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Physical Environment Report: A Geotechnical Aid for Planners

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Since 1976, the Soil Mechanics Bureau of the New York State Department of Transportation has produced reports that delineate information on the physical base of a potential transportation corridor or project. These reports have their origin in the traditional engineering soil map. The transportation planner must identify potential changes in the physical base of an area that could result from a transportation improvement and determine how these changes may affect the environment. The reports present physical-base data on geology, soils, groundwater, and surface water in map form and include an explanation of the mapped units in an explanatory legend. Information contained in the reports includes topography, slopes, terrain units, bedrock, aquifers, erodibility, runoff, floodplain and watershed delineation, and stream-classification data. A brief description of the use of the mapped information is included, along with a listing of references and data sources. This paper briefly describes the data-collection and presentation procedures and the cautionary statements and uses made of the reports.

The Soil Mechanics Bureau of the New York State Department of Transportation (NYSDOT) has for many years provided department planners and designers with reports delineating soil and surficial geologic conditions on a reconnaissance level (1, 2). In the mid-1970s, departmental regional planning engineers began requesting additional information on water-soil interactions such as runoff and erosion potential. At this time, bureau personnel were studying a physical inventory—termed a physical environment report—prepared for the Saskatoon, Canada, area (3) that contained many concepts that could be included in an expanded reconnaissance-level report.

A study showed that an inventory limited to factors within the basic terrain-reconnaissance expertise of the bureau could give planners information on topography, geology, soil type, internal drainage, and soil erodibility. Other easily acquired information such as precipitation data, floodplain delineations, stream classification, and widlife food-and-cover criteria based on soil wetness could also be included. This type of inventory information could alleviate the problems of regional planning personnel attempting to provide physical-base data from often inadequate sources or without the necessary interpretations of source data.

INVENTORY DATA BASE

Because more physical-base information would be collected and interpreted for the physical environment reports than for the previous terrain-reconnaissance reports, a review of accessible source material was made. Terrain reconnaissance as practiced in New York relies heavily on the soil surveys produced by the Soil Conservation Service (SCS), U.S. Department of Agriculture. SCS soil mapping units were converted to NYSDOT terrain units (which are based on landform, mode of deposition, and parent material). Because of the ready availability of soil survey data and the bureau's experience in its use, this information was retained as the basis for interpretation into surficial geologic (terrain) units. In addition, information contained in the soil survey on slope, erodibility, runoff, wetness and ponding, and habitat elements for wetlands wildlife was extracted, evaluated, and interpreted. Supplementary references or information sources to which the report user may go for more detailed information on uses and interpretation of the soil survey information were found; these range from the Soil Survey Manual (4) to papers from various technical journals.

Bedrock information was obtained from the New York State Geological Map (5); groundwater bulletins, the Geological Survey, U.S. Department of the Interior (USGS); and New York State Museum and Science Service publications. Information on aquifers, both surficial and bedrock, was obtained from the same sources.

Climatic data were obtained from the monthly and annual summaries for New York reporting stations prepared by the National Weather Service, U.S. Department of Commerce. Floodplain, wetland, and stream data were acquired from the New York State Department

of Environmental Conservation and the U.S. Army Corps of Engineers.

LIMITATIONS OF INFORMATION

The limitations-of-information section of the reports contains the cautionary statements that must be made concerning reconnaissance-level studies, facts, and inferences; for example, the following is a typical general statement that precedes the body of a physical environment report:

> The information contained on the included maps is preliminary and general and as such the maps must be considered as generalizations. The boundaries of the units depicted on the maps represent general indications of where a change occurs. In most instances the changes are transitional and not abrupt as shown on the maps. Some small inclusions of a differing unit may occur within areas mapped as a single unit.
>
> The source data used for statements and interpretations often were specifically intended for purposes other than engineering evaluation. The evaluation of these data together with previous experience and field reconnaissance contribute significantly to the final interpretations. Where information was obtained directly from source material without interpretation on the part of the Soil Mechanics Bureau, the source material will be cited. Inferred or interpreted information will be indicated as such along with the data base source.

