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ENGINEERING GEOLOGY OF THE NORTHWEST RESOURCE MAPPING PROJECT AREA

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ENGINEERING GEOLOGY USER GUIDE

I. INTRODUCTION

A. General Comments

Engineering Geology includes the analysis, interpretation, and classification of earth materials which affect projects planned, designed, and constructed by man. Engineering Geology studies vary in scale and scope from detailed site-specific water well sampling to geological analysis of large areas of the earth's surface. The properties of natural earth materials (sediment, rock, ice, and water) effect and sometimes control the types of human development possible in a particular region.

The geological analysis of the Northwest Resource Mapping Project Area (NWRMPA) was performed by the Engineering Geology Section utilizing the principles and methods of terrain unit mapping by air photo interpretation devised by Kreig and Reger (1976, 1982). This terrain analysis is directed towards documenting the materials which would effect development in the NWRMPA as well as interpretation of generalized properties of these materials. In addition, care was taken to identify and document those materials which may be constrained by geologic processes to such an extent that development on those materials may be impractical or hazardous. The resultant Interpreted Geological Constraints and Characteristics Charts should be used with the Terrain Unit maps to identify those areas that may be impractical or hazardous for development.

The user must notice that the term terrain unit is used only with its engineering geology context (i.e. a 30 ft thick unit of the landscape with characteristic form and constituent materials). The term is not equivalent to integrated terrain unit as used in some Geographic Information Systems (GIS) where a unit of the landscape is described with certain attributes including soils, vegetation, landform, slope, and general geology. Usually the Integrated Terrain Unit (ITU) is coded numerically to describe these attributes and the user must refer to computer attribute files which describe the polygon.

Engineering Geology, through the process of terrain unit mapping, was done at two levels of detail for the Northwest Resource Mapping Project. Level I Engineering Geology was mapped at 1:250,000 scale. Level II mapping occurred in a more detailed "window" area at a scale of 1:63,360. Through the remainder of this user's manual, the terms 1:250,000 scale and 1:63,360 scale will be used respectively as synonyms for Level I and Level II mapping.

The following discussion is intended to provide users with general background information and to introduce common terms and definitions used in connection with geology terrain analysis.

B. Engineering Geology Analysis by Terrain Unit Mapping

The engineering geology analysis of the NWRMPA was accomplished using the air photo interpretation process termed terrain unit mapping. Terrain unit mapping has proven to be an effective means of identifying the geologic materials comprising specific parts of a project area and interpreting their probable geological characteristics. Through this analysis, large land areas can be qualitatively described in terms of meaningful geologic data useful for decisions involving land planning, land management, and development.

Geologic terrain units are based upon landform analysis by air photo interpretation usually followed by spot field verification. Landforms are elements of the landscape formed by a singel geologic or a combination of associated processes. As a result they have identifiable visual characteristics. Such characteristics include topography, vegetation, drainage patterns, and permafrost indicators (Kreig and Reger, 1976). Although the term "form" implies shape and aerial extent only, for engineering geology and geotechnical engineering puproses, internal constituent materials must be an important consideration in subdividing the terrain. Each landform also has characteristic constituent materials with a recurrent range of geotechnical properties. These include characteristic distributions of engineering soil properties such as density, moisture, and soil grain size class. Thus, the term landform is used to describe not only the form, but the geologic materials (soils, ice, and/or rock) comprising the feature (Kreig and Reger, 1976).

Terrain Unit Landforms were mapped from the ground surface to a depth of about 10 meters (30 ft). Each landform is labeled with a two segment letter code. The uppercase letter indicates the genesis of the deposit, for example F for Fluvial (stream or river) Deposits; the lowercase letters indicate specific landforms in each genetic group, for example Ft for Fluvial Terrace Deposits and Fp for Fluvial Floodplain Deposits.

Geologic Terrain Units may be composed of one or more landforms. Several different kinds of terrain units are possible, depending on the spatial arrangement of these landforms. All of the following types occur within the project area.

Simple Terrain Units consist of only one landform. An example is meandering floodplain deposits with terrain unit symbol Fpm.

Layered Terrain Units consist of one landform overlying another. An example is organic deposits overlying old glacial till deposits. A line "__" is used between the symbols and the terrain unit designation is $\frac{O}{Gto}$.

