# FM 30-10

DEPARTMENT OF THE ARMY FIELD MANUAL

# TERRAIN INTELLIGENCE



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# TERRAIN INTELLIGENCE


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*This manual supersedes FM 30-10, 28 October 1959.

# CHAPTER 1

# INTRODUCTION

## 1. Purpose and Scope

*a.* This manual serves as a guide in the production and use of terrain intelligence. It shows how terrain and weather are evaluated in military planning and how terrain influences combat. The manual also serves as a guide in understanding the purpose, scope, limitations, and applications of terrain analysis. The manual provides information concerning the acquisition and use of terrain intelligence at unit level in a theater of operations.

*b.* This manual covers basic characteristics of the natural and manmade features of an area and their effect on military operations. It defines terrain intelligence and explains the intelligence process of collection, evaluation, interpretation of information, and dissemination of the finished intelligence. It discusses some of the sources of terrain information, including their relative value and use. Guidance is furnished for the preparation of the terrain study. The material presented herein is applicable to both nuclear and nonnuclear warfare.

## 2. Changes and Comments

Users of this manual are encouraged to submit recommended changes or comments to improve it. Comments should be keyed to the specific page, paragraph, and line of the text in which the change is recommended. Reasons should be provided for each comment to insure understanding and complete evaluation. Comments should be forwarded to the Commandant, U.S. Army Engineer School, Fort Belvoir, Va., 22060.

## 3. Relation to Other Manuals

The material presented in this manual is related to material in FM 5–30, FM 30–5, and TM 5–545. Other manuals of the FM 30- series cover specialized intelligence activities. FM 100–5, FM 100–15, and FM 101–5 cover intelligence in general staff activities and in the plans and operations of large units. Field manuals of the 5-series contain detailed information on the operation of engineer troop units and their intelligence functions.

# CHAPTER 2

# CONCEPTS AND RESPONSIBILITIES

## Section I. NATURE OF TERRAIN INTELLIGENCE

### 4. Definitions

*a. Terrain* is part of the surface of the earth, including natural and manmade features. Both its natural and manmade features affect military operations.

*b. Terrain* intelligence is processed information on the military significance of the natural and manmade characteristics of an area.

*c. Terrain analysis* is the process of interpreting a geographical area to determine the effect of the natural and manmade features on military operations. It includes the influence of weather and climate on those features.

*d. A terrain study* is an analysis and interpretation of natural and manmade features of an area, their effects on military operations, and the effects of weather and climate on these features.

*e. A terrain estimate* is that portion of an analysis of the area of operations concerned with the military aspects of the terrain, and the effects of the characteristics of terrain on enemy and friendly courses of action, including the possible use of nuclear weapons.

### 5. Purpose

The purpose of terrain intelligence is to obtain data about the terrain, weather, and climate, thereby assisting the commander in making decisions and the troops in attaining their missions. In planning an operation, the commander and his staff analyze the effects that the terrain and weather conditions will have upon the activities of both friendly and enemy forces. The commander must make the most effective use of the terrain assigned to his unit. If he is furnished with adequate terrain intelligence, he will be able to exploit the advantages of the terrain and avoid or minimize its unfavorable aspects. By the proper utilization of terrain, a numerically inferior force may achieve combat superiority over a larger enemy force. The compilation of terrain intelligence is not limited to enemy areas. It also covers the area occupied by the friendly force and also the adjacent terrain.

### 6. Classifications

*a. Mission.* Terrain intelligence is classified according to the mission and level of the command at which it is used. These categories are considered broadly as strategic and tactical or operational. Terrain intelligence is one element in the intelligence requirements of a commander. Engineers have considerable interest in terrain because they are trained and equipped to make terrain studies and to conduct field reconnaissance.

*b. Strategic.* Strategic terrain intelligence is concerned with large-scale plans and may include the military capabilities of nations. Strategic intelligence is produced continuously and requires the compilation and interpretation of information by highly specialized personnel. Included in strategic intelligence are descriptions and analyses of beaches, water terminals, inland waterways, urban areas, and major terrain features; transportation and communication systems; soils, rock types, underground installations, climate and weather, vegetation, state of ground, and hydrography.

*c. Operational.* Operational terrain intelligence is produced for use in planning and conducting tactical or other operations. It is based upon information secured locally or provided by higher headquarters and is concerned primarily with the effects of weather and terrain upon the particular operations of the unit. Route reconnaissance reports are of greatest importance in providing current information about routes of communication.

*d. Objectives.* The difference in the type of terrain intelligence required by strategic and tactical planners reflects their objectives. The strategic planner may consider an entire country or continent, while the tactical planner is concerned only with the terrain in the area of his operations. Where the strategic planner often studies problems that may arise some years ahead and applies terrain intelligence in a wide variety of hypothetical situations, the tactical planner is primarily engaged with problems that currently involve his unit, although he will study the terrain in his entire area of possible operation.

## 7. Applications

*a. Planning.* Terrain intelligence is essential to the commander in order to plan strategic and tactical operations. Detailed and reliable terrain intelligence is required for all logistical plans, particularly those prepared for special operations or for operations under extremes of climate. Special studies, prepared from a logistical viewpoint, are essential in planning operations in mountains, jungles, or deserts, in snow and extreme cold, and for airborne and amphibious operations.

*b. Problems.* Research and development agencies are concerned with the problems resulting from adverse climate, weather, and terrain. Terrain intelligence is necessary to determine the requirements for new means of transportation, types of shelter and construction, weapons, and clothing. It is a basic requirement in the development of new equipment and in the maintenance and modification of existing equipment.

*c. Needs.* Current and accurate terrain intelligence is required by topographic engineer agencies for use in preparing or revising military maps. Civil Affairs operations depend on accurate terrain intelligence, particularly concerning matters of economic and political impact on tactics and logistics.

# Section II. RESPONSIBILITIES

## 8. Department of Defense

*a. Defense Intelligence Agency (DIA).* The Defense Intelligence Agency (DIA) is an agency of the Department of Defense (DOD) and under the direction, authority, and control of the Secretary of Defense. It is administered by a director, a deputy director and a chief of staff at the headquarters which has such subordinate units, facilities, and activities as are specifically assigned to the Agency by the Secretary of Defense or by the Joint Chiefs of Staff acting under the authority and direction of the Secretary of Defense. DIA is responsible for—

(1) The organization, direction, management, and control of all DOD intelligence resources assigned to or included within DIA.

(2) Review and coordination of those DOD intelligence functions retained by or assigned to the military departments. Overall guidance for the conduct and management of such functions is subject to review, approval, and promulgation by the Secretary of Defense.

(3) Obtaining the maximum economy and efficiency in the allocation and management of DOD intelligence resources. This includes analysis of those DOD intelligence activities and facilities which can be fully integrated or collocated with non-DOD intelligence organizations.

(4) Responding directly to priority requests levied upon the DIA by the United States Intelligence Board (USIB) and satisfying the intelligence requirements of the major components of the DOD.

*b. Assistant Chief of Staff for Intelligence (ACSI).* The Under Secretary of the Army is the DA's responsible officer for its intelligence, counterintelligence, and communications security in international affairs. The intelligence and counterintelligence activities of the United

States Army are the responsibility of the Assistant Chief of Staff for Intelligence (ACSI). His duties include directing the Army mapping and geodesy program and the military geographic intelligence program. He also has the responsibility for coordinating those activities with Army components of unified and specified commands.

*c. Chief of Engineers.* Under the program direction of the Assistant Chief of Staff for Intelligence, the Chief of Engineers is responsible for—

(1) Providing direct support to the Assistant Chief of Staff for Intelligence in mapping and geodesy activities.

(2) Providing technical supervision and coordination of worldwide geographic intelligence activities.

(3) Providing and directing assigned elements engaged in mapping, geodesy, military intelligence, and related services, to include maintenance of the Department of Defense (DOD) master worldwide mapping and geodesy library and the DOD World Geodetic System.

## 9. Command

Commanders at all levels are responsible for the production of intelligence, including terrain intelligence. A commander must insure that he and his staff are aware of the effects of weather and terrain on their mission. He must know and utilize the capabilities for producing terrain intelligence that exist within his command or in outside agencies and insure that his command gathers pertinent information on the weather and terrain, and transmits this to all units requiring it. To do this properly, his command must be trained in the basic skills of terrain analysis. At theater level terrain intelligence is more detailed than the intelligence compiled at national level, and the production of theater intelligence may be assigned to a unit formed for that sole function. At field army and lower levels, combat terrain intelligence is the principal concern, becoming increasingly detailed and localized at successively subordinate levels.

## 10. Intelligence Officer

The terrain intelligence that a commander needs to make a sound decision and an effective plan must be provided by the unit intelligence officer. As a part of his intelligence report, the intelligence officer makes an analysis of the area of operations normally based upon a terrain study. The intelligence officer must plan and coordinate the collection of terrain information and the production, maintenance, and dissemination of terrain intelligence. Concurrently, he should keep the officer responsible for the preparation of terrain studies informed of the planning that is in progress or in prospect, so that the required terrain information may be secured and compiled.

## 11. Engineer

Under the general staff supervision of G2 the staff engineer, or the senior engineer commander in the event a staff engineer is not authorized, carries out the terrain intelligence functions. He produces and maintains terrain studies based upon terrain analyses. This involves—

*a.* Determining the requirements for terrain information, based upon requests from G2.

*b.* Collecting and evaluating terrain information.

*c.* Assembling terrain intelligence into a terrain study. He provides technical interpretation of the terrain covering such factors of military significance as obstacles, routes, and avenues of approach, cover and concealment, landforms, hydrology, crosscountry movement, and related subjects. He also disseminates terrain studies and technically evaluated information.

# CHAPTER 3

# PRODUCTION OF TERRAIN INTELLIGENCE

## Section I. INTELLIGENCE CYCLE

### 12. Phases

The intelligence cycle described in FM 30-5 is also followed in the production of terrain intelligence. The activities associated with intelligence operations follow a four-step cycle, oriented on the commander's mission. The four steps are—

*a.* Planning the collection effort and preparing orders.

*b.* Collecting the information.

*c.* Processing the collected information.

*d.* Disseminating and using the resulting intelligence.

### 13. The Collection Effort

*a. Direction.* Terrain intelligence is directed by the responsible intelligence officer in the name of the commander. This direction involves—

(1) Determination of intelligence requirements.
(2) Preparation of a collection plan.
(3) Issuance of orders and requests to appropriate collection agencies.
(4) Continuous check on the production activities of the collection agencies.

*b. Steps.* Five successive steps are involved in direction—

(1) Determination of the information requirements.
(2) Analysis of the requirements to determine indications that would answer the questions presented.
(3) Translation of these indications into orders and requests for information pertaining to specific activities, localities, characteristics, or conditions.
(4) Selection of collection agencies to be employed and issuance of the necessary orders and requests.
(5) Followup.

### 14. Collecting

Collecting is the systematic exploitation of sources of information and the reporting of the information thus obtained to the proper intelligence agencies. A source is the person, thing, or activity from which information is obtained. An agency is any individual or organization which collects or processes information. Sources of terrain information and collection agencies are discussed in paragraphs 17 through 23.

### 15. Processing Sequence

*a.* Processing is the step in the intelligence cycle whereby information becomes intelligence.

*b.* Recording involves the reduction of information to writing or other graphical form of presentation and the grouping of related items to facilitate study and comparison.

*c.* Evaluation is the appraisal of an item of information to determine its pertinence, the reliability of the source or agency, and the accuracy of the information.

*d.* Interpretation is the result of critical judgment involving analysis, integration, and deduction. Analysis is the sifting and sorting of evaluated information to isolate significant elements with respect to the mission and operations. Integration is the combination of the elements isolated in analysis with other known information to form a logical picture of enemy activities or the influence of the characteristics of the area on the mission of the command. Deduction is the acquisition of a meaning from the hypothesis developed, tested, and considered valid.

### 16. Dissemination and Use

Terrain intelligence is disseminated to commanders and staffs as one element of the overall intelligence report. Dissemination may be accomplished by means of briefings, conferences, messages, or such intelligence documents as the estimate, summary, periodic report, an analysis of area of operations, annex, maps, photointerpretation reports, and climatic summaries. The information and intelligence are instruments in detecting enemy targets and developing effective combat power. The means and methods selected for dissemination depend upon the detail, pertinence, and urgency of the information and intelligence as well as its intended use. Consideration is given to the needs of the user, his resources for using the material, and the capabilities of available communications.

## Section II. SOURCES AND AGENCIES

### 17. Maps and Terrain Models

*a. Maps.* Maps are a basic source of terrain information. They are intelligence documents, not supply items. Accordingly, the intelligence officer usually is responsible for staff supervision over military maps and survey activities. The classification of US maps by type and scale is explained in AR 117–5. Foreign maps, or those copied from maps that were prepared by foreign agencies, often vary from US standards and procedures. Reliability information is indicated in the margin of US produced topographic maps. Foreign maps may not provide this. Portions of one map sheet may be fully reliable and yet other parts of the same sheet may be based on obsolete data. The use of a map must be regulated by an estimate of the probable changes in manmade features that have occurred since the date of the latest revision. All personnel must be impressed with the importance of reporting errors, changes, and omissions in existing maps, so that new editions may incorporate the necessary corrections. Maps prepared for a special purpose may not be reliable for information that is not related to that purpose. A railway map, for example, may be quite accurate in presenting railway information, but may be unreliable for data shown on roads or other features. Special maps and overlays may be prepared for a specific military purpose or to show only particular characteristics of the terrain.

(1) Soil maps are prepared primarily for agricultural purposes to show the potentialities of the soil for crop production. This type of map shows soils of various types, indicating their degree of acidity, nutrients, suitability for certain crops, and similar information. Engineering soil maps indicate the qualities of soil construction or vehicle movement. Agricultural soil maps may be used for engineering purposes after they have been interpreted according to engineering nomenclature and requirements.

(2) Geologic sketch maps indicate the geology of an area. Outcrop maps show the bedrock that is exposed. Bedrock maps show the surface of the bedrock as it would appear if the overlying soils were removed. These maps are useful in locating sites for major structures and in finding sources of rock for construction purposes when the overburden has been described.

(3) Communication maps include those that show the system of lines and sequence of stations of railways, provide automobile route information, and indicate navigable waterways and the routes and stops of airlines. These really could be considered transportation maps.

(4) Relief maps show differences in elevation by the use of various tints and shading patterns. A plastic relief map is a standard topographic map printed on a plastic and molded into a three-dimensional form with a 2:1 exaggeration in the relief. Because of the shrinkage characteristics inherent in

plastic materials, there is considerable distortion of the features shown on this type of map. For example, some stream lines may appear not coincident with valley bottoms.

(5) Pictomaps are maps on which the photographic imagery of a standard photomosaic has been converted into interpretable colors and symbols. Desert sands, swamps, jungle, glaciers, and extra terrestrial topography are some of the features that are ideally portrayed on a pictomap. Shadows of map features are emphasized on the pictomap. They accurately delineate many cultural features, and they lend a three-dimensional effect to buildings and vegetation. This effect symbolizes and establishes relative heights of these cultural features. The pictomap is an excellent source for terrain information.

(6) Other special maps show the distribution of major vegetation types and show depth of depressions for use in mountain and winter operations; water supply sources and distribution systems; structure of town and city plans; conditions affecting cross-country movement; and similar detailed information that can be presented most effectively in graphic form.

*b. Terrain Models.* A terrain model is a three-dimensional graphic representation of an area showing the conformation of the ground to scale. Usually it is colored to emphasize various physical features, and the vertical scale is exaggerated to convey relief. Terrain models may be made for use in strategic or tactical planning, assault landings, airborne landings, and aerial target delineation.

## 18. Photographs and Remote-Sensor Imagery

*a. General Features.* Aerial and ground photographs provide an accurate visual record of the terrain. They furnish information that is not readily available or immediately apparent by ground reconnaissance or by visual observation from the air, especially of enemy-held areas.

Photographs preserve information in a permanent form, so that it is available for later study and comparison. Remote-sensor imagery includes infrared photography and side-looking airborne radar. It provides imagery records of terrain, vegetation, and cultural features that may be obscured by atmospheric, natural, or artificial cover.

*b. Advantages.* Properly interpreted, aerial and ground photography and airborne infrared and radar imagery will furnish detailed information concerning:

(1) The identification of vegetation soils and rocks.

(2) Both surface and subsurface drainage characteristics. Indications of surface drainage can be located, marked, and evaluated through detailed stereo study. In some cases, subsurface drainage can be predicted in general terms, such as, "well-drained" or "poorly drained."

(3) Suitability of terrain for construction of airfields, roads, and underground installations, based upon topography, drainage, soils, and engineering materials. General characteristics can be given, such as"flat plain, predominantly fine-grained soils, well-drained, forest cover, deposits of gravel suitable for borrow."

(4) Suitability of terrain for cross-country movement and airborne and airmobile operations. Photographs and photomaps can be used advantageously in studying and rating areas as to their suitability for movement, based on the evaluation of relief, slopes, drainage, soils, and vegetation. General characteristics may be determined, such as "flat plain, grass-covered, silty soils, hedgerows, poor drainage."

(5) Aerial and ground photographs, interpreted by skilled personnel, can give highly detailed information about all types of manmade features, from artificial obstacles to large industrial complexes.

(6) Photographs depict up-to-date terrain features. Maps depict only what the

mapmaker saw at the time the mapping information was gathered.

*c. Limitations.* The amount of information that can be derived from interpretation of photography is limited by adverse weather and by densely forested terrain. Aerial photographs may not provide detailed factual information concerning the engineering properties of soil, vehicle type and trafficability relationships, and quantitative data for materials and other items. This type of information usually can be obtained only through field sampling and laboratory testing procedures or by comparison with information from reconnaissance reports, geological surveys, and similar sources. It is important that information obtained from aerial and ground photographs should be correlated with information from other sources, such as maps, personal reconnaissance, and reports from intelligence agencies.

*d. Requirements.* There should be sufficient aerial photograph coverage made to enable the interpreter to determine the extent of local conditions and the expected variations. Usually vertical coverage is best for measurements, although oblique photographs are more useful for certain purposes, such as in the study of dense forest areas. Scales of 1:5,000 to 1:20,000 are desirable for detailed terrain analysis. Photographs in this range provide good area coverage and stereoscopic perception of relief. They show such details as major gully characteristics, and the outstanding terrain features.

(1) Photographs with scales smaller than 1:30,000 provide excellent area coverage in the broadest sense. Major physiographic details are easily seen and studied; relief must be great, however, before stereovision is practicable because only major relief forms are clearly differentiated at these scales, and small details are lost. Major gullies can be plotted, for example, but in some cases their characteristics cannot be determined. As a rule, landforms can be delineated only when there is a great contrast in pattern. Slopes associated with landforms at times cannot be seen or distinguished. While such manmade features as roads, railroads, bridges, and buildings can be identified, the interpreter may have difficulty in determining their structural details. Colored film is frequently the most effective for identifying vegetation. The best scale depends on the data needed. Vegetation can also be identified from differences in tone on black and white aerial photographs.

(2) Stereopairs, vectographs, and anaglyphs are particularly useful in making terrain studies. A stereopair consists of two photographs of the same terrain taken from different positions. Usually they are taken from a position vertically above the area being photographed with about 60 percent of each photo (called the overlap) common to both photographs. Examination with a stereoscope gives an exaggerated third-dimensional view of the terrain included in the overlap. A vectograph is a print or transparency in which the two photographs of the stereoscopic pair are rendered in terms of degree of polarization presenting a stereoscopic image when viewed through Polaroid spectacles. An anaglyph is a picture combining two images of the same object, recorded from different points of view, as images of the right and left eye, one image in one color being superimposed upon the second image in a contrasting color. Viewed through a pair of light filters, the anaglyph produces a stereoscopic effect.

(3) Controlled mosaics of an area provide an accurate map from which measurements of distances can be obtained. The amount of detail useful for terrain analysis will depend upon the scale of the mosaic.

## 19. Books and Periodicals

Valuable terrain information can be found in a wide variety of books and periodicals. These include trade journals, economic atlases, tide tables, pilots' handbooks, tourist guides, and similar publications. Unpublished systematic records covering meteorological, hydrological, and similar scientific data prepared by government agencies, engineering firms, private societies, and individuals also contribute valuable terrain information. Although utilized chiefly for terrain studies made by higher headquarters, material of this type, when locally available, can be of considerable value to lower echelons.

## 20. Intelligence Reports

Strategic intelligence studies prepared by Department of Defense agencies provide detailed terrain information concerning major geographical areas. Such studies include—

*a. National Intelligence Survey (NIS).* This is a series of documents covering the countries of the world, presenting a digest of the basic intelligence required for strategic planning and for the operations of major units. Each survey describes in detail the terrain characteristics of a specific area or nation supported by descriptive material, maps, charts, tables, and with reliability ratings assigned to all data.

*b. Engineer Intelligence Studies (EIS).* These are no longer published, but the EIS files are still an important source. These documents describe in detail those natural and manmade features of an area that affect the capabilities of military forces, particularly with reference to engineer operations. They were produced by the Office, Chief of Engineers.

*c. Lines of Communication (LOC).* These studies, prepared on either medium scale maps or single, small-scale foldup sheets, contain an analysis of transportation facilities with information on railroads, inland waterways, highways, airfields, pipelines, ports, and beaches.

*d. Terrain Studies.* These contain area intelligence depicted on medium and small scale maps with accompanying textual and graphic material. They are for strategic planning, and describe principal terrain characteristics, major aspects of land, water and air movement, and key installations.

*e. Special Reports on Military Geography.* These are designed primarily for strategic planning and generally directed towards analysis of a major aspect of military geography such as cross-country movement, amphibious operations, and airborne operations.

*f. Engineer Reconnaissance Reports.* Reports that summarize data obtained by reconnaissance are a major source of terrain information. They are of particular value in providing current, detailed information about lines of communication and availability of natural construction materials.

## 21. Captured Enemy Documents

Maps and other intelligence documents captured from the enemy often are of great value as sources of terrain information. Usually, enemy-prepared military maps and terrain studies of enemy territory will be more up to date and detailed than our own. The processing of captured enemy documents is described in FM 30–15.

## 22. Interrogation

Interrogation personnel should be kept informed of the terrain information that is required by intelligence officers. Useful information about the area held by enemy forces frequently can be obtained from prisoners of war, deserters, liberated civilians, refugees, escapees, evadees, cooperative enemy nationals, and self-surrendered and apprehended enemy espionage agents.

## 23. Collection Agencies

*a. Units.* Collection agencies include intelligence personnel, troop units, and special information services. FM 30–5 discusses the types and capabilities of these agencies. All units within a command may be employed by the intelligence officer to secure terrain information. In addition, he may request higher headquarters to use their units and facilities to secure information he requires.

*b. Troops.* Reconnaissance missions to secure terrain information may be assigned to combat or combat support units. Such missions may be accomplished by units specifically organized for reconnaissance or by other units assigned reconnaissance missions in addition to their normal activities.

*c. Aircraft.* In addition to ground reconnaissance, aircraft may be employed to secure information about the terrain. Although it may be limited by adverse weather or enemy air defense, air reconnaissance is the fastest means of gathering terrain information and, at times, may be the most practical means of reconnoitering enemy territory. Information on objects such as trees, structures, and communication lines is of great importance for airmobile and air landing operations. Army aviation has the capability to conduct air reconnaissance missions, but additional support may be requested through intelligence channels for reconnaissance flights to be accomplished by the Air Force.

*d. Specialized Agencies.* An engineer terrain detachment usually is assigned to each corps. The detachment is composed of personnel in various fields of engineering and the natural earth sciences who prepare special terrain studies, evaluate all types of terrain information, and serve as consultants to agencies faced with technical problems. Terrain information may be provided by personnel whose normal duties are not primarily concerned with terrain intelligence. These include military intelligence personnel of the MI battalion, field army, and MI detachments at corps. Civil Affairs staffs acquire terrain intelligence in considerable detail, particularly in the areas of agriculture, forestry and fishing, transportation, and other economic functions. Civil Affairs area studies and surveys are sources of information and intelligence.

# CHAPTER 4

# WEATHER AND CLIMATE

## Section I. WEATHER

### 24. Definition

Weather comprises the day-to-day changes in atmospheric conditions. The physical properties and conditions of the atmosphere that must be measured or observed to describe the state of the weather are termed the weather elements.

### 25. Air Temperature

*a. Measuring.* Air temperature is the degree of hotness or coldness of freely circulating air as measured by a thermometer that is shielded from the sun. The thermometer is calibrated by using the melting point of ice and the boiling point of water at sea level as standard references. In most English-speaking countries, the Fahrenheit scale is used, with the melting point of ice designated as 32°F above zero and the boiling point of water as 212°F above zero. Countries using the metric system employ the centigrade (Celsius) scale, with the freezing point of water designated as 0° C and the boiling point, 100° C. In the United States, surface air temperatures are indicated in degrees Fahrenheit and upper air temperatures in degrees centigrade. Temperatures may be converted from one of these scales to the other by use of the following formulas:

$C = \frac{5}{9}\ (F - 32°)$ Example: Change 77° F to C. Multiply 77° F – 32° by $\frac{5}{9}$, which equals 25° C.

$F = \frac{9}{5} \times °C + 32°$ Example: Change 25° C to F. Multiply 25° C by $\frac{9}{5}$ and add 32°, which equals 77° F.

*b. Recording.* Temperature data may be recorded in the following forms:

(1) *Mean daily maximum temperature.* The average of the daily maximum temperatures for a month.

(2) *Mean daily minimum temperature.* The average of the daily minimum temperatures for a month.

(3) *Mean daily temperature.* Average of daily maximum and minimum temperatures for any specific day.

(4) *Mean monthly temperature.* Average of daily mean temperatures for any specific month.

(5) *Mean annual temperature.* Average of daily mean temperatures for any specific year.

(6) *Mean annual range.* Difference between the mean monthly temperatures of the warmest and coldest months.

(7) *Diurnal variation.* Difference between the maximum and minimum temperatures occurring in a day.

(8) *Normal values, or long-term mean.* The average of temperature values for the entire period of record. These values usually are used to evaluate the climate.

(9) *Extreme values.* Absolute maximum or absolute minimum or extreme values.

(10) *Length of freezing period.* Number of days with minimum temperature below freezing.

*c. Use of Data.* Monthly daily maximum and mean daily minimum temperatures usually are employed to provide a general definition of the type of climate, and the mean annual range to indicate its variability. Extreme values show the limits which must be anticipated in the climate being considered. Temperatures also are recorded at various altitudes above the ground level in order to provide data for estimating certain types of nuclear-weapon effects.

## 26. Atmospheric Pressure

*a. Definition.* Atmospheric pressure is the force exerted per unit of area by the weight of the atmosphere from the level of measurement to the top of the atmosphere. At sea level this pressure is approximately 6.66 kilograms per 6.45 square centimeter or 14.7 pounds per square inch. Mean sea level is used as a reference for surface weather observations, and pressure measurements are shown on weather maps and climatic charts as if the entire surface of the earth were at sea level. Atmospheric pressures are recorded at various altitudes to provide data for estimating nuclear-weapon effects.

*b. Measurement.* The standard device for measuring atmospheric pressure is a mercurial barometer which balances the weight of the atmosphere with a column of mercury. The standard atmospheric sea-level pressure is equal to that exerted by a 760 millimeter (29.29 inch) column of mercury at 32°F. and at standard gravity. For some scientific purposes, it is desirable to indicate atmospheric pressure in units of pressure (weight per unit of area) rather than in units of length(centimeters or inches). In the metric systems, a bar is the unit of measure. The millibar (1/1000 of a bar) is used in meteorology to designate the value of atmospheric pressure. The standard sea level pressure is 1013.2 millibars. One millibar equals .0762 centimeters or 0.03 inches of mercury. Most weather stations today observe pressure on an aneroid barometer, calibrated in both millibars or inches or millimeters of mercury. Barometer readings significantly below 760 millimeters usually indicate low-pressure areas and those significantly above 760 millimeters usually indicate high-pressure areas. In general, cold air, being heavy and dense, causes high barometric pressures, while hot air, which is light and thin, causes low pressures. High-pressure systems usually are associated with fair, dry weather; low-pressure systems, with unsettled, cloudy conditions.

## 27. Winds

*a. Description.* Wind is air in motion and results from differences in atmospheric pressure. A wind is described by its direction and speed. The direction of a wind is the direction from which it is blowing. A wind coming from the north, for example is termed a north wind. As reported in observations, wind direction is determined with reference to true north and is expressed to the nearest 10 degrees. Thus, a direction of 090 degrees (a wind from due east) would be reported as 09. Wind velocities are reported by the Air Weather Service in knots. A table of wind speeds and their specifications is given (table 1) to aid in estimating speeds. Over irregular terrain, a wind does not move with a steady force or direction, but as a succession of gusts and lulls of variable speed and direction. These eddy currents, caused by friction between air and terrain, are called gusts or turbulence. Turbulence also results from unequal heating of the earth's surface, the cooler air of adjacent areas rushing in to replace the rising warm air from heated areas. Usually the turbulence produced by surface friction is intensified on a sunny afternoon.

*b. Systems.* Local pressure and wind systems are created by valleys, mountains, and land masses that change the weather characteristics of areas. Since land masses absorb and radiate heat more rapidly than water masses, the land is heated more than the sea during the day and cools more at night. In coastal areas, warm air over the land rises to a higher altitude and then moves horizontally out to sea. To replace this warm air, the colder air over the water moves on to the land, creating the so-called sea breeze. The circulation is reversed at night, so that the surface air moves from the land to the sea, resulting in a land breeze.

*Table 1. Weather Map Scale of Wind Velocity*

| Descriptive item | Knots | Meters/seconds | Specifications |
|---|---|---|---|
| Calm | less than 1 | 0–0.2 | Calm; smoke rises vertically. |
| Light air | 1–3 | 0.3–1.5 | Direction of wind shown by smoke drift but not by wind vanes. |
| Light breeze | 4–6 | 1.6–3.3 | Wind felt on face; leaves rustle. |
| Gentle breeze | 7–10 | 3.4–5.4 | Leaves and small twigs in constant motion; wind extends light flag. |
| Moderate breeze | 11–16 | 5.5–7.9 | Raises dust and loose paper; small branches are moved. |
| Fresh breeze | 17–21 | 8.0–10.7 | Small trees in leaf begin to sway; crested wavelets form on inland waters. |
| Strong breeze | 22–27 | 10.8–13.8 | Large branches in motion; whistling heard in telegraph wires; umbrellas used with difficulty. |
| Near gale | 28–33 | 13.9–17.1 | Whole trees in motion; inconvenience felt when walking against wind. |
| Gale | 34–40 | 17.2–20.7 | Breaks twigs off trees; generally impedes progress. |
| Strong gale | 41–47 | 20.8–24.4 | Slight structural damage occurs (chimney pots, slates and shingles removed). |
| Storm | 48–55 | 24.5–28.4 | Seldom experienced inland; trees uprooted; considerable structural damage occurs. |
| Violent storm | 56–63 | 28.5–32.6 | Very rarely experienced; accompanied by widespread damage. |
| Hurricane | 64 and over | 32.7 and over | |

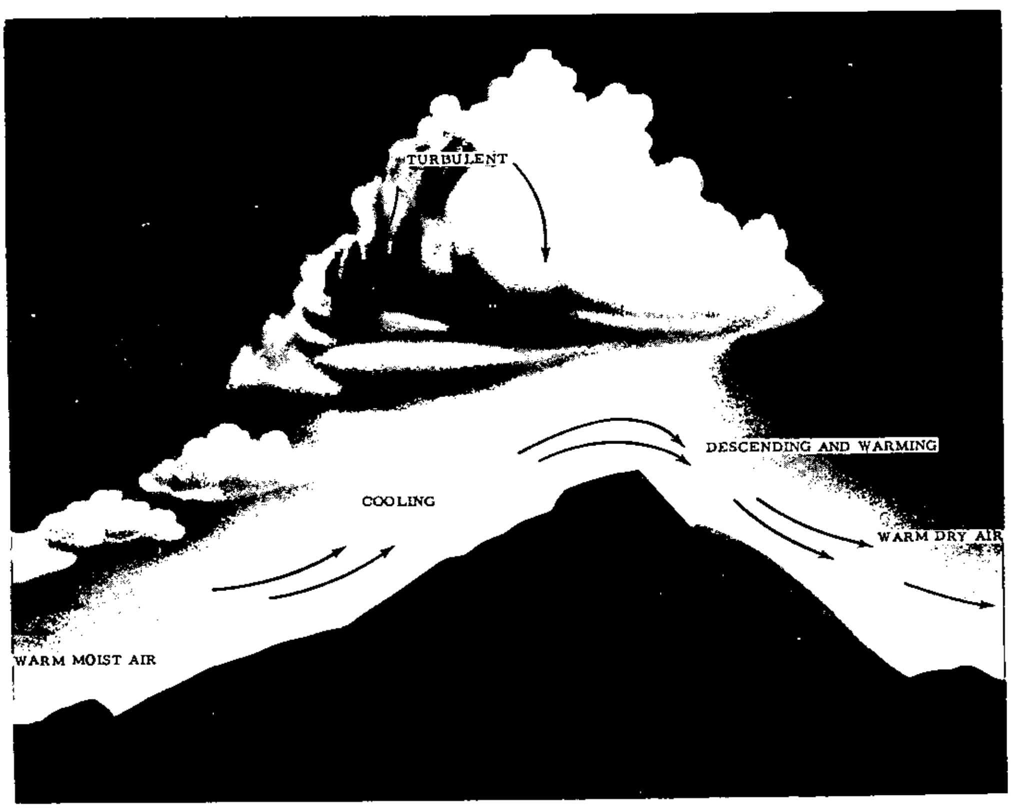



*Figure 1. Chinook or foehn effect.*

*c. Vally Wind.* Heated by the daytime sun, the air in contact with a mountain slope becomes lighter than the surrounding air and rises up the slope, being replaced by denser, colder air. This air movement is called a valley wind because it appears to be flowing up from the valley. At night the air in contact with the slope becomes colder and more dense, sinking down along the slope to create a mountain breeze that seems to flow out of the mountain. Mountain breezes generally are stronger than valley winds, especially in the winter.

*d. Chinook.* A chinook (North America) or foehn (Europe) (fig. 1) is a phenomenon that occurs in winter and spring on the lee or downwind side of mountain ranges over which there flows a steady crosswind of moisture-laden air. As the air rises over the windward side of the mountains it expands and cools rapidly, producing clouds and precipitation. As the air moves down the lee side of the mountain range it compresses and warms. As a result, there are warm, dry winds on the lee side of the mountains.

*e. Fall and Gravity.* Fall and gravity winds are caused by the descent of downslope air through the action of gravity. They are typical of the Greenland coast, which is essentially a high plateau sloping abruptly to the sea along an irregular coastline cut by many fiords. The central plateau area remains ice-covered throughout the year, developing extremely cold air masses which frequently drain off through the fiords to the sea and attain a near-hurricane speed. At sea level the winds remain relatively cold and very dry. Similar winds are the bora, which drain off the southern Alps and the Balkan Plateau into the Adriatic Sea, and the mistral of the Rhone Valley in France.

*f. Monsoon.* A monsoon wind is any seasonally changing or reversing wind. It is strongest and steadiest on the southern and eastern sides of Asia. It blows outward from high-pressure centers overland toward the sea in winter and inward toward low-pressure overland in summer. In most regions, the summer monsoon season is generally characterized by extensive cloudiness and frequent precipitation. The winter monsoon season is characterized by dry air and infrequent cloudiness except where the monsoon winds pick up moisture by moving over warm seas before striking an island or peninsular coastline.

## 28. Humidity

*a. Vapor.* Water vapor is the most important constituent of the atmosphere that determines weather phenomena. Although the oceans are the primary source, a limited amount of water vapor also is furnished to the atmosphere from lakes and rivers, snow, ice fields, and vegetation. The percentage of water vapor by volume in the air may vary from practically zero in deserts to 4 or 5 percent in humid tropical areas.

*b. Amount.* Humidity is the term used to describe the amount of water vapor in the air. The amount that the air actually contains compared with what it could hold at a given temperature and pressure is termed the relative humidity. When a specific air mass holds all the moisture that it can at a given temperature, it is described as having a relative humidity of 100 percent.

*c. Dew Point.* The dew point is that temperature at which the air becomes saturated. The higher the dew point, the greater amount of water vapor the air can hold. The closer the dew point temperature is to the actual temperature, the greater the likelihood of condensation. Condensation results when the capacity of the atmosphere to hold water is reduced by cooling, so that the water vapor in the air is changed to visible moisture such as fog or clouds.

## 29. Clouds

*a. Classification.* Clouds are masses of condensed moisture suspended in air in the form of minute water droplets. They are classified according to their form or appearance and by the physical processes producing them. The Air Weather Service reports the type of clouds present, the heights of the cloud bases and cloud tops, the amount of cloudiness, and the direction in which the clouds are moving. Cloud amounts are reported in terms of the fraction of the sky that is covered by clouds (fig. 2). The following terms are used:

(1) *Clear.* No clouds, or less than 0.1 of the sky covered.

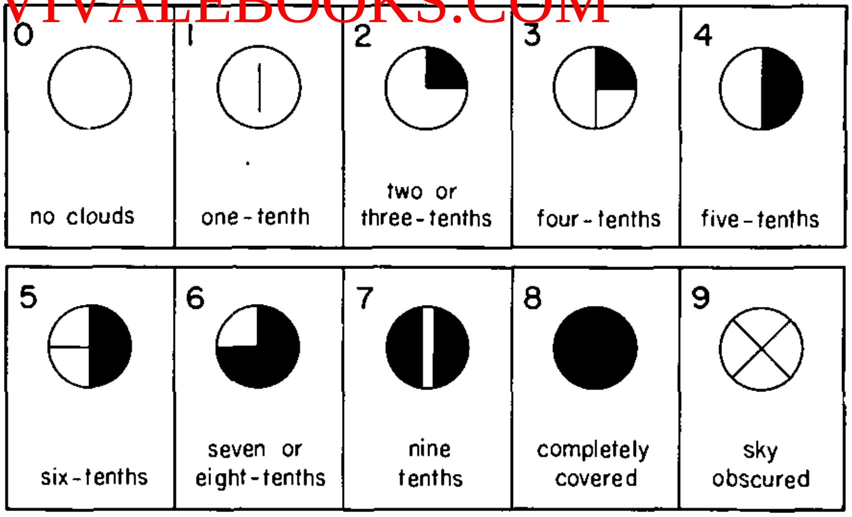



*Figure 2. Cloud cover symbols.*

(2) *Scattered.* 0.1 to 0.5 of the sky covered.

(3) *Broken.* 0.6 to 0.9 of the sky covered.

(4) *Overcast.* More than 0.9 of the sky covered.

*b. Heights.* Cloud heights are reported in meters above the ground. The heights of clouds below 1,500 meters (5,000 feet) are reported to the nearest 30 meters (100 feet); clouds from 1,500 to 3,000 meters (5,000 to 10,000 feet) are reported to the nearest 150 meters (500 feet), and clouds above 3,000 meters (10,000 feet) to the nearest 300 meters (1,000 feet). A ceiling is defined as the lowest layer of clouds that is reported as broken or overcast and not classified as thin. Heights of clouds are reported in meters or feet above the point of observation.

*c. Direction.* Cloud direction is the direction toward which the cloud bases are moving. It is reported according to the eight points of the compass.

*d. Appearance.* According to their appearance, clouds are either cumiliform or stratiform. Cumiliform clouds are formed by rising currents in unstable air. Stratiform clouds result from the cooling of air in stable layers.

(1) Cumiliform clouds are dense with vertical development. The upper surface of a cumiliform cloud is dome-shaped, while the base is nearly horizontal. Usually clouds of this type are separate from each other and rarely cover the entire sky. The precipitation from cumiliform clouds generally is showery in nature.