It is important to identify information that is passed on from a source or sources virtually unchanged from that which has been subjected to an interpretive process during assimilation and presentation. In addition, some information that is passed on may have been inferred at its source. The reasoning process for the basis of interpretation must be made clear to the user by the inclusion of references to which he or she may turn for further study.

Greer and Moorhouse (6) in their discussion of engineering-geological studies for sewer projects stated that "any generalized data presentation or interpretation contained in an engineering soil or geologic report... should be used only with an understanding of the degree to which such generalizations must be regarded with skepticism." The general statement on limitations of information should put the reconnaissance level of the study firmly in the mind of the report user.

DATA PRESENTATION

There are no new or exciting methodologies used in reporting the data. A brief narrative section precedes the graphical portion of the report. This section contains an introduction that includes the scope of the report, the method of investigation, and an area description. The area description briefly summarizes the location, culture, and climate of the study area, along with the generalized geologic setting (including physiography and topography, unconsolidated deposits, and bedrock). Drainage is described and any USGS surface-water recording stations are tabulated as to type, number, and location.

The next section presents a short discussion of the interactions of soil, water, and transportation facilities. The erosion and sediment production caused by devegetation or increased runoff, along with the resultant potential problems on floodplains, are described, and the transportation facilities impacts on surface waters and on groundwater in shallow surficial aquifers are briefly discussed.

With the exception of three tabular forms of data presentation, all the information is presented on maps. Many decisions about map scale were made. In some instances, especially in urban-suburban areas, regional planning engineers will recommend a map scale, usually 1:9600. It is preferable to use the standard 7.5′ USGS topographic quadrangles. NYSDOT has prepared updated planimetric maps at the same scale (1:24000) as the USGS sheets, and some information is more clearly presented on these sheets. Many mechanical problems present themselves because most pedologic and geologic maps are not prepared on this scale, and one must always remember that enlarging or reducing a data source does not change its accuracy. If the data source is greatly reduced in scale, an interpretation that combines data will be done so as not to clutter the map. If the source data are modified, the modifications should be described in the legend that accompanies the map presentation.

Each parameter is presented as a map that graphically depicts the areal extent of each mapping unit, along with the usual map-related legend, scale, contour interval, north arrow, and such, and is accompanied by an explanation of the map units and an explanation of the rationale for each map-unit division. The purpose of each map and the use of the factor depicted are briefly described. Finally, the references used to produce the map-unit information and any corroborating data sources or references are included. The information presented is divided into three broad categories: physical aspects, soil aspects, and water aspects (although some information may logically appear in more than one category).

Physical Aspects

An elevation map that uses the layer method of representing elevations is produced from the 7.5′ USGS topographic sheet and the total relief of the project area. A series of elevation bands based on the elevation difference that best shows the landscape configuration is used.

A topographic slope map of the project area is used to delineate areas of common slope from level to steep. Because these maps depict average slope ranges (which assumes a uniform slope for the map unit), a cautionary note explaining that slopes may be complex rather than uniform is included. Data are taken directly from SCS map-unit slope-phase information or interpreted from topographic maps if slope data are unavailable.

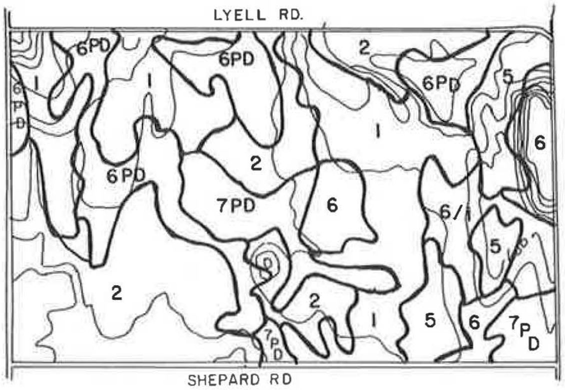
The generalized terrain-unit map (Figure 1) is the basic terrain-reconnaissance map produced by the landform-depositional-process parent-material interpretations developed in the past (1, 2). This is the type of engineering soil map that many transportation agencies routinely produce. The determination of terrain units is based on a review of the existing literature on the subject area and includes a geotechnical engineering interpretation of the pedologic and geologic maps of the area, as well as a geotechnical engineering interpretation of aerial photographs, a field reconnaissance of the area, and an evaluation of the existing subsurface data. Complementing the terrain-unit map are two tables. The first (Table 1) presents the general characteristics of each terrain-map unit, including the mode of origin, typical landform, common topographic position, soil fractions found in the terrain unit and in the internal structure, relative permeability, and others. The second (Table 2) presents the anticipated earth engineering behavior of the terrain units with respect to vertical gradeline location, subgrade and cut-slope conditions, and utility as a source of construction material. All data sources used for both the map-unit and table information are reported.

