CHAPTER 4

SITE INVESTIGATION

4-1. Background data.

a. Introduction. The principal background intelligence data required to evaluate the suitability of an area for a military port are as follows: (1) Physical and cultural aspects of the shoreline and contiguous interior.

(2) Weather regimes, intensities, and extremes.

(3) Bathymetric and subbottom characteristics. The types of data from which this intelligence data may be derived can be categorized as maps, photography and imagery, documents and records, and historical data.

b. Maps.

(1) *Topographic maps*. Scales of these maps vary widely. Coverages of 1:50,000 and 1:250,000 are available for sizable portions of the world, although more extensively for highly developed areas. Slope, relief, and configurations of shoreline landscapes are obtainable directly from the maps, with the degree of accuracy being a function of the scale and contour interval. Drainage patterns, land use, natural vegetation, and cultivation are also portrayed on these maps, as well as population centers and transportation networks. Bathymetric contours and navigation hazards (e.g., mud, shoals, cock, coral, and other natural characteristics) are delineated.

(2) *Soil maps*. These maps are prepared for a variety of purposes, e.g., agricultural potential, land use, and construction. Soil surveys have been conducted for entire countries in some instances but more frequently cover only limited areas. The distribution of soils is portrayed on soil maps, and the descriptions are normally in textural terms. Soil depths data are available for portions of West Germany, while 1:1,000,000 maps represent the best coverage for certain poorly developed countries. World soil maps, excluding the United States, have been prepared by the United States Soil Conservation Service (USCS) with the descriptions in United States Department of Agriculture terms. The distribution of soils portrayed on these maps is usually determined by landform and physiographic association and is of questionable accuracy. Detailed soils maps prepared in support of agricultural and engineering studies provide comparative detail, but their occurrence is sporadic and unpredictable. In many cases, the descriptive agricultural terms used in soil surveys are translatable into the engineering terms (USCS) required for site investigations (figure 4-1).

(3) *Geologic maps.* Geologic maps depict a number of geologic or geologic-related conditions, such as the surface and substrate distribution of formations, structure, and the distribution of landforms. Such maps often provide information regarding the configurations and dimensions of shoreline landforms, engineering characteristics of overburden materials, the nature of surficial soils, and classification and distribution of surface or near-surface rock and associated soils. In addition, the maps usually symbolize drainage patterns, land use, and vegetative patterns.

Geologic maps, when prepared in sufficient detail, can provide a general basis for the selection of construction sites as well as sources of suitable construction materials.

(4) *Pictomaps*. Pictomaps are usually large-scale maps, viz. 1:25,000, which have been prepared from controlled aerial photomosiacs. Colors and symbols are used to denote vegetation, hydrologic and cultural patterns, which are superimposed upon the photographic image. Surface and bathymetric contours are included on the maps most frequently at 1-, 5-, and 10-metre intervals. The pictomap probably represents the most suitable base for generation of a three-dimensional terrain model of a port area.

(5) *Hydrographic charts*. These charts depict hydrologic conditions along and immediately inland of the shorelines of the world. Depth soundings in feet are presented for both offshore and inland waters.

Navigable waterways are indicated, and navigation hazards and man-made structures, such as platforms, stakes and markers, and lighthouses are located. Tidal information is provided for selected stations on the chart.

(6) *Climatic maps*. These maps may be compiled for individual countries; however, they are most often compiled for the entire world and thus are usually small scale. They portray the distribution of areas characterized by ranges of mean annual temperatures, precipitation, and climatic types determined by combinations of temperature ranges; amount and frequency of precipitation, and natural vegetation. Other climatic maps depict the distribution of major ocean currents, mean sea surface temperatures, hurricane tracks, air masses, and other relevant characteristics.

c. Photography and remote imagery. Photography

as potential port sites provide several definite advantages over other data types as follows: (1) Large-scale photography or photographic reproduction of imagery provides details that are not presented on topographic and other map coverages. For instance, even large-scale topographic maps with 5and 10-metre contour intervals may fail to identify surface features or conditions that are relevant to port site investigation.

(2) Remote imageries can be obtained immediately after the occurrence of dramatic climatic or hydrologic events to permit assessment of damage or modification. Such events would include flooding, hurricanes, tidal surges, and other natural disasters. This information may often dictate the location for, type of, and method for construction.

(3) Photography and imagery coverage permits current assessments to be made of man-made features such as transportation networks, industrial complexes, urban development, and existing port facilities.

(4) Photography and imagery coverage permits periodic monitoring of shoreline evolution and modification to determine the influence of the physical and climatic elements on port location and construction.