(2) Stratiform clouds usually occur in layers that may extend from horizon to horizon, without the vertical development of cumiliform clouds. Precipitation from this type of cloud usually is in the form of light continuous rain, drizzle, or snow.

*e. Groupings.* Clouds may be grouped into four families (fig. 3)—

(1) *High.* Cirrus, cirrostratus, cirrocumulus.

(2) *Middle.* Altostratus, altocumulus.

(3) *Low.* Stratus, nimbostratus, stratocumulus.

(4) *Vertical development.* Cumulonimbus for an example.

*f. High Clouds.* High clouds usually occur at heights of from 6,000 to 12,000 meters (20,000 to 40,000 feet), although they may be found at much lower altitudes in polar regions. They are composed of ice crystals. The characteristics of the major cloud types in this group are as follows:

(1) *Cirrus.* This is a delicate white fibrous cloud that often appears bright yellow or red from the reflection of light from a rising or setting sun. Cirrus

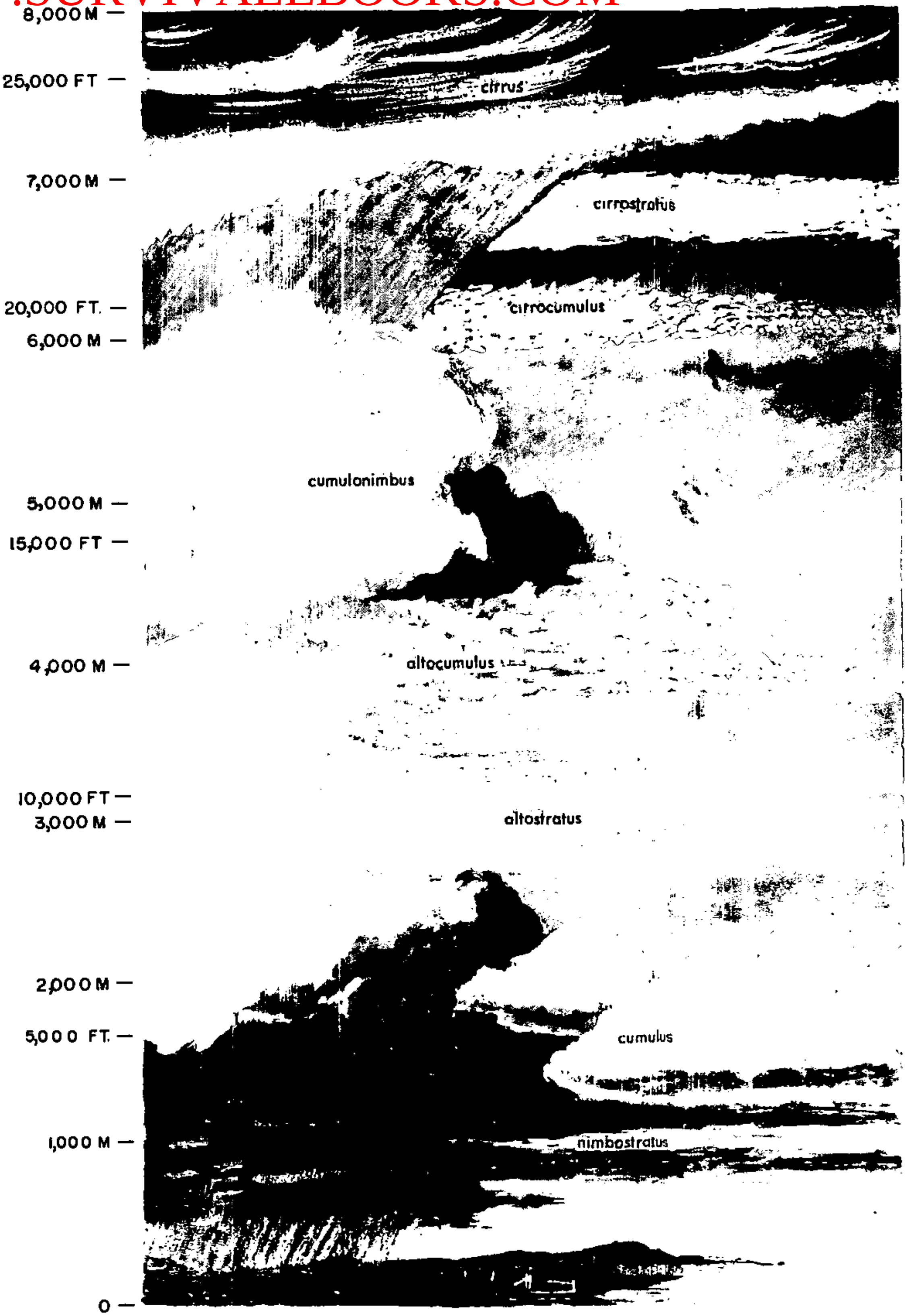



*Figure 3. Major cloud types.*

clouds may appear as isolated tufts, featherlike plumes, or streaks with upturned ends often referred to as mare's tails. Because of their thinness, cirrus clouds do not blur the outlines of the sun or moon, and usually do not make an appreciable change in the appearance of the sky.

(2) *Cirrostratus.* These are thin, whitish veils of clouds that give the sky a milky look. Usually they can be distinguished from cirrus clouds by the halo which light from the sun or moon produces in them.

(3) *Cirrocumulus.* Clouds of this type consist of patches of small, rounded masses or white flakes arranged in groups or lines.

*g. Middle Clouds.* Middle clouds usually occur at altitudes of 1,800 to 6,000 (6,000 to 20,000 feet) meters in the lower limit of this range in the colder seasons, and at altitudes near the upper limit in the warmer seasons. The major types are—

(1) *Altostratus.* Clouds of this type appear as a veil of gray or bluish fibrous clouds, the thinner forms resembling the thicker forms of cirrostratus. Altostratus clouds are associated with smooth or stable air layers, and occasionally they produce light rain or snow.

(2) *Altocumulus.* This cloud type can appear as a layer or in patches, is white or gray in color, and the cloud elements appear as rounded masses or rolls. They occur in a variety of forms, and may exist at several levels at the same time.

*h. Low Clouds.* Low clouds usually have bases below 1,800 meters (6,000 feet) and include the following types:

(1) *Stratus.* These form a low layer resembling fog, although they do not rest upon the surface. They give the sky a hazy appearance. The base of this cloud is usually rather uniform in height but it often occurs in the form of ragged patches or cloud fragments. Layers of stratus clouds may cover hundreds of thousands of square miles. Usually they are thin, and range in thickness from a few hundred feet to several thousand feet. Frequently, stratus clouds are accompanied by fog, haze, or smoke between their bases and the ground. Visibility is very poor under stratus clouds, and precipitation from them usually is in the form of light snow or drizzle.

(2) *Nimbostratus.* Clouds of this type form a low, dark gray layer. Precipitation usually is in the form of continuous rain or snow of variable intensity. Because of its thickness, sometimes more than 4,500 meters (15,000 feet), the nimbostratus is frequently classified as a cloud of vertical development.

(3) *Stratocumulus.* This type of cloud forms a lower layer of patches of rounded masses or rolls. The base of the stratocumulus usually is higher and rougher than the stratus clouds. Frequently these clouds change into the stratus type.

*i. Vertical.* Vertical development clouds cannot be classified according to height, since they extend through all the levels assigned to other cloud groups. The bases vary from 150 to 3,000 meters (500 feet to 10,000 feet) or higher, while the tops may vary from 450 meters (1,500 feet) to more than 12,000 meters (40,000 feet). They all occur in relatively unstable air and frequently are associated with strong vertical currents and intense turbulence. In this category are the following:

(1) *Cumulus.* Clouds of the cumulus type are dense, with vertical development. The base is horizontal and uniform in height above the earth, with a top that is domed or cauliflower-like in shape. Cumulus clouds appear white when they reflect sunlight toward the observer, but when viewed from directly underneath or when they are between the observer and the sun, they may appear dark with bright edges. Over land, cumulus clouds tend to develop during the warming of the day, dissipating at night when the

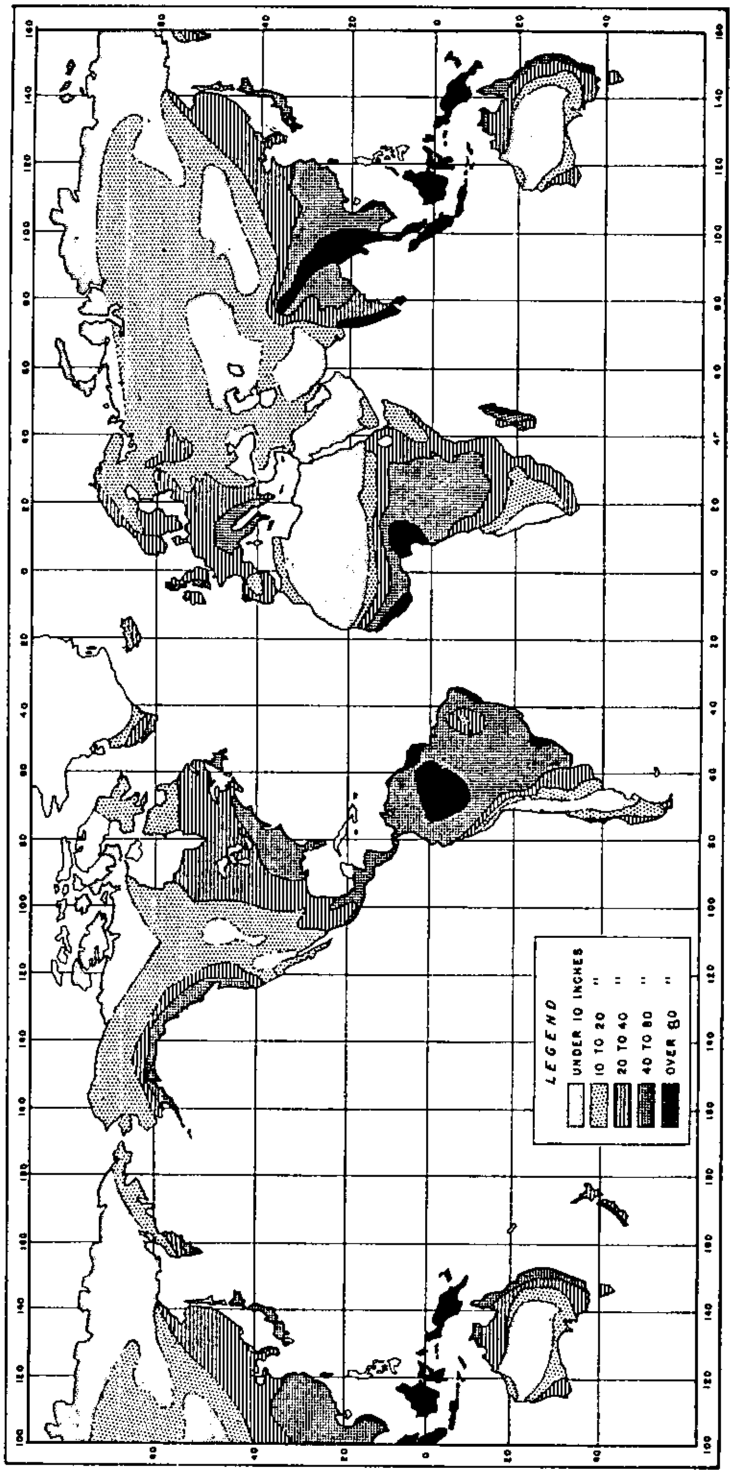



*Figure 4. World rainfall.*

earth's surface cools. Over water, cumulus clouds tend to develop at night as the water surface remains warm while the air mass cools slightly.

(2) *Cumulonimbus.* Clouds of this type are heavy masses which extend to great heights. Their upper portions resemble mountains or towers capped with a fibrous texture. They develop only in unstable air. Cumulonimbus clouds are distinguished from cumulus clouds chiefly by the veil of ice crystal clouds which surrounds their upper portions. Thunderstorms, squalls, turbulence, and hail are characteristic of cumulonimbus clouds.

## 30. Precipitation

*a. Description.* Precipitation (fig. 4) is visible moisture that falls from the atmosphere, such as rain, sleet, snow, hail, drizzle, or combinations of these. As an air mass rises, its ability to hold moisture decreases and clouds form. When the cloud droplets become too large to remain in suspension, rain occurs or if the air temperature is below freezing, snow is formed. Sleet is frozen rain formed by droplets passing through a layer of below-freezing air. Hail consists of rounded particles composed of layers of ice falling from cumulonimbus clouds with strong updrafts. Raindrops are carried to high altitudes and frozen into ice pellets. They then fall and are carried up again by the updraft until the weight of the pellet is greater than the force of the updraft, whereupon it falls to earth. Freezing rain falls from the air in liquid form but freezes upon contact with objects on the surface that are at a temperature below the freezing point. The ice formed on these surfaces is called glaze. Air Weather Service observations include information on the form of precipitation and its character, intensity, and amount.

*b. Character.* The character of precipitation refers to its duration and to changes in its intensity. It is reported as continuous, intermittent, or showery. Continuous precipitation is that in which the intensity increases or decreases gradually. Intermittent precipitation is characterized by a gradual change in intensity, but ceases and recommences at least once an hour. Showery precipitation is marked by rapid changes in intensity and by starting and stopping abruptly. The intensity of precipitation is determined on the basis of its rate of fall. It is described as follows:

(1) *Very light.* Scattered drops or flakes which do not completely wet an exposed surface, regardless of duration.

(2) *Light.* Not more than 0.25 millimeter (0.01 inch) in 6 minutes.

(3) *Moderate.* 0.26 to 0.75 millimeter (0.01 to 0.03 inch) in 6 minutes.

(4) *Heavy.* More than 0.75 millimeter (0.03 inch) in 6 minutes.

*c. Intensity.* The intensity of snow and drizzle is determined on the basis of the reductions in visibility which result, as follows:

(1) *Very light.* Scattered drops or flakes which do not completely wet an exposed surface, regardless of duration. Negligible effect on visibility.

(2) *Light.* Visibility 1 kilometer (5/8 statute mile) or more.

(3) *Moderate.* Visibility less than 1 kilometer (5/8 statute mile), but not less than 1/2 kilometer (5/16 statute mile).

(4) *Heavy.* Visibility less than 1/2 kilometer (5/16 statute mile).

*d. Amount.* The amount of precipitation is expressed in terms of the vertical depth of water (or melted equivalent in the case of snow or other solid forms) accumulated within a specified time on a horizontal surface. This is expressed to the nearest 0.25 millimeter (0.01 inch). A depth of less than 0.13 millimeters (0.005 inch) is called a trace. In the case of snow, both the actual depth and the equivalent in water are required. Snow depth is measured to the nearest whole inch, and less than 1.3 centimeters (0.5 inch) is termed a trace. The water equivalent of snow is determined by melting a representative sample and measuring the resulting depth of water. As an average figure, 25 centimeters (10 inches) of snow are considered to be equivalent to 2.5 centimeters (1 inch) of water, although this is subject to wide variation. The depth of snow is of concern in estimating the trafficability and the water equivalent is significant for problems involving water supply, flood prediction, stream flow, and drainage.

### 31. Fog

Fog is defined as a mass of minute water droplets suspended in the atmosphere at the surface of the earth that reduces horizontal visibility. It is formed by the condensation of water vapor in the air. The most favorable conditions for the formation of fog are an abundance of water vapor, high relative humidity, and a light surface wind. A light wind tends to thicken fog. Increasing wind speeds will usually cause fog to lift or to dissipate. Fog usually is more prevalent in coastal areas than inland because there is more water vapor in the atmosphere. Inland fogs may be very persistent in industrial regions. In most areas of the world, fog occurs more frequently during the colder seasons of the year than it does in the warmer seasons.

### 32. Storms

*a. Thunderstorms.* A thunderstorm is a local storm accompanied by thunder, strong gusts of wind, heavy rain, and sometimes hail, usually lasting for no more than an hour or two. A thunderstorm is cellular, each of its many cells having violent up and down drafts in close proximity. The overall mass has a characteristic frontal zone with violent cool winds racing inward toward the storm in spite of its forward motion. When a thunderstorm reaches its mature stage and the rain begins, a downdraft starts in the lower and middle levels of the storm. This large body of descending air causes strong, gusty surface winds that move out ahead of the main storm area, often resulting in a radical, abrupt change in wind speed and direction termed the first gust. In general, the strongest thunderstorm winds occur on the forward side of the storm where the downdraft first reaches the surface. These winds ascend upward at various rates, depending on the intensity and size of the storm. The actual storm has layers conducive to icing and hail formation depending on the altitudes obtained by updrafts and so on. The speed of a thunderstorm wind may reach 80 to 120 kilometers (50 to 75 miles) per hour for a short time.

*b. Tornadoes.* Tornadoes are circular whirlpools of air which range in size from about 30 meters to .8 kilometer (100 feet to one-half mile) in diameter. A tornado appears as a rotating funnel-shaped cloud extending toward the ground from the base of a cumulonimbus. The low pressure and the high wind speeds encountered in the center of the tornado are very destructive. The paths of tornadoes over the ground usually are only a few miles long and the tornadoes move at speeds of 40 to 90 kilometers (25 to 55 miles) per hour. Although the maximum wind speeds associated with tornadoes never have been measured directly, property damage and other effects indicate that they may exceed 800 kilometers (500 miles) per hour. When they occur over water, tornadoes are termed *waterspouts.*

*c. Tropical Cyclones.* A tropical cyclone is a low-pressure system of cyclonic winds that forms over tropical water areas (fig. 5). Cyclones of great intensity are called hurricanes in the Atlantic and Eastern Pacific Oceans, typhoons in the Western Pacific Ocean, cyclones in the Indian Ocean, and *willi willi* in Australia. The average life span of a tropical cyclone is 6 days, although some last only a few hours and others as long as 2 weeks. Tropical cyclones of hurricane intensity are characterized by extremely strong and gusty surface winds, with speeds of 117 to more than 240 kilometers (73 to more than 150 miles) per hour; continuous intense rain in the central area, and a relatively calm area near the center known as the eye. These storms vary in size from 80 to 800 kilometers (50 to 500 miles) in diameter. The precipitation associated with tropical cyclones is extremely heavy. They are frequently accompanied by violent thunderstorms, with the heaviest rainfall usually occurring some distance ahead of the eye of the moving cyclone. Abnormally high tides are a common companion of hurricanes and are responsible for a great amount of damage.

### 33. Weather Forecasts

*a. Factors.* A weather forecast is a prediction of the weather conditions expected to occur at a place, within an area or along a route at a specified future time. The accuracy and reliability of weather forecasts depend upon a number of factors, including the climatic characteristics of the forecast area, the amount

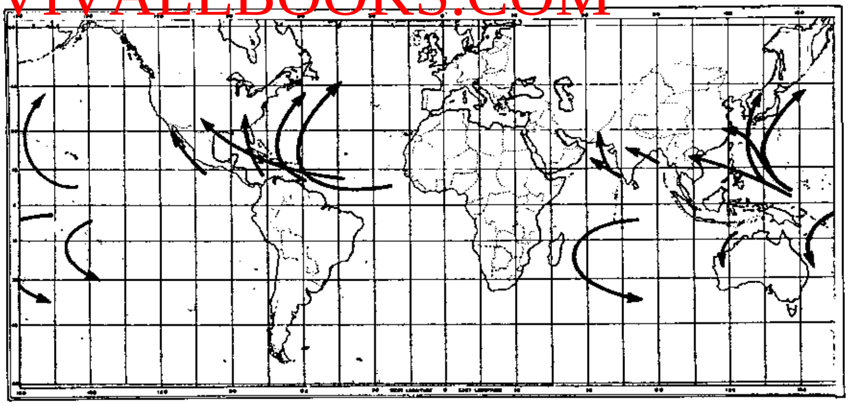


*Figure 5. Tropical cyclones.*

of weather data available, the reliability of weather communications facilities, the length of the forecast period, and the experience of the forecaster. Other factors being equal, the reliability of forecasts generally decreases as the length of the forecast period increases.

*b. Format.* Weather forecasts may be presented in coded (numerical), graphical (pictorial), or written (plain language) format. Normally, weather forecasts for use by Army units will be issued in plain language form. Because forecasts are subject to sudden change, they are usually transmitted by electrical means. Abbreviations are used extensively. The abbreviations used in weather messages are contained in AR 320–50 and in the Federal Aviation Agency (FAA) publication, *Contractions.*

*c. Sources.* Weather forecasts and special studies are provided by agencies of the Air Weather Service of the Air Force. Air Weather Service is found on all Air Force bases and on many Army bases that have Army aviation units. Division and lower units receive weather forecasts from either attached personnel of Air Weather Service or from higher headquarters.

*d. Short-Period Forecasts.* These forecasts cover a period up to 48 hours in advance of issue, giving detailed values of the weather elements expected to occur during the period and the time of anticipated weather changes. They are sufficiently reliable for use in detailed short-range planning.

*e. Medium-Period Forecasts.* This class covers a period of 3 to 5 days, and extended-period forecasts cover periods in excess of 5 days. They are less detailed and specific than short-period forecasts. Usually the weather information is expressed in terms of departure from normal conditions and is suitable only for preliminary planning purposes.

*f. Severe Weather Forecasts.* These provide warnings of weather conditions that will create unusual difficulties. Examples of severe weather include tropical cyclones, thunderstorms, strong and gusty surface winds, heavy precipitation, and extremes of temperature. The Air Weather Service furnishes such warnings when requested by commanders, based upon the needs of their particular unit or installation. The weather conditions that will be critical vary with the type of unit or installation. For example, one unit may require warnings of winds in excess of 15 to 20 knots, but another may not be adversely affected by wind until the speed reaches 35 to 40 knots or more.

## 34. Weather Intelligence

*a. Dissemination.* Timeliness is the critical factor in disseminating weather reports and forecasts. Normally they are transmitted by radio or teletype. Weather information is incorporated in such documents as the intelligence estimate, periodic intelligence report, analysis of area of operations, and the intelligence summary.

*b. Responsibility of Intelligence Officer.* The intelligence officer at corps and lower levels is responsible for determining the weather information requirements and submitting them to the Air Weather Service personnel. He informs subordinate units of the weather data required by the Air Weather Service and instructs them in the procedure for collecting and forwarding the data. He disseminates the received weather information and coordinates with G3/S3 in the weather training of subordinate units.

*c. Requirements.* Weather requirements are of two types—those established by the Army and passed to the Air Weather Service for action, and those established by the Air Weather Service and passed to the Army for action. The intelligence officer coordinates all activities directed toward satisfying these requirements. At division and higher levels this coordination is effected through the Air Force Staff Weather Officer, a special staff officer at those echelons. Below division, the intelligence officer requests Air Weather Service support through intelligence channels. Army weather requirements may include climatic information to be used in the planning phase of an entire campaign or operation, weather forecasts, reports of current weather, and weather summaries. Under conditions of nuclear warfare, timely and accurate weather data, particularly that concerning upper air wind speeds and direction, is essential in fallout predictions. Fallout predictions are required both for friendly and enemy employment of nuclear weapons.

*d. Requests.* Requests for specific weather information received by the intelligence officer are evaluated to determine whether or not the information can be secured by organic agencies before they are forwarded to the Air Weather Service. In all cases, before forwarding the request the intelligence officer insures that requests from various units do not overlap and that they cannot be fulfilled from information already available.

*e. Information Sources.* Weather data required by the Air Weather Service from Army units may be secured by artillery meteorological sections, Chemical Corps units, Army aviation, and forward combat troops. Artillery meteorological sections are capable of making winds-aloft observations and of determining upper air pressure, temperature, and humidity. In addition, they measure and report data for fallout prediction and use by the Air Weather Service. This information is transmitted every 3 hours. Chemical Corps smoke battalions can furnish information concerning surface winds and temperature. The pilots of Army aircraft are capable of reporting weather conditions within their area of flight operations. Forward combat units can provide weather data obtained by visual observation, and if required, they may be equipped with instruments for obtaining additional weather data.

*f. Interpretation.* An intelligence officer does not merely disseminate verbatim the weather forecast received from higher headquarters. He must interpret it in relation to particular operations. He also receives interpretations from such special staff officers as the chemical officer (toxic chemical interpretations and interpretations relative to fallout predictions and travel of fallout clouds), the aviation officer, and the Staff Weather Officer. The weather information that he transmits to the command must be presented in its most usable form, with the operational aspects of the data indicated whenever applicable.

## 35. Effects of Temperature

*a. Temperature.* Periods of freezing temperatures will increase the trafficability of some soils, while with others it may create ice sheets on roads, making movement more difficult. Thawing temperatures may make frozen soils difficult to traverse and may damage roads with poor foundations. The ability of projectiles to penetrate the earth is decreased by frozen soil, but freezing increases the casualty effect of contact-fuzed shells. Melting snows may cause floods and in mountain areas result in avalanches.

*b. Inversions.* Temperature inversions create an exception to the normal decrease in temperature that occurs with increases in altitude. In a temperature inversion, the air nearest the ground is colder than the overlying air. The lower air remains stable. Dust and smoke remain near the ground, reducing visibility and air purity. Inversion conditions are favorable to either enemy or friendly employment of toxic chemical or biological agents. Radar beams may also be refracted or ducted due to inversions.

*c. Site Selection.* In selecting sites to provide protection against low temperatures in the northern hemisphere, preference should be given to the southwesterly slopes of hills and mountains, where the temperature usually is higher than on other slopes. Cold air flows downslope and remains pocketed in inclosed drainage areas or is dammed by forests or other barriers. These cold air pockets have the lowest temperature of the terrain, and often are characterized by freezing or fog when adjacent areas are frost-free or clear. In areas of frequent calm or near calm conditions such cold air drainage areas should not be selected for troop bivouacs or for such facilities as motor pools and hospitals. In hot climates, caution is required in utilizing cold air pockets, since they are likely areas for the formation of ground fog and excessive humidity. In windy areas, on the other hand, these pockets provide shelter from the chilling effects of the wind. Areas susceptible to cold air drainage can be readily located by ground reconnaissance or from topographic maps by visualizing the flow of cold and dense air over the terrain. In general, concave land surfaces facilitate the accumulation of cold air, and convex surfaces favor drainage of air from the surface. Toxic chemical and biological aerosols also tend to collect in depressions and low places. In areas where heating is required, careful selection of the terrain in locating bivouacs and other installations will save fuel. If temperature data are available for various possible sites, or can be estimated by altitude factors and terrain configuration, fuel requirements may be closely ascertained. Toxic chemical agents vaporize more rapidly in high ambient temperatures than in low ambient temperatures. The effects of weather on toxic chemical and biological agents, and on radiological contamination, are discussed in FM 3–5 and TM 3–240. Temperature has no significant effects upon the intensity of blast or the thermal radiation of nuclear weapons.

## 36. Winds

*a. Description.* In arid or semiarid areas, strong winds frequently raise large clouds of dust and sand which greatly reduce observation. Similar effects result in snow-covered regions, where blowing snow may reduce visibility over wide areas. Observation aircraft may be grounded entirely during such periods. The speed and direction of the wind are prime considerations in areas contaminated by toxic chemical agents, biological agents, and radiological fallout. Winds of 5 to 16 kilometers (3 to 10 miles) per hour provide the most favorable conditions for the employment of contaminating agents. Winds below or above that range cause a loss of effectiveness in the use of gas, smoke, chemicals, radioactive clouds, and mists. The direction of the wind must be considered for the protection of friendly troops. In areas characterized by great turbulence and variable winds the use of contaminating agents is highly dangerous.

*b. Projectiles.* Winds tend to deflect projectiles from their normal paths, particularly when they are fired at long ranges. The effect that wind will have on a projectile increases with an increase in the velocity of the wind and the size of the projectile. To obtain accuracy in artillery fires, the direction and velocity of the wind must be known in order to apply compensating corrections to firing data. Winds also affect the efficiency of sound-ranging equipment.

*c. Parachute Landings.* Parachute landings are feasible in winds up to 25 kilometers (15 miles) per hour. At higher velocities, the wind tends to scatter troop concentrations, to foul equipment, and increase the number of casualties from landing accidents. Strong winds also increase the time that parachutists must remain in the air, as well as the time required to secure equipment and prepare for combat after landing.

*d. Amphibious.* Strong winds hinder amphibious operations by creating high seas which will prevent landing craft from landing or retracting.

*e. Nuclear.* Wind speed and direction have no influence upon the blast or thermal radiation effects of nuclear weapons, nor upon the range of the initial nuclear radiation. Winds at all atmospheric levels are significant factors, however, in determining the location of radiological fallout resulting from the surface, subsurface or airburst of a nuclear weapon. Contaminated dirt and debris carried upon the column and cloud will be deposited downwind.

*f. Aerosols.* The effectiveness of toxic chemical and biological agent aerosols is influenced by the direction and speed of the wind. Such aerosols are dissipated rapidly in high winds. The use of toxic chemical agents in vapor form is most effective on clear or partially clear nights when the air usually is most stable.

*g. Radar.* Strong winds can damage radar antennas or even prevent use of the radar.

## 37. Effects of Humidity

*a. Ballistics.* The effects of humidity upon ballistics are important because of the relationship of humidity and density. The amount of water vapor in the air affects the trajectory of projectiles by the influence that it has upon air temperature and density. Humidity also has an effect upon the distance that sounds travel, thus affecting sound-ranging operations. Humidity does not seriously decrease the effectiveness of most toxic agents and may increase the effectiveness of some, such as blister gas. The effectiveness of some biological agent aerosols may tend to be increased by moisture in the air since living organisms are affected adversely by dry air and direct sunlight.

*b. Smoke.* In the use of a screening smoke, a humidity of 90 percent will have twice the obscuring effect of a humidity of 40 percent. With this increase in relative humidity, only one-fourth of the amount of smoke-producing material need be used.

*c. Nuclear.* Humidity has no influence upon the blast effect or nuclear radiation of a nuclear weapon and no direct effect upon thermal radiation intensities. It will affect target vulnerability to a degree, because it will determine the moisture content of clothing, structures, equipment, and vegetation and their susceptibility to ignition. This effect is pronounced, however, only when a very high or very low relative humidity has prevailed over a long period.

## 38. Cloudiness

*a. Effects.* Daytime cloudiness reduces the amount of heat received from the sun at the earth's surface, slowing down the drying of roads and affecting the trafficability of soils. Extensive night cloudiness prevents the loss of heat from the earth's surface due to radiational cooling and results in higher nighttime temperatures. Cloudiness chiefly affects air operations by limiting aerial observation and reconnaissance. Dense clouds above the camera level may reduce light intensity to the point that photography becomes difficult or impossible. A high, thin layer of clouds, on the other hand, may eliminate ground shadows and thus improve the quality of aerial photographs. In cloudy areas, close combat air support may be prohibited or restricted to aircraft equipped with suitable navigation instruments.

*b. Searchlights.* Low-lying clouds may be used to advantage by reflecting searchlight beams to illuminate the ground surface. Any considerable degree of night cloudiness reduces the amount of moonlight that reaches the ground. If the fullest utilization of twilight periods is desired, the extent of cloud cover must be considered.

*c. Nuclear.* Clouds have no influence upon the blast effect of nuclear weapons that are burst below them, nor do they affect nuclear radiation, but they may affect the intensity of thermal radiation reaching a target. If a weapon is burst above or within a continuous cloud layer over the target, a large portion or all of the thermal radiation may be attenuated, with a serious loss of effect. The amount of loss will depend upon the thickness and continuity of the cloud layer and the position of the burst with respect to it. If a weapon is burst below a continuous or nearly continuous cloud layer, some of the thermal energy may be reflected from the cloud layer downward on the target area, enhancing the total thermal effect.

## 39. Rainfall

*a. Amount.* When planning extended operations, the average amount of precipitation occurring in the proposed area must be considered. An area with 50 centimeters (20 inches) or less of rainfall in a year normally will not have adequate supplies of water for military purposes. Rainfall of 50 to 200 centimeters (20 to 80 inches) a year presents no serious problems in operations, other than those that occur in rainy seasons through localized flooding and poor soil trafficability. Annual rainfall in excess of 200 centimeters (80 inches) generally hinders normal operations during the seasons that the greater amount of this rainfall occurs. The seasonal and daily cycle of precipitation (fig. 6) affects the scheduling of military activities. Seasonal distribu-

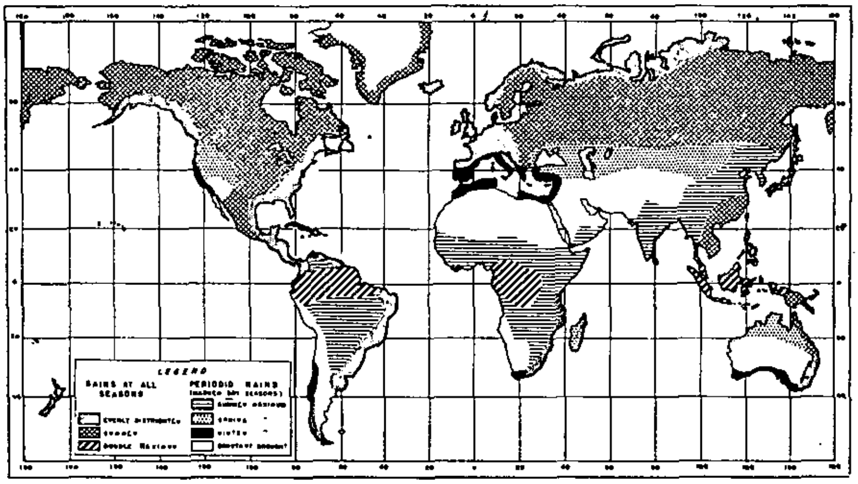


*Figure 6. Seasonal distribution of rainfall.*

tion may be uniform throughout the year or it may occur in distinct wet and dry periods. In the monsoon areas of southeast Asia, for example, the rains come suddenly and with such violent downpours that some military operations must cease almost entirely, and plans must be revised. During rainy seasons in most tropical or semitropical areas, there usually are predictable periods of maximum rainfall occurring at certain times of the day which must be considered when planning construction work or tactical activities. The maximum rate of precipitation expressed in inches per day or hour may also be critical in designing culverts or other facilities for draining excess water.

*b. Trafficability.* Precipitation affects soil trafficability and hence cross-country movement. In areas of seasonal precipitation, the cross-country movement characteristics of an area may change drastically each season. Seasonal floods may swell or flood streams, making fording and bridging operations difficult or impossible. Snow and sleet hamper movement on roads in winter, often making them impassable in mountainous areas. The snow that accumulates in mountains during the winter months frequently affords a water supply throughout the year to lower, drier regions.

*c. Visibility.* Precipitation usually has an adverse effect on visibility and observation, although rain sometimes may wash excessive impurities from the air. Rain and snow aid concealment, and may facilitate surprise attacks. Operation of listening and sound-ranging posts is often limited by precipitation.

*d. Neutralization.* Rain and snow normally reduce the effectiveness of toxic chemical and biological agents. Heavy or lasting rain washes away these agents and may neutralize them. Snow may cover liquid toxic agents so that little vapor or contamination hazard appears until the snow melts. Heavy precipitation will tend to dilute the concentration of biological agent aerosols.

*e. Communication.* Precipitation may have an adverse effect upon communications, reducing the range of field wire circuits and producing radar "clutter" which tends to obscure target echoes.

*f. Nuclear.* Precipitation has a significant influence upon the blast effect of a nuclear weapon, but no effect upon initial nuclear radiation. It affects the range of thermal intensity to the degree that it reduces visibility. Buildings, equipment, debris, vegetation, and other normally flammable elements will require higher thermal intensities for ignition, and the spread of primary or secondary fires will be limited. Residual radiation may be affected. If the radioactive particles formed in an airburst are ingested into rain-bearing clouds, the nuclear cloud (if it does not rise above the rain-bearing clouds) will become so mixed with the rain cloud that it will become an integral part of the rain-producing system. The radioactive material will be deposited with the rain over a large area. Heavy rain over an area would wash away some of the material from a contaminating burst, either air, surface or subsurface, possibly concentrating it in other areas where there are watercourses, low ground, drainage system, or flat undrained areas.

## Section II CLIMATE

### 40. Definition

*a. Elements.* Climate (fig. 7) refers to the general variation and pattern of the primary climatic elements which include temperature, precipitation, humidity, winds, and air pressure. It is a composite or generalization of the day-to-day weather at a given place or area over a long period of time. The strength and direction of winds, amount of precipitation, and average temperatures (figs. 8 and 9) that will prevail in an area can be approximated, based upon statistics compiled for previous years. These climatic elements may be described by graphs or charts in terms of means, ranges, average maximums and minimums, extremes, and frequencies of occurrence.

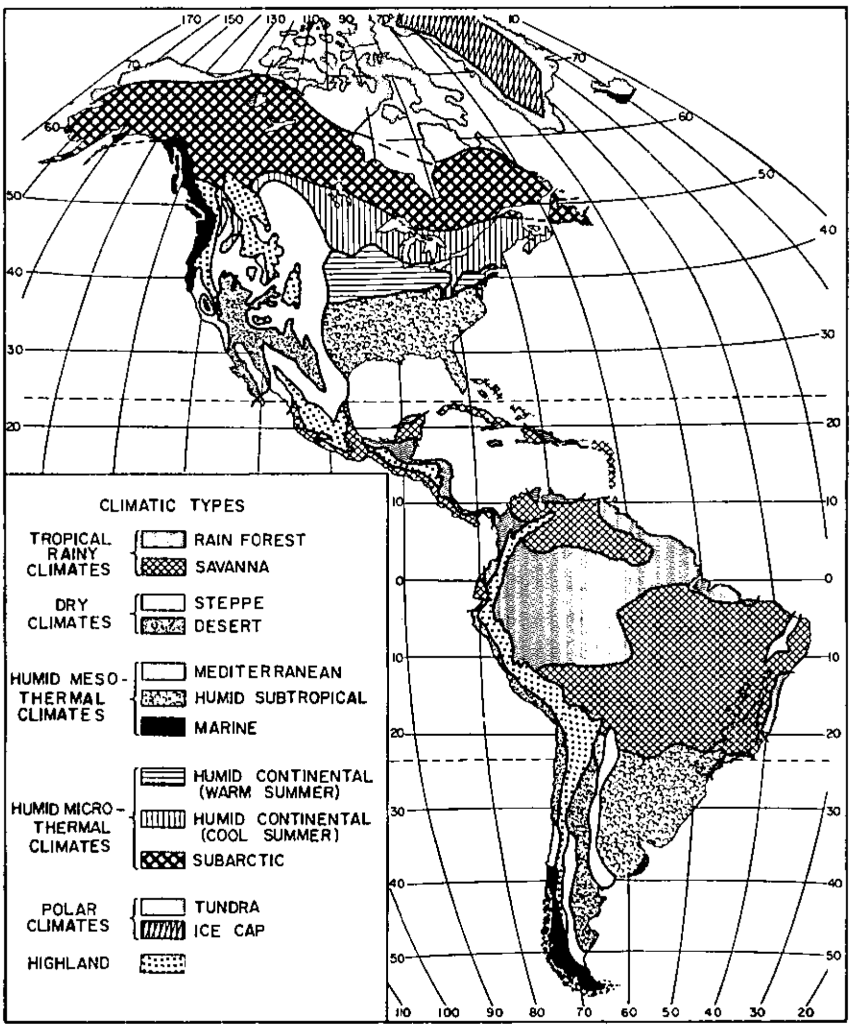



*Figure 7. Major climate regions.*

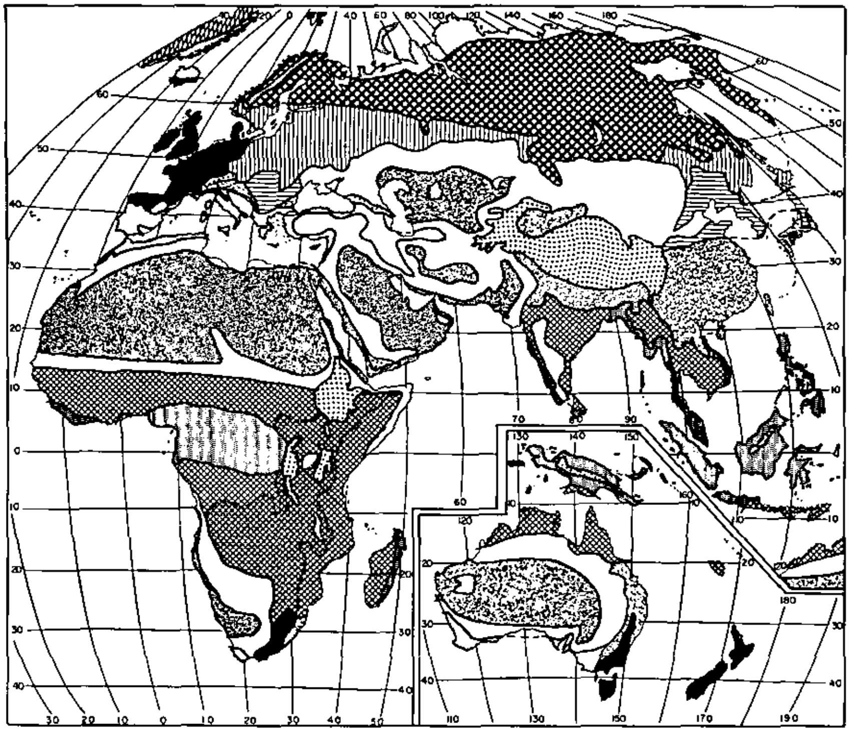


*Figure 7*—Continued.