Mosaic Terrain Units consist of two to four landforms each of which comprise more than 20 percent of the area. However, because of complex distribution patterns or mapping resolution, the landforms cannot be separated. The plus connective "+" is used with the dominant landform listed first. An example is meandering floodplain deposits plus abandoned floodplain deposits, Fpm + Fpa. Another example is periglacial patterned ground deposits plus thermokarst thaw lake drainage deposits plus organic deposits plus eolian loess deposits, Ppg + Ttl + O + El.

Complex Terrain Units consist of three or more landforms in various arrangements indicating both layered and mosaic aspects and employing the line and plus connectives. An example is colluvial slopewash deposits plus periglacial gelifluction deposits overlying bedrock, or colluvial slopewash deposits plus periglacial deposits overlying bedrock plus coarse colluvium, $\frac{\text{Cbs + Cgs}}{\text{Bx}}$ and $\frac{\text{Cbs + Cgs}}{\text{Bx + Cc}}$. Other complex combinations are: colluvial slopewash deposits overlying bedrock plus coarse colluvium, $\frac{\text{Cbs}}{\text{Bx + Cc}}$, colluvial slopewash deposits plus periglacial geligluction deposits overlying weathered bedrock plus exposed bedrock, $\frac{\text{Cbs + Cgs}}{\text{Bx - W}}$ + Bx. Another complex terrain unit encountered is a mosaic of colluvial slopewash deposits plus periglacial gelifluction deposits both overlying a veneer of old glacial till deposits which in turn are overlying weathered bedrock, $\frac{\text{Cbs + Cgs}}{\frac{\text{Gco - v}}{\text{Bx - w}}}$.

Again, these kinds of terrain units exist because one or more landforms occur from the ground surface to a depth of 30 ft. Notice the examples cited above. A simple terrain unit such as meandering floodplain deposits (Fpm) indicates stream-deposited sands and gravels occur from the ground surface to an interpreted depth of 30 ft. A layered terrain unit might consist of a thickness of 3 ft of organic deposits overlying glacial till which extends to an interpreted depth of 30 ft. Similarly, the two portions of a mosaic terrain unit occur from the surface to a depth of 30 ft.

The user should realize that the geological characteristics and significance of a landform does not change if that landform is part of a combination terrain unit. That is, the significance of Cbs (slopewash) as a saturated organic-rich silt and fine sand soil deposit is the same for simple terrain unit or layered terrain unit, such as slopewash overlying weathered bedrock, $\frac{\text{Cbs}}{\text{Bx-w}}$. Thus, the combination terrain units are the sum of the component landforms.

C. Engineering Soils

The user must also keep in mind that the term soil is used in this chapter as defined in engineering geology practice and not as used in soil science or agriculture. That is, a soil is all unconsolidated material that overlies bedrock (AGI Glossary of Geology, 2nd ed., p. 272.). To minimize confusion, only the term engineering soils will be used throughout this chapter. The engineering soil classification used in this section is the Unified Soil Classification, which is defined based on particle size (for example, the amounts of clay, silt, sand, and gravel [Krynine and Judd, 1957, p. 146]).

The following sections discuss the regional geologic setting of the project area, the two levels of investigation, the methods and procedures used, map reliability, mapping unit descriptions, and geological characteristics and hazards of the terrain units.

II. REGIONAL GEOLOGIC SETTING

A. Physiography

The NWRMPA lies in northwestern Alaska and consists of eighteen 1:250,000 scale quadrangles. They are Nome, Solomon, Norton Bay, Teller, Bendeleben, Candle, Shishmaref, Selawik, Shungnak, Hughes, Survey Pass, Ambler River, Baird Mountains, Noatak, DeLong Mountains, Point Hope, and Point Lay. The project area includes the Intermontane Uplands and Lowlands division, and the Rocky Mountain System division. These two major physiographic divisions of Alaska are further segmented within the project area into physiographic provinces and sections as shown below (Péwé, 1975, plate 1).

Intermountain Uplands and Lowlands Division
- Seward Peninsula Province
- Western Alaska Province
- Kobuk-Selawik Lowland Section
- Nulato Hills Section
- Koyukuk Flats Section

Rocky Mountain System Division
- Arctic Mountains Province
- Central and Eastern Brooks Range Section
- Baird Mountains Section
- Noatak Lowland Section
- DeLong Mountains Section

The physiographic classification was devised in order to effectively describe Alaskan land areas each of which have unique, discrete, internal geological characteristics. The boundaries of these physiographic regions occur where the topography changes markedly in character. The basis of the classification consists of the parameters general topography, drainage, lakes, glaciers, permafrost, surficial geology, and bedrock geology.