(5) In the absence of map coverages, photography and imagery coverage would serve to provide topographical, geological, pedological, hydrographical, vegetational, and even cultural information required for site selection and investigation. Identification of the required physical and natural science features necessitates interpretation by personnel skilled in these various disciplines.

d. Documents and records. Documents and records are valuable sources of various types of topographical, hydrographical, and historical information. Some of the most common types of documents include: trade journals; geologic, geographic, soil and oceanographic bulletins; environmental handbooks; tourist guides and traveler accounts in periodicals and professional journals; published tide tables; pilot handbooks; economic and transportation atlases; climatic records; and various indigenous governmental reports. Unpublished environmental, meteorological, and scientific data are available at government offices and research centers in the continental United States (CONUS). Reference materials are also available from engineering firms, private societies, and individuals with personal interests.

e. Historical port intelligence data. Historical data concerning existing port facilities represent potentially the best source of information. The types and orientation of piers, breakwaters, and dock facilities, are often the result of comprehensive investigations or at worst trial-and-error type construction. The construc

and imagery coverages of the areas being investigated

tion of these facilities is normally well documented, with feasibility and investigative reports being available at the old port headquarters; local governmental administrative offices; private engineering firms; or in government archives. The types of information to be expected include soil borings, soil bearing and shear tests, soil classification and analysis, pile friction tests, tidal station data, weather data, groundwater investigations, severity of flooding, locations and characteristics of construction materials, and bathymetric surveys indicating the slope and configuration of the harbor bottom and the presence of obstacles, such as rocks, reefs, and debris. Many potential military port locations will be devoid of existing facilities or in other cases, the facilities may be in evidence but lacking documentary data.

4-2. Hydrographic and topographic surveys.

a. Introduction. Although the general location of the port may be established by careful consideration of background information, the precise location of the component facilities, such as wharves, piers, and quay, shall result from comprehensive hydrographic and topographic surveys.

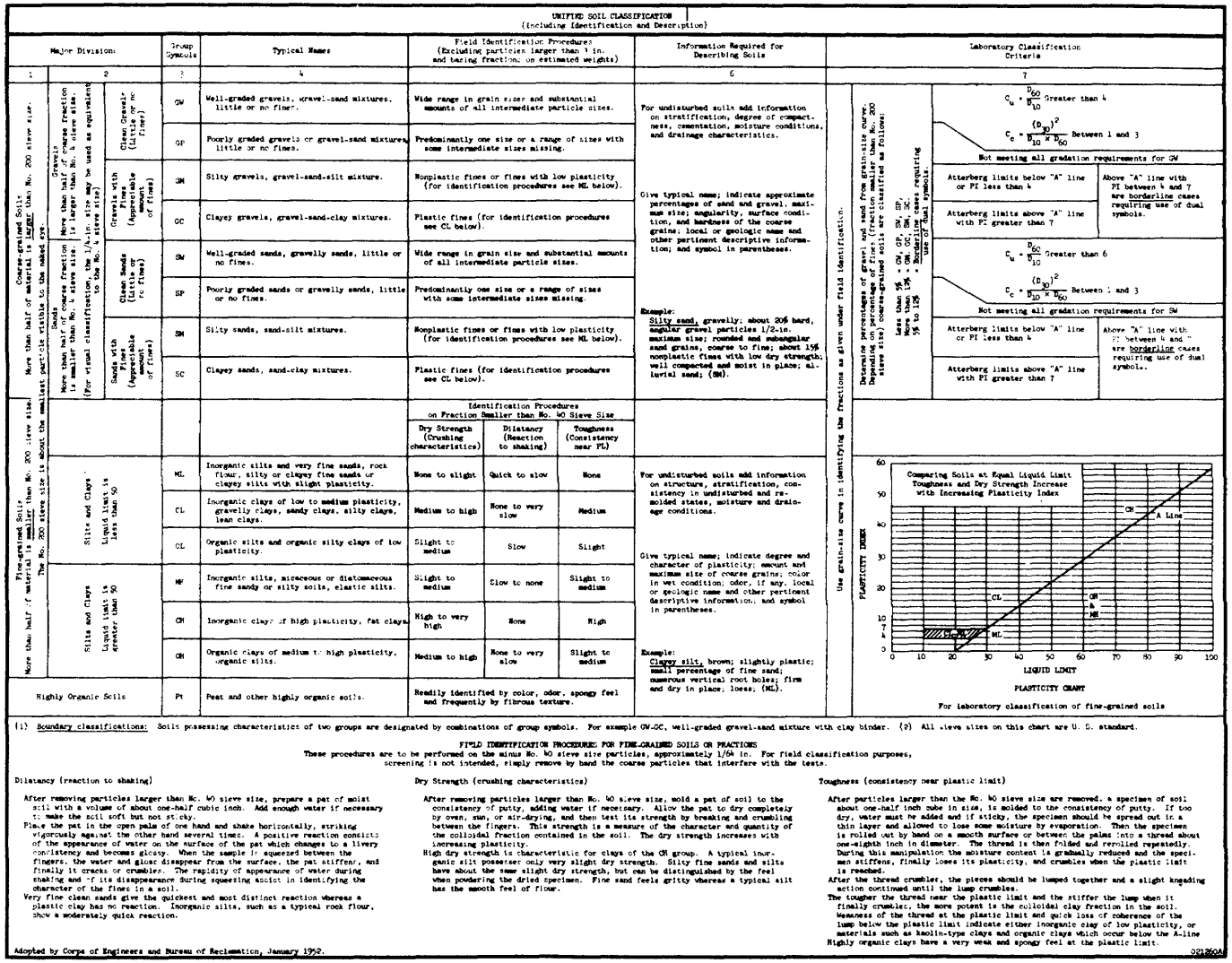
b. Hydrographic surveys. The surveys will include the collection, reduction, and analysis of hydrographic data and the effective presentation thereof to permit subsequent decisions. The following hydrographic parameters should be considered during the survey:

(1) *Depth of water*. Accurate bathymetric movements can be obtained throughout the port area as well as in seaward approaches to the facilities. Water depth is critical to the operation of ships and craft that will use the facility. The maximum draft for a container ship is expected to be 40 feet; pier construction and location should have suitable hydrographic conditions.

(2) *Bottom character*. Detailed determinations can be made as to the lithographic and microrelief character of the bottom. Foreign and random natural objects, such as boulders, oil drums, and ship wreckage, must be delineated to facilite removal or ensure avoidance by using ships.

(3) *Tidal characteristics*. These characteristics are the controlling factors in the effective operation of a port. Tidal parameters requiring determination are heights, range, interval, times, and behavior of tidal currents; on a daily and seasonal basis, and during periods of unusual intensity resulting from storm activity. Significant daily tidal ranges in certain parts of the world may exceed 20 feet.

(4) Discharge volumes and flow velocities of rivers. Discharge volumes and flow velocities at or in the vicinity of the port are important considerations in the regulation of vessel traffic, location and orientation



UNIFIED SOIL CLASSIFICATION
(Including Identification and Description)

Major Divisions			Group Symbols	Typical Names	Field Identification Procedures (Excluding particles larger than 3 in. and basing fractions on estimated weights)	Information Required for Describing Soils
1	2		3	4		5
Coarse-grained Soils: More than half of material is larger than No. 200 sieve size.	Gravels: More than half of coarse fraction is larger than No. 4 sieve size.	Clean Gravels (little or no fines)	GW	Well-graded gravels, gravel-sand mixtures, little or no fines.	Wide range in grain sizes and substantial amounts of all intermediate particle sizes.	For undisturbed soils add information on stratification, degree of compactness, cementation, moisture conditions, and drainage characteristics.
			GP	Poorly graded gravels or gravel-sand mixtures, little or no fines.	Predominantly one size or a range of sizes with some intermediate sizes missing.	
		Gravels with Fines (Appreciable amount of fines)	GM	Silty gravels, gravel-sand-silt mixture.	Nonplastic fines or fines with low plasticity (for identification procedures see ML below).	Give typical name; indicate approximate percentages of sand and gravel; maximum size; angularity, surface condition, and hardness of the coarse grains; local or geologic name and other pertinent descriptive information; and symbol in parentheses.
			GC	Clayey gravels, gravel-sand-clay mixtures.	Plastic fines (for identification procedures see CL below).	
	Sands: More than half of coarse fraction is smaller than No. 4 sieve size. (For visual classifications, the 1/4 in. size may be used as equivalent to the No. 4 sieve size.)	Clean Sands (little or no fines)	SW	Well-graded sands, gravelly sands, little or no fines.	Wide range in grain size and substantial amounts of all intermediate particle sizes.	Example: Silty sand, gravelly; about 20% hard, angular gravel particles 1/2-in. maximum size; rounded and subangular sand grains, coarse to fine; about 15% nonplastic fines with low dry strength; well compacted and moist in place; alluvial sand; (SM).
			SP	Poorly graded sands or gravelly sands, little or no fines.	Predominantly one size or a range of sizes with some intermediate sizes missing.	
		Sands with Fines (Appreciable amount of fines)	SM	Silty sands, sand-silt mixtures.	Nonplastic fines or fines with low plasticity (for identification procedures see ML below).	
			SC	Clayey sands, sand-clay mixtures.	Plastic fines (for identification procedures see CL below).	
Fine-grained Soils: More than half of material is smaller than No. 200 sieve size. The No. 200 sieve size is about the smallest particle visible to the naked eye.					Identification Procedures on Fraction Smaller than No. 40 Sieve Size: Dry Strength (Crushing characteristics) / Dilatancy (Reaction to shaking) / Toughness (Consistency near PL)	
	Silts and Clays: Liquid limit is less than 50		ML	Inorganic silts and very fine sands, rock flour, silty or clayey fine sands or clayey silts with slight plasticity.	None to slight / Quick to slow / None	For undisturbed soils add information on structure, stratification, consistency in undisturbed and remolded states, moisture and drainage conditions.
			CL	Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays.	Medium to high / None to very slow / Medium	
			OL	Organic silts and organic silty clays of low plasticity.	Slight to medium / Slow / Slight	Give typical name; indicate degree and character of plasticity; amount and maximum size of coarse grains; color in wet condition; odor, if any; local or geologic name and other pertinent descriptive information; and symbol in parentheses.
	Silts and Clays: Liquid limit is greater than 50		MH	Inorganic silts, micaceous or diatomaceous fine sandy or silty soils, elastic silts.	Slight to medium / Slow to none / Slight to medium	
			CH	Inorganic clays of high plasticity, fat clays.	High to very high / None / High	
			OH	Organic clays of medium to high plasticity, organic silts.	Medium to high / None to very slow / Slight to medium	Example: Clayey silt, brown; slightly plastic; small percentage of fine sand; numerous vertical root holes; firm and dry in place; loess; (ML).
Highly Organic Soils			Pt	Peat and other highly organic soils.	Readily identified by color, odor, spongy feel and frequently by fibrous texture.	