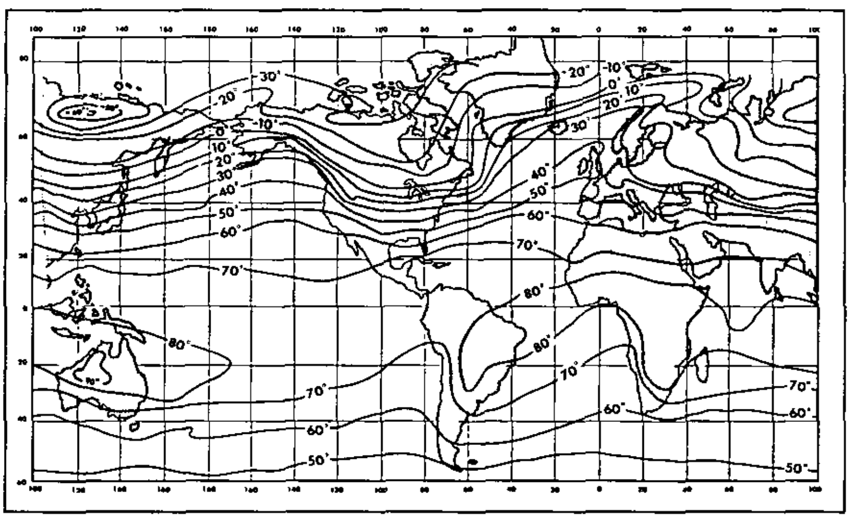



*Figure 8. World temperatures in January.*

*b. Terrain.* Although the heat transmitted by the sun to the earth is the dominant factor in weather and climate, terrain has a major effect upon the climate in many regions. High mountains can block the movement of air masses and act as climatic divides. Terrain can also effect differences in climate between land and ocean areas, where the land has higher summer temperatures and lower winter temperatures than the adjacent body of water. Local terrain influences may also be highly significant in military operations. The ground configuration often strongly affects the pattern of occurrence of fog, surface winds, and other

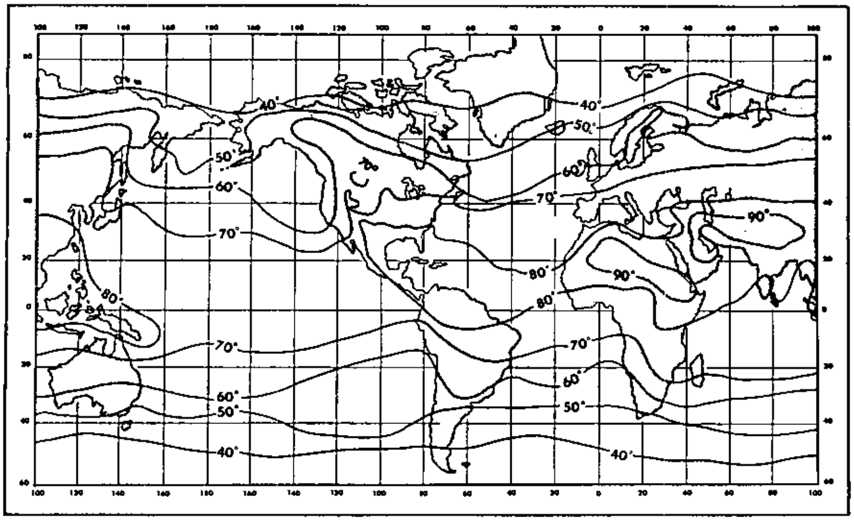


*Figure 9. World temperatures in July.*

conditions. Information about these local conditions frequently can be obtained only by the analysis of topographic maps, ground reconnaissance, and the interrogation of inhabitants.

*c. Plants.* The influence of climate on the growth of plants is a predominant factor in their distribution, and the relation between soil formation and climate is so close that the pattern displayed by a soil map will provide an indication of the climatic conditions.

## 41. Tropical Rainy Climates

*a. Rain Forest Climate.* The tropical rain forest climate occurs in a belt generally extending from 5° to 8° on either side of the Equator. In some regions, such as the Amazon Basin and the Congo Basin, the air is always hot and damp, there are frequent torrential rains of short duration, and the winds are feeble or absent for long periods of time. This climatic type is also found on windward coasts, where, between latitudes of 5° and 25°, easterly trade winds blow almost constantly over hills or mountains. The cooling of these winds as they rise over the barriers produces an extremely heavy rainfall. This occurs, for example, in portions of Hawaii, the Philippines, the eastern coasts of Central America, Brazil, Madagascar (Malagasy), and most of the islands in the southern Pacific Ocean. In this type of climate, the rays of the sun are nearly vertical most of the time, so that days and nights are practically equal in length throughout the year. Night temperatures usually are a few degrees lower than daytime temperatures. There are no clearly marked seasons. Relative humidity is high at all times, and cloudy weather prevails. There are heavy rains on at least 4 or 5 days each week during the rainiest months, with the greatest amounts during the periods when the sun is most directly overhead. The rains are torrential, often accompanied by thunder and lightning. Ordinarily the rain begins in the afternoon, when the heated air is rising most rapidly, and ends before nightfall, although occasionally a light rain will continue into the night.

*b. Savanna Climate.* The tropical savanna climate occurs generally in the regions from 5° to 15° on either side of the Equator, between the dry climates and the tropical rain forest regions. Instead of the dense forests typical of the tropical rain forest climate, the savanna regions have more open forests and large areas covered with tall grasses. Savanna regions have high temperatures, with annual ranges (difference between mean temperature of the warmest and coldest months of the year) varying between 5° and 15° F. The total amount of rainfall is less than that of the tropical rain forest climate. There are distinct wet and dry seasons, and usually the rainy season begins and ends with squalls and violent thunderstorms. During the rainy season, periods of intensely hot sunshine also alternate with brief, violent deluges of rain. The amount of rainfall varies considerably, so that there are years of drought and years of flood. In the dry season the weather resembles that of desert regions, with very little rainfall. Trees lose their leaves, many small streams are dry, and the soil becomes hard and cracked. Visibility is greatly reduced by dust and the smoke from grass fires.

*c. Monsoon.* In certain parts of southern and southeastern Asia, the climate is greatly influenced by monsoon winds. The wet and dry seasons coincide respectively with the onshore and offshore winds.

## 42. Dry Climates

*a. Description.* Dry climates are those in which the evaporation rate exceeds the precipitation rate. The dry climates are located on the leeward interior portions of continents. There are two subdivisions: the arid or desert type, and the semiarid or steppe type. In general, the steppe is a transitional region surrounding the desert and separating it from the humid regions. Dry climates are characterized by extreme seasonal temperatures with large annual ranges. Daily ranges also are high. Humidity is relatively low, averaging from 12 to 30 percent around the middle of the day. Generally the skies are clear and cloudless. Because vegetation is meager, the barren surface of the dry earth becomes very hot during the day and cools rapidly at night. The vegetation offers little friction to the moving air, and accordingly, strong, persistent winds are typical of desert regions.

*b. Low-Latitude Desert Climates.* These occur in the vicinity of 20° to 25° north or south, with the average positions of their extreme margins at approximately 15° and 30°. The Sahara and Australian Deserts are typical examples of this type of climate. In these desert regions, rainfall is not only small in amount, but erratic and uncertain. However, infrequent heavy showers may turn dry streambeds into raging torrents. Often there is no rainfall for several years, and the skies are almost always clear and cloudless.

*c. Low-Latitude Steppes.* These are semiarid, having a short period of rain-bearing winds and storms each year. Precipitation, however, is meager and erratic. Steppe regions on the poleward sides of deserts have almost all their annual rainfall in the cool season. Those adjoining savannas on the equatorward sides of deserts generally have a brief period of relatively heavy rains during the time when the sun is highest.

*d. Middle-Latitude Dry Climates.* These occur within the deep interiors of continents, in the regions surrounded by mountains or plateaus that block the humid maritime air masses. Rainfall is meager and undependable, as in the low-latitude deserts, but there is also a season of severe cold. In winter there may be a small amount of snow, frequently accompanied by strong winds. The temperature and weather characteristics are similar to those of humid continental climates in comparable latitudes, except that there is less rainfall. The area immediately to the east and west of the Caspian Sea is a typical example of this climate.

*e. Middle-Latitude Desert Climate.* This climate is characterized by lower temperatures and precipitation than low-latitude desert climates. This climate occurs in the basinlike, low-altitude areas, surrounded by high-land rims, that exist in some continental interiors. The Great Basin of the U.S. and the Turkestan Basin of Asia have this type of climate. Summer temperatures are high. Middle-latitude steppes occupy intermediate locations between deserts and humid climates. They have small amounts of rainfall, which is usually unpredictable in amount or time of occurrence.

## 43. Humid Mesothermal Climates

*a. Description.* These climates are characterized by moderate temperatures that occur in a seasonal rhythm. They are divided into three general categories—Mediterranean climate, humid subtropical climate and marine west coast climate.

*b. Mediterranean Climate.* This climate has hot, dry summers and mild winters, during which most of the annual precipitation occurs. Annual rainfall usually ranges from 38 to 64 centimeters (15 to 25 inches). In the winter months, the average temperature is usually between 40° and 50°F.; in the summer, it ranges generally from 70° to 80° F. This type of climate occurs in five regions—the borderlands of the Mediterranean Sea, central and coastal Southern California, central Chile, the southern tip of South Africa, and parts of southern Australia. Coastal areas often have a modified type of Mediterranean climate, with cool summers accentuated in some areas by the cool ocean currents offshore. There is apt to be a cool daily breeze along the seacoast and for a short distance inland. Relative humidity is high. Fogs are frequent, but usually are dissipated by the heat of the sun in the early morning hours. Winters are mild and frost infrequent, and the annual change in temperature at some locations is uncommonly small. Summer days in Mediterranean climates are warm to hot, with bright sunshine, low relative humidity, and nearly cloudless skies. Daily weather becomes erratic and unpredictable in autumn. The winds are less regular and there is occasional rain. Temperatures remain relatively high. Winters are mild and warm, with occasional frosts and relatively abundant rainfall.

c. *Humid Subtropical Climate.* This climate occurs in regions located on the eastern sides of continents, generally from about latitude 25° poleward (north or south) to 35° or 40°. This type of climate is found, for example, in the American Gulf States. Temperatures are similar to those of the Mediterranean climate, with less contrast between regions on the coast and those located inland. Rainfall ranges from 75 to 165 centimeters (30 to 65 inches) a year at most locations. In the summer, humidity is high, temperatures average from about 75° to 80°F. in the hottest month, and there are frequent thundershowers. Nights are hot and sultry. There is no drought season, but normally there is less rain in winter than in summer. Severe tropical cyclones occur most frequently in the late summer and early fall. Winters are relatively mild in this type climate. Temperatures in the cool months usually average between 40° and 55°F. with the midday temperature around 55° to 60°F. and the night temperature from 35° to 45°F. The high humidity, however, makes the nights chilly and uncomfortable. Snow may fall occasionally, but it does not remain for more than 2 or 3 days. Daytime temperatures may be raised above 60° or 70°F. by the arrival of a tropical air mass, then be reduced by a subsequent polar wind as much as 30° F. in 24 hours, resulting in a severe freeze.

d. *Marine West Coast Climate.* This climate occurs on the western or windward sides of continents, poleward from about 40° latitude, and results from onshore westerly winds that blow over the land from adjoining oceans. It borders the Mediterranean type on its equatorward margins, extends into the higher middle latitudes and ends at the subarctic or tundra climate. Where mountains are closely parallel to the west coast, as in Scandinavia, this type of climate is confined to a relatively narrow region on seaward side of the highlands. In parts of western Europe, where there are extensive lowlands, the effects of the ocean conditions have an influence on the climate for many miles inland. Summers are cool with occasional hot days but no severe or prolonged heat waves. Rainfall is fairly abundant. Winters are mild, particularly in western Europe, where a great mass of warm water known as the North Atlantic Drift lies offshore. Cloudy skies and a humid atmosphere are prevalent. There are frequent severe frosts. The midday temperatures of most winter days are relatively high. During unusually cold periods, temperatures may remain below freezing for several days. The winter season is marked by severe storms, fogs, and mist. Where the western coasts are bordered by mountain ranges, as in Norway and Chile, precipitation may reach a total of 250 to 380 centimeters (100 to 150 inches) a year. In areas consisting predominantly of lowlands, rainfall usually averages from 50 to 90 centimeters (20 to 35 inches) a year and may fall steadily for several days at a time. In mountainous regions, such as the Cascade Range or the Scandinavian Highlands, snowfall is very heavy. The marine west coast climate is cloudy, and has mist or fog for at least 40 days a year at many locations.

## 44. Humid Microthermal Climates

a. *Types.* The humid microthermal climate occurs in the Northern Hemisphere northward from the subtropical climatic regions and in leeward interior locations. Latitudinal spread is from about 40° N to 60° or 65° N. It has colder winters than the mesothermal type, with larger annual changes of temperature, longer frost seasons and snow cover that lasts for considerable periods. Humid continental and subarctic are the principal types of microthermal climate.

*b. Humid Continental Climates.* These climates border the marine west coast climatic regions. Where there are mountain barriers, as in North America, the change between the two types of climate is abrupt, but it is very gradual where there are no barriers, as in the lowlands of western Europe. Seasonal differences are extreme, with very cold winters and warm to hot summers. Along the seaboard, the summer heat is oppressive and sultry because of the higher humidity, and the winter cold is more raw and penetrating than in the drier interior regions. Along the interior margins, humid continental climates border upon the dry climates and have subhumid characteristics. The prairies of North America and interior Eurasia are examples of such climatic regions. In these areas, the maximum rainfall usually occurs in late spring and early summer, rather than at the time of greatest heat. In winter, regions with a humid continental type of climate normally have a permanent snow cover that lasts from a few weeks to several months. Summer rains usually occur in sharp showers accompanied by thunder and lightning. Winter in the prairie regions is characterized by frequent changes in weather conditions, with occasional blizzards, known as burans. A blizzard is marked by violent gales, drifting snow, and extreme cold. Although there may be no precipitation falling, the air is filled to a height of several hundred feet by swirling masses of dry, finely pulverized snow. Afternoon thunderstorms frequently occur during summer in prairie regions.

*c. Southern Margins.* Regions on the southern margins of microthermal climates have long, hot, and humid summers lasting from 150 to 200 days between the periods of frost. Winters are cold, with frequent intervals of mild, rainy weather.

*d. Winter.* Winter is the dominant season on the poleward side of regions with this type of climate. Summers are relatively short, usually comprising a period of about 5 months. Temperature changes of as much as 40° F. in 24 hours are common in spring and autumn.

*e. Subarctic Climate.* This climate occurs in latitudes of 50° to 60° in the Northern Hemisphere. The Eurasian region extends from Finland and Sweden to the Pacific coast of Siberia, and in North America, the subarctic stretches from Alaska to Labrador and Newfoundland. Long, extremely cold winters and very brief summers characterize this type of climate. Winter quickly follows summer, with only a short period of autumn intervening. A large part of these regions are frozen to a considerable depth, with only a few feet of the upper part thawing out in the summer. There is little precipitation in subarctic regions. No more than 40 centimeters (15 inches) a year falls over the greater part of the Siberian area. In most of subarctic Canada the precipitation is less than 50 centimeters (20 inches) annually. Precipitation exceeds 50 centimeters (20 inches) chiefly along the oceanic margins of Eurasia and North America.

## 45. Polar Climates

*a. Location.* The poleward limit of forest growth usually is considered the dividing line between polar climates and those of intermediate latitudes coinciding with a line (isotherm) connecting points having a temperature of 50°F. for the warmest month. A mean annual temperature of 32°F. or below is also a distinguishing feature of polar climates. In the Southern Hemisphere, the only large land area with a polar climate is the Antarctic continent. In the Northern Hemisphere, this climatic region includes the Arctic Sea, the borderlands of Eurasia and North America, with the island groups that are north of these continents, and ice-covered Greenland. The Arctic is almost a landlocked sea and the Antarctic is a seagirt land with important climatic differences between them. The climate has fewer wide variations in the Antarctic because it is a single land mass surrounded by oceans with a uniform temperature.

*b. Temperature.* Polar climates have the lowest mean annual and summer temperatures and although the sun remains above the horizon for 6 months of the year, the rays are too oblique to raise the temperature significantly. Much of the energy from the sun is reflected by snow and ice, and is consumed in melting the snow cover and evaporating the water. As a result neither the land surface nor the air adjacent to it becomes warm.

*c. Precipitation.* Precipitation averages less than 25 centimeters (10 inches) a year over large parts of the polar land areas. Because of the low evaporation and small amount of melting, permanent ice fields several thousand feet thick have accumulated on Greenland and the Antarctic continent.

## 46. Tundra and Icecap

*a. Tundra.* Polar climates usually are divided into two types—icecap and tundra. Icecap climates are those where the average temperature of all months is below 32° F., vegetation will not grow, and a permanent snow-and-ice cover prevails (figs. 10 and 11). When one or more months in the warm season have an average temperature above 32°F. but below 50°F., the ground is free from snow for a short period and low sparse vegetation is possible. This climate is designated as tundra. It is less rigorous than that of the icecap regions. The warmest month isotherms of 50°F. on the equatorward side and 32°F. on the poleward side are considered to be the boundaries. Over land areas, tundra climate is confined largely to the Northern Hemisphere. Ocean prevails in those Antarctic areas where the tundra climate normally would be found. Summers warm enough to develop a tundra climate occur only in the most northerly fringes of the Antarctic and on certain small islands of the region. The most extensive tundra areas are on the Arctic Sea margins of Eurasia and North America. Long, cold winters and brief, cool summers characterize the tundra climate.

*Figure 10. Arctic terrain.*

*b. Temperatures.* Average temperatures usually are above freezing only for from 2 to 4 months of the year, and killing frosts may occur at any time. Fog is prevalent along the coast, frequently lasting for days at a time. Snow cover disappears for 1 or 2 months during the summer season, and the lakes usually are free from ice. Drainage is poor because of the permafrost, resulting in many bogs and swamps. Summer temperatures do not differ greatly in the various tundra regions. There is, however, a considerable variation in winter temperatures. Average temperatures in the Arctic coastal areas of Siberia average about −35° to −40°F. in January and February, with even lower temperatures inland. Along the Arctic borders of North America, the temperature for comparable periods is higher, and winters are less severe.

*c. Precipitation.* Annual precipitation normally does not exceed 25 cm to 30 cm (10–12 inches) in the tundra regions, although larger amounts are received in parts of eastern Canada, particularly in Labrador. Usually the most precipitation occurs in summer and autumn, the warmest seasons. Most of it is in the form of rain, with occasional snow. The winter snow is dry and powdery, forming a compact cover.

*Figure 11. Arctic tundra, showing warm-weather drainage.*

Often it is accompanied by strong blizzard winds which pile up the snow on the lee sides of hills and in depressions, sweeping exposed surfaces bare. There is no vegetation to break the force of the wind and to hold the snow cover.

*d. Icecap.* This climate characterizes the permanent continental ice sheets of Greenland and Antarctica and the ocean in the vicinity of the North Pole. The average winter-month temperatures range from −35° to −45°F. Storms or violent winds do not occur as frequently in the inner portions of the icecaps as in other climatic regions, but in some marginal areas there are extreme gales caused by the precipitous descent of cold air from the continental ice plateau.

### 47. Climatic Studies

*a. Records.* Climatic studies are based upon the records of past weather in a given area compiled over a long period of time. They are used in preliminary planning to provide an estimate of the climatic averages that may be expected during the period of the proposed operations. These studies are of particular value in developing new equipment and in anticipating logistical problems. Special climatic studies may be prepared covering winds, rainfall, tides, sea conditions, state of ground, and similar aspects of a specified area. Such studies have been made, for example, to provide data for use in determining—

(1) Location of camps, training areas, depots, and landing fields.

(2) Coastal areas most suitable for amphibious operations.

(3) Operations of aircraft over certain mountainous areas.

(4) Smoke behavior in specified localities.

(5) Seasonal fuel requirements by weight, quantity, and type.

*b. Requests.* Requests for climatic studies should be made as far in advance as possible, and should provide all pertinent information, including mission, area and time, operational limits, flexibility permitted, and the form of presentation.

## Section III. OPERATIONS IN EXTREME CLIMATES

### 48. Desert Regions

*a. Weather.* High summer temperatures are normal in desert areas; the summer maximum may reach 120° to 130°F. During daylight hours the thermal action may be so violent that planes cannot operate safely at lower altitudes. The variation between day and night temperatures is great, the temperature often dropping below the freezing point in winter. These sudden changes in temperature occasionally give rise to winds of hurricane force that carry large quantities of dust and sand. Under these conditions, visibility is very poor and movement may be impossible. Climatic conditions in desert areas also increase maintenance requirements of mechanized units. Rain is infrequent in desert regions, usually averaging less than 25 centimeters (10 inches) a year, but it may come in sudden downpours. Water sources are few, and frequently are polluted and brackish. Usually water for military forces must be transported by tank truck, rail, or pipeline from sources outside the desert area. Winds blow almost constantly in the desert, frequently limiting the use of smoke and other chemical weapons. Minefields may be made useless by the blowing dust and sand. The wind either blows away the sand, exposing the mines, or deposits large quantities of it on the minefield, preventing detonation of the mines. In heavy dust and sandstorms, the operations of mechanized units are similar to those conducted at night.

*b. Natural Features.* There are few landmarks in a sandy desert region. The most prominent features are the huge dunes created by sandstorms (fig. 12). Usually the surface of a sand dune is packed firmly by the wind for a depth of about 5 centimeters (2 inches). This surface will support considerable weight, but detours may be necessary because many of the dunes are high, with steep slopes. Areas of loose sand impede movement on foot or by wheeled vehicles, but tracked vehicles are able to operate in shallow sand. In flat, hard-surfaced areas, roads and trails are not necessary and all types of vehicles can move cross-country. Salt marshes, dry lakes, and wadis (dry streambeds) occur along coastal areas or inland in depressions. Wadis and dry lakes are impassable when wet and contain a powdery silt when they are dry which may cause vehicles to bog down.

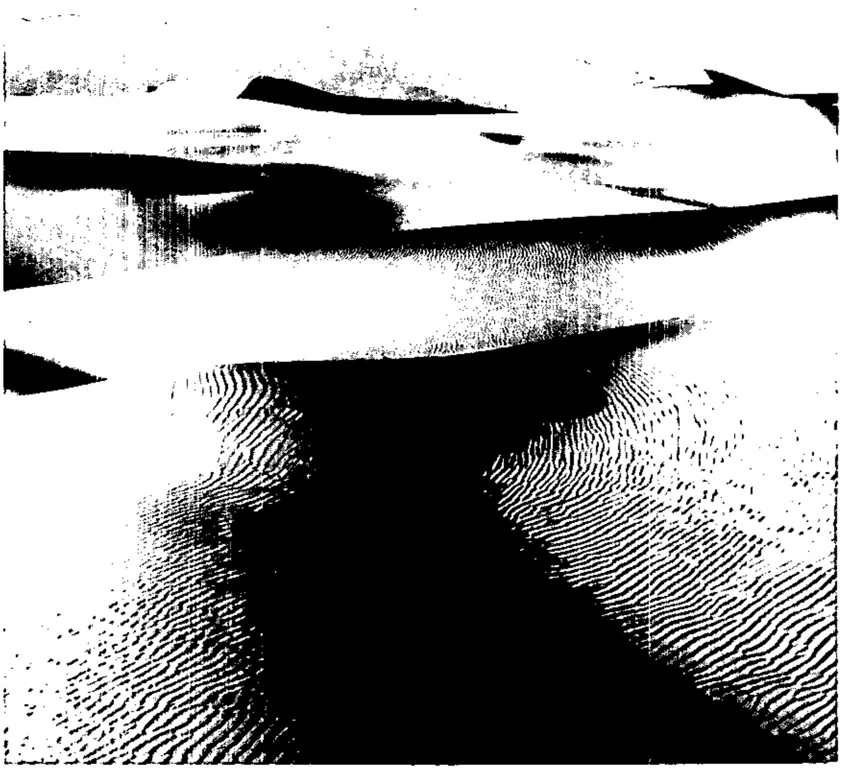


*Figure 12. Sand dunes (Death Valley, California).*

*c. Manmade Features.* Well-defined roads are scarce in desert regions, although there usually are trails between water sources. Occasionally flash floods may cut the routes for short periods of time. Dust and sand storms may prevent traffic through lack of visibility and maintenance difficulties. A surfaced main supply route is essential and usually must be constructed. Road location is difficult and time-consuming, requiring extensive map study and area reconnaissance. Buildings must be strong enough to withstand the frequent high winds and constructed tightly to reduce the infiltration of blowing sand and dust. Field fortifications in sand require adequate strengthening, with a maximum use of sandbags. In rocky deserts, field works can be installed only with great difficulty. Field fortifications are easy to dig in sandy deserts, but they must be revetted, and may be filled quickly with drifting sand.

*d. Military Aspects.*

(1) *Key terrain features.* In desert operations, terrain features usually are not major objectives, since the possession of a particular piece of ground seldom contributes materially to the destruction of the enemy force. Oases and other water sources are always critical, however, because an adequate water supply is a fundamental requirement of military operations in arid or semiarid regions.

(2) *Observation and fields of fire.* The brilliant sunlight of desert areas reflected from the light colored ground surface creates a glare. An observer with the sun to his back may see well, but the glare greatly reduces visibility when he faces toward the sun. He loses his depth perception and will confuse objects which are in shadows or haze. On hot days, a shimmering haze may nullify ground observation at ranges of 450 meters (500 yards) or less, depending on local conditions. An optical phenomenon encountered in desert regions is the mirage, an effect produced by layers of air of varying density across which the observer sees reflections, usually inverted, of some distant object or objects. These occur frequently in summer and are evident in a wide arc which increases as the sun becomes higher in the sky. The effect of a mirage generally is the distortion of objects, particularly in the vertical dimension. This has an adverse effect upon observation, making it particularly difficult to identify vehicles. Distances in deserts are underestimated. Shadows on the light-colored terrain can be seen for miles but tend to distort distant objects. Moonlight in desert areas is much brighter than in other regions and nights usually are very clear, with the haze and glare eliminated. Observation at night may be better than during some periods of the day. In open terrain, sound- and flash-ranging are particularly effective. Artillery observers, however, may find few positions that will allow a commanding view of the terrain. The ability of a weapon to fire effectively in the desert usually is limited only by the range of the weapon and the ability of the observer to adjust fire. There is little vegetation or relief to mask weapons.

(3) *Cover and concealment.* Cover from enemy fire may be afforded by sand dunes, hills, and other irregularities in the desert terrain. Concealment is hard to obtain, since the vegetation is sparse. Camouflage is used more extensively in desert areas than in normal terrain, and reliance must be placed upon artificial means. Camouflage from air or ground observation is extremely difficult to achieve. The movement of troops during daylight is greatly restricted due to the lack of concealment and cover from air attack and troops must be widely dispersed.

(4) *Obstacles.* There are relatively few major obstacles to movement in most desert regions. Although the road net is limited, cross-country movement may be good, varying with the type of surface materials.

(5) *Nuclear weapons.* The ease of dispersion in desert areas avoids a concen-

tration of troops that could provide a profitable target for nuclear weapons. Suitable targets are provided, however, by airfields, communication centers, and supply installations.

(6) *Toxic chemical and biological agents.* Two characteristics of desert regions which limit the employment of toxic chemical agents are the sparseness of vegetation and the extreme variations in ambient temperature. Toxic agents present storage problems because of the wide temperature ranges and the extreme conditions existing during the day. Effective use of toxic chemical agents usually is limited to night. The direct sunlight and dry air which characterize desert regions may present unfavorable environmental conditions for some biological agent aerosols.

(7) *Screening smokes.* Under desert conditions when the winds are still, large-area smoke screening is of considerable importance because of the normal lack of adequate natural concealment and cover.

## 49. Tropical Regions

*a. Weather.* Excessive heat and humidity except in tropical deserts characterize tropical regions throughout the year. In the rain forest type of climate, there is little seasonal variation in temperature. The weather is marked by sudden changes, with torrential rains that end abruptly to be followed at once by bright sunshine. Humidity tends to remain high because the vegetation checks evaporation. Although monsoon areas have a dry season, the total rainfall is so great that rain forest vegetation is dominant. High temperatures prevail in the tropical savanna regions, which have distinct wet and dry seasons; but in most of these areas, grass is the predominate vegetation. Both rainfall and relative humidity are high in the wet season, and rainfall is rare and relative humidity ranges from low to high.

*b. Natural Features.* Military operations in tropical regions are influenced chiefly by the rain forest vegetation. In some areas, such as the Amazon Basin of South America, and in central and west Africa, the rain forest consists of several stories of trees, the foliage of which forms a dense canopy, preventing sunlight from reaching the forest floor, and thus precluding dense undergrowth. In other areas, such as in Southeast Asia and some islands in the Pacific Ocean, where a monsoon climate prevails, the rain forest has a canopy only partly continuous and a dense undergrowth. Rain forest is commonly called "jungle," but the term "jungle" is not recognized as a vegetation type. Terrain covered by the rain forest varies from mountain ranges to low, swampy plains. In Southeast Asia, the Pacific Islands, and parts of Latin America, the rain forest covers irregular terrain. Other rain forest areas, such as those in central Africa and South America, generally are low and level. Some coastal portions of rain forest areas are characterized by mangrove swamps or by open beaches lined with bamboo or coconut groves. Beyond the shoreline there may be paddy fields or pineapple, coconut, sugar cane, or rubber planations. Between these and the rain forest there may be low-lying foothills covered with brush or tall grass. Streams are numerous in rain forest areas, but they are generally muddy and subject to sudden floods. In wet seasons an entire area of flat rain forest may become a continuous swamp. In mountainous areas streams that normally are shallow become torrential shortly after a heavy rain. The characteristics of rain forest terrain and its effects upon military operations are discussed in FM 31–30.

*c. Manmade Features.* There are few roads or trails in rain forest areas. Usually roads must be constructed, and the use of these is limited to light trucks or light tracked vehicles. Except for coral in some coastal areas, there is a lack of materials suitable for road construction. The dense vegetation, unstable soils, and poor drainage make roadbuilding difficult. To establish and maintain a road net of even minimum standards calls for greater engineer effort than in other types of terrain. Navigable waterways often provide the most efficient routes of communication, although they are highly vulnerable to ambush. Bridges suitable for military loads rarely exist in jungle regions. The construction of bridges is complicated by the frequency and intensity of flash floods, the tendency of some jungle streams to shift their courses, and the rapid decay of wooden structural members. Engineers must be prepared to repair or replace bridges rapidly at short notice. Aerial trams are useful because of the deep cuts made by jungle streams in hilly or mountainous terrain. Towns and villages in jungle regions rarely provide suitable facilities for military installations. Usually settlements are avoided for hygienic reasons. Excellent anchorages may be found along many tropical coasts, but there are very few water terminals sufficiently developed to be of any value in military operations.

*d. Key Terrain Features.* In jungle areas, the key terrain features generally are those that provide control of trails, navigable waterways, and beaches suitable for amphibious landings. Possession of the edges of an area of high rain forest could provide observation points, thus giving advantages similar to those derived from the possession of high ground.

*e. Observation and Fields of Fire.*

(1) *Observation.* In rain forest, the dense vegetation often limits observation to short distances. Usually the canopy in a primary rain forest, which consists of a virgin growth of mature trees, is so thick that it cuts off most sunlight, and visibility is limited to about 20 or 30 meters (20 or 30 yards). Visibility may be limited about 5 meters (5 yards) or less in the secondary forest, which is composed of a second growth that develops when the original forest has been burned off or cut. Rain, clouds, and the steamy exhalation from wet areas also tend to reduce visibility. Because of the limited visibility and the lack of conspicuous landmarks, it is often difficult to locate a ground position from a map. Camouflage from close ground observation is of the greatest importance in the rain forest. In most areas, however, there is less need for artificial camouflage against air observation. Whenever possible, the natural overhead is preserved, since any break in the normally uniform tree canopy is readily noticeable from the air. Because observation is limited, tactical units must employ narrow frontages, reduced distances and intervals between elements, increased patrol activity, and a larger number of liaison parties than required in more open terrain. The difficulties of observation greatly restrict the employment of supporting arms and weapons. Artillery forward observer teams on the ground usually cannot see the burst and must adjust fire by sound spotting and sound sensing methods. Aerial forward observers may be utilized with a higher degree of reliability. Data based on maps or photomaps can be used only to a limited extent.

(2) *Fields of fire.* Since natural fields of fire generally are limited to about 5 or 10 meters (5 or 10 yards), lanes must be cleared. Where the undergrowth is heavy, several days of labor will be required to clear 90-meter (100-yard) fire lanes around a position. In order to avoid revealing weapon positions, a fire lane in dense vegetation usually is in the form of a tunnel from 1 to 3.5 meters (1 to 4 yards) wide, with the overhanging foliage left intact. In rain forest, the most effective weapons are those that can be supplied easily with ammunition and are readily transportable over difficult terrain. Suitable weapons include mortars, machineguns, automatic rifles, and grenades. Armored vehicles cannot move through rain forest unless routes have been prepared. Usually the movement of tanks is limited to beaches, coconut groves, clearings, and improved trails. The principal value of tanks is in the use of their flamethrowers, direct fire weapons, and crushing weight in the destruction of enemy field fortifications. Tanks are highly vulnerable to ambush and close in attack in rain forest terrain. Because the heavy vegetation reduces the ef-

fective bursting radius of artillery shells, weapons of 105-mm or higher calibers must be employed to blast away jungle undergrowth and destroy enemy positions. Artillery pieces should be capable of high-angle fire and should be drawn by tractors or transported by helicopters. Engineer equipment must be available for the improvement of trails, construction of firing positions, and clearing of fields of fire. In some mountainous areas, only pack artillery may be practicable. Air forces are effective in close tactical support of ground elements, but their utility for tactical bombing is less than in other types of terrain. Armed helicopters are used extensively in close support of ground forces.

*f. Cover and Concealment*. Rain forest provides concealment from air and ground observation and may furnish some cover from small arms fire. The amount of cover given by slit trenches and other field fortifications is often limited by the high water table, which prevents excavating more than a few feet below the surface of the ground.

*g. Avenues of Approach*. Cross-country movement in rain forest is slow and difficult. Troops may have to cut their way through continuous thick undergrowth or make lengthy detours to avoid impassable swamps. On most trails, troops must move in a column of files, and the average rate of movement rarely exceeds 1.5 km per hour. Usually foot movement may be made most easily on ridges, where the vegetation is more open and the better drainage results in less muddy surfaces. Except for small, fast streams with traversable beds, movement is poorest along the banks of rivers, because of the dense vegetation, mud, swamps, and tributary streams. Even in comparatively dry weather, mud slows down vehicular traffic in the jungles. It may be necessary to supplement motorized transport by the use of helicopters and carrying parties. Jungle roads and trails rapidly disappear unless they are in constant use. Accordingly, maps showing these features seldom are reliable. Air photographs of jungle terrain rarely reveal more than the treetops.

*h. Communications*. Visual signaling is seldom effective in the rain forest because of the dense growth. The use of messengers is slow and may be hazardous. Wire circuits are hard to install and maintain. The range of radio sets may be greatly reduced by the vegetation, resulting in ranges from 40 to 70 percent less than those considered normal in open or lightly wooded terrain.

*i. Toxic Chemical and Biological Agents*. Both the weather and terrain conditions in rain forest areas are favorable for the employment of chemical and biological agents. Where the overhead canopy is very dense, however, sprays from aircraft usually are only moderately effective against personnel. The large-scale use of defoliants will increase the fields of fire of weapons, and provide increased observation.

## 50. Arctic and Subartic Regions

*a. Weather*. Severe changes in weather are common in arctic and subarctic regions. These changes include shifting periods of severe frosts, mild weather, sudden freezing, snowstorms, strong winds, and dense fogs. Reliable and timely weather forecasts are essential to guard against damage to equipment and installations and to gain any tactical advantages that may be possible by exploiting changes in weather conditions. Arctic operations frequently are hindered by strong winds, which usually occur more often along the coast than in the interior. Wind speeds in excess of 128 kilometers (80 miles) per hour have been recorded at coastal stations. Winds blow continually, and in most areas there are no hills, mountains, or other natural barriers to provide protection. Blowing snow constitutes a serios hazard to flying operations. Winds of 16 to 24 kilometers (10 to 15 miles) per hour will raise the snow several feet off the ground, obscuring such surface objects as rocks and runway markers. The short days and long nights of winter reduce the amount of daylight available for tactical operations and work activities. Nights often are bright because of the illumination of the moon, stars, aurora borealis, and reflections from the snow, so that night movements are possible. The short summer nights permit military operations through the 24-hour period.

*b. Natural Features.* Following a heavy snowfall, landmarks and other objects become covered, making orientation difficult. Gullies and ditches are filled and obscured so that movement is made more hazardous. The freezing of swamps and lakes may convert obstacles into avenues of approach for the enemy. Warmer temperatures in spring will create thaws and mud in the subarctic, causing rivers and streams to overflow. In mountainous or hilly country, landslides can be expected in the spring, as the result of boulders and smaller rock formations expanding from the warmth of the thawing temperatures.

*c. Manmade Features.* In the subarctic, routes of communication and transportation are affected by every heavy snowfall and traffic may come to a halt. Strong winds cause snowdrifts requiring a constant clearing of routes, and transportation is slowed greatly by ice and sleet. To avoid these drifts, roads may be routed through woods, where drifts seldom occur, or along the crest of high ground where the snow usually is less deep. In extremely cold temperatures, railroad operation is restricted. Blocked tracks and derailments are frequent; switches often are frozen; snow and rock slides, washouts, and frost heaving damage the lines; and the ice caused by water seepage must be cleared from tunnels before they can be used. Excavation is difficult in either frozen or thawed ground. In frozen ground, handtools are ineffective. Explosives are effective, but they must be employed in quantities greater than required in other terrain. Gravel is easier to excavate than soil, because it has better drainage and accordingly does not freeze as solidly. Foxholes, trenches, breastworks, and emplacements may be provided by digging into the snow or through it into the underlying ground. Snow trenches usually need revetting. In very deep snow, tunnels may be dug to provide concealment. They furnish cover from small arms fire, but do not give protection from artillery fires. The spring thaws in subarctic climates must be considered when planning structures and fortifications. Bunkers, trenches, and other field fortifications must be designed and sited so as to insure good drainage. In the thawing period, roads in low-lying areas and bridges are apt to be washed out. Floating ice will destroy or damage bridges of temporary construction. Runways and landing strips will require considerable maintenance. Airfields that have been improperly designed and constructed may become wholly inoperative for extended periods.