B. Permafrost

Permafrost underlies a significant portion of the NWRMPA. Permafrost underlies 85 percent of Alaska and creates engineering problems in the design, construction, and maintenance of roads, railroads, airfields, pipelines, buildings, and sewage and waste disposal. Permafrost is defined as frozen soil, surficial material and bedrock that has remained below 0°C (32°F) continuously for at least two years. In most areas, however, the ground has remained frozen for many thousands of years. Permafrost is not dependent upon terrain unit grain sizes or textures, compaction, moisture content, or composition. Permafrost is of critical importance in Arctic land-use planning and its environmental impact. Within the NWRMPA the Arctic Foothills is underlain by thick permafrost in areas of either fine grained or coarse grained deposits. The Central and Eastern Brooks Range, DeLong Mountains, and Baird Mountains is underlain by continuous permafrost. On the Seward Peninsula, the York, Kigluaik, and Bendeleben Mountains are underlain by discontinuous permafrost. The remainder of the Seward Peninsula, Kobuk-Selawik Lowland, Nulato Hills, and Koyukuk Flats is underlain by moderately thick to thin permafrost in areas of fine grained deposits and by discontinuous or isolated masses of permafrost in areas of coarse grained deposits. The Purcell Mountains north of the Koyukuk Flats is underlain by discontinuous permafrost.

III. LEVEL I AND LEVEL II SCALE ENGINEERING GEOLOGY

A. Terrain Unit Mapping Methods

1. General Methods. The terrain unit mapping of State of Alaska land within the NWRMPA was done at 1:250,000 scale with a mapping minimum of approximately 640 acres (one sq mi), and at 1:63,360 scale which had a mapping minimum of approximately 40 acres. Aerial photo interpretation was used to map terrain units. NASA 1:60,000 to 1:65,000 scale color infrared aerial photography was used. A Leitz mirror stereoscope mounted on a movable track attachment was used to do the photo interpretation. Terrain units were mapped on clear acetate overlays registered to the photos. The terrain units were manually tranferred from the clear acetate photo overlays to mylar overlays which were registered to the U.S. Geological Survey topographic quadrangle base maps. The terrain maps (simple, layered, mosaic, and complex) are based upon the standard heirarchical catalog of landforms developed for terrain analysis projects in Alaska (Kreig and Reger, 1976, 1980).

B. Use of the Terrain Unit Maps

The terrain unit mapping was done to provide information that will be useful for land management and natural resource decision making.

1. Geological Characteristics and Constraints Chart

In order to evaluate potential development with respect to the terrain units, a qualitative interpretation of the geologic characteristics and constraints of each terrain unit is provided (see charts). The geological characteristics and constraints described for the various terrain units are not intended to be used for detailed design purposes. Additional site-specific mapping, sampling, drilling, and testing would be required for final developmental planning.

2. Geological Characteristics Definitions

Slope Classification: Following guidelines established by the U.S. Forest Service, the Bureau of Land Management, and the American Society of Landscape Architects, slopes in the project area are described by the following classes: Flat - 0-5%, Gentle - 5-15%, Moderate - 15-25%, and Steep - greater than 25%.

Interpreted Engineering Unified Soil Types: Based on previous work in similar areas and definitions of the engineering soils, a range of soil types based on particle size definitions employed by the Unified Soil Classification (USC), has been assigned to each terrain unit. Often several engineering soil types are listed, some of which are much less prevalent than others. The reader is reminded of the difference between the engineering definition of soil as used in the USC and that used by the U.S. Department of Agriculture.

Drainage and Permeability: Permeability (hydraulic conductivity) refers to the rate at which water can flow through such soils. Drainage describes the ability of the surficial portion of the terrain unit to handle rainfall and snow melt taking into account a combination of permeability, slope, topographic position, and the proximity of the water table.

Erosion Potential: Erosion potential considers the likelihood of constituent sediments being moved by eolian and fluvial processes such as sheetwash, rill, and gulling. In general this relates to the particle size of the sediments. Mass wasting potential is considered under slope stability.