A bedrock geology map is used to show the contacts between formations and the areas of outcrop or shallow overburden [which is defined as having less than 1.2 m

(4 ft) of soil cover over bedrock]. Water-wells and NYSDOT borings that reach the bedrock surface are shown and depth to rock is given. The bedrock lithology and structure is explained in descriptive paragraphs that accompany the map. References are cited to enable the reader to obtain more-detailed bedrock information.

A map that shows the unconsolidated aquifers is usually taken without change from the appropriate groundwater publications, where they exist. Where no groundwater data are available, the map is based on interpretations of the terrain-unit map. The basis for delineation is the probable yield of a well in volume per minute. In general, glacial till and layered silt and clay deposits yield less than 19 L/min (5 gal/min), layered silts and sands are expected to yield 19-76 L/min (5-20 gal/min), and layered sands and gravels usually yield 76-379 L/min (20-100 gal/min). Where known, the chemical quality of the groundwater is briefly described. This map is accompanied by a table of climatological data, usually limited to monthly and annual average precipitation values, for the nearest weather station.

Figure 1. Generalized terrain-unit map.



1 THICK TILL
2 THIN TILL
5 OUTWASH DEPOSITS
6 LACUSTRINE SHORE DEPOSITS
6PD LACUSTRINE SHORE DEPOSITS - POORLY DRAINED
6/I LACUSTRINE SHORE DEPOSITS OVER THICK TILL
7PD LACUSTRINE BOTTOM SEDIMENTS - POORLY DRAINED

Soil Aspects

The soil engineering classification map (Figure 2) is intended to indicate the geotechnical effort that would be involved at various locations so that lead times can be established for an adequate soils program for proper design. Also, in the early planning stages, information about subsurface conditions can be obtained where necessary to determine whether or not these would become a constraint in design and construction.

The classifications presented are based on an interpretation of the engineering characteristics of the terrain units encountered in the project area. Those terrain units that have similar engineering features are grouped into the following types of map units.

Class 1: Those soil deposits that require minimal exploration, testing, and analysis for proper soils design. These generally have good bearing capacity, negligible settlements, and good cut-slope and subgrade characteristics.

Class 2: Those soil deposits where exploration is necessary to establish the soil profile and detailed exploration, testing, and analysis may be necessary for proper soils design. Included in this class are veneer deposits such as lake-laid sands and floodplain soils,

Table 1. General terrain-unit characteristics.

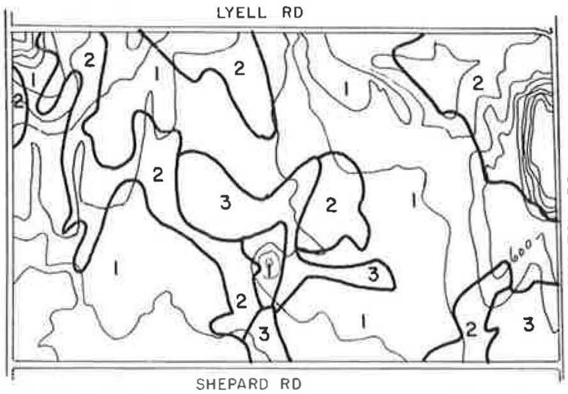
Terrain Unit	Mode of Origin	Landforms	Common Topographic Position	Particle Size and Distribution	Relative Permeability	Other
Outwash deposits	Sediments transported by meltwaters away from ice mass	Flat to gently undulating terraces	Lower valley walls and floors	Silt to cobbles, mostly sand and gravel; well-sorted, massive, horizontal stratification with some bedding	Moderate to rapid	May have high water table; nonplastic
Lacustrine bottom sediments	Sediments deposited in deep, quiet waters of proglacial lakes	Flat to gently undulating plains	Valley floors; lowlands	Clay to fine sand; mostly silt and clay in well-sorted beds; nearly horizontal, distinct stratification	Very slow vertically; slow horizontally	Laminations of the type commonly called varves, plastic

Table 2. General earth engineering considerations.