*d. Observation and Fields of Fire.*

(1) *Observation.* Arctic air is exceptionally transparent, providing visibility over long distances. There is a lack of contrast between objects, however, particularly when they are covered by a layer of new snow. Observation in the Arctic is restricted chiefly by fog, blowing snow, and local smoke. The latter is a serious problem only in the vicinity of larger settlements, where it often accompanies the shallow radiation fogs of winter. A radiation fog results from the radiational cooling of air near the surface of the ground on calm, clear nights. Depth perception is adversely affected by arctic conditions, principally by the extremely clear, dry air, the lack of color differences, and the diffusing effect of light on the crystalline surface of the snow and ice. A hazardous phenomenon that reduces visibility to near zero is the whiteout. When this condition exists, the horizon, shadows, and clouds are not discernible, and only very dark objects can be seen. The amount of light reflected from a snowcovered surface is much greater than that reflected from a darker surface, and accordingly the sun provides greater illumination in the Arctic than in other regions. When the sun is shining, sufficient light is reflected from the snow almost to eliminate shadows except in polar areas where the shadows are quite long when the sun is shining. This causes a lack of contrast, making it difficult for the observer to distinguish the outlines of objects even at short distances. The landscape may appear as a featureless grayish-white field. Dark mountains in the distance may be recognized but a crevasse immediately in front of a mountain may be undetected because of the absence

of contrast. There is good illumination from a full moon, and even the stars create considerable illumination. Only during periods of heavy overcast does the arctic night approach the darkness of other regions. A fog condition peculiar to the arctic climate is ice fog. This is composed of minute ice crystals instead of the water droplets of ordinary fog. Ice fog forms in very cold, still air in a shallow layer next to the ground. It is almost always present at temperatures of −45°F to −50°F in the vicinity of a source of water vapor and remains as long as these conditions persist. Where the smoke from building chimneys contributes water vapor to cold, still air, ice fog may form at temperatures as high as −20°F. When the temperature increases rather than decreases with height through a layer of air, it is termed an inversion. The strong temperature inversions present over the Arctic during winter cause several phenomena that affect observation. Sound tends to carry great distances. Light rays are bent as they pass through the inversion at low angles, often causing objects beyond the horizon to appear above it. This effect, termed looming, is a form of mirage.

(2) *Fields of fire.* The fields of fire of automatic weapons are subject to the effects of wind and snow and the final protective line fires may be rendered ineffective by snow drifts. Impact bursts of high trajectory light artillery, mortar, and hand grenade fires are rendered relatively ineffective by the cushioning effect of deep snow; heavy artillery, however, remains highly effective. The employment of proximity or mechanically timed air bursts and overhead fire usually is advisable. Because of the lack of identifying objects and landmarks on snow-covered terrain, the adjustment of fire is difficult. Registration fire with air observation and by sound and flash is hampered, since the snow obscures projectiles and bursts. A round bursting on impact in deep snow appears as a small white splash, making sensing extremely difficult. Because of the cushioning effects of the snow, mines may fail to detonate. The clear air and snow cover may increase the thermal radiation effect of nuclear detonations in flat terrain and snow shelters will be vulnerable to blast effects. Heavy snow and hard-to-maneuver terrain will slow troops in traversing areas contaminated by induced and residual nuclear radiation. When used in deep snow, impact-detonating chemical ammunition burns in the snow and the chemical agent tends to be smothered by the snow. Toxic chemical munitions produce less vapor concentration because of the low temperature and the smothering effect of the snow. On the other hand, low temperatures increase the persistency of toxic chemical agents in both vapor and liquid form. Decay of biological agents is not as rapid in arctic areas as it is in temperate or tropical areas.

*e. Cover and Concealment.* The snow-covered terrain offers few features that provide adequate concealment and cover. Tracks in the snow are almost impossible to hide, and dirt on fresh snow can be observed at a great distance. Due to the high visibility, effective camouflage is difficult. Because of the difficulties of concealment, night movements are frequently advisable.

*f. Obstacles.* During the winter months, the lakes, swamps, and rivers are frozen over and cannot be employed as natural obstacles. Artificial obstacles may be devised by freezing large masses of snow or icecrete (a dense frozen mixture of water, sand, and sometimes, gravel) into desired shapes, or by icing deep drifts. Roadblocks may be made by icing a section of the road, preferably one which the enemy must approach on an upgrade. Tank traps may be devised by cutting the ice on a lake or river, then allowing it to refreeze slightly.

*g. Avenues of Approach.* Winter is generally the best time to travel in the Arctic and subarctic, since the lakes, streams, and muskeg areas are frozen over. Frozen rivers and water ways often become the best routes of advance and lines of communications during the winter months. In general, most vehicles are immobilized in snow from 1 to 1.5 meters (3 to 5 feet) deep. The consistency of the snow, whether it is dry and loose, moist, or packed, affects the mobility of vehicles to a great extent. Tracked vehicles usually can move at low speeds in packed snow that is no more than 1 meter (3 feet) deep. After a packed snow trail has been formed by the passage of several heavy vehicles, normal speeds may be maintained. A thaw or the passage of a great many vehicles on a relatively warm day will melt the snow surface, resulting in a coating of glare ice. The road then becomes practically impassable to tracked vehicles unless ice cleats are installed on the tracks or the road is sanded. Foot movements are slow in 50 centimeters (20 inches) of snow and impossible in more than 100 centimeters (40 inches) deep without the use of snowshoes and skis. Hard-packed snow, however, is not difficult for troops to negotiate. With reasonable care lakes and streams may be crossed by vehicles in winter. The ice first must be checked for thin spots, cracks, and pressure ridges. During the spring thaws, movement in ice and snow across tundra is difficult and dangerous and cross-country movement is practically impossible. After the snow cover has melted from the ground, both wheeled and tracked vehicles can move relatively freely on it as long as the surface remains frozen. This layer of ground that thaws in the summer and freezes again in the winter is termed the active layer. As soon as the active layer has melted, the tundra cannot support heavy concentrated loads and ordinary vehicles will bog down. Even special-purpose vehicles become roadbound during the thaw period and cannot move across the tundra.

# CHAPTER 5

# NATURAL TERRAIN FEATURES

## Section I. SIGNIFICANCE

### 51. Definitions

*a. Topography.* Topography refers to the physical features, both natural and manmade, of the earth's surface. In terrain analysis, the following categories of topographical features are considered: relief, drainage, surface materials, vegetation, special physical phenomena, and manmade (cultural) features. Terrain refers to a consideration of topography in terms of military significance. Weathering and erosion play a major role in shaping natural features (fig. 13). Weathering comprises the effects of the weather elements and erosion includes the action of running water, waves, moving ice and snow, and wind upon rock and soil.

*b. Landforms.* Landforms are the physical expression of the land surface. The principal groups of landforms are plains, plateaus, hills, and mountains. Within each of these groups there are surface features of a smaller size, such as flat lowlands and valleys. Each type results from the interaction of earth processes in a region with given conditions as to climate and as to kind and structure of rock. The indications of relative elevations given are to afford specific definitions for the purposes of this manual. Other distinctions may be found in other references. A complete study of a landform includes determination of its size, shape, arrangement, surface configuration, and relationship to the surrounding area.

*c. Relief.* Relief refers to the irregularities of the land surface. Local relief indicates the difference in elevation between the highest and lowest points in a limited area and the size of this area depends upon the purpose for which the surface is being considered. In terrain studies, it is usually five square miles. Relief features are the individual forms of the land surface, such as hills or ridges and major relief features are plains, plateaus, hills and mountains. Minor relief features include:

(1) *High ground*—swells, knolls, mounds, knobs, hummocks, hillocks, spurs, ridges, buttes, mesas, and dunes.

*Figure 13. Landforms caused by erosion in arid climate (a) Pinnacle. (b) Butte (Grand Canyon, Arizona).*

(2) *Depressions*—gullies, draws, gulches, wadis, ravines, gorges, arroyos, canyons, and basins.
(3) *Breaks in high ground*—saddles, notches, cols, passes, cuts, and gaps.
(4) *Special features*—alluvial fans, talus slopes, talus cones, and boulder fields.

## 52. Military Operations

*a. Influences.* Terrain influences strategy and tactics. What aspects of the terrain are most important at any given time will depend upon the particular requirements of the command concerned. Logistic requirements, for example, may emphasize the importance of communication centers, routes and rail nets, and waterways. The tactics of a large-scale campaign may be dictated chiefly by the barriers imposed by major rivers and lakes, mountains, forests, or swamps.

*b. Attack.* In the attack, the correct use of terrain increases fire effect and diminishes losses. Dominant terrain forms the framework of the system of observation, which in turn directly determines the effectiveness of supporting weapons, the disposition and control of the attacking forces, the selection of objectives, and protective measures. Broken terrain, dense woods, built-up areas, and abrupt changes in elevation hinder the offensive employment of armor but afford cover and concealment for infantry. Open, rolling terrain, although providing little cover and concealment for infantry, is suitable for rapid advances by armored formations. Soil trafficability may be a determining factor in selecting type of attack or an avenue of approach.

*c. Defense.* The nature of the terrain is a major factor influencing the commander when deciding upon position defense or a mobile defense. When the terrain restricts the ability of an attacking enemy to maneuver and provides natural lines of resistance, a position defense may be desirable and of course, terrain that facilitates maneuver by defending forces will favor a mobile type of defense. In selecting the key areas for defense, the commander depends largely upon a terrain study. In addition, a terrain study frequently will give valuable indications of probable enemy assembly areas, field and air defense, artillery positions, observation posts, and avenues of approach.

*d. Retrograde.* In retrograde, good observation and fields of fire permit engagement of the enemy at long ranges. Natural and artificial obstacles are exploited to strengthen defenses, protect exposed flanks, and impede the enemy advance. Concealment and cover are essential for assembly areas and routes of movement. Road nets are exploited to expedite the movement of friendly forces and to facilitate control, and are denied to the enemy for the same reasons. The effects of weather on the terrain influence observation, trafficability, control, and the performance of troops and equipment.

*e. Nuclear.* The maximum effects of a nuclear weapon are subject to many variables, depending on how the weapon is employed. Blast and thermal effects would extend to a greater distance in open terrain, but the missile effect and thermal fires obtained with a certain height of burst could create many adverse conditions, such as tree blowdown, induced radiation, and immediate residual radiation.

# Section II. LANDFORMS

## 53. Plains

*a. Definitions.* As a landform group, plains are generally flat to rolling areas with uplands or interstream areas less than 150 meters (500 feet) above adjacent valley bottoms. A dissected plain is one with a surface that is interrupted by erosional features, and an undissected plain is one with a smooth uninterrupted surface.

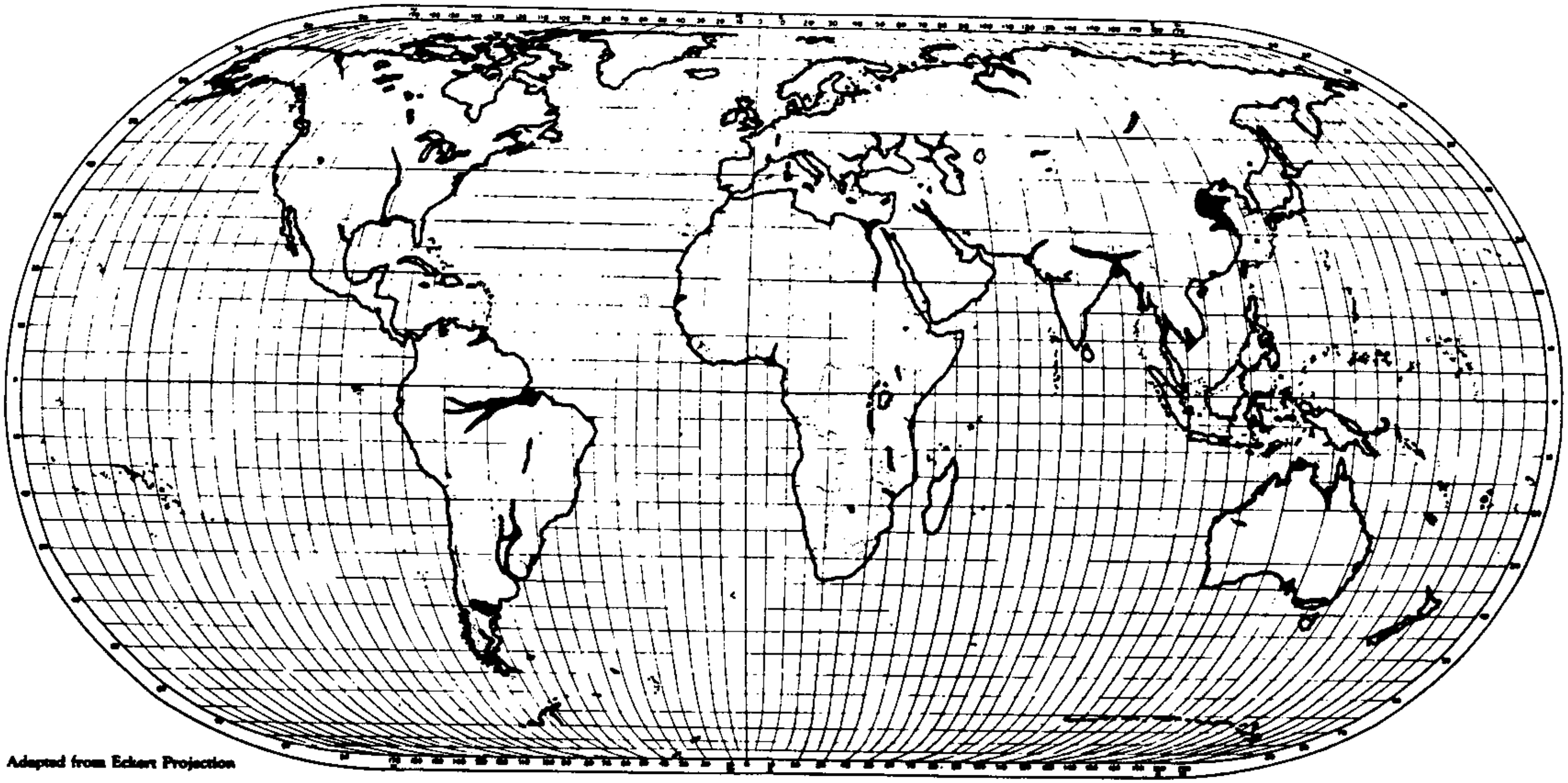
*b. General Characteristics.* Plains may be situated at any elevation. Some are thousands of feet above sea level and others are at sea level. Some are rough and rolling and others are flat. Because of their low degree of local relief, plains generally have low angles of slope. In temperate climates, this characteristic makes them favorable for transportation routes. Where there is monsoon weather or a tropical climate, however, more reliable routes may be provided by higher terrain. The details of relief include uplands and lowlands, ridges and valleys, and hills and hollows, all within local ranges of elevation of 150 meters (500 feet) or less.

*c. Classification.* Plains are classified as—

(1) *Flat.* Local relief of less than 15 meters (50 feet).

*Figure 14. Coastal plain formed by volcanic lava (Hawaii).*

*Figure 15. Outer delta features (Moses Point, Alaska).*



Adapted from Eckert Projection

*Figure 16. Flood plain, terrace, and delta deposits of the world.*

(2) *Undulating.* Local relief of 15 to 45 meters (50 to 150 feet).

(3) *Rolling.* Local relief of 45 to 90 meters (150 to 300 feet).

(4) *Roughly dissected.* Local relief of 90 to 150 meters (300 to 500 feet).

(5) *Slope.* In terms of slope, plains are considered smooth when they have large areas with a slope of less than 2 percent, and rough when there are large areas with a slope of more than 2 percent or many small areas with steep slopes.

*d. Coastal Plains.* These are generally low and featureless (fig. 14). Frequently they have shallow valleys formed by streams that originate inland. Swamps usually are numerous. Cuestaform coastal plains are characterized by long, low ridges alternating with lowlands in bands several miles wide and many miles long generally parallel to the coast. The ridges on this type plain are usually asymmetrical, the steeper slope being inland.

*e. Delta Plains.* These plains, which are formed by sediments deposited at the mouths of streams and rivers, are usually low and marshy, with a local relief of less than 15 meters (50 feet) (fig. 15). The features of greatest relief are the natural levees, which are low, broad banks of alluvium on either side of the stream channels. For protection against stream overflow, artificial levees may be built near the stream on top of the natural levees.

*f. Flood Plains* (fig. 16). These, also called

*Figure 17. Meandering river, showing flood plain and oxbow lakes.*

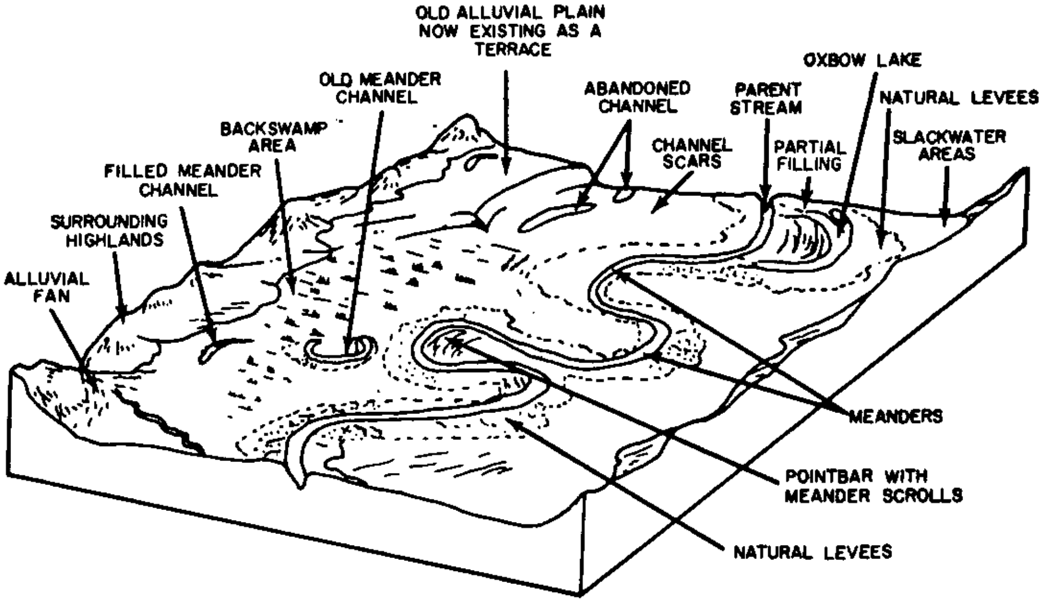



*Figure 18. Flood plain with evidence of pre-existing meander.*

alluvial plains, are formed by weathered and eroded material deposited by streams upon the floors of their valleys. The flood plain usually is poorly drained, and may contain marshes, swamps, lakes, and former stream channels. Unless protected by levees, it may become partly or completely covered by water in times of flood. The surface is flat, the levees alternating with swamp areas. Meandering rivers and crescent-shaped (oxbow) lakes are characteristic of this type plain (fig. 17 and 18). The silts and clays deposited on flood plains make productive soils, and this type plain is used extensively for agriculture.

*g. Piedmont Plains.* These are alluvial plains formed by mountain streams with steep gradients that deposit a sediment, consisting largely of gravel and sand, at the point where the stream enters the lowlands. This type of plain is found in arid and semiarid regions with meager vegetation and torrential rains. Although the plain may appear level, actually it slopes away from the mountain base. Many piedmont alluvial plains are covered only with shrubs or sparse grasses. Those with fine soils are high in mineral plant foods and, if irrigation water is available, they are suitable for agriculture.

*h. Glacial Plains.* These (fig. 19 and 20) are classified as either ice scoured or drift plains.

(1) Ice-scoured plains are level to gently rolling areas composed largely of bare rock. They are characterized by rounded rock hills and broad open valleys and basins with comparatively low local relief. Over the valley floors there may be a thin covering of glacial debris which serves as an anchorage for shallow-rooted trees, chiefly conifers. There are numerous falls, rapids, and lakes. Some small shallow lakes become filled with remains of marsh vegetation, such as sphagnum moss, creating bogs of the type called muskeg in Canada.

(2) Drift plains consist largely of boulders, gravel, sand, or clay in layers of varying thickness on top of other strata of rock and soil. The principal characteristic is a gently undulating surface which includes broad, low hills, or swells, and wide, shallow depressions, or swales. Commonly the local relief is less than 30 meters (100 feet). Large areas of drift plains are essentially flat, with poorly developed natural drainage. Although soils are generally heterogeneous mixtures,

*Figure 19. Glacial plain (Moose Jaw, Saskatchewan, Canada).*

areas of impervious clays are common. After heavy rains, ponds several acres in extent may form; and unless artifically drained, the water may stand until it evaporates. In some localities there are hills of clayey till called drumlins (fig. 21) that occasionally reach heights of more than 30 meters (100 feet) and may be a mile long. Streams in this type of plain may be interrupted by swamps, lakes, falls, or rapids.

*i. Lacustrine Plains.* These are formed by sediment settling on lake bottoms. Subsequently the lake was drained by natural forces, or evaporated because of a major change in climate. They are level and often contain salty or alkaline lakes. Generally they are characterized by poor drainage and alkaline soils.

*j. Loess Plains.* These are formed by windblown particles of silt, called loess, which have been deposited over large areas, forming a smooth, gently sloping surface. The ability of loess to stand in vertical walls results in steep escarpments along gullies, stream valleys, and artificial cuts (fig. 22).

*k. Karst Plains.* These (fig. 23) are a type of erosional plain developed on limestone. They have a pitted surface along with exposed bedding plain edges (pinnacles) tilted through the surface. The pitting is formed from subsurface collapsing due to the solvent action of underground water. Between the depressions there are low, irregular ridges or hillocks. Numerous caverns are formed beneath the surface of a karst plain, and there are also large underground streams which may issue at the surface as springs of considerable volume.

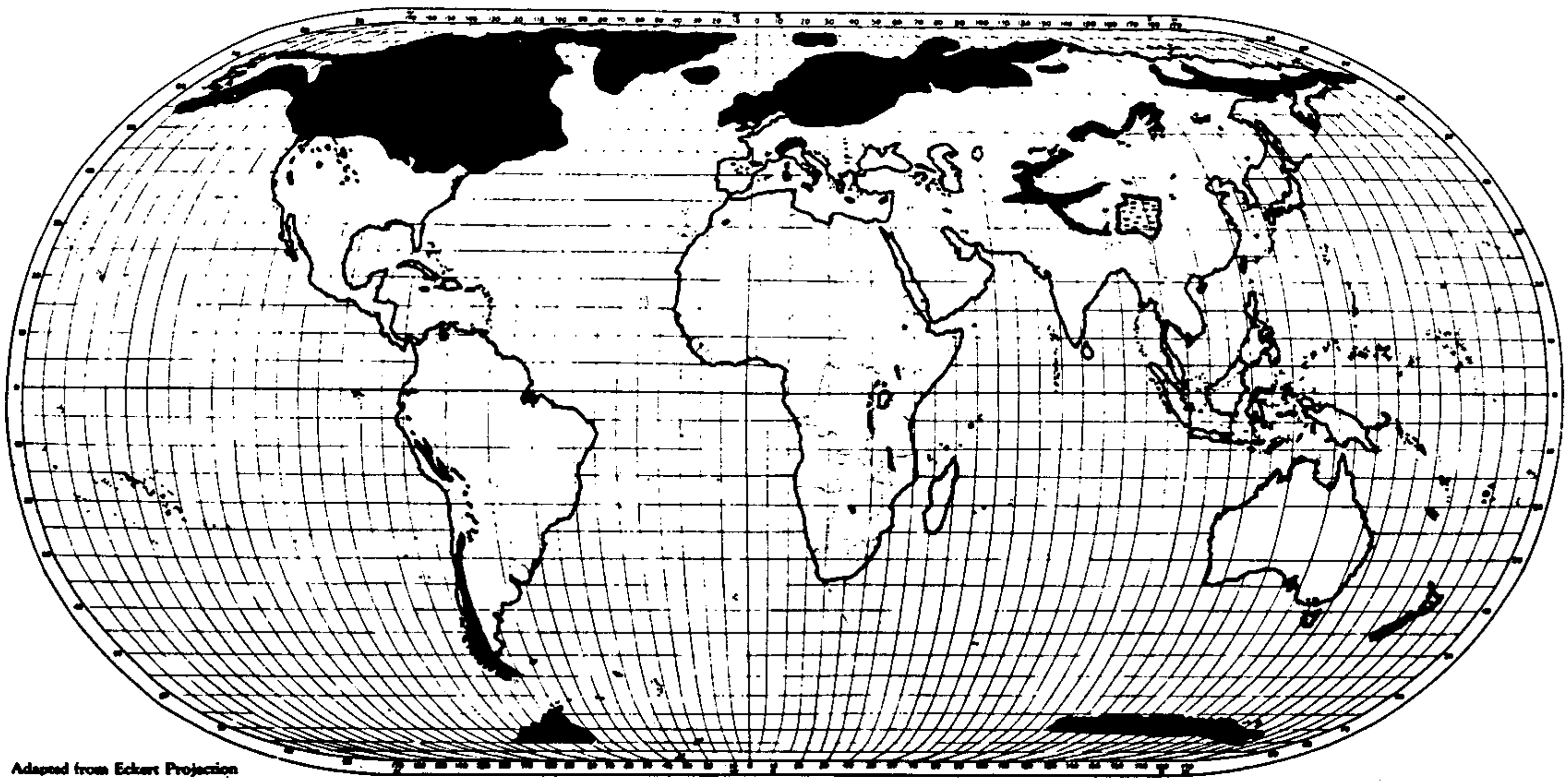
## 54. Plateaus

*a. Description.* A plateau is commonly bordered by an escarpment or steep slope on at least one side. The plateau surface may be cut by deep, narrow stream valleys, but the interstream areas are mostly broad and nearly level. Tabular uplands with a local relief of more than 150 meters (500 feet) may be considered plateaus. They vary greatly in configuration, but most have broad flat surfaces high above sea level, and are deeply trenched by narrow valleys. Depending upon the stage of the erosion cycle, the valleys that dissect the plateau may be widely spaced early in the cycle or very closely spaced late in the cycle (fig. 24). Most large plateaus are in regions with arid or semiarid climates. Plateaus may be classified into three major types:

(1) *Intermountain* (fig. 25). Surrounded or nearly surrounded by mountains.

(2) *Piedmont.* Lying between mountains and plains, or between mountains and the sea.

(3) *Continental* (fig. 26). Rising abruptly from bordering lowlands or the sea on most or all margins; usually without conspicuous mountain rims.



Adapted from Eckert Projection

*Figure 20. Glaciated areas of the world.*

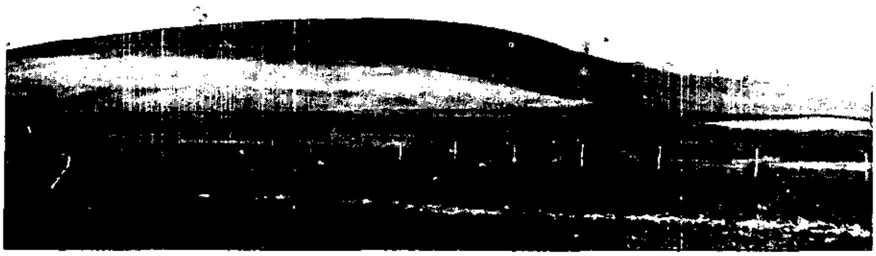


*Figure 21. Drumlin (New York).*

*b. Climates.* In arid climates, streams usually flow in canyons cut into the plateau, the typical canyon having a narrow bottom offering little space for a roadway. The stream is seldom navigable and follows a steep, boulder-strewn course interrupted by rapids and falls. Sudden and extensive changes in stream level are common. Canyons usually are too deep to be crossed easily and too wide to be bridged economically. They rarely provide a transportation route and are a difficult obstacle to movement. Areas between the streams usually are flat or rolling uplands, some of vast extent. Areas of interior drainage called bolsons exist on some plateaus. The streams empty into these, resulting in level areas that may contain large salt lakes or salt marshes. Plateaus in humid climates tend to be more dissected by stream erosion than those in arid climates. Broad divides with rounded and irregular uplands are common.

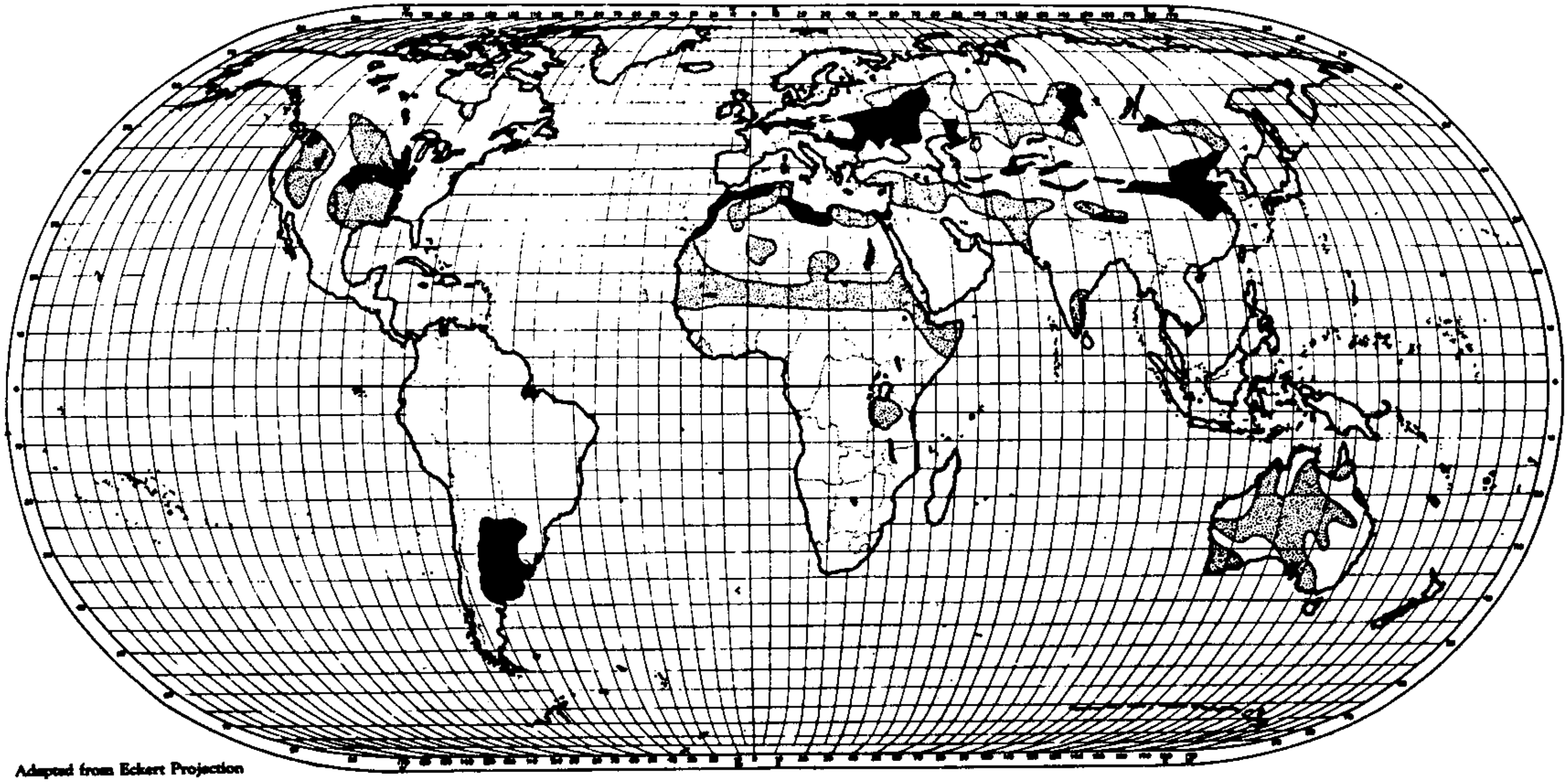
*c. Ice Plateaus.* The vast sheets of ice that cover most of Greenland and Antarctica may be regarded as great plateaus. Greenland is an intermontane plateau, surrounded by a fringe of mountains. In most of Antarctica, the ice rises in a sheer wall, then slopes up rapidly to a fairly level interior with an average elevation of about 1,830 meters (6,000 feet), the maximum elevation of 3,050 meters (10,000 feet) being found in regions inland from the Pacific coast. In general, the surfaces of an ice plateau are flat or have parallel ridges a few feet in height which result primarily from the wind and drifting snow.

(1) *Marginal features of Greenland.* The highland or mountainous rim and the higher summer temperatures of Greenland produce marginal features which are different from those of Antarctica. The ice is confined by the highlands, melting some distance inland on the southern and western margins. Where ice does not discharge into the sea, it protrudes through gaps in the bordering highlands (fig. 27). Irregular icebergs form, drifting into the Atlantic Ocean during the spring months.

(2) *Marginal features of Antarctica.* The marginal ice of Antarctica is thin and traversed by deep cracks. Except in a few localities where it is retained by the fringing mountains, the ice overruns the land margins, so that the exact position of the continental shoreline is not known. The edge of the ice is marked by sheer cliffs. From these cliffs giant icebergs split off along crevasses as a result of undercutting by waves and the buoyant effect of sea water. Some of these are tens of square miles in area. The icebergs disintegrate by melting and disperse as masses of floe and drift ice which fringe the continent for many miles.

## 55. Military Effects of Plains and Plateaus

*a. Variety.* Although plains and plateaus are characterized by relatively low relief compared to hills and mountains, they present a wide variety of topographical conditions. Since each type of plain or plateau differs in its features and effects, one can only generalize about their influences on military operations.




(STIPPLING INDICATES SCATTERED AND/OR SHALLOW DEPOSITS)

*Figure 22. Loess deposits of the world.*

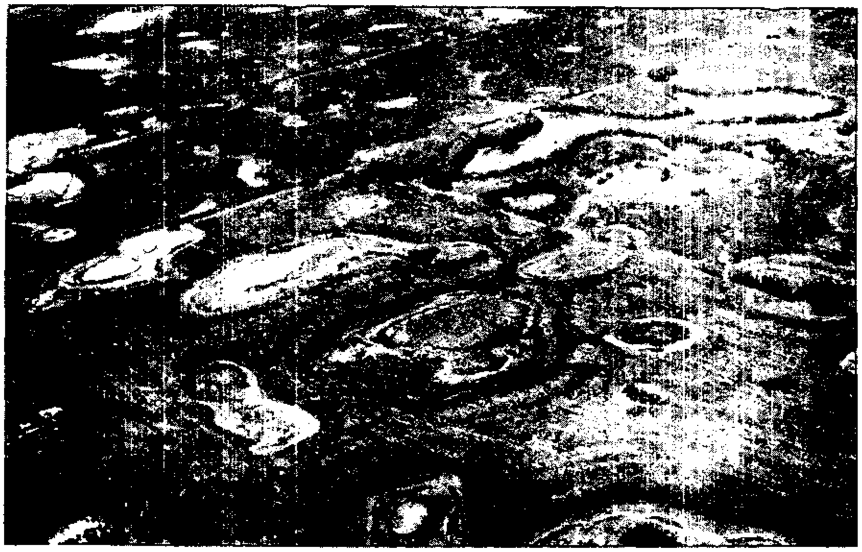


*Figure 23. Karst plain (Canada).*

*Figure 24. Plateau dissected by stream (Deschutes River, Oregon).*

*b. Movement.*

(1) *Coastal plains.* In general, the topography of coastal plains offers no major obstacle to the cross-country movement of tracked vehicles, although there may be areas that are difficult or impracticable because of unfavorable soil conditions and dense vegetation in areas of medium to heavy rainfall. Movement along an indented shore usually is difficult because the terrain is separated into compartments by streams and estuaries. Cross-country movement in-

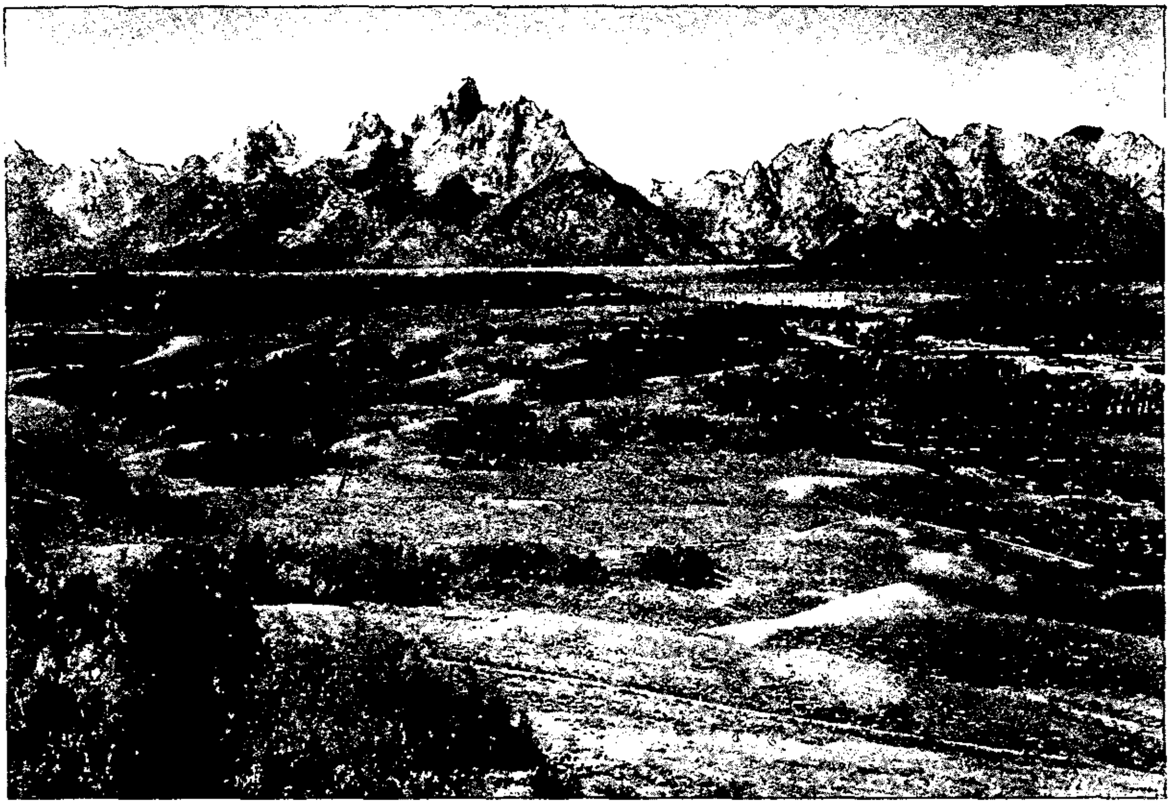


*Figure 25. Intermountain plateau (Jackson Hole, Wyoming).*

land may be limited to narrow areas bordered by water. In such terrain, attacks may require amphibious support. Coasts with beach ridges hinder an advance inland because vehicles must cross poorly drained areas between relatively stable sand ridges. Terrain of this type impedes the adequate dispersal of troops and supplies.

(2) *Delta plains.* On delta plains cross-country movement usually is hindered by marshy ground, shifting streams with loose sand and mud bottoms, and thick vegetation. Soils are better drained in the inner regions of the delta. Normally the natural levees of streams provide the highest, best-drained, and most trafficable parts of the delta. Movement on the low-lying grounds of delta plains is always threatened by the possibility that the enemy will destroy dikes or levees and flood the area. The use of waterways as avenues of approach by the enemy must not be overlooked.

