE IS TO BE USED IN PROCESSING INFORMATION STORED WITHIN THE GEOTECHNICAL DATA BANK.

12345,ABC,TP2,P20,TC200,TU38000,CM77000,T350.

PASS=

PFILES(GET,PROG3)

REQUEST(SOIL1,1414)

COMMON(SPSS)

SPSS(I=PROG3,D=SOIL1,S=PROG)

REQUEST(TAPE,1580,WRITE,UP=****)

COPYBF(PROG,TAPE,,RB,RA)

RETURN(SOIL1)

6/7/8/9

APPENDIX F

USER'S MANUAL: PART V

The user is referred to the discussion under Data Processing and the SPSS text (42) for a description of the control cards which may be used for data processing.

Example Problems

Example 1:

Existing soils data from Tippecanoe County (code 79) are desired for the preliminary design of a highway in the northeast corner of the county. The area is included in Township 24 North and Range 5 West. Information required includes: compaction test data; California bearing ratio test data; and depths from which the soil samples were removed. Additionally, the frequency of soil types according to the AASHTO soil classification system is desired. The program deck setup would be:

12345,ABC,CM150000,L10000,T350,P20,TU38000,TC200,TP1.

PASS=

DAYBAN. *SOIL DATA FOR THE STATE OF INDIANA*

REQUEST(TAPE,1580)

COPYBF(TAPE,PROG)

REWIND(TAPE)

RETURN(TAPE)

REWIND(PROG)

COMMON(SPSS)

SPSS(G=PROG)

7/8/9

GET FILE

PROG

SELECT IF

(COUNTY EQ 79 AND TOWN EQ 24 AND TOWNDI EQ 1 AND RANGE EQ 5
AND RANGDI EQ 2)

LIST CASES

CASES=2508/VARIABLES=TESTEF,MAXDD,MAXWD,OPTIMC,CBRS01,CBRS02,
DEPTHT,DEPTHB

FREQUENCIES

INTEGER=AASHTO (1,13)

FINISH

6/7/8/9.

Example 2:

A researcher at a prestigious Midwestern University suspects that a relationship exists between the coefficient of consolidation (CC) and the initial void ratio (EO) of soils found within the State of Indiana. The following deck setup would produce a plot of the coefficient of consolidation versus the initial void ratio:

12345,ABC,CM150000,L10000,T350,P20,TU38000,TC200,TP1.

PASS=

DAYBAN. *SOIL DATA FOR THE STATE OF INDIANA*

REQUEST(TAPE,1580)

COPYBF(TAPE,PROG)

REWIND(TAPE)

RETURN(TAPE)

REWIND(PROG)

COMMON(SPSS)

SPSS(G=PROG)

7/8/9

GET FILE

PROG

SCATTERGRAM

CC WITH EO

FINISH

6/7/8/9

COVER DESIGN BY ALDO GIORGINI