Laboratory Classification Criteria

Use grain-size curve in identifying the fractions as given under field identification.

Determine percentages of gravel and sand from grain-size curve. Depending on percentage of fines (fraction smaller than No. 200 sieve size) coarse-grained soils are classified as follows:

Less than 5% — GW, GP, SW, SP.
More than 12% — GM, GC, SM, SC.
5% to 12% — Borderline cases requiring use of dual symbols.

$C_u = \frac{D_{60}}{D_{10}}$ Greater than 4 $C_c = \frac{(D_{30})^2}{D_{10} \times D_{60}}$ Between 1 and 3 Not meeting all gradation requirements for GW	
Atterberg limits below "A" line or PI less than 4	Above "A" line with PI between 4 and 7 are borderline cases requiring use of dual symbols.
Atterberg limits above "A" line with PI greater than 7	
$C_u = \frac{D_{60}}{D_{10}}$ Greater than 6 $C_c = \frac{(D_{30})^2}{D_{10} \times D_{60}}$ Between 1 and 3 Not meeting all gradation requirements for SW	
Atterberg limits below "A" line or PI less than 4	Above "A" line with PI between 4 and 7 are borderline cases requiring use of dual symbols.
Atterberg limits above "A" line with PI greater than 7	

PLASTICITY CHART

For laboratory classification of fine-grained soils

(1) Boundary classifications: Soils possessing characteristics of two groups are designated by combinations of group symbols. For example GW-GC, well-graded gravel-sand mixture with clay binder. (2) All sieve sizes on this chart are U. S. standard.

FIELD IDENTIFICATION PROCEDURES FOR FINE-GRAINED SOILS OR FRACTIONS

These procedures are to be performed on the minus No. 40 sieve size particles, approximately 1/64 in. For field classification purposes, screening is not intended, simply remove by hand the coarse particles that interfere with the tests.

Dilatancy (reaction to shaking)

After removing particles larger than No. 40 sieve size, prepare a pat of moist soil with a volume of about one-half cubic inch. Add enough water if necessary to make the soil soft but not sticky.

Place the pat in the open palm of one hand and shake horizontally, striking vigorously against the other hand several times. A positive reaction consists of the appearance of water on the surface of the pat which changes to a livery consistency and becomes glossy. When the sample is squeezed between the fingers, the water and gloss disappear from the surface, the pat stiffens, and finally it cracks or crumbles. The rapidity of appearance of water during shaking and of its disappearance during squeezing assist in identifying the character of the fines in a soil.

Very fine clean sands give the quickest and most distinct reaction whereas a plastic clay has no reaction. Inorganic silts, such as a typical rock flour, show a moderately quick reaction.