Ground Water Table: Depth to ground water table is described in relative terms ranging from very shallow to deep. In construction involving excavation and foundation work, special techniques and planning will be required in most areas with a shallow water table and in some of the areas with a moderately deep water table. In areas of permafrost a shallow perched local water table may occur.

Probable Permafrost Distribution: The occurrence of permafrost and the degree of conitnuity of frozen engineering soil is described on the chart by the following relative terms: Unfrozen - generally without any permafrost; sporadic - significantly large areas are frozen and site specific work may be required before design; discontinuous - most of the area is underlain by frozen soils and site-specific work is required unless design incorporates features relating to permafrost; continuous - the entire area is frozen and all designs should be based on occurrence of permafrost.

Frost Heave Potential: Those engineering soils that contain significant amounts of silt and fine sand plus available water to form ice have the potential to produce frost heave problems. A qualitative low, moderate, and high rating describes the various landforms based on the potential severity of the problem. Where the engineering soil stratigraphy is such that a frost susceptible material overlies a coarse-drained deposit, a dual classification is given. For these cases the frost susceptible material might be excavated and replaced with non-frost susceptible material.

Thaw Settlement Potential: Permafrost in sediments with a significant volume of ice may display differential settlement of the ground surface upon thawing. Clays, silts, and fine sands have generally the greatest settlement potential, forming the basis for the three-fold classification presented on the chart. Unfrozen engineering soils do not have the potential for thaw settlement; however, some of the weak soils may settle under the weight of a roadway or structure.

Bearing Strength: Based on the terrain unit engineering soil types and stratigraphy a qualitative description of bearing strength is given. In general, coarse-grained gravels have a higher bearing strength than fine-grained silts or clays. However, the presence of permafrost may significantly increase the strength of some fine-grained sediments.

Slope Stability: The slope stability qualitative rating was derived through evaluation of topographic position, slope, engineering soils composition, water content, ice content, etc. The stability assessment considers all rapid, mass-wasting processes. The qualitative stability of the terrain units on over-steepened slopes and natural slopes is described on the chart in terms of low, moderate, and high stability.

Suitability as a Source of Borrow: Great quantities of construction materials will be needed for all phases of development. These materials include sand and gravel. Commonly a borrow source is a gravel pit. The rating considers suitability as pit run and coarse aggregate consisting largely of well-graded sand and gravel. A good to excellent rating denotes a terrain unit as a source without processing. A fair rating indicates the aggregate would be acceptable, after processing (crushing and/or screening). A poor rating indicates that the effort of processing would likely be subeconomic.

3. Generalized Land Use Comments

Based upon the geological characteristics and constraints charts, and knowledge of the terrain unit geotechnical properties found within the study area and similar areas of Alaska, some generalized commends can be made. Ideally, terrain units with moderate to deep water tables, high slope stability, low erosion potential, low slopes, and consisting of unfrozen engineering soils with low frost susceptibility and high bearing strength would be most suitable for the location of buildings, roads, and other development.

In the past 10 to 15 years considerable strides have been made in the design of building foundations (including active and passive refrigerated systems) in order to keep the underlying soils frozen. Similarly, insulated fill systems have been developed for construction of roads. Therefore, less suitable areas can be developed if a shortage of "good land" occurs. The trade of is, of course, cost. The systems required to minimize thawing of frozen ground are expensive compared to "standard" construction practices.

As indicated on the geological characteristics chart, the Fluvial and Glaciofluvial terrain units are most likely to be suitable sources of borrow. Mining of the constituent sands and gravels provides materials for construction. Present practice attempts to avoid use of active floodplain deposits because of environmental conflicts: mining of abandoned floodplain and terrace deposits minimizes such environmental factors.

C. Reliability of Terrain Unit Maps

The terrain unit maps are, with few exceptions, the result of original air photo interpretation of terrain units and their boundaries. Field verification of the terrain units was only done along the Nome road network. Therefore, questions may arise concerning the accuracy or correctness of terrain unit interpretations, or comments based on the general geological characteristics of the material constituents of the terrain units that are not located near the Nome road network. The air photo interpretation and registration-transfer processes were done carefully so that the identification, configuration, and location of the terrain units is a reasonable geological interpretation.

References

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