(3) *Alluvial Plains.* The stream valleys in alluvial plains generally provide corridors through areas of greater relief. In dry weather, the cross-country movement conditions usually are excellent, except for such obstacles as streams and local areas of unfavorable soil or dense vegetation. In wet weather or during floods movement may be limited to small areas of higher, better-drained ground, such as levees. Alluvial terraces are above flood levels and may be well-drained, but they are commonly isolated by steep slopes. It is not unusual for a stream to meander from one side of its valley to the other. If the valley slopes are steep, such meandering may eliminate vehicular movement up or down the valley.

(4) *Glacial plains.* The topography of

*Figure 26. Eroded continental plateau (Grand Canyon, Arizona).*

glacial plains usually presents no insurmountable obstacles to movement. Large boulders may be obstacles in some area. In regions containing large areas of soft ground, lakes, or marshes, movement in the rainy season may be greatly hindered by mud (fig. 28).

(5) *Lacustrine plains.* No topographic obstacles to movement are offered by the level surface of lacustrine plains (old lake beds). During wet weather, however, the fine soils may be slow-drying and become nontrafficable (fig. 29).

(6) *Loess plains.* Loess is a fine-grained, yellowish-brown silt deposited by the wind. In dry weather, movement conditions on loess plains are good, except where escarpments and ravines

*Figure 27. Tongues of icecap descending toward fiord (Greenland).*

are encountered. Ground conditions may become very poor in wet weather, making cross-country movement impracticable.

(7) *Karst plains.* Movement on karst plains, a limestone region, is limited chiefly by the sinkholes, which may have steep slopes and contain swamps and ponds. In wet weather the clayey residual soil overlying the limestone may limit movement in some areas. Karst regions vary greatly in their characteristics—from a plain with an occasional sinkhole to a surface so pitted and broken as to make even dismounted movement very difficult. Knowledge of the erosional development is necessary to evaluate such an area properly.

*c. Observation.* The degree of observation available on coastal plains is normally good along the coastline, but inland the flat country and forest cover usually offer few observation points. Observation is limited on delta plains because the low, level ground generally is covered thickly by vegetation. On alluvial plains, observation from the valley bottoms usually is poor, but the bordering regions provide commanding views into the valleys. Where vegetation does not interfere, it may be good on the more level portions of these plains. Vegetation also determines the amount of observation that may be secured in lacustrine, loess, and karst plains.

*d. Cover and Concealment.* Coastal plains provide few areas with sufficient cover and concealment for larger units. Except for the levees, there are also few topographic features on delta plains that will conceal or protect troop bodies of any size. Little cover and concealment are available on alluvial plains, except for that provided along terraced scarps, river banks, and levees. On glacial plains, cover is lacking in the more level parts, but there may be some limited cover and concealment provided by knobby and forested areas. The sinkholes of karst plains also provide a moderate degree of concealment and cover.

*e. Construction.*

(1) *Coastal plains.* Although generally there is no hard rock on coastal plains, sand and gravel are abundant on beaches and along streams. The ground of coastal plains is excavated easily, but the depth of excavation usually is limited by the high water table. Long and straight road aline-

*Figure 28. Glacial boulders (Yosemite National Park).*

ments normally can be obtained. There are many suitable sites for airfields, particularly along the marine terraces.

(2) *Delta plains.* Abundant sand and fine binder material may be obtained on delta plains, but gravel is scarce. There are no exposed hard-rock formations or bedrock. Generally the location of airfields and roads must be confined to the levees. Structural foundations not built upon levees are unreliable, and may settle due to the low, poorly-drained ground with a threat of periodic flooding. Drainage always is a serious problem because the levees prevent the return of surface water to the river, and the high water table limits underground return. Accordingly, drainage and pumping systems may be required.

(3) *Alluvial plains.* Rock is scarce in flood plains except where it may crop out along the scarps of terraces. Sand, gravel, and binder material are abundant along stream channels and the terrace scarps. Terraces also may provide suitable sites for bunkers and underground installations. Excavations in flood plains are limited by the high water table, but these plains and terraces if well-drained are suitable for the construction of roads and airfields.

(4) *Glacial plains.* Sand and gravel are

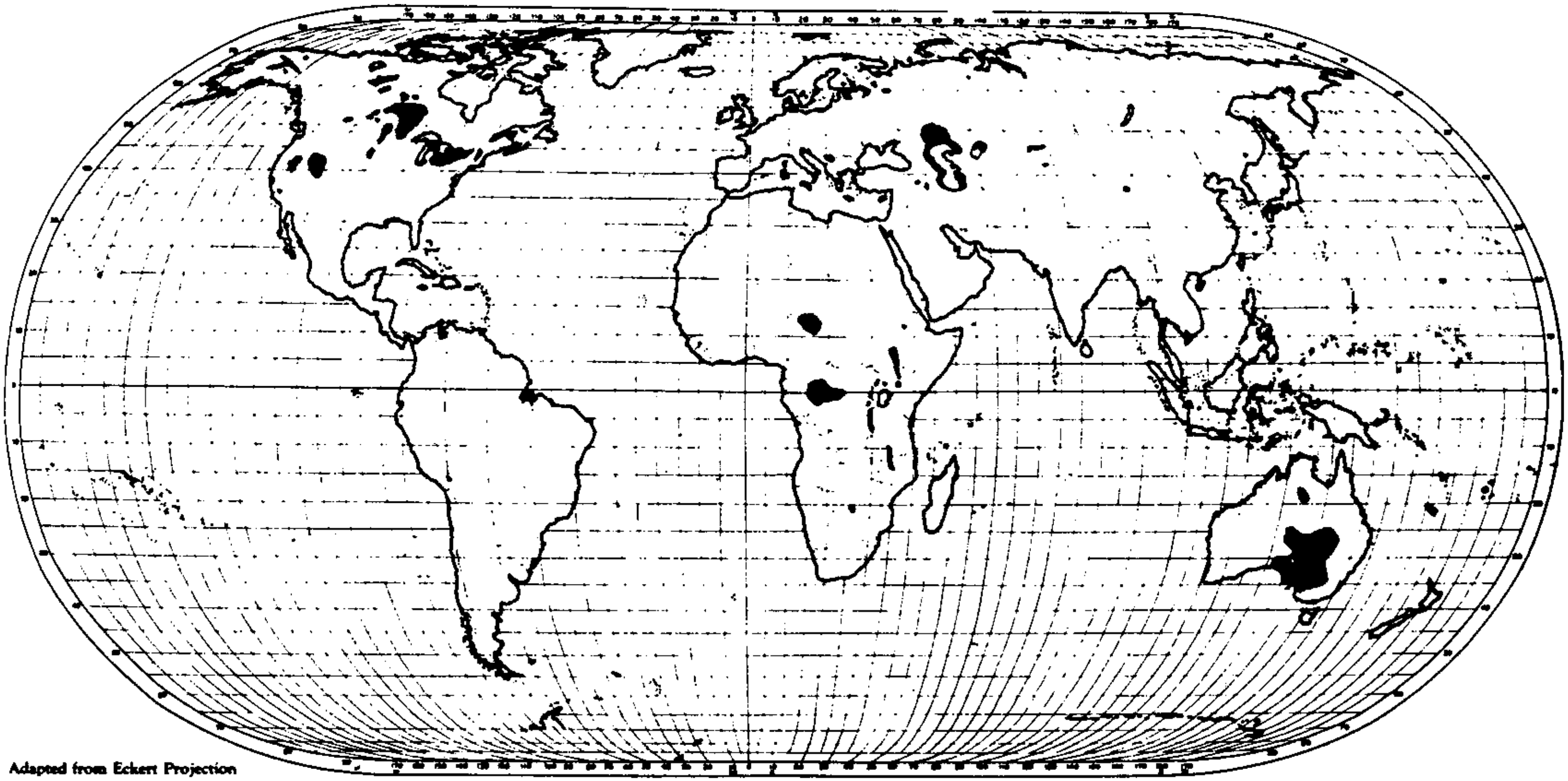



*Figure 29. Lake bed and related deposits of the world.*

widely distributed on glacial plains, and rock usually is abundant. On till plains, boulders may provide building stone, but there is bedrock only in a few locations, such as in deep valleys where the overlying till has been cut through. Wet ground and weak soils may create foundation problems where the drainage is not good.

(5) *Lacustrine plains.* Except at the marginal slopes, where sand, gravel, and rock may be obtainable, lacustrine plains usually can provide only clay and fine sand for construction purposes. The fine-grained soil makes a poor foundation for structures, particularly in humid climates. Lacustrine plains provide level sites for airfields with few natural obstructions and allow unrestricted road alinements.

(6) *Loess plains.* Loess plains are a poor source of gravel or rock, except where there are underlying deposits. Foundations require stabilization and in cold climates the loess may heave. In dry climates, thick loess deposits are easily excavated and are well suited for underground installations. Many good airfield sites and road alinements usually are available.

(7) *Karst plains.* Large quantities of limestone for building stone and crushed rock may be obtained on karst plains. Sand and gravel usually are lacking. Excavation often is difficult because of the irregular rock surface, with deep clay-filled pits, and the high pinnacles of rock that lie beneath the residual soil. Grading usually requires the excavation of rock. There is always a possibility of foundation subsidence.

## 56. Information Requirements — Plains and Plateaus

*a. Plains.*

(1) Extent of area covered by plain.

(2) Surface (elevation, slope, kind of surface).

(3) Major interruptions (hills, mountains, river valleys).

(4) Minor interruptions (gullies, sinks, levees).

*b. Plateaus.*

(1) Area covered by plateau.

(2) Surface (elevation, slope, surface, relief features).

(3) Major interruptions (hills, mountains, canyons, valleys).

(4) Margins (mountains above plateau, abrupt descending cliffs).

## 57. Mountains

*a. Description.* As a landform group, mountains are rugged areas with crests that are, in general, more than 600 meters (2,000 feet) above adjacent lowlands. They are commonly distinguished from other major relief features by the predominance of slopes and their overall massiveness. In terms of local relief, mountains may be classified as low when they have a local relief of 900 meters (3,000 feet) or less, and high when their height exceeds that figure. According to their size and arrangement, mountain features may be classified as peaks, ranges, chains, and cordilleras.

*b. Peaks.* A peak is a conical high mass, that rises above its surroundings. Ordinarily a peak is a feature of minor order upon a range, but as in the case of an isolated volcanic cone, one peak may stand alone and comprise the entire mountain mass.

*c. Ranges.* A range is an arrangement, usually linear, of many peaks, ridges, and their valleys. The term ordinarily applies to mountains that have a general unity of form, structure, and geologic age.

*d. Mountain Chain.* A mountain chain consists of several associated ranges, usually more or less parallel, having unity of position, form or structure, but separated by trenches or basins.

*e. Cordillera.* A cordillera is a large regional grouping of mountain chains.

## 58. Mountain Features

*a. Relief.* Mountains are distinguished from hills by their greater relief, more rugged contours, and more complicated surface patterns. The average slope of large mountains seldom is more than 20° to 25° from the horizontal, and only a few have slopes of more than 35° near the summit. Even walls that seem vertical seldom have slopes that average more than 70°.

*b. Valleys.* Except where they have reached grade level and meander in flat alluvial valleys, mountain streams have high gradients and flows of high velocity. The rapid downward cutting action of the stream may uncover bedrock of unequal hardness, so that falls and rapids develop. Some streams, in cutting through bedrock of unequal resistance, erode valleys which are broad at their headwaters, then narrow to gorges, and subsequently open out again downstream. Valleys formed by glacial action have wide rounded bottoms and steep sides. They have U-shaped profiles, in contrast to the V-shaped profile of a stream eroded valley. The walls are steep and rugged. Most glaciated valleys have one or more basins in which impounded drainage creates lakes, ponds, or marshes.

*c. Divides.* Between the mountain valleys there are uplands formed by remnants of the original elevation. Rainfall on these uplands separates according to the surface slopes and descends by numerous rivulets into adjacent valleys, modeling the uplands as it flows. The uplands are called divides. When they separate the drainage destined for opposite sides of a continent they are termed continental divides.

*d. Foothills and Spurs.* The lowest and least massive features of mountain uplands are the foothills and spurs that fringe the principal highlands. Foothills are hills located at the base of higher mountains or hills. A spur is a ridge projecting laterally from the main crest of a hill or mountain.

*e. Passes.* The erosion by streams or glaciers creates saddle shaped notches, or passes, in a mountain barrier. The term pass is applied to any type of natural passageway through high, difficult terrain.

## 59. Hills

As a broad landform group, hills are rough areas with crests generally from 150 to 600 meters (500 to 2,000 feet) above adjacent lowlands. They usually contain a predominance of moderate slopes. Hills may be classified as low when they have local relief of from 150 to 300 meters (500 to 1,000 feet), and high, when the local relief is from 300 to 600 meters (1,000 to 2,000 feet). Some very rough hills may appear mountainous in relation to adjacent plains, and locally may be called mountains, but they are not properly of a size or nature to merit the term. Mature hill lands may be almost entirely a succession of hills, valleys, and narrow ridges, with level land occupying less than five percent of the total area. Hill regions in an early stage of erosion may include some fairly level, plateaulike uplands separated by steep-sided valleys. Those in a more advanced erosional stage may have broad open valleys and reduced slopes that are suitable for agriculture. Because some of the slopes in hill regions are steep and untillable, they have retained their forest cover and have streams with steep gradients that are capable of developing waterpower.

## 60. Military Effects of Hills and Mountains

*a. Key Terrain Features.* In both attack and defense, the key terrain features may include the heights which dominate valleys, the routes of communications, passes and valleys which permit cross-country movement through the mountains, and aircraft landing areas. Dominating heights which may be used by the enemy for observation of avenues of approach must be controlled.

*b. Observation and Fields of Fire.*

(1) *Observation.* In hilly and mountainous areas, observation may be restricted. In most cases, commanding heights provide only partial observation of adjacent valleys and slopes. Foothills and spurs extending into a valley obscure observation along the valley.

(2) *Fields of fire.* Mountains and hills place some restrictions upon the em-

ployment of supporting weapons. Armor loses much of its mobility because it cannot move across country. Occasionally tanks can be used in small numbers against limited objectives, but their action often is confined to providing direct fire support. Artillery is effective, but the limited visibility in mountainous terrain restricts observation and adjustment of fire. Terrain features may also reduce the effectiveness of air defense artillery by making radar siting difficult and reducing the target acquisition range of the system. Survey and fire control are hampered, and more time is required for artillery to displace. There is difficulty in finding gun positions that do not have too much defilade. The heavier crew-served weapons of the infantry and their ammunition are difficult to carry over the rugged terrain. Mortars and recoilless rifles are effective and are favored for operations in mountains and hill regions. Deep valleys and ravines afford a degree of protection from the blast effect of nuclear weapons when the axis of the valley or ravine points well away from ground zero. When it does not, there is little or no shielding effect, and blast damage may be increased because the blast is canalized. Deep valleys and ravines afford substantial protection from thermal and nuclear radiation to troops, materiel, and buildings located within the shaded portions. In terrain characterized by deep valleys and ravines, however, blast effects of nuclear weapons may cause serious avalanches and rock slides. Concentrations of toxic chemical agent aerosols are extremely hard to achieve on marked downward slopes. Toxic chemical agents and biological agent clouds tend to flow over rolling terrain and down valleys, to remain in hollows and on low ground and in depressions, but to go around obstacles. Local winds, coming down valleys at night or up valleys in the daytime, may deflect the clouds or reverse the forecast flow; likewise they may produce favorable conditions for cloud travel.

*c. Cover and Concealment.* The rugged topography of mountains offers abundant cover and concealment, although movement across slopes or crests above the timberline will be exposed. Sounds carry from valley bottoms to hilltops, but within the valley, sounds are muffled by ground forms and streams.

*d. Obstacles.* Major obstacles to movement include steep, high ridges and ranges, high valley routes and escarpments, sloping cliffs and terrace faces. Minor obstacles include stream embankments, valley terraces and benches, spurs, talus, and debris-choked valleys, and presence of boulders.

*e. Avenues of Approach.* Hills and mountains parallel to the axis of advance offer flank protection, but limit lateral movement. When perpendicular to the axis, they are an obstacle to the attacker and an aid to the defender. Mountain roads must be improved because the roads are generally narrow, have steep grades, and poor surfaces. Sharp turns may prevent the use of trailers. Roads in valleys or along defiles require that the adjacent high ground be secured to insure control of the roads. Mountain roads are subject to slides and may be blocked by snow. Those on the crest of ridges may be exposed to enemy observation. Roads in defiles may be flooded and may also have large boulders. The best sites for military roads in mountain areas are normally on the sides of slopes.

*f. Communications.* Hills and mountains contain dead spaces that often limit the range and effectiveness of radios, although these restrictions usually can be overcome by the use of relay sets. Wire laying is difficult, and visual signals are not always dependable and often can be seen by the enemy.

*g. Air Support.* The hazards in mountainous regions place limitations upon the use of low-flying combat aviation. Targets are difficult to locate and in many cases close air-support strikes must be controlled by aerial FAC's (Forward Air Controllers) or by indirect means, since the functions of tactical air-control parties are hindered by the terrain and weather.

*h. Combat.* Combat in mountains and hilly areas usually consists of a series of independent actions to seize and hold key terrain, strike communication lines, and protect friendly routes of supply and evacuation. Infantry plays the dominant role, since it is not roadbound and can close with the enemy under any condition of terrain. Commanding positions in mountain terrain are often rocky ridges or eminences with little or no soil. If the importance of the position justifies the time and effort required, trenches, emplacements, and galleries can be cut into the solid rock. Parapets and breastworks of cobbles and boulders are effective against small arms, but they are vulnerable to artillery fire. Log breastworks and protective shelters may be built if timber stands are conveniently located. Mines and obstacles find their most important use in obstructing movement on roads and trails and through defiles. Roadblocks are effective because of the difficulty of bypassing them. Mountain terrain favors the defender because available obstacles enable him to use minimum troops to deny the attacker the use of existing routes. He can force deployment of major enemy units and the expenditure of large amounts of mortar and artillery ammunition, and can inflict the maximum punishment from protected positions.

*i. Construction.* Hard rocks suitable for construction purposes are readily obtained in hills and mountains. Sand is scarce, but gravel may be secured in the lower stretches of streams where they approach the foot of the mountains or flow through hills. There are few suitable locations for airfields because of the difficulty of excavation in rock, the obstructed and limited approaches, the poor accessibility, and the turbulent air currents. Highways, railways, and tunnels are vulnerable in these areas. Geologic data may be useful in indicating rock conditions favorable to initiating rock slides by bombing or artillery fire to block enemy lines of communication. Geological information will also assist in selecting sites for gun emplacements and other fortifications, in estimating the probable effect of fire on rock fragmentation, and determining the possible ricochet effects of projectiles. The soil usually is thin or stony, with underlying bedrock, so that it is difficult to construct field fortifications. Geologic study will assist in selecting areas where excavations may be made and in choosing the required explosives and equipment.

## 61. Information Requirements — Hills and Mountains

*a. Extent and Type of Mountains or Hills.*

*b. Ridge Crests.*

(1) Location and orientation.

(2) Elevations (typical, highest, lowest).

(3) Height above adjacent valley flats (average, highest, lowest).

(4) Pattern (long straight, parallel ridges; branchlike and crooked ridges; clusters of knobs and peaks).

(5) Skyline (flat-topped and broad, or knifelike).

*c. Slopes.*

(1) Shape (convex, concave).

(2) Angle, in percent or degrees (near crest, middle, near base).

(3) Minor relief features (rough lava, boulder fields and gullies).

*d. Valley Flats.*

(1) Location.

(2) Width (of main and tributary valleys; average, widest, narrowest for both categories).

(3) Pattern (long, straight, and parallel valleys or branchlike and crooked valleys).

(4) Transverse profile (degree of slope near center and margin of valley).

(5) Longitudinal profile (degree of slope near mouth and head of valley).

(6) Terraces (benchlands) along borders of valley flats (number of terrace steps, width, continuity, elevation of steps one above another, slope between terrace levels).

(7) Stream channels within valley (straight or meandering, bordered by bluffs, gentle downslopes, or natural levees).

*e. Intermontane Basins.*

(1) Location.

(2) Width (average, widest, narrowest).

(3) Shape (round, oval, long and narrow, irregular).

(4) Flat bottom lands (extent and location).

(5) Terraces (benchland) about borders of flat bottom lands (number of terrace steps, width, continuity, elevation of steps above one another, slope between terrace levels).

*f. Passes.*

(1) Location.

(2) Elevations (average, lowest, highest).

(3) Number of passes (distance between passes).

(4) Gradients (near head of pass, downslope).

(5) When closed by ice and snow.

(6) Character of defile formed by pass and approaches (width, length, character of slopes).

(7) Routes over each pass.

## Section III. DRAINAGE

### 62. Effects of Drainage

*a. Description.* The water features of an area comprise its drainage. They include streams and canals; drainage and irrigation ditches; lakes, marshes, and swamps; artificial bodies of standing water such as reservoirs and ponds, as well as such subsurface outlets as springs and wells. The character of these drainage features is determined by precipitation, relief, surface runoff and ground-water flow, and various manmade improvements. Vegetation has a major influence upon drainage. Dense grass and tree growth on slopes tend to slow up and absorb a considerable amount of the runoff, but slopes with few trees and sparse vegetation permit rapid runoff and the formation of channels by erosion.

*b. Catchment.* A catchment basin or catchment area is the total area drained by a stream or system of streams. All water features within this area are related and are considered as a whole. The limits of the drainage basin are marked by the topographic divide which separates it from neighboring drainage systems. The amount of water reaching the stream, reservoir, or lake depends upon the size of the area, the amount of precipitation, and evaporation and transpiration. The rate of evaporation depends upon the temperature, vapor pressure, wind, and solar radiation.

*c. Patterns.* Drainage patterns (fig. 30) reflect the subsurface structure. They are of three major types—dendritic, trellis, and radial defined as follows:

(1) A *dendritic* drainage pattern is a treelike arrangement of streams found most frequently in an area underlain by homogeneous rock.

(2) The *trellis* pattern results from the influence of tilted alternating strata of weak and resistant rocks. The resistant strata separate each stream, producing the overall trellis effect.

(3) The *radial* pattern has streams that radiate from a central dome that lies within a relatively flat area.

### 63. Rivers and Streams

*a. Perennial Stream.* A perennial stream flows throughout the year. The regular flow may result from a spring lake or a glacier at the head which furnishes a constant supply of water, from direct precipitation of fairly constant quality, or because the beds are deep enough to be permanently below the fluctuating upper level of the ground water or water table.

*b. Intermittent Stream.* An intermittent stream originates in a source of water that fails periodically and is particularly common

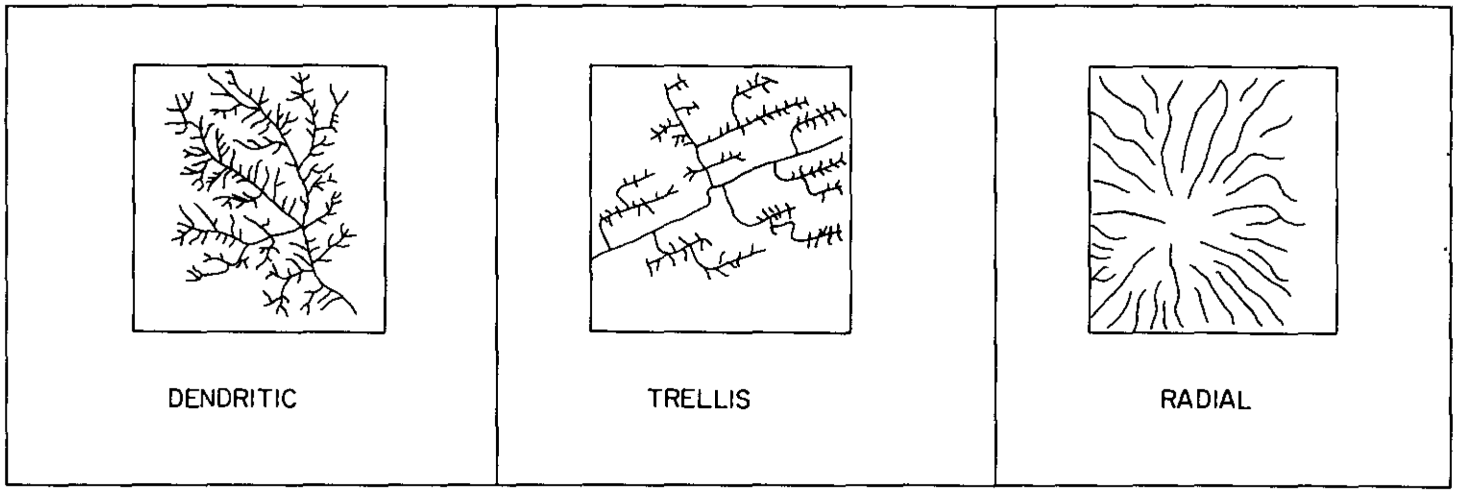



*Figure 30. Drainage patterns.*

in semiarid regions with seasonal rain or snowfall. Some streams are intermittent because they depend for supply upon the water table and do not have beds deep enough to be independent of fluctuations in the table.

*c. Ephemeral Stream.* An ephemeral stream is temporary, depending upon infrequent rainfall for supply.

*d. Bottoms.* Rivers and streams deepen their beds by erosion of the underlying rock. As stream erosion continues, the velocity of the current decreases, with a resulting decrease in down-cutting potential. Eventually, the cutting potential is balanced by the sediment load carried by the stream. Subsequently, unless there is a change in the topography of the catchment basin, the stream alternates between build-up and cutting down. Differences in the load carried by the water at different points, in velocity caused by changes in grade, and in the degree of hardness of the rock make the beds uneven, producing gorges, cataracts, rapids, and potholes. Where streams have a high velocity and flow over loose materials, the bottoms commonly are rocky. In slow-moving water, fine material such as silt and clay is deposited, and the bottoms will be muddy.

*e. Banks.* As down-cutting potential decreases, side-cutting begins and the river widens its bed or develops a curving course. As a rule, these curves will have steep banks on the outside and gentle, low banks on the inside. The conformation will vary with the composition of the bank, the velocity of the stream, and the kind of materials transported by the stream. Swift streams in rough relief commonly cut deep channels with low banks.

*f. Flooding.* Some streams flood annually and others infrequently. Floods may be caused by rapidly melting snow, by excessive precipitation and runoff, by ice jams, or by any combination of these. When a river is in flood, the velocity of water is greater than normal, with the fastest current in the main channel.

*g. Desert Drainage.* Arid climates have long dry periods with infrequent precipitation. Desert streams for this reason are irregular in volume and duration of flow. Large areas of many deserts do not have streams flowing out of their immediate vicinity because the drainage net is centralized in interior basins. There may be separate basins at different elevations in each desert. Many large streams flow into desert lakes that have no outlet, or disappear through evaporation and seepage into porous surface material. Some streams encountered in deserts originate in humid regions, flow across the arid land, and then continue their course in another adjoining humid area. When precipitation occurs in desert areas, it is likely to be in cloudbursts that generate a tremendous runoff as the water rushes down. Sheltered dry washes or wadis may become extremely dangerous locations for bivouacs, gun positions, and installations during these brief but violent floods.

## 64. Lakes

Some lakes are formed by glacial action creating a depression which subsequently fills with water, by the damming of a river by ice or a moraine, or by water filling a natural depression as a glacier recedes. A stream may be formed into a lake because of interference with its natural course by a lava flow, dam, or avalanche. Coastal lagoons frequently are formed by the deposition of silt or sand at the mouth of a river. The crater of an extinct volcano often collects water and becomes a lake basin. Salt lakes occur when a lake is so poorly drained that the minerals in the water remain while the water evaporates. In limestone country, lakes caused by the filling of depressions of dissolved rocks are common.

## 65. Marshes and Swamps

*a. Description.* A swamp (fig. 31) is an area of saturated ground dominated by trees and shrubs. A marsh (fig. 32) is an area of saturated ground dominated by grasslike aquatic plants. A bog is an area of soft, wet, spongy ground consisting of peat which supports mosses, low shrubs, and in some cases poorly developed trees.

*b. Formation.* Swamps, marshes, and bogs are formed by the overflow of rivers, dams, flooding by tides, a lack of balance between rainfall and runoff or seepage, impervious subsoil in level areas, or the spread of vegetation in lakes, particularly in oxbow lakes. They may

*Figure 31. Swamp (Okefenokee Refuge, Georgia).*

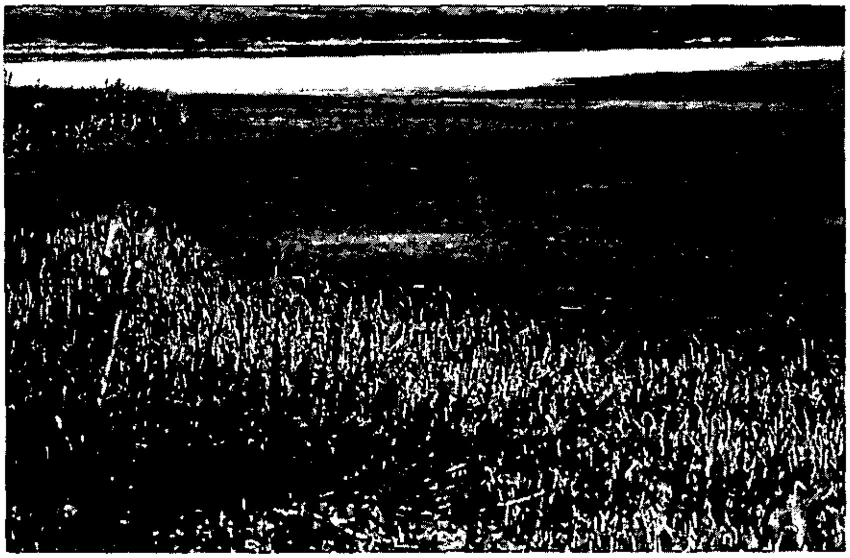


*Figure 32. Marsh (Foxholm, North Dakota).*

be numerous on delta and flood plains, where surface water is not readily drained. Extensive marshes and swamps are encountered on the plains of humid areas. In glaciated regions, marshes, bogs, and swamps are common.

## 66. Glaciers

*a. Description.* A glacier is a thick mass of ice that moves slowly on a land surface. Glaciers depend on the receipt of an annual amount of snow, and form only where there is a carryover of snow from one season to the next. Abundant precipitation is more important than extreme cold. The ice is formed by the crushing of snow flakes from the weight of new snowfalls and shortly altered to a loose aggregate of rounded granules of ice. With deeper burial these granules are deformed, locally melted and re-frozen and recrystallized, to produce a solid mass of interlocking ice crystals. There are two types of glaciers: *valley glaciers* and *continental glaciers*.

*b. Valley Glacier.* A valley glacier (fig. 33) begins in the summit areas of the high mountains. Patches of snow are converted into ice-fields. Those icefields at the heads of former stream valleys may eventually become thick enough so that the ice begins to move downward following pre-existing stream valleys. As the glacier moves down the valley, rock fragments become plucked from the walls and become frozen tightly in the sides and bottom of the ice. These fragments abrade the walls like a giant rasp. This abrasion scratches and polishes the walls and straightens out the valley by grinding away irregularities on opposite sides. Narrow "V" stream valleys are reamed out into much more even "U" shaped valleys.

*c. Ice Front.* The lower end of a glacier, or the ice front, stands at that point where the supply of ice from up the valley is just equal to the loss through melting and evaporation. If supply is greater than loss, the ice front moves down the valley; if loss exceeds supply, the ice front retreats.

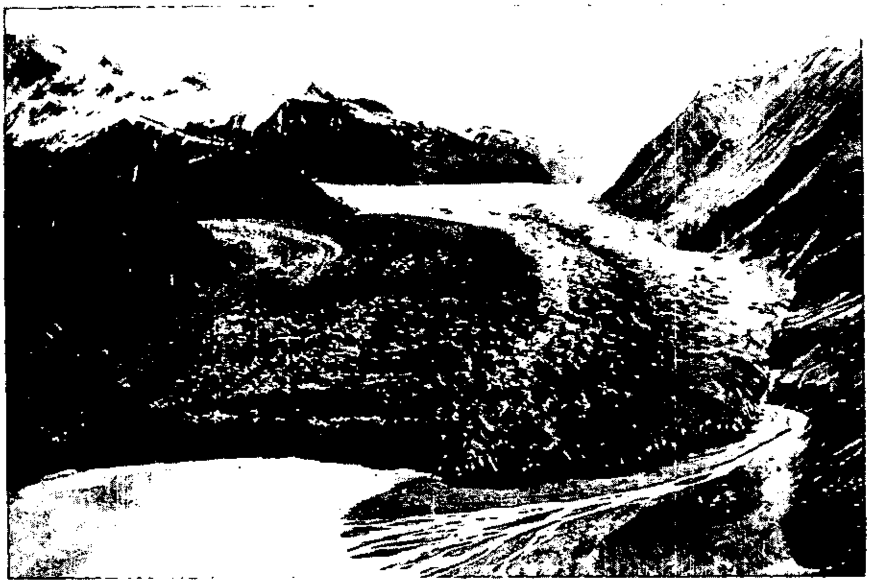


*Figure 33. Valley glacier (Alaskan coast. Kame terrace and outwash plain in right foreground).*

*d. Debris.* Rock debris carried in or on the glacier may be dumped at the ice front when the ice melts. This material, called *till*, consists of an unsorted mixture of rock powder, pebbles, cobblestone, and boulders. If the ice front remains stationary for a period of time, a ridge of till, extending across the valley, is formed. This ridge is termed an *end moraine*.

*e. Continental Glaciers.* Continental glaciers, such as those covering most of Greenland and Antarctica, begin in one or more central areas of snow accumulation. The ice starts to move outward when it becomes so thick that the pull of gravity on the mass exceeds the strength of the ice. No slope is required and in many cases the centers of accumulation lie at low elevations. Continental glaciers make extensive deposits dumped directly from the ice. End moraines mark positions at which the glacier edge stood for some time. They are long ridges or belts of low hills that extend across the country for many miles. Large areas on the glaciated side of the end moraines commonly receive a sheet of till plastered on the underlying rock. This *ground moraine* or *till sheet* was left behind as the heavily loaded ice sheet melted away.

*f. Meltwater.* Streams of meltwater leaving an ice sheet may flow down valleys that lead away from the glacial front. The material previously left from frozen ice is deposited along the stream valleys in the form of *valley trains*. Where the land surface slopes evenly away from the edge of the ice sheet, meltwater streams may spread over the countryside in branching, braided patterns forming wide-spread *outwash plains*. Outwash plains are composed of relatively well-sorted, evenly bedded sand and gravel which may be many feet thick and cover many square miles.

## 67. Ground Water

*a. Hydrologic Cycle* (fig. 34). Water evaporated from the ocean is condensed into clouds, from which it falls to the earth as rain, snow, sleet, or hail. Part of this water runs off into lakes and streams, or is retained by the soil, passing into underlying rock formations. Moving through openings in the rocks, the water issues at the surface as springs, streams, and lakes. Ultimately all the water that is precipitated returns to the atmosphere by evaporation from water surface or from the foliage of vegetation. Some also is released from foliage by transpiration, the process by which a plant transmits water through its tissues, discharging water vapor from its foliage. Although this hydrologic cycle is irregular and may extend over a period of years, no water is lost permanently from circulation, but a stage of the cycle may be bypassed or interrupted. Rain falling upon a heavily forested area, for example, may return directly to the atmosphere by evaporation without going through other stages of the normal natural process.

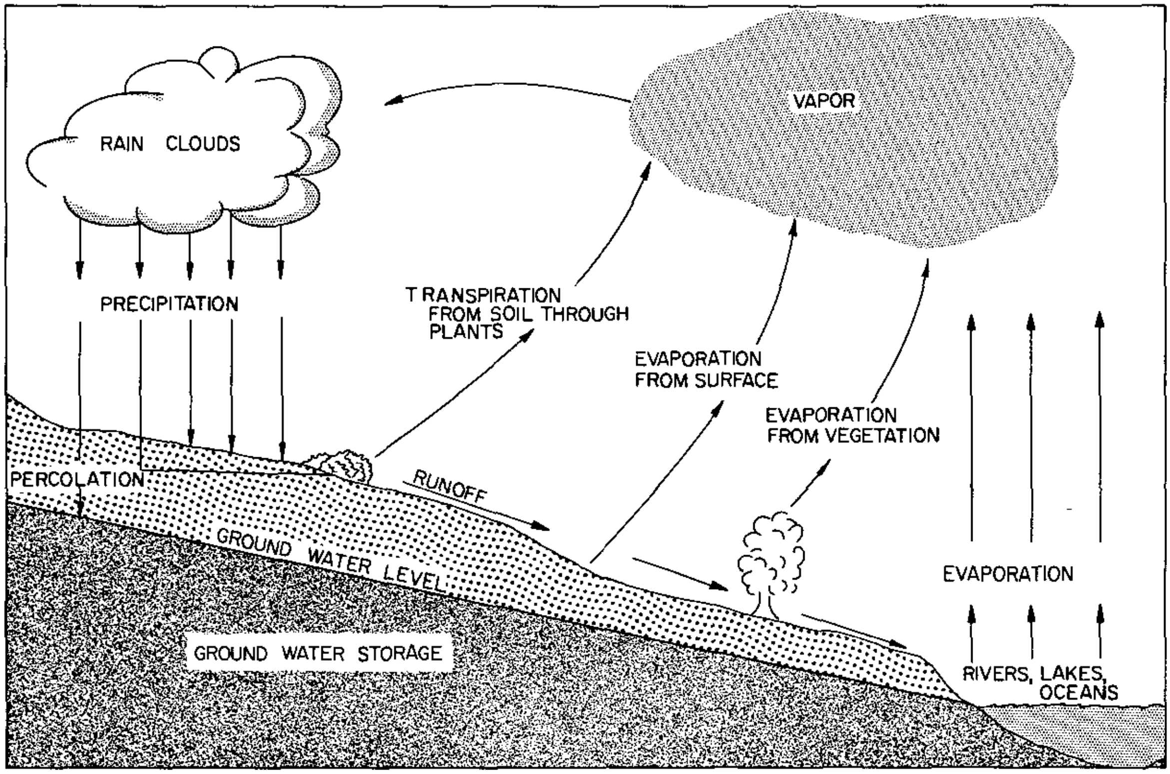



*Figure 34. The hydrologic cycle.*

*b. Water Table.* When water fills the pores and crevices of the underlying rock, a zone of saturation results. This is ground water and the top of the saturated zone is the ground-water table, or simply, the water table (fig. 35). The depth of the water table beneath the surface varies according to topography, structure of the rock formations, amount of rainfall, and nature of the pore spaces in the soil or rock. Water stored below the water table is the source of supply for springs and wells. If the water table intersects the land surface, as it may on the sides of valleys, the water will flow or seep out as gravity springs or seeps.