Dry Strength (crushing characteristics)

After removing particles larger than No. 40 sieve size, mold a pat of soil to the consistency of putty, adding water if necessary. Allow the pat to dry completely by oven, sun, or air-drying, and then test its strength by breaking and crumbling between the fingers. This strength is a measure of the character and quantity of the colloidal fraction contained in the soil. The dry strength increases with increasing plasticity.

High dry strength is characteristic for clays of the CH group. A typical inorganic silt possesses only very slight dry strength. Silty fine sands and silts have about the same slight dry strength, but can be distinguished by the feel when powdering the dried specimen. Fine sand feels gritty whereas a typical silt has the smooth feel of flour.

Toughness (consistency near plastic limit)

After particles larger than the No. 40 sieve size are removed, a specimen of soil about one-half inch cube in size, is molded to the consistency of putty. If too dry, water must be added and if sticky, the specimen should be spread out in a thin layer and allowed to lose some moisture by evaporation. Then the specimen is rolled out by hand on a smooth surface or between the palms into a thread about one-eighth inch in diameter. The thread is then folded and rerolled repeatedly. During this manipulation the moisture content is gradually reduced and the specimen stiffens, finally loses its plasticity, and crumbles when the plastic limit is reached.

After the thread crumbles, the pieces should be lumped together and a slight kneading action continued until the lump crumbles.

The tougher the thread near the plastic limit and the stiffer the lump when it finally crumbles, the more potent is the colloidal clay fraction in the soil. Weakness of the thread at the plastic limit and quick loss of coherence of the lump below the plastic limit indicate either inorganic clay of low plasticity, or materials such as kaolin-type clays and organic clays which occur below the A-line.

Highly organic clays have a very weak and spongy feel at the plastic limit.

Adopted by Corps of Engineers and Bureau of Reclamation, January 1952. 931260A

Figure 4-1. Unified soil classification.

of structures, sediment transport and deposition, and dredging.

(5) *Extent, duration, and causes of flooding.* Flooding at times during the year may affect the inland portions of a port. Harbor routine may vary during the flood season, and sediment introduced into the harbor areas may create navigation problems. Knowledge of the causes of flooding enables the adverse effects to be minimi7ed. Examination of historical data permits reasonably accurate forecasts.

(6) *Tidal and river currents and velocities*. Current directions and velocities, such as longshore currents, wind currents, river currents, and permanent great currents, are a constant problem to navigation. In some cases, several of these currents may be in action concurrently, and the results should be considered.

(7) *Shoreline data*. The land-water interface can be established for the various daily and seasonal stages of the tide. Extreme tidal states occurring during severe storms can also be established.

(8) *Location of landmarks as navigational aids.* Location of landmarks can be greatly facilitated through the use of hydrographic and topographic maps and aerial photography. Field checks to ensure acceptable levels of visibility are required.

(9) *Location of structures in water and along shore margins.* These structures are currently being utilized or abandoned.

(10) *Subbottom characteristics*. Subbottom information includes data on the type of sediments, layering, bearing capacities, and consolidation.

c. Topographic surveys. All land-implemented surveys conducted in support of the construction of offloading, storage, and connection facilities should be included. Parameters to be considered as part of the topographic surveys are as follows: (1) Topographic detail at site locations. Fine detail will be required to assure optimum layout of facilities and the transportation network required to service them. Land-water interfaces at all possible tide levels can be checked with the hydrographic surveys.

(2) *Pedologic parameters*. A comprehensive investigation of the pedologic character of surficial materials is considered essential. The ability of the soils to support various types of construction and the suitability of construction materials can be determined. The identification of soils can be greatly facilitated by use of aerial photographs.

(3) *Drainage characteristics.* Surface drainage patterns should be determined. Drainage can influence site selection, particularly if the overflow from streams cannot be controlled and the inundation of a site is possible. Streams may also provide convenient supplies of surface water for port use.

(4) *Surface rock.* An investigation of available sources of surface rock will be conducted to determine the suitability of local supplies to construction requirements.

(5) *Subsurface characteristics*. Investigation of subsurface soil conditions is required to determine the parameters relevant to pile-type construction at shore locations.

(6) *Vegetation types*. A survey of natural vegetation in the vicinity of the port is necessary to determine the construction effort required to clear an area to accommodate the port facilities, as well as the suitability of the timber for use in the construction of certain facilities, (e.g., wharves, piers, bridges, and warehouses).

(7) *Cultural features*. A survey is required at and in proximity to the port area, including private, business, and government buildings, the transportation network, utilities, recreation areas, and agricultural lands.