Terrain Unit	Highway Location	Cut-Slope Conditions	Subgrade Conditions	Utility as Source of Materials
Outwash deposits	Generally not critical; embankments more than 7.6 m high may have unstable foundations	Generally good; positive drainage may be required to prevent erosion	Generally good; may be nonuniform	Common borrow and granular materials
Lacustrine bottom sediments	Embankments more than 7.6 m high may have unstable foundations; cuts will be troublesome	Generally poor; problems of fine-grained flowing materials; may require slope protection and flattening for stability	Generally soft, wet, fine-grained materials; trafficability difficulties; consider undercut or underdrains	Common borrow; may have moisture content greater than optimum

Note: 1 m = 3.28 ft.

Figure 2. Soil engineering classification map.



1 MINIMAL EXPLORATION, TESTING AND ANALYSIS NECESSARY FOR PROPER SOIL DESIGN

2 EXPLORATION IS NECESSARY TO DETERMINE SOIL PROFILE. DETAILED EXPLORATION, TESTING AND ANALYSIS MAYBE NECESSARY FOR PROPER SOIL DESIGN

3 EXTENSIVE EXPLORATION, DETAILED TESTING AND ANALYSIS NECESSARY TO PROVIDE PROPER SOIL DESIGN

man-modified areas of fill, and urban areas where general soils information is unavailable.

Class 3: Those soil deposits where extensive exploration, detailed testing, and intensive analysis are usually required for proper soils design. These are usually deposits of fine-grained wet soils and organic deposits.

A soil-erodibility rating map is used to delineate areas having similar erodibility characteristics. The ratings are the average of a range determined by the soil erodibility or K-factor of Wischmeier (7, 8). The basic data are obtained from published SCS reports or by using Wischmeier's nomograph. Two maps can be made, one that depicts the relative erodibility of the surface or pedologic A-horizon and one that depicts the parent material or pedologic C-horizon. It is preferable to use the relative erodibility of the parent material, as in most instances surface horizons are removed during construction operations. The narrative that accompanies this map briefly describes the soil parameters used in determining the erodibility factor. Much of the narrative is aimed at defining the difference between soil erodibility (which is based solely on soil characteristics) and soil erosion (which is determined by topographic, vegetative, and climatic considerations, as well).

The soil-runoff factor first proposed by Musgrave (9) is the basis for the map units of the soil-runoff-factor map. Where this information is not available from SCS, the method of Chiang (9) is used to determine the runoff factor. The map units are the same as SCS ratings, i.e., low, moderate, high, and very high runoff. This map is accompanied by a narrative that explains how the factors are derived, what they mean, and how to use the map information.

A soil-wetness-and-ponding map is used to delineate areas of similar soil drainage, based on SCS soil series descriptions [interpretations of the SCS soil-drainage classes based on the depth to soil mottles in the soil pedon (4)]. Those soils not wet for significant times are those whose natural drainage classes are excessively, somewhat excessively, or well drained. Those wet for significant periods include the moderately well and the somewhat poorly drained soils, and those continuously wet or ponded fall into the poorly to very poorly drained range. A 1.2-m depth to seasonal water is used as a break point by assuming a 1.2-m-deep highway ditch from original ground surface. Work by Latshaw and Thompson (11) confirms these categories to be valid. The narrative that accompanies this map explains soil drainage and how the map units were derived.

Water Aspects

Floodplain delineations are based on the 1:24000 scale flood-prone area maps produced by the USGS in their Albany, New York, office for the U.S. Army Corps of Engineers. These are estimated from available flood information and indicate areas that may be occasionally flooded but provide no information on the frequency, depth, duration, and other details of flooding. This information is passed along unchanged. However, where available, a listing of flood maps produced by the Federal Insurance Administration, U.S. Department of Housing and Urban Development, is included to allow the user access to more-detailed floodplain delineations.