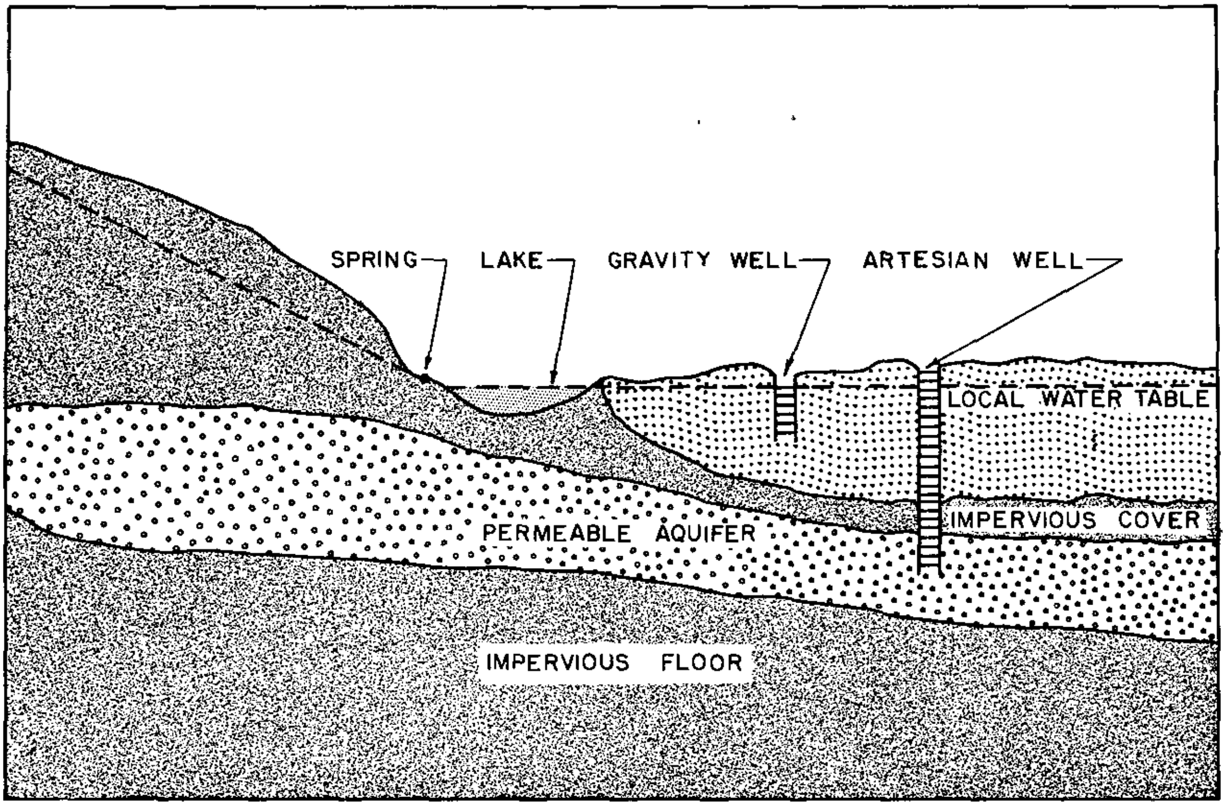



*Figure 35. Water sources.*

*c. Springs and Seeps.* Subsurface water issuing at the surface as a spring has a distinct current, flowing continuously or intermittently from a localized area. Water issuing as a seep emerges slowly over a large area, without a noticeable current. Springs and seeps are of two principal kinds; gravity and artesian.

(1) *Gravity springs.* Gravity springs and seeps are those in which the subsurface water flows by gravity from a higher point of intake to lower point of issue. This may occur where the water table comes near or intersects the surface of the ground, usually around the margins of depressions, along the slopes of valleys, and at the foot of alluvial fans. Another type occurs along an exposed contact between the overlying pervious stratum and an underlying impervious stratum. They may appear at almost any elevation along a slope.

(2) *Artesian springs.* Artesian springs occur where confined subsurface water acting under the influence of pressure from a higher water level is forced to the surface of the ground. Fissures in the rock, fault zones, and, in some cases, solution channels may serve as avenues along which water can move to the surface. The water is generally under much hydrostatic pressure, and therefore rises in the spring. Because of this rise, the spring or well is classified as artesian. A well with enough pressure to bring the water above ground is called a flowing artesian well. If the water rises only to an intermediate level, it is a nonflowing artesian well.

*d. Circulation.* Ground water is not static but moves slowly through openings in the rock and soil toward points of discharge. The rate of movement is controlled by gravity or hydrostatic pressure (the pressure exerted by water at a higher level) and by the capacity of the rock or soil to transmit water, termed its permeability. Climate governs the amount of water that will be contributed to the surface. The amount that will be absorbed depends upon the amount of pore space, or the porosity of the ground.

## 68. Hydrological Effects on Military Operations

*a. Rivers.* Wide, deep rivers with valleys that offer concealment may provide good defensive areas. The employment of a river as a forward edge of battle area (FEBA), however, may also result in a frontage too wide for effective defense and with many covered areas that interfere with observation and fields of fire. Marshy terrain and ditches or tributaries interfere with lateral communications and the movement of reserves.

*b. River Line.* In the attack of a river line, the initial objectives are key terrain features that could permit the enemy to bring effective small-arms fire on the crossing area. Next are features that allow the enemy to deliver observed artillery fire, and, finally, those areas on the enemy side of the river that are required to accommodate the troops, equipment, and installations necessary to prevent the enemy from delivering effective sustained artillery fire. A river or stream may be a temporary obstacle to cross-country movement, but it slows down advancing forces only until it is bridged or assault boats can be brought to the site or a crossing by helicopter is effected. The effectiveness of a river as an obstacle increases with its width, depth, and velocity. Rivers more than 150 meters (500 feet) in width are major obstacles.

*c. River Floods.* Floods may cause long traffic interruptions particularly by damaging temporary bridges. A flood may immobilize a theater of operations unless an adequate system of stream-gaging stations and flood-warning agencies has been established for all key rivers. Streams in mountainous areas are characterized by a high velocity with considerable variation in their flow. While they may be effective obstacles during flood periods, they usually are so low in dry seasons that their beds may offer routes of approach rather than obstacles to movement. Such streams, however, are likely to have beds so rocky as to eliminate vehicular movement.

*d. Lakes.* Usually lakes are obstacles to movement because few are narrow enough to be bridged. They must be bypassed or crossed in amphibious vehicles or boats and where they exist in chains or large groups, as in glaciated areas, they become major obstacles (fig. 36). The narrow land corridors separating the lakes canalize troop movements and limit maneuver, rendering troops highly vulnerable to attack. A series of interconnected lakes may provide an extensive communication system and may also include navigable rivers and canals as in Finland. An ice cover that is 1 meter (3 feet) or more in thickness will support heavy loads. Roads across frozen lakes may be prepared by clearing away the snow.

*Figure 36. Arctic lake region (Northwest Canada).*

*e. Marches and Swamps.* Normally movement through a swamp or marsh is usually limited to causeways, but many vehicles are now used in swamps in what is known as a riverine operation. These may be key terrain features that could be seized by airborne, airmobile, or mechanized forces prior to a large-scale movement. Mud and peat bottoms usually prevent cross-country movement. Special engineer floating and portable bridging equipment may be necessary to supplement other means of traversing a swampy area or to cross or bypass a gap in a causeway. Snow roads may be built over swamps by removing the snow and then pouring water over the cleared surface until a frozen surface is obtained.

## 69. Information Requirements — Drainage

Major drainage areas are shown on maps of appropriate size accompanying some terrain studies. Textual notes are provided if the important facts cannot be shown adequately on a map. Detailed information on features of military significance along a stream or portions of it may be shown on a strip map or annotated photomosaic. Information may include—

*a. Rivers and Streams.*

(1) Name or other identification, and location.

(2) Channel characteristics (form (fig. 37), length, profile, gradient of stream bed).

(3) Bottom characteristics (composition, depth, firmness, unusual conditions).

(4) Flow characteristics.

(*a*) Measurements and periods of occurrence at low, high, and mean water of depth, width, volume of discharge, and velocity (minimum, maximum, and mean).

(*b*) Special phenomena (crosscurrents, undertows, eddies, floods); periods; area covered; destructive effects. Tidal effects at low, high, and mean tides.

(5) Physical and chemical characteristics of water (turbidity, color, odor, taste, temperature, chemical composition, bacterial pollution, seasonal variations).

(6) Bank characteristics (composition, stability, height, and slope).

(7) Regulatory structures (levees and dams).

(8) Islands, bars, shoals, and rapids (name, size, surface roughness, elevation, and pattern).

(9) Ice (earliest, latest, and mean freezing and breakup dates, extent of frozen surface; thickness of ice; carrying capacity; and frequency and location of ice jams).

(10) Kind and prevalence of animal and vegetable life.

(11) Type and location of crossings.

(12) Utilization of watercourse (for water supply, irrigation, disposal of waste).

(13) Accessibility for military water supply (relation of road nets to potential water points, off-road approaches, intake problems).

*b. Lakes.*

(1) Name or other identification, and location.

(2) Length, width, depth and surface area at low, high, and mean water; periods of occurrence of each.

(3) Gage locations and periods of record, zero gage elevations, mean and extreme gage heights and periods of occurrence.

(4) Shore characteristics (composition, stability, height, and slope).

(5) Physical and chemical characteristics of water (turbidity, color, odor, taste, temperature, chemical composition, bacterial pollution, seasonal variation).

(6) Bottom characteristics (composition, depth, and firmness of material, unusual bottom conditions, profiles).

(7) Regulatory structures.

(8) Islands, bars, and shoals (name, size, surface roughness, elevation, and pattern).

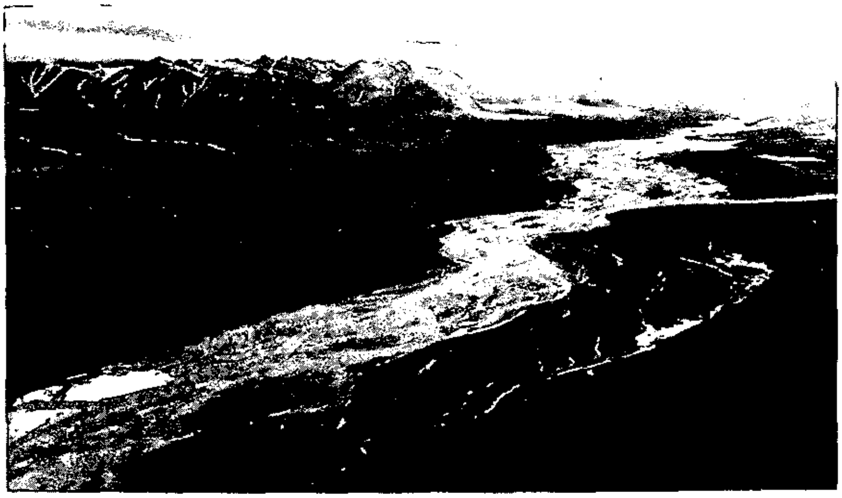


*Figure 37. Characteristic braided stream drainage pattern (Canada).*

(9) Ice (earliest, latest and mean freezing and breakup dates; extent of frozen surface; type and thickness of ice; and carrying capacity).

(10) Kind and prevalence of animal and vegetable life.

(11) Type and location of crossings.

(12) Utilization of water body (for water supply, irrigation, disposal of waste).

(13) Accessibility for military water supply (relation of road nets to potential water points, off-road approaches intake problems).

*c. Marshes and Swamps.*

(1) Information in *b* above, as applicable.

(2) Seasonal variations (months when variations in extent and wetness are greatest and least).

(3) Cross-country movement under various seasonal conditions.

(4) Existing or potential causeways.

(5) Special conditions (quicksand, permafrost).

## Section IV. NEARSHORE OCEANOGRAPHY

### 70. Beaches

*a. Description.* A beach is defined as the area extending from the shoreline inland to a marked change in physiographic form or material, or to the line of permanent vegetation (coastline). In amphibious operations, it is considered that portion of the shoreline designated for landing a tactical organization. Beaches are characterized according to their predominant surface material, such as sand, silt, cobble, pebble, boulder, or by combinations of these materials, such as sand and pebble. Mud beaches are common, but silt is not usually found in beach form, occurring more commonly in underwater banks and shoals. In general, beaches are long and continuous on low-lying coasts, or on shores with soft rock formations, and where there is an abundant supply of material deposited by streams. Along hard-rock coasts and on those not well supplied with stream-carried material, beaches are short and discontinuous, and are usually separated by bold headlands or rock outcrops (fig. 38).

*b. Width.* The width of a beach is subject to considerable change. Where there are seasonal variations in wave attack and the supply of material, beaches may disappear or be greatly damaged when the wave attack is heaviest. Beaches formed principally by streams usually show marked seasonal variations in width, and are widest during the period of least rainfall. Beach widths are most nearly constant when the beaches are protected by groins or similar structures.

*Figure 38. Characteristic coastline, hard-rock terrain (Brazil).*

*c. Slope.* The slope of a beach is determined chiefly by the size of the beach material and the intensity of wave attack. Beaches of fine sand that are not subject to intense wave action commonly have slopes ranging from 1 on 5 to 1 on 60. Coarse material under light wave attack results in beach slopes from 1 on 5 to 1 on 10. The band of wave uprush on a beach is a good indication of the slope. On air photographs it may appear as a dark band lying just landward of the waterline. A wide uprush band indicates a flatter slope than a narrow band. On gravel beaches, however, uprush bands are always narrow, and usually do not appear clearly on aerial photographs.

*d. Firmness.* There is a wide variation in firmness between different beaches and different parts of the same beach. Beaches are most firm when damp and when the material size is small. Dry sand usually is soft, except when the material size is small. Pebble, cobble, and boulder beaches are firm as far as bearing strength is concerned but are loose, making it difficult for tracked vehicles to cross them. Silt and clay are invariably soft, but combinations of mud and sand provide a hard surface. As a rule, exposed beaches are firmer than similar beaches in sheltered locations.

*e. Vegetation.* Vegetation immediately in rear of a beach is an indication of stability. Such areas are firmer than other parts of the beach and always lie above the limit of wave uprush. There is no vegetation on gravel beaches, but beaches composed of gravel and sand in combination may have a vegetation cover.

*f. Assault Landing.* Assault landing is based upon the potential of the beach and hinterland to permit the initial landing and the logistical support for the operation. Attack transport ships (APA) and attack cargo ships (AKA), which have a loaded draft of 8 meters (27 ft) and 7.3 meters (24 ft), respectively, require landing crafts for unloading. A landing ship tank (LST) requires a maximum draft of 4 meters (13 ft), a landing craft medium (LCM) 1.5 meters (5 ft), and a landing craft, utility (LCU) 2 meters (6.5 ft). Additional aid in landing supplies and personnel include mobile pier sites such as the Spud Barge pier, bridging and engineer equipment required to prepare the terrain for landing.

*g. Fresh Water.* Fresh water is seldom available on undeveloped beaches, although it may be obtained from nearby streams or in completely inclosed pools or lagoons that lie immediately behind the beach. Streams or rivers with steep gradients that cross the beach will provide fresh water at sites above the highest reach of the tide.

## 71. Terrain Adjacent to Beaches

*a. Ridges.* Beach ridges are mounds of beach material heaped up by wave action along the upper limit of wave uprush as single ridges or as a series of approximately parallel ridges extending some distance inland. Commonly these ridges reach from 1 to 2.5 meters (3 to 8 feet) above mean high tide, but individual ridges may be as high as 9 meters (30 feet). High ridges are found only in exposed locations, and are signs of occasionally severe storm wave action. Ridges occur only when there is an abundant supply of material on or in back of the beach. In some locations belts of beach ridges extend for 2 or 3 kilometers (a mile or two) inland, with a vertical difference in elevation of only a meter (few feet). Usually these areas are covered with grass or low bushes.

*b. Dunes.* Dunes are formed by windblown sand carried inland from the beach and deposited as irregular hills or mounds. The sand is of fine to medium size. Dunes may reach heights of 90 meters (300 feet), although commonly they do not exceed 30 meters (100 feet) in height. Where there is vegetation, low bushes, and grass the dunes are fairly firm and can be crossed by light vehicles. Fresh water may be obtained from wells sunk in depression between dunes (fig. 39).

## 72. Underwater Topography

*a. Description.* An examination of the terrain as shown in photographs, topographic maps, and hydrographic charts will indicate the probable characteristics of the hydrography. If the land behind the beach is flat and sandy or marshy, the sea bottom close inshore also will be fairly flat. A beach located on a long stretch of regular coastline normally will have one or more sandbars offshore. Large rock outcrops along the beach or close inland indicate that there are probably similar outcrops under-

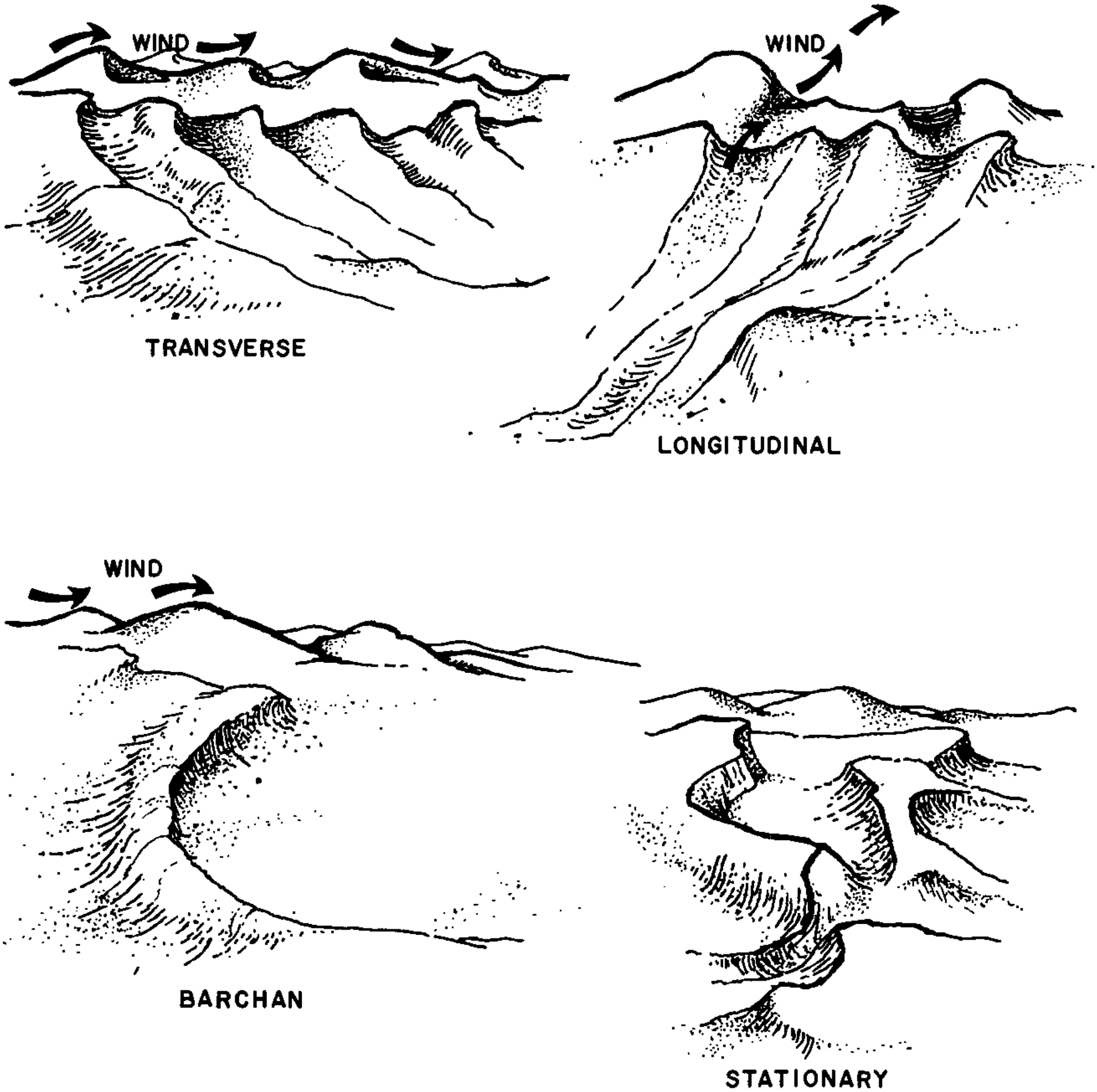



*Figure 39. Windblown stationary dunes.*

water near the shore. Beaches backed by cliffs or steeply rising hills generally will have a fairly steep underwater gradient. The form of the beach also indicates the underwater contours. A wide, flat beach is an indication of a gently sloping bottom offshore, and a sharp narrow beach suggests a steep slope. Sand beaches have flat to steep slopes, and beaches of gravel, cobble, or boulders are usually steep. It must be remembered, however, that the entire beach profile is changeable, varying with the wave conditions that act upon it. Short concave or pocket beaches (fig. 40) flanked by well-developed headlands are the most constant in their form.

*b. Bottoms.* The characteristics of the materials that comprise the nearshore bottom are significant in relation to their suitability for the movement of men, vehicles, and landing craft. Bearing strength and smoothness of grad-

*Figure 40. Concave beach.*

uations are the most important factors. Sand, sand and shell, and gravel bottoms are ideal for landing operations. They are firm and usually quite smooth, although bank, bar, and shoal formations are common. Sand and mud mixtures may be either firm or soft, but they usually are smooth. Mixtures with a high percentage of sand are firm, the firmness decreasing as the sand content is reduced. This type of bottom often has soft spots that may prove hazardous. Mud bottoms are generally avoided, since they are soft, smooth, and slippery. An exception is the case of a thin mud cover overlying a rock bottom, where the rock provides an underlying formation that will give a satisfactory bearing surface if the mud is not more than a meter thick. Clay bottoms are unsatisfactory, since they are soft and slippery and have little strength.

## 73. Coral Reefs

*a. Description.* Reef-building corals are marine animals that remove lime from sea water and deposit it around their living bodies, making hard structures of many types. They do not flourish at temperatures much under 75° F. Consequently coral reefs are found only in tropical waters. Since corals cannot move, securing microscopic food from water moving around them, they are usually found near the edge of reefs, along channels, and out from headlands. They cannot form opposite muddy streams or those with a heavy discharge. If the water movement in coral areas is swift enough, rounded coral heads will predominate, and in more quiet water there usually is an open growth of branching corals. Reef corals cannot stand exposure to the air for more than a few hours, so that their upward growth is limited by the level of mean low water. They belong to one of three types—fringing reefs, barrier reefs, or atoll reefs (fig. 41).

*b. Fringing.* A fringing reef is attached to the shore. If the wave attack is weak, there will be a gently sloping beach of coral sand. Strong wave attack results in steep gravel, cobble, and boulder beaches. On most fringing reefs there are boat channels about 0.3 to 4.5 meters (1 to 15 feet) deeper than the rest of the reef-flat, from 10 to 45 meters (10 to 50 yards) or more wide, and more than a mile in length. These run approximately parallel to the land, opening into breaks in the reef, and providing convenient waterways for small craft.

*c. Barriers.* Barrier reefs are located roughly parallel to the coastline at some distance offshore. Whether or not a craft can cross a barrier reef depends upon the depth of the coral below water. Usually the coral surface is about 15 centimeters (6 inches) above mean low water, but it may be deeper. Walking upon the reef is dangerous, since the reef-flat is seldom above water and the holes between coral colonies are irregularly spaced, deep, and lined by jagged coral. At low water, extensions of the reef into the lagoon behind it may create compartments that hinder or prevent the free movement of craft along the reef.

*d. Atoll.* Atoll reefs (fig. 42) are more or

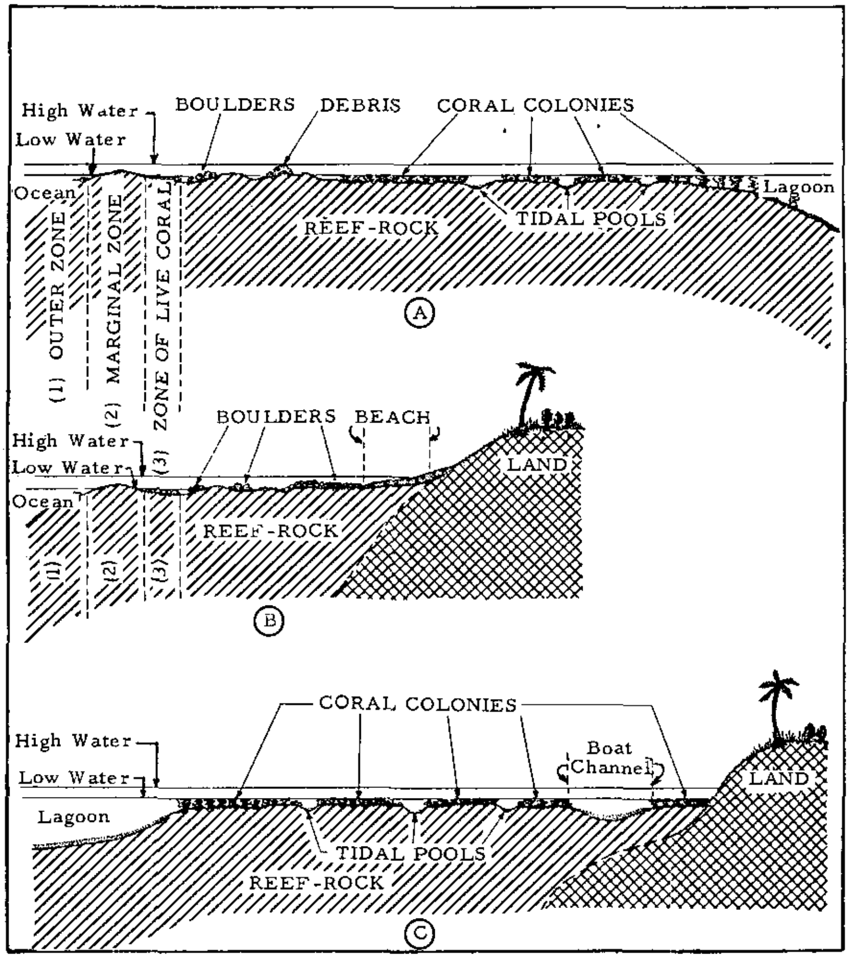



*Figure 41. Barrier and fringing reefs—diagrammatic cross-sections.*
(A) Wide barrier reef.
(B) Narrow exposed fringing reef.
(C) Protected fringing reef. (Not drawn to scale.)

less rings of coral inclosing circular lagoons. The marginal zone of the reef is a strip from 25 to 70 meters (25 to 75 yards) wide, across which a belt of surf moves with the rise and fall of the tide. If the outer, seaward slope of the reef is steep, there is a clear approach for landing craft. A gentle slope will have coral heads growing just outside, making an approach dangerous. At high tide it may be possible to cross the marginal zone by boat. Reef islands usually are located on higher parts of an atoll reef. Typically these islands are surrounded or partly surrounded by a beach 3 to 15 meters (10 to 50 feet) or more wide, consisting of coral sand and organic debris. Reef islands are seldom more than 3 to 4.5 meters (10 to 15 feet) higher than the reef-flat, and their interiors usually are flat and featureless. From the viewpoint of landing operations, the most unfavorable feature is the high, surf-covered marginal zone. Surf intensity is less on the leeward side. On the lagoon side by entering through channels or breaks in the reef, craft may land on the sand beach at high water. Crossing the reef-flat at low tide is impracticable.

## 74. Military Considerations

*a. Coastlines.* A concave coastline is formed by a projection of water (bay or gulf) extending into the coast. From the flanks, converging fires may be brought upon landing forces. The convex type of shoreline includes gently outcurving shores, points, capes, and peninsulas. Supporting fires may be placed on the defender

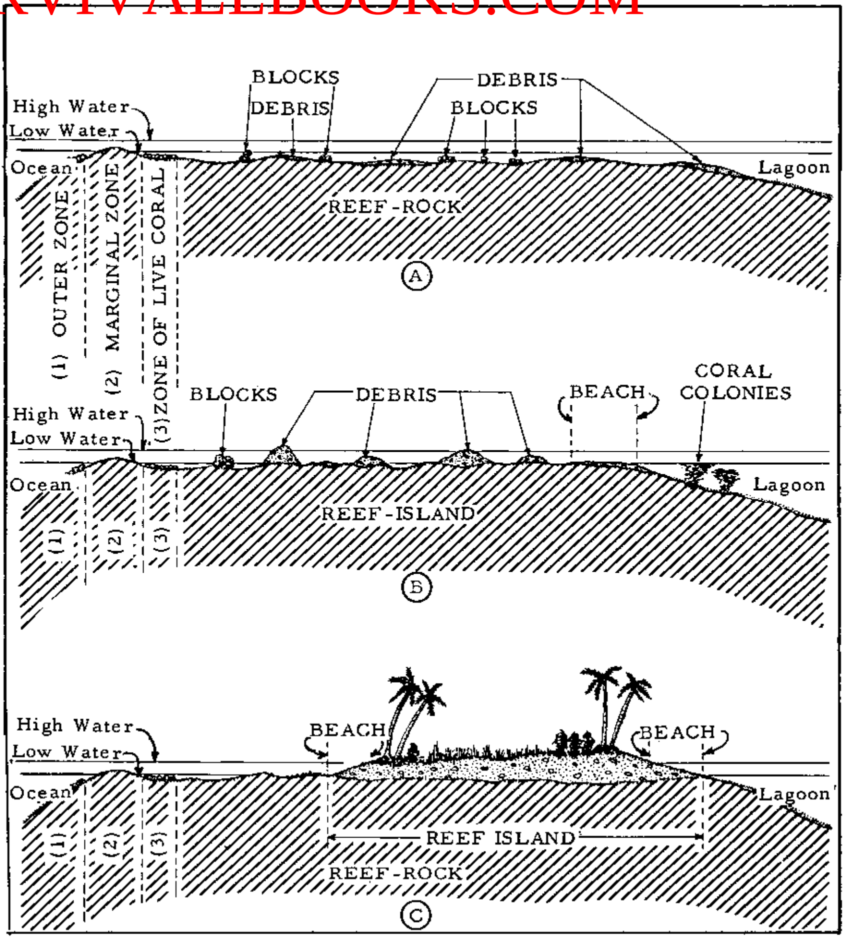



*Figure 42. Atoll reefs—diagrammatic cross section.*
(A) Open reef area.
(B) Area of impermanent debris accumulation.
(C) Reef-island area. (Not drawn to scale.)

from his flanks and, occasionally, from his rear. His routes of withdrawal or reinforcement are restricted. It is difficult for the defender to organize his fires and to secure extensive fields of fire. Convex shorelines are more exposed to currents, winds, and surf and are often steep and rocky, making landing difficult. A straight shoreline has no prominent indentations or promontories. It offers no decisive advantage either in attack or defense. Very few coastlines, however, are so straight that provide no positions for flanking fires. An irregular coastline is a complex of concave and convex shorelines.

*b. Reefs.* Barrier and atoll reefs may be obstacles at a distance from the landing beach. A fringing reef forms a nearshore obstacle, normally with a rough tablelike surface, that extends seaward from the shoreline at a level slightly above or below the water. A wide fringing reef provides an area well suited to the organization of defensive smallarms fires.

*c. Offshore Islands.* Frequently shorelines are protected by groups of small islands lying so close to the mainland that they form a complicated system of waterways immediately offshore. Routes of approach to the mainland through the islands may be tortuous and restricted, making an approaching landing force highly vulnerable throughout its shoreward movement. These islands may be neutralized with nuclear weapons or may be isolated and reduced in detail by successive minor landings preceding the main amphibious attack. Once secured, they provide the attacker with favorable artillery positions to support the landing.

### 75. Information Requirements — Landing Areas

Terrain studies made for planning amphibious operations are very detailed. Normally they are based upon the complete data that is provided by special studies and major sources. In general, the following items represent the fundamental information requirements relative to a proposed landing area:

*a. Location.*

(1) For a beach 3 kilometers (2 miles) or more in length, the latitude and longitude of its limits; for a beach less than 3 kilometers (2 miles) long, the center of the landing area is given.

(2) Nearness to objective of the operations, if known, and to developed areas such as water terminals, harbors, and adjacent beaches.

*b. Sea Approach.*

(1) Landmarks, both natural and manmade.

(2) Hydrography (nearshore and offshore depths; flats (tidal or other), character of the material and its bearing strength; length of and depths over reefs, bars, shoals, or other natural obstructions; anchorage areas and their conditions; character of nearshore bottom material).

(3) Tides and currents (tidal rise and fall, local peculiarities, direction and magnitudes of currents; neaps and springs).

(4) Winds (strength, direction, effect on tidal heights and surf, local peculiarities).

(5) Waves and surf (height and period of offshore waves; intensity).

*c. Beach.*

(1) Material (type and size, firmness, variability with weather or season, subsurface material).

(2) Gradient (note particularly scarps and ledges).

(3) Beach structures (groins, bulkheads, jetties, submerged remains of former structures).

(4) Rivers and streams (variability in beach character where rivers cross beach; river channels).

(5) Effects of weather and duration of darkness and daylight.

(6) Local use of beach.

(7) Sources of fresh water on or near beach (both potable and nonpotable).

*d. Terrain Inland or on Flanks.*

(1) Topography (topographic features, waterways, swamps or marshes, vegetation, location and size of possible dump or assembly areas).

(2) Exits (existing exits by roads or trails; cross-country exits; roads, with details of width, surface, construction; railways, tramways).

(3) Aircraft landing sites within a 16– to 24–kilometer (10– to 15–mile) distance from beach (dimensions, surface, topography).

(4) Utilities (communications, electricity, water supply, transportation).

(5) Helicopter landing sites.

## Section V. SURFACE MATERIALS

### 76. Types of Soils

*a. Composition.* Soil is defined as the unconsolidated material that overlies bedrock. Soil is made of disintegrated rock, in the form of sand or clay, and humus, the disintegrated remains of past vegetation. Detailed information about soils, their engineering properties, and testing techniques is contained in TM 5—541. Some essentials of soils trafficability are given in chapter 9. For field identification and classification, soils may be grouped into five principal types: gravel, sand, silt, clay, and organic matter. These types seldom exist separately but are found in mixtures of various proportions, each type contributing its characteristics to the mixture.

*b. Gravel.* Gravel consists of angular to rounded, bulky mineral particles ranging in size from about 0.6 to 8 centimeters (¼ inch to 3 inches) in diameter. It is classified as coarse or fine; well or poorly graded; and angular, flat, or rounded. Next to solid bedrock, well-graded and compacted gravel is the most stable natural foundation material. Gravel is easy to drain, easy to compact when well graded, affected little by moisture, and not subject to frost action.

*c. Sand.* Sand consists of mineral grains ranging from about 6 millimeters (¼ inch) down to about 0.08 millimeters (.003 inch) in diameter. It is classified according to size and gradation as coarse, medium, or fine; and as being angular or rounded. Well-graded angular sand is desirable for concrete aggregate and for foundation material. It is easy to drain, little affected by moisture, and ordinarily not by frost action. Sand provides an excellent road subgrade material when it is confined. Care is required, however, to distinguish between a fine sand and silt.

*d. Silt.* Silt consists of natural mineral grains ranging from about 0.08 millimeters (.603 inch) to about .005 millimeters (.0002 inch) in diameter. It lacks plasticity and possesses little or no cohesion when dry. The term rock flour is commonly used to describe inorganic silts of glacial origin. All silts are treacherous for trafficability and as a foundation material. Because of its inherent instability, slight disturbances in the presence of water, such as traffic vibrations transmitted to a wet silt subgrade, will cause the silt to become soft or to change to a "quick" condition. When ground water or seepage is present, silts exposed to frost action are subject to intensive ice accumulation and consequent heaving. Silts are difficult to compact and drain.

*e. Clay.* Clay generally consists of particles smaller than 0.005 millimeters (.0002 inch), microscopic in size. Its plasticity and adhesiveness are outstanding characteristics. Depending upon the proportion of coarser grains, clays vary from lean clays (low plasticity) to fat clays (high plasticity). Many clays which are brittle or stiff in their undisturbed state become soft and plastic upon being worked.

## 77. Soil Maps

*a. Contents.* Soil maps or overlays indicate the predominant soils in given areas, identifying them according to their engineering characteristics. Such maps may be constructed from air photographs or ground reconnaissance or made from existing soil and geologic maps and reports with the classifications expressed in engineering terms. Agricultural soil maps can be large enough to provide detail for tactical planning, but often the designated soil type applies only to the surface soil. These maps should indicate the following properties of soils:

(1) Permeability.

(2) Stability under stress.

(3) Bearing capacity.

(4) Important variations of (2) and (3) above with changing moisture content.

*b. Coverage.* For strategical planning, soil maps should cover the area of the study. A large amount of general information may be presented, because detailed plans may not be firm and the future weather conditions uncertain. The information includes the effects of weather upon the soils. The reliability of the information must be clearly indicated.

*c. Planning.* Soil maps for tactical planning cover a smaller area than do strategical soil maps. They are of a larger scale and contain more precise, detailed information. Greater accuracy is possible because more details are known about the proposed operations. Reconnaissance and patrol reports make it possible to check the ground, and weather forecasts are available to indicate what the prevailing weather will be. The information contained on such maps is useful in determining—

(1) Areas critical to cross-country movement as they affect both advances and counterattacks.

(2) Stretches of road liable to failure under heavy traffic.

(3) Suitable and unsuitable areas for airfields, field fortifications, and other installations.

(4) Areas with soil conditions that are unsuitable for tank and vehicle parks.

(5) Difficult areas for field and air defense artillery deployment.

(6) River bank conditions for bridge foundations and crossing operations.

*d. Rear Areas.* In planning rear area activities, soil maps are useful for determining road conditions. In order to stand up under heavy traffic during periods of frost and thaw, a road must have a well-drained subsoil foundation. A knowledge of the soils in an area will reveal which stretches of road will be most susceptible to breakdown during a thaw, providing a guide to selecting the best supply routes and indicating portions of the road where precautions must be observed. When supplemented by an aerial reconnaissance, soil maps are a valuable aid in highway location and relocation. They indicate the soil areas with desirable or undesirable engineering characteristics and also show the nearest sources of materials for road construction and maintenance. The information about soil conditions given by a soil map is invaluable in selecting sites for airfields, storage installations, ammunition dumps, and vehicle parks. Preliminary study of the map prevents unnecessary field reconnaissance.

## 78. Military Aspects of Soils

*a. Weather.* The actual identity of the type of soil in any area is of little practical value unless the soil is also evaluated in relation to the existing or predicted weather. In general, the major soil types have the following characteristics:

*b. Gravel.* Weather has little or no effect on the trafficability of a gravel soil which is excellent for tracked vehicles. It it is not mixed with other soil, however, the loose particles may roll under pressure, hampering the movement of wheeled vehicles.

*c. Sand.* When wet enough to become compacted, or when mixed with clay, sand gives excellent trafficability. Very dry, soft, or loose sand is an obstacle to vehicles, particularly on slopes.

*d. Silt.* When dry, silt provides excellent trafficability, although it is very dusty. Silt absorbs water quickly and turns to a deep, soft mud when wet, imposing a definite obstacle to movement. It dries quickly after a rain, soon becoming trafficable again.

*e. Clay.* When thoroughly dry, clay provides a hard surface with excellent trafficability, but it is seldom dry except in arid climates. Although clay absorbs water very slowly during a rain, it also takes a long time to dry. Wet clay is very sticky and slippery. Slopes with a clay surface are difficult or impassable, and deep ruts form rapidly on level ground. A combination of silt and clay makes a particularly poor surface when wet.

*f. Special Soil Conditions.* If a soil has underlying bedrock near the surface, it will become thoroughly saturated after a rain. The water cannot drain away, making the surface untrafficable.

*g. Manmade Effects.* Soil under cultivation because it has been worked is softer and absorbs water more quickly than other soils and may therefore have poorer trafficability. Usually the presence of irrigation structures indicates that the soil is soft and contains water and the soil generally will have poor trafficability. The types of crops cultivated in an area provide indications as to the nature of the soil. Since gravelly soils are especially suitable for fruit orchards, for example, the presence of extensive orchards, especially on flat areas, may indicate that the soil has a high gravel content. Many cultivated plants have specific soil and water requirements, giving a clue to the soil and drainage of the area.

*h. Nuclear Weapons.* Soil composition and density affect the amount of damage by shock that will result from a surface or subsurface burst. Propagation of the shock wave is poorest in light, loamy soils and best in plastic, wet clay. The pressures transmitted by the blast may be 50 times greater than those transmitted through sandy clay. The size and shapes of craters produced by a surface or subsurface burst, their effectiveness as obstacles and the intensity and decay rate of induced radiation in the soil are also affected by the soil composition and density.

## 79. Information Requirements—Soils

In a terrain study, soil information usually is presented in tabular form, with the data keyed to a soil map or overlay. It covers—

*a.* Extent of each dominant soil type.

*b.* Depth of each type in areas indicated.

*c.* Surface texture (fine or coarse).

*d.* Parent material.

*e.* Description of material.

*f.* Properties when wet, dry, or frozen, including suitability for specified military vehicles under various conditions, bearing capacity for structure foundations, and permeability when wet.

*g.* Variations from dominant soil type in specified areas.

*h.* Areas of permafrost, permanent ice and snow.

*i.* Seasonal state of the ground (dry, wet, flooded, frozen, snowcovered) by seasons, months, or shorter periods. Effects of each state on cross-country movement, construction, excavation, cover and concealment, and other military aspects.

## 80. Rock

*a. Classification.* Rock may be defined as the firm and coherent or consolidated material of the earth's crust. Bedrock is solid undisturbed rock either exposed at the surface or underlying the soil. Igneous rock is formed by cooling and solidification from a molten or partly molten state; sedimentary rock, from material accumulated as a deposit from water or the air, and metamorphic rock, by the recrystallization of igneous or sedimentary rock under the influence of heat, pressure, or both. The information, characteristics, and uses of rock are explained in TM 5–545.

*b. Underground Installations.* Underground installations require rock and soil that are easily worked and locations that are accessible to transportation and power facilities. Plains, terraces, and alluvial fans usually are best for bunker type installations. The most favorable terrain for tunnels normally is found on plateaus, escarpments, high hills, and mountains with steep bare-rock surfaces. Large bunkers require deep, well-drained soils, with the water table at least 4.5 to 6 meters (15 to 20 feet) below the surface. They should be protected against surface-water flooding, especially if they are located on low plains. Military tunnels may be constructed for tactical, communication, storage, and shelter purposes, including—

(1) Undermining of enemy positions and countermining.

(2) Galleries for water supply.

(3) Fortifications (headquarters, gun emplacement, ammunition storage, defensive installations).

(4) Underground factories and hangars.

*c. Tunneling.*

(1) *Construction.* Before tunneling operations are initiated, a geologist should evaluate the proposed site. Tunnel type installations are favored by high, steep slopes of exposed bedrock. The tunnel is kept dry by placing the lowest levels above the water table and by constructing it in rocks that have a minimum of fissures, joints, and faults that would permit seepage and flooding. The size of the chambers depends upon the stability of the rock. The thickness of natural cover required to give adequate protection depends upon the type of rock and soil, degree of soundness of the rock, absence of joints and fissures, and the size and shape of the underground openings.

(2) *New methods.* In Viet Nam extensive hand-dug tunnels and tunnel complexes have been found. They are used as hiding places, caches for food and weapons, headquarters, and protection against air attack and artillery fire. They have concealed entrances and exits, camouflaged bunk-

ers, trap doors, and dead ends to confuse the attacker. One trap door may lead to a short change-of-direction tunnel and another door to a second change of direction, and a third door to the main tunnel. There are also multilevel complexes with storage and hiding rooms at lower levels. Some of these have air or water locks as "firewalls" to prevent blast, fragments, gas or smoke from passing from one section to another. The entrances are camouflaged and booby-trapped.

### 81. Information Requirements—Rock

Terrain studies of an area will be concerned chiefly with the availability of unexploited natural deposits suitable for the construction of roads, protective works, airfields, and underground shelters. The particular information that will be required depends upon the purpose of the study. Requirements may include—

*a. Rock Deposits.*

(1) Location and extent of deposit.

(2) Type and properties of the material.

(3) Suitability for construction use (as aggregate, binder, surfacing, ballast, riprap, masonry construction material).

(4) Accessibility.

*b. Underground Shelters.*

(1) Existing areas (mines, caves, underground manmade installations). Characteristics. Special constructions.

(2) Areas suitable for development (rock structure, comparative advantages and disadvantages of indicated locations).

## Section VI. VEGETATION

### 82. Broad Classification of Plants

Vegetation may be classified in four broad categories—trees, shrubs, grasses, and cultivated vegetation. The type of vegetation in an area gives an indication of the climatic conditions, soil type, drainage, and water supply. Seasonal seepage or a rise in the ground-water supply often is indicated by vegetation such as reeds, sedges, cottonwoods, and willows, which thrive wherever seepage occurs. Similarly, arid conditions are also indicated by characteristic desert vegetation. TM 5–545 describes the indications typical of various plant species.

### 83. Trees

*a. Definitions.* Trees are defined as perennial woody plants at least 10 feet in height, with single stems and definite crown shapes. A forest is an extensive area covered by trees growing in a close formation, so close that in most cases their crowns touch. Smaller areas covered by trees may be termed woods, groves, or woodlots. In the terminology used on U.S. Army maps, any perennial vegetation high enough to conceal troops or thick enough to be a serious obstacle to free passage is classified as woods or brushwood. Commonly, a deep woods is considered as one that is large enough to provide ample concealed maneuver space for large units deployed in depth. This would include a woods that would conceal both the assault and reserve echelons of a brigade in the attack. A shallow woods is one that is not large enough to conceal elements of this size. Dense woods are those where the growth is thick enough to interfere with visibility sufficiently to limit the maneuver of troops.

*b. Characteristics.* In temperate regions, trees are commonly found at elevations of not more than 2,440 meters (8,000 feet) above sea level. A good forest climate is one with a warm, rainy vegetative season, a continually moist subsoil, and low wind velocity. The growth of trees is greatly influenced by the temperature of the air and soil; even the hardiest conifers require a mean warm month temperature of at least 50° F.

*c. Classification.* Trees are classified as either deciduous or evergreen (fig. 43). Deciduous trees drop all their leaves seasonally, but evergreen trees retain their leaves throughout the year. Trees are also either needleleaf or broadleaf. In the middle latitudes, needleleaf trees are predominantly evergreen, and broadleaf trees are predominantly deciduous. In the humid tropic, nearly all trees are evergreen because the climate remains uniform throughout the year. Almost all deciduous forests are located in the Northern Hemisphere. The important dimensions of trees in a wooded area are the diameter of the tree stems at breast height, the average height of the trees, and the average height above ground of the lowest branches.

*Figure 43. Mixed vegetation, showing (a) evergreen trees, (b) deciduous trees, (c) brush, and (d) sedges (Northern Manitoba).*

## 84. Low-Latitude Forests

In the low latitudes, tropical rain forests, swamp forests, and moss forests are the principal types.

*a. Tropical Rain.* In the tropics, rain forests (selva) blanket many square miles of moist low lands in regions where rainfall is heavy and well distributed throughout the year, with no marked dry season. The Amazon Basin and West Central Africa are the two largest areas of tropical rain forest, although it is also found along many rainy coasts and on tropical islands. This type of forest covers more than one-tenth of the earth's total land surface and comprises nearly one-half of the total forest areas of the world. The rain forest consists of broadleaf trees of many species that form a canopy thick enough to shut off most sunlight. The trees are commonly from 30 to 45 meters (100 to 150 feet) in heights, with large diameters, smooth trunks, and few lower branches. *Lianas*, rope-like plants that entwine themselves around trunks and branches, are common. Usually the undergrowth is not dense, although it restricts observation. In the deepest shade, there is usually only a thick mat of ferns or herbs that offers no obstacle to movement. Typical jungle conditions, with thick and impenetrable undergrowth, are characteristic chiefly of sections where light reaches the forest floor, as one precipitous wet slopes, along rivers and coasts, and in abandoned agricultural clearings.

*b. Tropical Swamp* (fig. 44). This forest occurs in low terrain near or in swampy regions. Mangrove swamp forests (fig. 45) cover large areas along tropical salt-water coasts, presenting an almost impenetrable barrier to movement. This type of forest is found in the soft mud around river mouths, deltas, and inlets, along shallow bays on small islands, and upstream as far as the tidal influence is felt. Mangrove forests include several kinds of trees, all with thick buttressed roots that extend as high as 3 meters (10 feet) above the ground. These spread outward becoming interlaced in a network that makes movement by foot almost impossible and prohibits any type of vehicular movement. Nipa palms, which generally grow in or near mangrove swamps, also present almost impassable barriers (fig. 46).

*c. Moss.* This forest is found in the higher latitudes just above the rain forest areas, chiefly at altitudes of 915 meters (3,000 feet) or higher on the tops of tropical mountains wherever high humidity and cloudiness are persistent. The trees are small with long overhanging branches. Moss grows on the branches, tree trunks, and ground, where it is intermingled with ferns and vines to form a blanket that conceals the earth. This moss often covers chasms and ravines, making them appear to be level terrain. The moss forest accordingly is hazardous to movement. It is dark and gloomy and so dense that very little sunlight penetrates the canopy. Visibility is extremely limited.

*Figure 44. Swamp forest (air view) (Sanibel National Wildlife Refuge, Florida).*

*Figure 45. Mangrove swamp (Malay Peninsula).*

## 85. Middle-Latitude Forests

*a. Types.* The principal forest types in the middle latitudes include Mediterranean scrub forests, broadleaf forests, and needleleaf forests.

*b. Mediterranean Scrub.* These consist of broadleaf evergreen trees adapted to regions with long, hot periods of summer drought. They are found in the borderlands of the Mediterranean Sea, as well as in California, Chile, southern Australia, and the Capetown region of Africa. These areas are subtropical, with mild, rainy winters and long, dry, hot sum-

*Figure 46. Nipa palms (Northern New Guinea).*

mers. This type of forest consists of low trees and woody shrubs. Where climate and soil conditions are most favorable, the virgin forest is composed of low, widely spaced trees with massive trunks and gnarled branches. Between the trees the ground is completely or partially covered by a pale, dusty bush and shrub vegetation resembling the soil in color. Cork oaks and olive trees are typical of this type of forest.

*c. Broadleaf.* Most of the temperate broadleaf forest is composed of deciduous trees with a seasonal leaf fall, such as oak, hickory, maple, ash, elm, walnut, beech, and poplar. Along the humid subtropical margins of the middle latitudes, principally in southern Japan, New Zealand, and southeastern Australia, there are evergreen broadleaf forests that resemble rain forests, with dense undergrowth and heavy vines. Temperate broadleaf forests vary widely in composition, the dominant tree species differing from one region to another. In some areas there are many conifers among them and the forest may be described as *mixed.*

*d. Needleleaf.* Needleleaf trees are almost exclusively evergreen. The growth and discard of the needles is a continuous process not confined to any particular period or season. Usually the needleleaf forests occupy the colder continental locations on the poleward side of the broadleaf forests. In areas of poor sandy soils, or on steep mountain slopes where soils are thin or rocky and temperatures are lower, needleleaf trees may supplant broadleaf trees even in the middle latitudes. South of the great belts of subarctic needleleaf trees there are large areas of needleleaf trees that provide valuable timber such as the forests of the Pacific Coast, western Canada, and Alaska. The southern pine forests in the Atlantic and Gulf Coastal Plains of the United States also are major sources of timber.

## 86. High-Latitude Forests

A wide belt of needleleaf forests extends from coast to coast in the subartic regions of Eurasia and North America below the treeless tundra regions. This Eurasian forest is the largest continuous forest area in the world. Needleleaf trees such as fir, spruce, larch, and pine predominate, although in the swamp areas there are some broad leaf trees such as aspen, willow, birch, or mountain ash. The area has short, cool summers and long, dry, cold winters so that growth is slow, and few trees are more than 0.45 meter (1½ feet) in diameter. There are numerous large swamps and marshes covered with moss, and containing such trees as balsam and spruce. These areas usually rapidly become impassable after precipitation or during a thaw.

## 87. Shrubs

*a. Description.* Shrubs are woody plants usually less than 3 meters (10 feet) high with more than 1 stem. They include a variety of trees that have had their growth stunted because of soil or climatic conditions. Scrub growth includes cactus, stunted shrubs, sagebrush, mesquite, and similar plants found most frequently in arid or semiarid areas. Shrubs comprise the undergrowth in the open forests of middle latitudes. In many arid and semiarid areas they are the dominant vegetation. They are prevalent in the subarctic and in large, burned-over or cutover areas in humid regions.

*b. Classifications.* Shrubs, like trees, are either deciduous or evergreen, needleleaf or broadleaf. In the middle latitudes, most broadleaf shrubs are deciduous, and all needleleaf shrubs are evergreen. In the humid tropics, nearly all shrubs are evergreen. Most arid regions of both low and middle latitudes have some vegetation, both deciduous and evergreen, although it is sparse (fig. 47). It may consist of low bunch grass with widely spaced bushes or fleshy, water-storing plants such as the cacti. Most commonly, the vegetation comprises sagebrush and similar scrub growth. Perennial shrubs of the desert areas grow far apart, with considerable areas of bare soil in between due to the low rainfall. The rate of growth is very slow.

*Figure 47. Characteristic desert vegetation (Arizona).*

## 88. Grasses

*a. Kinds.* Grasses include all kinds of nonwoody plants. A grassland is an extensive area where the natural vegetation consists primarily of grass. In low latitudes, grasslands often are termed savannas; in middle latitudes, prairies (tall grass) and steppes (short grass). Grasslands in wet or poorly drained areas commonly are called meadows. For terrain intelligence purposes, grass more than (1 meter) 3 feet high is considered tall, and below that height, short.

*b. Tropical Grasslands (Savanna).* In areas with heavy seasonal rains and a distinct dry season, the grasslands or savanna are composed mostly of tall, very coarse grasses that grow in tufts separated by intervals of bare soil. If there are trees, they usually are species that can withstand seasonal drought and they grow mostly in clumps in the grasslands or along the margins of streams. Savanna grass grows rapidly at the beginning of the rainy season, reaching heights of 1 to 3.5 meters (4 to 12 feet) in a few months. When dry, the blades become brown, stiff, and harsh in texture, burning very readily. The grasses usually diminish in height with decrease in the annual rainfall, and trees become fewer until under semiarid conditions nearly treeless steppes, composed of shorter grasses, are prevalent. Low-latitude savannas are usually located between desert and forest regions.

*c. Prairie.* The prairie type of grass occurs most frequently in areas where the soil remains moist for a depth of 75 centimeters (30 inches) or more. The prairies are covered with tall, luxuriant, and relatively deep-rooted grasses that grow to heights of from 30 to 90 centimeters (1 to 3 feet). Over most prairie regions, rainfall varies between 50 to 100 centimeters (20 and 40 inches) annually. Usually there is a large variety of flowering plants in spring and summer. The principal prairie regions include parts of central United States and the prairie provinces of Canada; the Argentine Pampa, Uruguay, and southeastern Brazil; the plains of the Danube in Hungary and Rumania; and parts of Manchuria and southern Russia.

*d. Steppe.* A steppe is an area of short, shallow-rooted grasses typical of semiarid regions where the depth of moist soil is less than 60 centimeters (2 feet). In common usage, the word steppe is used to describe all the drier, short-grass grasslands, both in tropical and middle latitudes. Some of the steppe grasses lie in a soft, fine mat on the ground, while others stand as hard, wiry tufts. Thorny shrubs and low, coarse bushes may dominate the steppe in some sections. Cacti and other succulent plants may be numerous. Steppe vegetation develops typically in regions that receive less than 50 centimeters (20 inches) of rainfall a year, with a hot summer and a cold, dry winter.

## 89. Cultivated Vegetation

*a. Field Crops.* Field crops constitute the predominant class of cultivated vegetation. Vine crops and orchards are common but not widespread, and tree plantations are found only in relatively few areas. The size of cultivated areas ranges from paddy fields covering a quarter of an acre to vast wheat fields. In a densely populated area, where all arable land is cultivated, each parcel will be used for the crop that brings the highest yield, making it possible to predict the nature of the soils from information about the predominant crops. Rice, for example, requires fine-textured soils. Other crops generally must have firm, well-drained land.

*b. Orchards.* An area of orchards or plantations usually consists of rows of evenly spaced trees, showing evidence of planned planting that can be distinguished on an aerial photograph. Usually such an area is free from underbrush and vines.

*c. Rice Fields.* Rice fields usually are flooded areas surrounded by dikes or walls approximately ½ or 1 meter (1½ to 3½ feet) in height and ½ to 1½ meters (1½ to 4½ feet) wide. When flooded for planting, the depth to the bottom mud ranges from 15 to 90 centimeters (6 inches to 3 feet).

## 90. Military Aspects

*a. Key Terrain.* Woods provide concealment and cover for assembly areas and during the approach march. Forests and heavy vegetation, however, increase the difficulty of maneuver in advancing to attack and in launching the assault. The attacker may have little or no information about the roads, trails, and topography in the area not under his control, due to the difficulty of securing detailed terrain intelligence without actual reconnaissance. Wooded and heavily vegetated areas provide cover and concealment for organized positions, shelter for reserve formations, and an obstacle to the attacking forces. Usually the defender is able to make a detailed reconnaissance of the area, so that he is familiar with the roads, trails, and other features of the terrain. Infantry weapons form the basis of the defense, due to the difficulty of securing observed artillery fire in heavily wooded areas.

*b. Observation and Fields of Fire.*

(1) *Observation.* The height and density of the trees and other vegetation largely determine the amount of ground observation that can be obtained. To secure an adequate field of view from an observation post, it may be necessary to clear away vegetation at the risk of losing concealment. The effects of cultivated crops upon observation vary with seasonal conditions. In two or three weeks a cornfield may be covered with high stalks that limit observation. Later in the season, this corn may be harvested in a day, allowing observation again.

(2) *Fields of fire.* Lanes may be cut through vegetation to provide fields of fire, but it is seldom practical to cut lanes that extend far enough to provide long-range observed fires. Extensive clearing indicates the location of weapon positions to the enemy. The extent of clearing that is practicable will depend upon the amount of vegetation, its density, and the length of time that the positions will be occupied. Indirect fire is less affected by vegetation than direct fire. Mortars require little more than overhead clearance. Artillery weapons require more clearance than mortars, but high angle fire may be employed to avoid extensive cutting and clearing. Air defense artillery can be employed effectively in forests and areas of heavy vegetation when clearance requirements are met. Forests and heavy vegetation may be set on fire as a tactical weapon, particularly during dry season. Wooded areas and those covered with heavy vegetation tend to increase the persistence of gas and smoke, particularly during wet seasons or periods of high humidity. The influence of forests and heavy vegetation upon nuclear weapons effects varies with the amount of overhead cover, density of growth, kind of trees, nature of the tree crowns, undergrowth, and the litter on the forest floor. Trees in leaf offer a high degree of protection from thermal radiation if the cover is sufficiently continuous, but protection from initial nuclear radiation is insignificant.

*c. Cover and Concealment.* Thick forests of deciduous trees in leaf give excellent concealment from air observation when troops observe proper precautions in camouflage and movement. Evergreen forests will provide concealment throughout the year, changing color very slightly from season to season. Deciduous trees lose their leaves, reducing concealment, and change color, which increase the difficulty of natural camouflage. Usually undergrowth and small trees growing closely together give better concealment from ground observation than a stand of larger trees. Unless the undergrowth is high, however, it will provide little concealment from aerial observation. The amount of concealment and cover provided by cultivated crops depends largely upon seasonal conditions. Disruption of the agricultural pattern is readily apparent to aerial observers and in aerial photographs.

*d. Obstacles.* Fire lanes and certain types of vegetation often canalize movement through forest areas. This is true, for example when lines of trees border streams. Normally, no serious obstacle to movement is offered by shrubs and grasses, but visibility can be reduced in high grasses, with the added danger of reptiles to foot soldiers. Small grain crops hold soil nearly as well as grasses, so that movement is better in such areas than in those planted with row crops. Some parts of vineyards present a tangled maze of poles and wires that constitute a definite obstacle to vehicles and dismounted troops. The terraces and retaining walls on hillsides are also obstacles. Wheeled vehicles and some tracked vehicles are unable to cross flooded paddy fields, although they can negotiate them when the fields have been drained and the soil is thoroughly dry. In some cases even dried paddy fields remain a serious obstacle to movement because some vehicles are unable to negotiate the dikes surrounding the fields.

*e. Avenues of Approach.* In most wooded areas, individual trees large enough to stop a tank are seldom so close together that they cannot be bypassed. Closely-spaced trees usually are of relatively small diameters and can be pushed over by a tank. The smaller trees and undergrowth, however, may be so dense that when they are pushed over the resulting mass of pileup vegetation will stop the tank. In most cases, wooded areas slow down the movement of tanks, and a guide may be required to lead each vehicle. Cutover portions of wooded areas usually contain stumps hidden in tall grass or weeds that are serious obstacles to armor. Trees that can stop a wheeled vehicle usually are too closely spaced to be bypassed. The pileup effect from pushing over vegetation is greater for wheeled vehicles than for tanks. Trailed loads are difficult to tow through wooded areas. Woods slow down the movement of dismounted troops. Some types of vegetation, such as mangroves or dense jungle, are frequently impenetrable until routes are cleared.

*f. Construction.* The usefulness of trees for timber is determined by their height and diameter, and by the nature of the wood as hard, soft, or fibrous. Deciduous trees generally are hardwoods. Needleleaf trees are softwoods that usually are easily worked, although some species are fibrous and difficult to saw. When a forest area must be cleared of trees prior to a construction project, a study of the ground will indicate the density and depth of the root systems. Where a forest is closely underlain by hardpan or rock, tree roots branch and remain near the surface, making them easy to uproot. In soil that is firm, with deep underlying rock, trees tend to form large taproots extending to a considerable depth, making them difficult to remove. Trees in inundated, marshy, and muskeg areas have thick widespreading and shallow root systems near the surface of the ground. In northern regions where permafrost occurs, its effect on the root systems of trees is similar to that of hardpan or rock. Where the permafrost is near the surface, the roots branch and lie close to the surface. Deeper taproots are developed where the permafrost is far below the surface.

## 91. Information Requirements—Vegetation

As far as practicable, information about the vegetation in an area is presented in the form of a map overlay that clearly indicates and identifies the major vegetation types by the use of color and symbols. The accompanying text briefly summarizes the additional information of military significance that cannot be shown adequately on the map. Pertinent information may include the following:

*a. Forests.*

(1) Name or other identification.

(2) Plant associations.

(3) Principal species (names, proportion in percent, density or average spacing, height range).

(4) Undergrowth species.

(5) Canopy: structure (continuous, open, broken) and seasonality (color, defoliation).

(6) Duff (partly decayed vegetable matter on the forest floor): abundance and nature of fallen trees, logs, and so on.

(7) Exploitation practices (normal cutting, overcutting, undercutting).

(8) Operational aspects (suitability for cover, concealment, blowdown susceptibility, camouflage, and fuel).

(9) Principal tree species.

- (*a*) Name (English and botanical).
- (*b*) Height (average).
- (*c*) Growth form (triangular, linear, and ovate).
- (*d*) Diameter (average).
- (*e*) Leaves (broadleaf or needleleaf).
- (*f*) Period of defoliation.
- (*g*) Roots (structure, size, toughness).
- (*h*) Suitability for construction.
- (*i*) Special features (toxicity, thorniness, edibility).
- (*j*) Indicator significance relation to

regional and local climates, kind and state of ground, and ground water, salinity, permafrost, depth and duration of snow cover, human activity).

*b. Shrubs.*

(1) Location and areal extent.

(2) Name or other identification.

(3) Principal species (names, proportion in percent, density or average spacing, height range).

(4) Foliage—density and seasonality (color, defoliation).

(5) Operational aspects (susceptibility to mass conflagration).

(6) Principal shrub species (for each). (Same information as for tree species.)

*c. Grasses.*

(1) Location and area extent.

(2) Identification.

(3) Principal species (names, proportion in percent, density, height range).

(4) Seasonality (dates of growth, color).

(5) Operational aspects (susceptibility to mass conflagration).

(6) Principal species (for each).

(*a*) Name (English and botanical).

(*b*) Date of maturity, height.

(*c*) Life span.

(*d*) Growth habit (sod or bunch).

(*e*) Suitability as forage.

(*f*) Special factors (toxicity, irritancy).

(*g*) Indicator significance.

*d. Cultivated Crops (general).*

(1) Location and areal extent.

(2) Name or other identification.

(3) Principal crops (names, proportion in percent, density or spacing height range; if applicable, months planted, cultivated, and harvested; crop rotation practices).

(4) Canopy, foliage, or stand (as applicable: structure, color, defoliation, density, rates of growth).

(5) Types of farming (irrigated, dry, and so on).

(6) Special factors associated with crops (irrigation ditches, flooding, terraces, hedgerows, dikes, and stone or other types of fences).

(7) Operational aspects (susceptibility to mass conflagration).

(8) Principal crops.

(*a*) Tree and shrub crops (same information as for tree species; in addition, months that the crops are harvested).

(*b*) Grass and grain crops (same information as for tree species; in addition, months of planting and harvesting).

# CHAPTER 6

# MANMADE TERRAIN FEATURES

## Section I. SIGNIFICANCE

### 92. Definition

Manmade features include all the changes in the natural environment made by man in the course of living on the earth and using its resources. Major manmade features are cities, defensive works, transportation and communication facilities, and similar features that have significant effects upon the military operations. Others are such features as cemeteries, hedgerows, and buildings, which affect only local operations.

### 93. Military Aspects

In preparing terrain studies, manmade features must be evaluated to determine their effect upon the military aspects of proposed operations. Recommendations may be made to destroy certain features or to retain them for future use after the operation has been completed. Usually each major manmade feature is the subject of a detailed study by military intelligence personnel.

## Section II. LINES OF COMMUNICATION

### 94. Importance

The lines of communication of an area consist of all the roads, railways, and waterways over which troops or supplies can be moved. The importance of particular features will depend upon the unit and the type of operations. The ability of an army to carry out its mission depends greatly upon its lines of communication. One of the primary considerations in planning large-scale operations is the extent and general nature of the transportation network. Planners must consider the advantages and disadvantages of the entire pattern of transportation facilities. An area with a dense transportation network, for example, is favorable for major offensives. One that is crisscrossed with canals and railroads, but possesses few roads, will limit the use of wheeled vehicles and the maneuver of armor and motorized infantry. Railroads extending along the axis of advance will assume greater importance than those perpendicular to the axis, and the direction of major highways and waterways assumes equal significance.

### 95. Roads and Routes

*a. Description.* The term roads includes all types of roads and tracks, but pack trails and foot paths are not included. Bridges, ferries, snowsheds, and similar structures and facilities that provide continuity of movement and protection for the way are also considered as integral parts of the road system. An adequate road system is a fundamental requirement in the conduct of any major military operation. Terrain studies must provide information about the roads which exist in the area under consideration and should indicate any major repair or rehabilitation required on existing roads, or where now roads will be needed to support a proposed operation. Roads in the combat zone usually need meet only minimum standards, but those in rear areas, especially in the vicinity of water terminals, airfields, supply installations, and those used as MSR's must be well-surfaced and capable of carrying heavy vehicle traffic without excessive maintenance. Operations on a wide front and the employment of nuclear weapons will require a large number of secondary roads in both forward and rear areas. The information presented in a terrain study should indicate the minimum maintenance and construction requirements that may be anticipated during a planned operation. Continual maintenance of road net is essential. In addition to the severe punishment given to roads by large volumes of heavy traffic, important bridges, intersections, and narrow defiles are primary targets for enemy bombardment. The maintenance of unnecessary roads must be avoided, and the construction of new roads held to a minimum.

*b. Route Types.* Routes usually are classified as follows:

(1) *All-weather route* (*Type X*). Any route which with reasonable maintenance is passable throughout the year to a volume of traffic never appreciably less than its maximum capacity. The roads which make up this type of route have a waterproof surface, adequate drainage, and are only slightly affected by precipitation or temperature fluctuations. At no time is it closed to traffic by weather effects other than snow blockage. In this route class are roads paved with concrete, bituminous surfacing, brick, or paving stone.

(2) *All-weather route* (*Type Y*) (*Limited traffic due to weather*). Any route which with reasonable maintenance can be kept open in all weather, but sometimes only to traffic considerably less than maximum capacity. The roads which form this type of route do not usually have waterproof surfaces and are considerably affected by precipitation or temperature fluctuations. Traffic may be halted completely for short periods. Heavy use during adverse weather conditions may cause complete collapse of the surface. Crushed rock or waterbound macadam, gravel, stabilized soil, or sand-clay, are typical roads in this route class.

(3) *Fair-weather route* (*Type Z*). A route which quickly becomes impassable in adverse weather and cannot be kept open by maintenance short of major construction. This type of route is so seriously affected by weather that traffic may be brought to a halt for long periods. In this route class are roads of natural or stabilized soil, sand-clay, shell, cinders, laterite, and other lightly metalled or light aggregate surfaces.

*c. Location and Use.* Military routes are classified also as follows:

(1) *Axial route.* Axial route is part of military road net work, and it leads toward the front and is generally perpendicular thereto. When designated as the principal traffic artery of a division or higher unit, such a route is termed a main supply route (MSR). When designated the principal traffic artery of a brigade or battalion, such a road is termed a supply route (SR).

(2) *Lateral route.* A route which generally parallels the front and leads into and across axial routes.

(3) *Reserved route.* A controlled route allocated exclusively to a command or unit, or intended to meet a particular requirement.

(4) *Supervised route.* A route over which control is exercised by means of traffic control posts, traffic patrols, or both.

(5) *Dispatch route.* A route over which full control, both priority and regulation of traffic, is exercised.

*d. Adverse Terrain.* Swamps, bogs, and lowlands such as delta areas may create special problems of drainage and ditching, necessitate added support to the roadbed and require the construction of many bridges. Rugged topography may result in steep grades and sharp curves, tunneling, bridging, cuts, and sidehill locations in laying out new roads. Sidehill locations, in turn, may require retaining walls, cribbing, and snowsheds to give protection against earth, rock, or snow slides. In the desert, sand fences and special crews and equipment to keep the roads clear of drifting sands may be required. Arctic terrain requires special techniques to build and maintain roads on permafrost and periodically frozen ground.

*e. Weather and Climate.* Sustained periods of freezing, heavy snowfalls, and similar extreme weather conditions may seriously affect the use, maintenance, and construction of roads. Protection must be provided against snow drifts, and provisions made to remove the snow and to repair damage due to frost heave and frost boils. Excessive rainfall may result in washouts and flooding in low areas and cause earth and rock slides in rugged terrain. Continuous wet weather may make unsurfaced roads impassable. In dry periods, dust control becomes an important factor on unsurfaced roads.

*f. Design and Construction.* Terrain studies should include an engineering evaluation of the structural soundness of all roads in an area under consideration. If the initial design did not provide for the increased loads and speeds that would accompany military use or if the road was improperly constructed originally, it may prove a serious obstacle to movement. Repairs and excessive maintenance may be required because of an unstable subgrade; inadequate drainage of the subgrade, surface, or slopes; sharp curves, and loose or unsealed wearing surfaces that result in saturated roadbeds.

*g. Poor Maintenance.* Poor maintenance of a road is shown by clogged culverts and ditches, potholed, bumpy, and rutted surfaces, soft and uneven shoulders, and badly worn and cracked pavements. Studies should indicate where these conditions exist and the maintenance that would be required to bring the roads up to minimum military standards.

*h. Trafficability.* The various types of soils affect trafficability differently. For example sandstone affords excellent trafficability when it is dry but is reduced to good trafficability when wet; trafficability on a clay surface is rated as fair when dry and impassable when wet.

### 96. Information Requirements — Roads

*a.* Information about roads is recorded on map overlays that show the alinement of the significant roads, with the location of associated bridges, tunnels, ferries, fords, and critical points such as rockslide areas. Ordinarily the local system of route numbers is used, but if no system exists that is satisfactory for terrain intelligence purposes, an arbitrary system is used to identify the main and secondary roads.

*b.* Information about individual roads usually includes the following:

(1) Name and route number.

(2) Terminal points; intermediate localities on the road; distances between major points.

(3) Terrain (elevations, irregularities, slopes, drainage, soils).

(4) Length and width.

(5) General condition (necessary repairs and improvements, with nature and location).

(6) Surface material (by sections, if there are changes in type of surface along the route).

(7) Ratings of alinement, drainage, foundation, and surface.

(8) Roadbed (width of traveled way; type and width of shoulders).

(9) Maximum grade.

(10) Sharpest curvature.

(11) Significant cuts and fills.

(12) Clearance (minimum vertical and horizontal clearances, with nature of restrictions).

(13) Bridges (load capacity, general condition).

(14) Tunnels (length, widths, clearances, condition).

(15) Fords and ferries (type, general characteristics, condition).

(16) Critical points; location and characteristics of possible bypass routes or detours around bottlenecks.

(17) Location and characteristics of routes that provide maximum protection from ground or air attacks.

(18) Snow (critical areas, snow fencing, snow removal equipment).

## 97. Bridges

*a. Importance.* Road and railway bridges are vulnerable points on a line of communication. Timely preservation, destruction, or repair of a bridge may be the key to an effective defense or to successful penetration of an enemy area. A bridge seized intact has great value in offensive operations, since even a small bridge facilitates the movement of combat troops across a river or stream. Information about bridge types and their classification is contained in **TM 5–312** and **FM 5–36.**

*b. Sites.* Because of the time and labor involved, new bridges are erected only when an existing bridge, ford, or detour cannot be used. Terrain suitable for a bridge site should meet the following requirements:

(1) Satisfactory river conditions, with no fast currents or great depths.

(2) Site readily accessible from the road it serves.

(3) Firm, well-drained approaches, preferably above flood level.

(4) For floating bridges, a riverbed free from snags, rocks, and shoals to a minimum depth of three feet and firm enough to hold anchors and to support trestles. Banks should be from two to six feet above water level to minimize excessive abutment preparation.

(5) Firm, stable banks of suitable height. Large differences in bank height require excessive grading. Low banks may be subject to a rising river level that will flood the bridge site.

(6) Adequate, well-drained working areas close to the site including a bivouac for the working party, space for construction materials, and turnarounds and parking places for vehicles and heavy mobile equipment.

(7) Areas close to the site, near or alongside the approach roads, where vehicles can park off the road and under cover while awaiting their turn to cross.

## 98. Information Requirements — Bridges

*a.* Detailed information about bridges cannot be obtained from topographic maps, but indications on air photographs usually will permit an approximate determination of the width, clearance, and height above water of a bridge. Details such as the condition, capacity, and structure of a bridge should be obtained by engineer reconnaissance. Reconnaissance procedures are described in TM 5–312 and FM 5–36. Basic information requirements for a bridge should include a summary of its structural characteristics, its critical dimensions (length, usable width, overhead clearance), an estimate of capacity, and general condition.

*b.* Detailed information includes the following:

(1) Type, number of lanes and width of each, number of spans and length of each length of panels, arrangement of spans.

(2) Height above riverbed, overhead clearance for vehicles, class.

(3) Stream data: width, depth, velocity of current, direction of flow, type of bottom, estimated bearing capacity of bottom, height, slope, and nature of banks.

(4) Description, dimensions, and condition of access roads and approaches.

(5) Type, dimension, and condition of abutments, stringers, flooring, girders, and other structural elements.

(6) If damaged or wrecked—

(*a*) Structural details of bridge in its original form.

(*b*) Nature and extent of damage; position of debris; details regarding any salvageable materials.

(*c*) What loads, if any, can still cross the bridge.

(*d*) If not suitable for use, information about alternate sites.

## 99. Railways

*a. Property.* The term railway includes all fixed property belonging to a line, such as land, permanent way, bridges, tunnels, and other structures. Railways assume increased military importance in areas where the soils are generally untrafficable, roads are poor, and rail transportation facilities are extensive. Frequently, railways can be used as substitute roads for vehicles. Most railway bridges will carry tanks without reinforcement. The basic elements of a railroad include motive power, rolling stock; trackage; yards, terminals, regulating stations, and railheads; transshipment points; water and fuel stations; maintenance and repair facilities; and signal communication facilities.

*b. Yard.* A yard is an area containing a system of interconnected tracks and is used for making up trains, storing cars, and general maintenance activities.

*c. Railhead.* A railhead is the point at which supplies destined for a particular unit, installation, or area are transferred from rail to another type of transportation, usually trucks.

*d. Regulation.* A regulating station is an installation on a military railway line at which the movement of supplies and personnel is controlled. Its facilities include a yard, open and covered storage, and usually, temporary housing and messing facilities for transient personnel.

*e. Construction.* The development and extent of a railway system largely reflect the topography of the region that it traverses. In desert regions, for example, a single railroad may extend in a straight line across vast barren wastes. In hill regions and mountain areas, the railways run through valleys, with short lines leading off into other terrain. On plains, railways will have few curves but may be subject to the effects of poor drainage conditions. Generally, railways tend to follow rivers because of the more uniform grades, the availability of straight routes, and the concentration of resources, industries, and population centers along the waterway. The terrain characteristics of an area can be determined to a considerable degree by a study of the railway routes, since the rail lines almost invariably follow the topography that offers the fewest obstacles.

*f. Military Use.* Railways are desirable for extended military operations. Their capabilities are of primary concern and are the subject of continuing studies by personnel at the highest levels. Detailed intelligence about the railways in an area of operations is produced by specialists of transportation and engineer units. Railways are highly vulnerable to enemy attack, particularly to sabotage and guerrilla operations. Keeping a railroad line in operation requires trained security forces and extensive protective measures.

## 100. Evaluation of Railways

In evaluating a railway for terrain intelligence purposes, consideration should be given to the effects of adverse terrain, weather and climate, and the overall design and construction of the system. The following factors should be considered:

*a. Adverse Terrain.* Railways passing over swamps, bogs, and delta terrain may encounter special problems of drainage, ditching, and roadbed maintenance. In mountainous areas, steep grades, sharp curves, and tunnels are common. Because of sidehill locations and deep cuts, there should be protection against earth, rock, and snow slides. In desert, drifting sand is a problem and provisions should be made to remove it.

*b. Adverse Weather and Climate.* Severe winter conditions seriously retard operation and maintenance of railways, requiring protection against drifting snow, provisions for snow removal, and repairs because of damage caused by frost heave. Excessive rainfall may result in washouts and flooding in low areas and cause earth and rock slides in rugged terrain.

*c. Design.* A railway may prove inadequate because the initial design did not provide for the increased loads and speeds or heavier volume of traffic needed. As a result, a railway might require either considerable reconstruction and repair or extensive maintenance. Among the more common defects are an unstable subgrade, lack of adequate drainage, light rail, poor ballast, and untreated ties. Improper maintenance is evidenced by such conditions as an uneven roadbed, improperly tamped ties, loose fastenings, badly worn rail, or uncleared drains.

## 101. Information Requirements — Railways

Railway information should be recorded on a map or overlay that shows the true alinement of all rail lines; their trackage, gage, and status; and the location of selected bridges, tunnels, and ferries. A convenient system of line numbers is used based on a standard reference or arbitrarily selected. Fundamental information about railways should include the following:

*a.* Total mileage.

*b.* Terminals and details of main lines.

*c.* Mileage by gage and locations of changes.

*d.* Number of tracks.

*e.* Maximum grade and minimum radius of curvature.

*f.* Location and length of passing tracks.

*g.* Type and weight of rail.

*h.* Permissible loads; capacity of bridges.

*i.* Yards and terminals (location, type, capacity).

*j.* Details of servicing facilities and other installations.

*k.* Operating factors (cars per train; speed; number of daily trains each way).

*l.* Bridges and tunnels (bridge data to include length, number of tracks, spans by type and length, height of structure; tunnel data to include length, number of tracks, and lining).

*m.* Rail ferries (location, type, capacity).

*n.* Electrification (location, type).

*o.* Transshipment points.

*p.* Individual rail line details—

(1) Name.

(2) Terminals, intermediate stations, length of each stretch.