Stream classifications and watershed boundaries are delineated, based on information obtained from the New York State Department of Environmental Conservation in regard to the surface-water classification of waterbodies in the project area. Standards in New York are based on best use of the waters and range from drinking-water source to suitability for secondary contact recreation. Watershed delineations are those defined by the U.S. Watershed Protection and Flood Prevention Act of 1954. Standards are briefly described, along with source information.

The wetland food-and-cover map depicts those areas that combine suitable soil and water conditions for the natural production of food and cover plants favorable to wetland wildlife. These ratings are obtained directly from SCS data based on the soil series and the slope phase of the map unit. The description that accompanies this map notes that it may not be substituted for an official freshwater wetlands map because New York law defines wetlands based on vegetation. As official freshwater wetland maps become available, this presentation will be deleted.

SUMMARY

Any or all of these maps may be included for a given project, depending on the regional project manager's desires. Possible future inclusions (when the information becomes available) would be sole-source aquifers, official freshwater wetland maps, and prime or unique farmlands maps.

These reports can help planners free themselves from the task of defining aspects of the physical or abiotic environment in early planning phases. Although these are reconnaissance-stage reports made for a study area or corridor, the references that are included will save much valuable time when more detailed information is required.

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Method for Determining Relative Suitability of Existing Geotechnical Data for Regional Planning

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During regional planning studies, the engineering geologists must choose among diverse, competing data sources, each having distinct cost and accuracy characteristics. Recognizing a need for guidelines in this area, the Missouri Division of Geology and Land Survey, Rolla, Missouri, evaluated a sequence of alternative sources of data on the Cape Girardeau quadrangle in southeastern Missouri. Several map sources were compared at three scales: statewide (1:500 000), countywide (1:62 000), and quadrangle (1:24 000). Engineering and geologic considerations were used to establish criteria for 10 land uses associated with residential development. These criteria were used with the appropriate source data to develop a sequence of limitations maps at each scale. Extensive field and laboratory programs were carried out to prepare the best-possible data-reference source with which other map products could be compared. A usefulness index was formulated to measure the degree of agreement between the competing interpreted products and the reference standards. Manual computation of this index proved impractical [a 10-km^2 (4-mile^2) area required 1 person day/comparison]. Thus, computer methods were used that permitted the rapid comparison of approximately 32 000 cells covering the quadrangle and the computation of the resulting usefulness index for about $50.00 (including all salaries and data-processing costs).

The growing interest in and demand for environmental assessment has caused a reappraisal of land-use planning activities and accelerated demands for suitable engineering geology maps. The majority of these demands emphasize the need to display the natural constraints to development of various land uses. These new types of map displays, which range from rather generalized, small-scale displays covering large regions, or even entire states, to more-specific larger-scale ones covering local areas or counties, must be understandable by a variety of people.

Many traditional map forms, however, poorly satisfy these new demands, and considerable experimentation on new mapping formats has been undertaken [some of the new techniques are reviewed elsewhere (1)]. The pressure for the development of new mapping techniques has been felt most intensely by the state geological surveys, and several states have expanded, or even created, agencies to undertake such projects.

In Missouri, a number of environmental geology maps have been developed (2, 3), but a single map, accompanied by tables describing natural conditions and constraints to development, does not always suffice. Planners frequently desire a series of interpretive maps, each showing the degree of constraint for some specified class of use. These maps, reflecting both geologic conditions and estimates of probable hazards to life and property, are used in combination with other planning factors in guiding future development.

In this paper, these interpretative land-use-limitations maps will be called limitations maps. Each such map analyzes for a single land use or for a group of closely associated uses. The development of these maps requires the setting of standards or procedures for their construction in order to maintain quality and consistency.

In the first stages of a program to develop such standards, four steps were undertaken.

1. Limitation categories were defined: Four limitations categories were selected—severe, moderate, slight, and none—to indicate the probable degree of limitation to development.
2. Standard land uses were defined: Ten land uses were chosen—sanitary landfills, road construction, foundations for light structures (i.e., houses), agricultural suitability, septic tank systems, ease of excavation, impoundments, sewage lagoons, soil erosion, and landslide potential—to represent the range of con-