(3) Obstructions (demolitions, washouts, blocked tunnels).

(4) Gage.

(5) Number of tracks.

(6) Weight of rails.

(7) Maximum grade and minimum radius of curvature with location of each.

(8) Ties, ballast.

(9) Sidings and passing tracks (location, lengths, switches).

(10) Tunnels (locations, clearances).

(11) Overhead structures and vertical clearances.

(12) Drainage facilities, including culverts.

(13) Bridge data.

(14) Operating and servicing facilities (location, availability of fuel and water and ice; signal, traffic control, and dispatching facilities).

(15) Availability of trained and dependable personnel.

(16) Transshipment points.

*q.* Equipment.

(1) Present condition, and interchangeability with equipment of other countries.

(2) Motive power (type, size, weight, tractive effort, wheel arrangement, type and height of couplings).

(3) Rolling stock (type, number, car dimensions, capacity, weight).

(4) Rail cars self-propelled and trailer-type, total by type, size, capacity.

(5) Work cranes (total by type, size, capacity).

(6) Snow plows (total by type, size).

(7) Armored equipment (total by type, size).

(8) Repair shops (location, types of equipment repaired, capacity by type, number of personnel employed).

## 102. Inland Waterways

*a. Definition.* The term inland waterway is applied to those rivers, canals, lakes, and inland seas of a country which are used as avenues of transport. It includes all the fixed structures which affect the movement of vessels carrying passengers or freight. Types of inland waterways include inland lakes and land-locked seas, rivers, and ship and barge canals, and the intracoastal waterways, usually running parallel to the coastline of a land mass and sheltered enough to permit the navigation of small vessels.

*b. Classification.* Inland waterways can be classified according to their depths as follows:

(1) *Very shallow.* Depths less than 1.4 meters (4½ feet).

(2) *Medium.* Depths between 1.4 and 2 meters (4½ and 6½ feet).

(3) *Deep.* Depths greater than 2 meters (6½ feet).

*c. Advantages.* Inland waterways provide an economical form of transportation for bulk supplies, freeing faster modes for shipments of a higher priority. Frequently, large or very heavy items that cannot be handled by truck and rail can be shipped by waterway. One of the major uses of waterways in an active theater is the transportation of supplies for the rehabilitation of the economy in liberated areas, thus reducing the demands upon military transportation facilities.

*d. Limitations.* Unless icebreaking operations can be conducted, traffic is halted completely during a freezing period. The thaw following a freezeup may cause floods, and periods of drought may result in insufficient water for the movement of vessels. The locks, bridges, cuts, dams, and other facilities are vulnerable to enemy action. Retreating enemy troops usually drop rail or road bridges into the waterway; damage locks and levees; obstruct channels with ships and barges; drain canals; and destroy, dismantle, or move essential equipment. Waterway transport is slow. It is also inflexible, since new waterways cannot be constructed during military operations. The depths of rivers and streams used as waterways fluctuate with maximum and minimum rainfall. Streams with fairly direct courses commonly are interrupted by falls and rapids. Streams of low and uniform gradients usually meander. Their channels shift constantly, depositing sandbars, which are a menace to navigation.

### 103. Information Requirements — Waterways

Inland waterway information should be recorded on a map or overlay that shows the true alinement of the navigable waterways, the location of all locks, dams, aqueduct bridges, tunnels, and major landing facilities, and the location of specific structures which limit the vertical and horizontal clearances on each navigable reach. The local names are used to identify waterways and structures whenever feasible. Detailed information requirements should include the following:

*a. Developed Waterways.*

(1) Geographical location (name, origin, terminus, length).

(2) Restricting widths and depths of channel.

(3) Frequency, duration, and effects of seasonal changes (floods, low water, droughts, excessive currents, normal freezeup and opening dates).

(4) Location, description, and restrictive effects of structures (locks, safety gates, dams, bridges, ferry crossings, aqueducts, tunnels, cable crossings).

(5) Speed and fluctuation of current.

(6) Name and location of waterway ports, including length of alongside wharfage and depths, and data on mechanical handling, storage, clearance and ship repair facilities.

(7) Maintenance requirements.

(8) Craft (number, type, cargo capacities).

(9) Communication facilities.

(10) Availability of labor force.

*b. Navigable Rivers.* In addition to the items listed in *a* above, the following additional information may be required:

(1) Physical characteristics of the river

(bottom, banks, feedwater streams, and important tributaries).

(2) Navigational hazards, such as falls, rapids, and sandbars.

(3) Navigational aids, location, and type (buoys, lights, range markers, radar, foghorns).

(4) Changes in channel.

(5) Dredging requirements.

## Section III. PETROLEUM AND NATURAL GAS

### 104. Location

*a. Source.* Oil is found only in the stratified sedimentary rocks and sands of ancient sedimentary basin areas. Because of geologic upheavals in past ages, today's oilfields may be found along the foot of mountain chains or in lowland or offshore areas. Petroleum, gas, and water are commonly found together.

*b. Gas.* Natural gas is found alone, as well as with petroleum. Gas from oil wells is commonly entrained with natural gasoline and is known as wet gas. When economically feasible, wet gas is piped to an absorption plant, where the gasoline is extracted. Gas from gas wells ordinarily is relatively free of natural gasoline and is known as dry gas. If sufficiently free of other unwanted gases and impurities, dry gas may be fed directly into pipelines for distribution.

### 105. Installations

*a.* Derricks are commonly the most distinguishing features of an oil or gas field. A derrick is required to position and handle the long sections of drill pipe and other equipment used in the well when drilling for oil. Depending on the type, the cost of moving or future needs, a derrick may or may not be left in place indefinitely following the completion of the well. Where a continuing need exists, the drilling derricks may be replaced with smaller derricks or gin poles. A producing oil well is characterized by a pump or by a "Christmas tree," so called because of its tree-like appearance. A pump is used where the subterranean gas pressure is too low to force oil to the surface. A Christmas tree is used where the underground gas pressure is sufficient to force oil to the surface. It consists of a system of pipes, valves, and gages capping a well for controlling the flow of crude oil and gas.

*b.* Refineries are located near either producing oil fields or distribution centers in major consuming areas. Adequate all-weather transportation and an abundance of cooling water are essential. Tall, cylindrical distillation or "cracking" towers are the most prominent features at refineries. Other equipment includes large furnaces, cooling towers, electric power plants or substations, and intricate piping systems. Tankage for storing crude oil charge stocks and semirefined and refined products is also required. Refinery capacities are usually rated in barrels per day (42 U.S. gallons per barrel) or metric tons per year of crude oil run to stills (crude oil started through the refining processes). A reliable rule of thumb for converting barrels per day to metric tons per year is to multiply the number of barrels per day by 50. Metric tons per year are divided by 50 to yield barrel-per-day figures. Crude oil for refinery fuel or lost otherwise amounts to about 7 to 10 percent of refinery capacity.

### 106. Distribution

*a. Systems.* A bulk distribution system for petroleum products may include ship-to-shore and dockside loading and unloading facilities, bulk storage tank farms, pipelines, pumping stations, bulk delivery points or pipeheads, warehouses, open storage areas, canning and drumming facilities and testing laboratories. Ocean-going tankers, tank barges, railroad tank cars, and tank trucks are also included in integrated distribution systems. For terrain intelligence purposes, pipelines and storage facilities are the most significant features of a distribution system.

*b. Pipelines.* Pipelines commonly consist of piping, pumping equipment, and regulating tankage. Other supporting equipment may include tele-communications facilities, cleaning devices and trays for removal of unwanted condensates or contaminants, control and heating devices. The capacity of a pipeline is expressed as a quantity of liquid capable of being transported per unit of time, ordinarily in the number of barrels, metric tons, or cubic meters per day. The quantity of fuel actually transported, usually will not exceed about 85 percent of the pipeline capacity.

c. *Military Pipelines*. Military pipelines are used chiefly to transport jet fuel and gasoline. Occasionally they are used also to transport diesel fuel and kerosene. Commonly, 15-cm (6-inch) pipe is used; 20-cm (8-inch) pipe is employed for ship unloading or trunk lines. The pipeline follows the most direct level route, within six to nine meters (20–30 feet) of all-weather roads, so as to facilitate construction, partrol, repair, and security of the line. Cross-country cutoffs are used where roads wind excessively. A military pipeline is diverted around difficult terrain, such as marshes, swamps, or land that is subject to periodic flooding. It also avoids populated areas and military installations that have a high element of hazard, such as ammunition dumps. Base terminals are located in rear areas, at or near theater ports of embarkation or other tanker unloading points, but pipehead terminals are located at the forward end of a military pipeline, moving forward with the army supply point to support the advancing forces.

d. *Civilian Pipelines*. Civilian pipelines are important for potential military support. They are generally permanently installed cross-country along the most economical route. These pipelines may range from about 10 cm (4 inches) to more than 100 cm (40 inches) in diameter. Pipe of extremely large diameter is ordinarily used only for natural gas or crude oil. Pipelines for crude oil are much more common than those for refined products, although use of the latter is rapidly growing. Crude oil pipelines can be converted for handling refined products. This is a costly and time-consuming undertaking, particularly if aviation-grade fuels are to be transported.

e. *Tanks*. Bulk petroleum and refined products are stored in tanks which differ greatly in size, shape, and construction, according to the function of the tanks and the nature of the product stored. The tanks may be completely above ground, partly or entirely buried. Tanks above ground are surrounded by dikes or low walls to form catch basins and to prevent the occurrence or spread of fires if the tanks are ruptured or overflow. Tanks are buried or partly buried for reason of safety, to reduce evaporation losses, for concealment, or to reduce their vulnerability to military attack. A group of storage tanks is called a tank farm. Tank farms vary greatly in size; some comprise major storage complexes, with storage capacities of millions of barrels. Ordinarily, the tanks are interconnected by an assembly of pipes and valves called a manifold, which permits the movement of products. Because of their vulnerability to air attack, and to nuclear attack, military tanks farms are limited to a total capacity of no more than 250,000 barrels. Military storage tanks are made of steel or aluminum and have capacities up to 10,000 barrels. Portable fabric tanks also are used in military operations at forward supply points and at beachheads.

## 107. Military Importance

a. *Targets*. The petroleum and natural gas resources of a country or region are valuable assets to its economy, and the degree of self-sufficiency in military fuels is fundamental to its conventional military capabilities. Accordingly, refineries, terminal facilities, distribution systems, and storage installations are primary targets for air attack and are major objectives. Major oil producing areas and refineries, key pipelines, storage facilities, and marine terminals may be the principal objectives of a campaign to seize them for our use or deny them to the enemy. The most militarily significant natural gas facilities are pipelines, which could be readily converted for handling petroleum products for military support.

b. *Planning*. Because military planners are interested in the availability of fuel for military use, avoiding possible disturbance to local economics, the typical normal operating conditions with respect to petroleum facilities are important. Included are seasonal variations in the supply and demand for petroleum products, and the principal consumers and their needs. Manufacturing and civil transport fuel requirements, as well as agricultural consumption by tractors and irrigating systems are militarily significant in modern planning.

### 108. Information Requirements — Petroleum and Natural Gas

The location and extent of petroleum and gas facilities should be recorded on a topographic map of suitable scale. A numbering system is established to identify the petroleum and the gas pipelines, producing fields, plants, and storage facilities. A separate series of numbers is used for each pipeline. Such pipeline facilities as pumping stations and tank farms are numbered serially, beginning from a designated initial point on the line. Local names may be used for individual installations. Basic information should include the following:

*a. General.*

(1) Location and type of raw material (oil, oil shale, natural gas) ; character of crude oil; well logs; and a geologic column which designates the producing formations and the depth to producing horizons.

(2) Reserves of raw material in million barrels, metric tons, or million cubic feet (cubic meters).

(3) Administrative, maintenance, and repair facilities.

(4) Security and safety provisions.

(5) Physical condition of installations and equipment; required major repairs or improvements.

(6) Availability of trained and reliable personnel.

(7) Principal consumers.

*b. Refineries.*

(1) Location and owner/operator.

(2) Capacity.

(3) Details of construction; type of equipment.

(4) Nature and quality of products produced.

*c. Pipelines.*

(1) Name, if any; location of lines; material transported.

(2) Terminals.

(3) Number and diameter of pipes; delivery capacity of system at present and under normal conditions; content of pipeline when full.

(4) Facilities at base terminal (if a water terminal, method of loading from tankers).

(5) Storage facilities at terminals and along pipelines; capacity of each installation.

(6) Pumping stations (location, capacity, equipment).

*d. Storage.*

(1) Location: geographic coordinates; topography; adjacent landmarks.

(2) Surface tanks: types and number; dimensions; protection (revetments, blast walls).

(3) Buried tanks; number; dimensions.

(4) Pump houses: location; number; dimensions; capacity.

(5) Connecting pipelines and distributing systems.

(6) Stocks (location and type).

## Section IV. MINES, QUARRIES, AND PITS

### 109. Mines

*a. Mineral Resources.* The important mineral resources of a country include metallic ores such as iron, copper, zinc, lead, tin, silver, gold, and uranium; mineral deposits, principally sulfur, phosphate rock, gypsum, graphite, asbestos, and bauxite; and solid fuels, chiefly coal, lignite, and peat. Terrain studies list each significant mineral, covering in detail the estimated quantities available and the methods and facilities employed to mine, process, and distribute each type of mineral. Mineral deposits are exploited either from the surface of the ground or from underground shafts and tunnels, the method depending upon the depth of the deposit below the surface. A typical underground mine consists of a vertical shaft, horizontal passages opening out of the shaft, and passages driven from above (winzes) connecting the levels. Openings branching off from the levels, where the ore is actually extracted, are called stopes. Supports in mine working usually are made of timber treated with preservatives or of reinforced concrete, steel, brick, or stone. Pillars of ore may be left as supports, finally being mined when the workings are vacated. Where ore beds lie close to the surface, the mineral may be removed from open pits after stripping off the overlying earth and rock. This is strip mining, the coal or other mineral being removed by power shovels.

*b. Placer.* Placer mining involves the removal of the unconsolidated rock material that lies above bedrock by hand, hydraulic nozzles or dredges, and subsequent separation of the ore from waste by panning and sluicing. It is widely employed to mine gold.

*c. Open-pit.* In open-pit mining, an excavation is made. In the case of deep pits, the sides usually are cut into steps or benches. Access to the below-ground-level site may be obtained by arranging these benches in spiral form, by cutting inclined approaches, or by sinking a shaft connected to the mine by an adit or tunnel (fig. 48).

*Figure 48. Open-pit copper mine.*

*d. Glory-Hole.* In glory-hole mining, the excavation is funnel-shaped, and a vertical passage (raise) driven from below connects with an underground haulage level. The ore slides down this passage into the haulage level for removal.

*e. Military Considerations.* The ability of any nation to support a war depends upon its mineral resources and enemy mines are accordingly a major objective for air attack. The seizure or defense of important mines may also be the mission of troop units of any size. Mines provide concealment and cover, but their use as shelter for troops may be hazardous and is seldom practicable. Most mines will not withstand the effects of heavy surface bombardment. Coal mines are especially unsuitable for troops or storage. Coal is structurally unstable and requires extensive supports even in ordinary mining operations. Many varieties of coal give off a gas known as fire damp or marsh gas. This is highly flammable and highly explosive when mixed with air. Coal dust and air also form an explosive mixture. Some mines, particularly salt mines, may be utilized for the storage of supplies and equipment. Adit mines, with their horizontal or slightly inclined entries, are more suitable than vertical-shaft mines for underground storage. The latter type may present drainage problems and offers more difficulties in transporting loads into and out of the mine. To prevent their use by the enemy, mines can be flooded or destroyed with explosives. The possibility of mines being used as headquarters for guerrillas must be considered, and inactive mines in a tactical area should be blocked, destroyed, or otherwise secured against occupancy.

## 110. Information Requirements — Mines

The information about a mine required for a terrain study will depend upon the purpose. Such information as the following usually is required:

*a.* Location and name of mine.

*b.* Product (Mineral extracted, quality, quantity, underground and in reserves).

*c.* Extraction methods (deep, placer, strip, special methods).

*d.* Details of layout and operation.

(1) Pits, shafts, galleries, wells.

(2) Hand and mechanical labor involved.

(3) Above ground structures, plant, and equipment.

(4) Refining processes.

(5) Storage facilities.

(6) Transportation facilities.

(7) Utilities (ventilation, electric power, lighting, water, firefighting).

*e.* Physical condition of installations and equipment.

*f.* Safety and security features.

*g.* Availability of labor.

*h.* Any major repairs needed for operation.

*i.* Access road and turn around availability.

## 111. Quarries and Pits

*a. Quarries.* A quarry is a site providing rock that is suitable in quality, quantity, and size for construction purposes. A hardrock quarry furnishes rock such as granite, limestone, or sandstone, which must be drilled and blasted in quarrying and which must be crushed for some uses. Igneous and metamorphic rocks are generally considered hard rocks. A soft-rock quarry furnishes material that can be removed readily by earthmoving equipment. Soft coral, caliche, shale, chalk, and tuff are materials of this type. Sedimentary rocks are generally considered soft. Quarries are generally the open-faced type, with the vertical surface of the rock exposed. Depending upon local conditions, they may be developed by the single or multiple bench method. A single-bench quarry has the entire floor on one level, the height of the bench worked in one operation varying from 2 to 30 meters (8 to 100 feet). A multiple-bench quarry is one having a series of ledges or terraces resembling steps.

*b. Pits.* A pit is a site where earth or rock particles suitable for engineer construction may be obtained in quantity. A borrow pit is a site providing soil suitable for fills, surfacing, or blending that can be removed with earthmoving equipment. A gravel pit consists predominantly of particles of gravel size. Unsorted gravel from pits is used extensively for surfacing secondary roads, in base courses for pavements for roads, taxiways, and runways, and as aggregate in concrete and bituminous operations. An alluvial gravel pit derives its name from the origin of the deposit, since the material is stream-deposited. The gravel obtained from these pits usually is very clean and free from clay and humus. It is therefore particularly desirable for concrete and bituminous work. A bank or hill gravel pit produces a clayey gravel or clayey sandy gravel. These materials are very desirable for surfacing work because of their binding qualities.

*c. Military Considerations.* Pits and quarries are important chiefly as sources of materials for engineering construction. They may be local objectives in tactical operations, if plans require extensive engineering development of the area. Individual pits and quarries usually can be bypassed by advancing forces, but an area containing a number of them may present difficulties to the movement of larger units and will tend to analyze movements. Flooded quarries are a particularly hazardous obstacle. Pits and quarries provide a varying degree of cover for troops. They may also furnish defiladed locations for artillery and missile positions.

### 112. Information Requirements — Quarries and Pits

*a. Quarries.*

(1) Location.

(2) Nature of stone.

(3) Actual and potential capacity in uncrushed stone.

(4) Capacity of crushing machinery in stone of various sizes.

(5) Details of machinery.

(6) Loading facilities

(7) Amount of crushed stone that can be hauled away in a day, considering the manner of loading, number of trucks that can be loaded at one time, access road, and turnarounds.

*b. Pits.*

(1) Location.

(2) Nature of source.

(3) Nature of raw materials; quality, quantity.

(4) Amount, depth, and type of overburden.

(5) Drainage; ground-water level; standing water.

(6) Utilities available (electricity, water).

(7) Equipment available.

(8) Method of extraction (hand labor, machinery, dredging).

(9) Method of cleaning and sorting.

(10) Daily production capacity.

(11) Transportation routes; access roads; surfaces of roads.

## Section V. AIRFIELDS

### 113. Size, Form, and Components

*a. Description.* Airfields range in size and function from short landing strips consisting of little more than a cleared area suitable for light liaison planes or helicopters to large permanent air bases with many complex supporting installations. The simplest form of operational airfield consists essentially of a runway, usually oriented in the direction of prevailing winds; one or more perimeter taxiways, with warmup aprons located where they join the ends of the runway; and hardstands to accommodate one or more groups of aircraft. The runway may or may not be surfaced. In addition, there will be a minimum of other facilities, such as access and service roads, fuel storage, ordnance storage, and a control tower. The particular characteristics will depend upon the type of aircraft that will use the field.

*b. Tactical Airfield.* A tactical airfield in a theater of operations includes the following major elements:

(1) Landing strips.

(2) A system of hardstands and runways.

(3) Warmup aprons close to one or both ends of the runway.

(4) Operation facilities, including control tower and operations and briefing rooms.

(5) Fuel storage and dispensing facilities.

(6) Ammunition storage facilities.

(7) General supply storage facilities.

(8) Repair and maintenance facilities for aircraft, accessories, and automotive vehicles.

(9) Roads, walkways, communications, firefighting unit, and other service facilities.

(10) Security and safety installations.

### 114. Terrain

*a. Location.* The general location of a proposed airfield is indicated by the Air Force commander or the Army aviation officer, as appropriate, while the exact site is chosen in coordination with the engineer after a careful evaluation of the terrain.

*b. Selection.* In selecting a site, the following factors should be considered:

(1) Adequate dimensions to meet operational requirements, with room for future expansion.

(2) Accessibility to supply routes and communication facilities.

(3) Obstructions along flightways and approaches, including critical topographical features, such as high hills or mountains. High tension wires, roads, and railroads crossing the flight way near the runway are dangerous mental and physical hazards to pilots.

(4) Meteorological conditions (wind, rainfall, fog, snow, frost action).

(5) Drainage.

(6) Topography. A site with favorable topography is one located on high ground with sufficient slope for natural cross drainage as well as longitudinal drainage and a reasonably smooth surface requiring little earthmoving.

(7) Clearing, grubbing, and stripping required. A large open area surrounded by sufficient covered areas to conceal all activities is ideal. Ground cover in areas adjacent to the flight strip is especially desirable to provide natural concealment for parked aircraft, dumps, and bivouac and other installations.

(8) Soil characteristics. The type of soil determines the type of equipment required for construction, drainage, effects of adverse weather, and the subgrade bearing capacity that can be obtained.

(9) Availability of gravel, sand, coral, or other materials for excavation.

(10) Water supply. Large quantities of water are required in both the construction and operation of airfields.

(11) Camouflage requirements. A desirable site is one that avoids identifying landmarks and affords cover for installations and aircraft at dispersed locations.

## 115. Information Requirements — Airfields

Based on available reports and files, detailed studies of particular airfields in local areas will be prepared by intelligence personnel. Pertinent information to be included in a terrain study should include the following:

*a.* Location (map coordinates, elevation, distance and direction from nearest city or town, principal landmarks, name if any).

*b.* Category (emergency landing strip, refueling and rearming strip, fighter field, bomber field, heliport, and civilian secondary airport).

*c.* Characteristics of site (type of terrain, character of soils, special aspects of weather and terrain differing from country-wide or regional conditions).

*d.* Detailed layout (sketch) of runways, taxiways, parking and service areas.

*e.* Runways.

(1) Identification.

(2) Length of runway and overrun; extensibility.

(3) Width of runway, overrun, shoulders.

(4) Type and depth of surfacing and base.

(5) Type and adequacy of drainage (ditches, subsurface drains).

(6) Load capacity (in pounds, or kilograms or aircraft type).

(7) Gradient.

(8) Present condition.

*f.* Taxiways and parking (dimensions, type and depth of surface material and base, load capacity, condition).

*g.* Detailed description of operation area; improvements planned or under construction.

*h.* Facilities.

(1) Buildings (type, material, dimensions).
(2) Maintenance and repair (number and extent of buildings and numbers and types of equipment used for airfield maintenance.
(3) Fueling (number and capacity of tanks, above or below ground).
(4) Electricity supply.
(5) Water supply.

*i.* Related transportation (railroad, road, water; details about type, location, and capacities of transportation facilities available).

*j.* Airfield construction sites.

(1) Topography.
(2) Wind (direction, intensity of prevailing wind; local peculiarities).
(3) Rainfall (average by months; wet seasons; intensity, duration, and frequency of rainfall).
(4) Other aspects (temperature variations, storms, fog, and ground haze).
(5) Availability of local construction materials.
(6) Water supply.
(7) Clearing and grading required.
(8) Drainage conditions and required improvements.
(9) Soil classification.
(10) Flight obstructions.
(11) Frost heaving, permafrost, flooding, extremely strong winds bear directly on airfield site construction and maintenance.

## Section VI. WATER TERMINALS

### 116. Ports

Water terminals (ports) may range in size from beaches suitable only for landing craft to giant complexes extending along many miles of coastline. They usually constitute key terrain features and primary objectives in military operations. FM 55–51 gives detailed information about the organization and operations of water terminals. Normally, major water terminals (fig. 49) are characterized by deep harbors protected from storms and free from ice in the winter months. The rail and road networks of the area usually extend from the terminals inland to developed portions of the country. Large terminals are often surrounded by commercial, industrial, and shipbuilding areas.

### 117. Military Significance

*a. Vulnerability.* Large water terminals are highly vulnerable to attack by nuclear weapons. When the enemy has a nuclear weapon capability, logistical support is provided through a number of dispersed small terminals, often little more than beaches developed to meet minimum requirements. Terrain studies should include an evaluation of all suitable locations for such terminals, indicating their physical characteristics, relative usefulness, and estimated capacities. A large-scale amphibious operation may include a number of separate secondary landings to secure beaches that are suitable for dispersed logistical terminals.

*b. Evaluation.* Information about established water terminals usually is contained in terrain studies prepared at the highest echelons, which form the basis for studies used in specific operations. The existing water terminals are evaluated as to their usefulness and their present physical condition. If an enemy-held terminal is to be used by friendly forces after its seizure, particular attention is given to the essential structures and facilities that should be spared from destruction, if practicable, during the preliminary bombardment and assault.

### 118. Information Requirements — Water Terminals

The information about a water terminal which is most essential in preparing a terrain study will depend upon the features that are of the greatest concern in a specific operation. Detailed information requirements for water terminals are contained in FM 55–8. Information required may include—

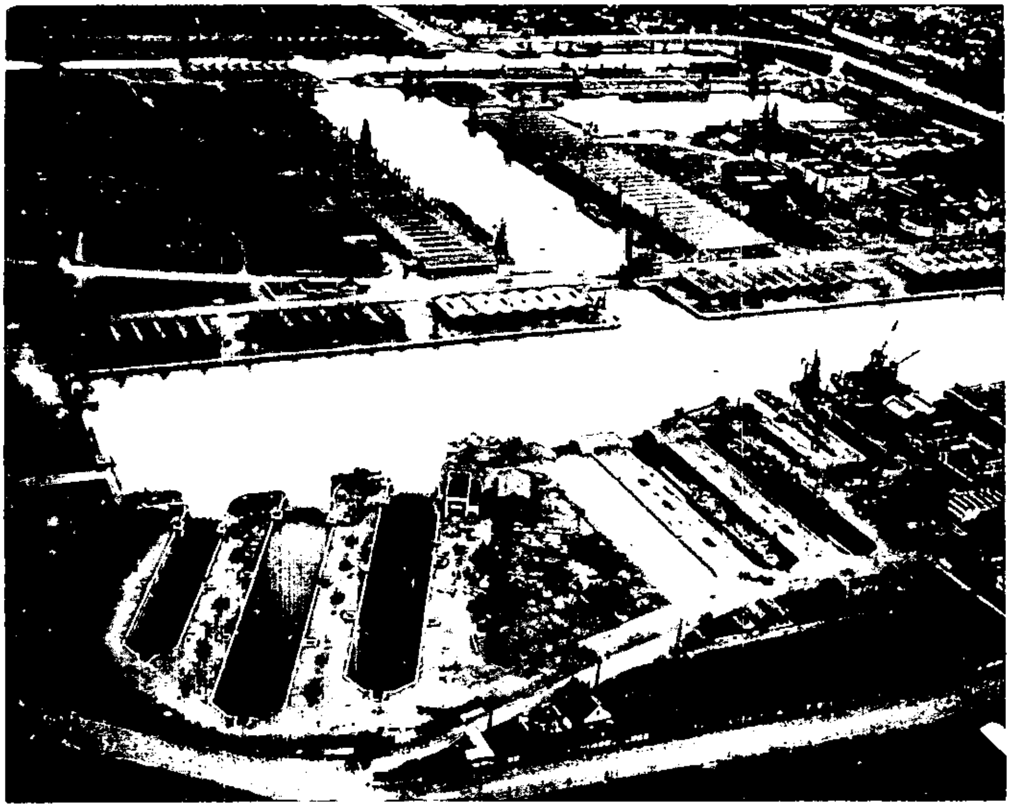


*Figure 49. Typical large water terminal (port).*

*a.* Name, location by map references and coordinates.

*b.* General characteristics (open roadstead, partly inclosed bay, landlocked harbor, sheltered area behind a barrier reef, and river).

*c.* Entrance and approach channels (controlling depth, length, width).

*d.* Breakwaters (position, length, construction).

*e.* Description of harbor.

(1) Type.

(2) Harbor and channel depths.

(3) Extent of silting.

(4) Nature and frequency of maintenance dredging.

(5) Location and nature of anchorages.

(6) Underwater obstructions.

(7) Pilotage information.

*f.* Bridges regarded as shipping obstructions (location, type, horizontal and vertical clearances at mean low water).

*g.* Hydrographic and weather conditions.

*h.* Adjacent beaches usable by landing craft (location, length, type, gradient, and accessibility).

*i.* Cargo-handling facilities.

(1) Wharves, piers, and quays (type, function, structural features, cargo-handling machinery, road and railroad connections, utilities, mooring facilities).

(2) Wet docks and semitidal basins.

(3) Mechanical handling facilities.

(4) Harbor-service craft (type, function, number).

*j*. Repair facilities.

(1) Repair yards.

(2) Graving docks.

(3) Floating docks.

(4) Marine railways.

*k*. Storage facilities.

(1) Location, type of commodities stored, type of constructions, capacity, transportation connections, fire protection, special handling equipment.

(2) Cold storage facilities (temperature, daily ice making capacity).

(3) Grain storage facilities.

(4) Bulk liquid storage (capacities in barrels).

(5) Open storage (location of suitable areas, rail and road connections, approximate capacity).

(6) Petroleum and coal storage (location, type, capacity, bunkering facilities).

(7) Special storage facilities for explosives and ammunition.

*l*. Clearance facilities (rail lines, highways, inland waterways, pipe lines).

*m*. Water supply (availability, quality, method and rate of supply).

*n*. Electric power and lighting (availability, source, and characteristics of current).

*o*. Capacity of the terminal as a whole, under both normal and present conditions.

*p*. Data needed for major repairs and improvements; vacant areas available for expansion.

*q*. Availability of trained, reliable personnel.

## Section VII. HYDRAULIC STRUCTURES

### 119. Types

*a*. *Flood Control.* The principal structure employed in flood control is the artificial levee, an embankment built along a river course to prevent flooding of the adjacent country during high water. It may be 6 meters (20 feet) or more in height, and usually is made by packing layers of earth upon a foundation, with grass planted on top of the levee to hold the soil. The levee may be faced with concrete. Usually an artificial levee is constructed some feet in rear of the river banks to provide a wider channel during flood periods.

*b*. *Dams.* Earth dams for reservoirs frequently are built of layers of homogeneous material with a center core of puddled clay or other impermeable material. Usually the inner surface is paved with stone or concrete as a precaution against erosion, and the outer surface is covered with grass to bind the surface and to protect it against the weather. Dams across rivers and deep ravines, or where there is considerable width and height, usually are made of stone masonry or concrete. They are built either straight across the river or in the form of an arc, the convex side fronting the stream (fig. 50).

*c*. *Reservoirs.* A reservoir is a wholly or partly artificial lake used for water storage. Types of reservoirs include those for flood control, irrigation, recreation, power production, and navigation. Reservoirs are utilized for municipal water supply systems, on rivers to aid in flood control, on canals to maintain the water level for navigation, and in hydroelectric installations to insure a constant water supply. The reservoir may have a lining of clay or other impervious material to prevent water seepage. The embankments or retaining walls may be of earth, loose rock, or masonry. Distributing reservoirs in municipal water systems sometimes are built of masonry or reinforced concrete. They serve to take care of fluctuations in demand and as a reserve in case of interruptions at the source. In reservoirs with earth embankments, overflow is provided for by a *waste weir* or canal, to carry off sur-

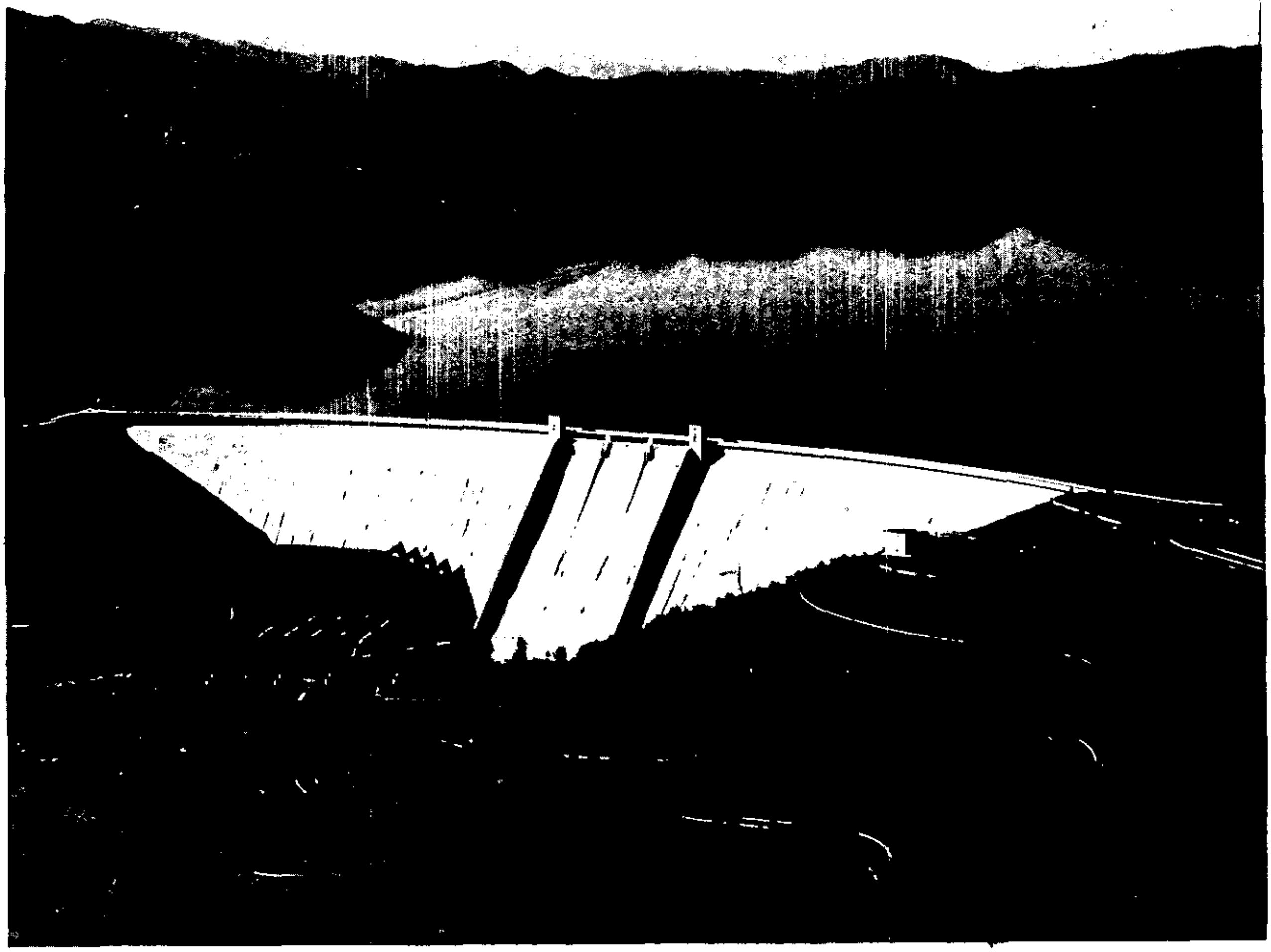


*Figure 50. Downstream face of Shasta Dam (California).*

plus water. When the reservoir is formed by a masonry dam across a river, the surplus water may be allowed to flow over the top, or spillways may be provided (fig. 51).

*d. Locks.* The dominant feature of developed waterways is the canal lock. A lock is an enclosed stretch of water with a gate at each end used to raise or lower vessels from one water level to another. When a vessel is to pass from a low level to a higher one, the water in the lock is lowered until it is level with that in which the ship is floating. The vessel is moved into the lock and the gate is closed. Water is then allowed to enter the lock until it reaches the higher level, and then the gate at the other end is opened and the vessel passes through. This procedure is reversed when the vessel goes from a higher to a lower level. Many locks have an intermediate set of gates so that only part of the lock is used for smaller vessels. Usually the water passes through culverts built into the lock walls and is controlled by sluice gates powered by hydraulic or electric power. Lock gates are made of either steel or wood. A pair of gates meets in the center of the lock entrance. When closed, the gates form an arc with the convex side toward the pressure of the water. The lift of a canal lock may be 12 meters (40 feet) or more.

*e. Polders.* Areas with an extensive network of canals, drainage ditches, and levees may create a major problem in operations. The most notable of these areas are the polders of Belgium and The Netherlands, which have

*Figure 51. Spillway, storage dam (Bartlett Dam, Arizona).*

been reclaimed from the sea by artificial levees called dikes. The terrain is traversed by numerous canals and basins that drain the excess water and serve as navigation routes. The surplus water empties into the sea at low tide. In places where the water courses lead from the interior to the sea, they may be caused to overflow, creating a practically impassable obstacle to movement. In the interior, the polders greatly limit the landing areas suitable for airborne and airmobile forces. When the dikes are destroyed, the cultivated areas are inundated. In these areas tanks and vehicles bog down, there is no cover for infantry, and the water is too shallow for boats.

## 120. Military Importance

The military importance of hydraulic structures arises from the extensive flooding that may be caused by their destruction. Vast areas may be inundated by the destruction of a large dam or the artificial levees along a major river. Releasing the waters of even a small dam may flood sections of roads and railways or increase the width and velocity of a stream so that crossing operations are impeded. Hydraulic structures in enemy territory may be destroyed by aerial bombardment so as to cause these effects, so they may be seized by airborne forces before the enemy can demolish them. Hydraulic structures are vulnerable to sabotage and guerrilla action. Those in territory under friendly control must be carefully guarded and subject to strict security precautions.

## 121. Information Requirements — Hydraulic Structures

The type of information that is required concerning a particular hydraulic structure will depend upon whether plans call for its defense, seizure, destruction, or reconstruction. Usually technical specialists are employed to prepare detailed studies of each structure that is being considered. In general, basic information includes—

*a.* Location and name.

*b.* Function: navigation, power, flood control, irrigation, water supply.

*c.* Construction features: design type, materials, height, width, mechanical equipment, capacity.

*d.* Extent and nature of repairs necessary.

*e.* Security requirements.

*f.* Effects of destruction upon the surrounding area.

## Section VIII. URBAN AREAS AND BUILDINGS

### 122. Urban Areas

*a. Description.* An urban area is defined as a concentration of structures, facilities, and population which forms the economic and cultural focus for some larger area. Usually the inhabitants do not depend upon agricultural activities for their basic economy. A city or town may have a number of functions that make it significant. It may be primarily industrial, commercial, or recreational; the headquarters of government institutions; a port or railway center; or the location of an important cultural feature, such as a cathedral, university, or historical landmark. A large urban area usually has a metropolitan area that includes various surrounding settlements or suburbs whose daily economic and social life is connected with or influenced by the city. Intelligence concerning an urban area covers its general description and importance; physical characteristics; external communication; services and utilities; and major industries, including storage facilities.

*b. Topography.* The topography and geology of the urban area and its environs are significant elements in the terrain study. Topography exerts a major influence upon the size and pattern of the populated area; the location of external communications; the possibility of inundation or other natural disaster; and the defense that can be made against possible land, waterborne, and air attacks. The development pattern of an urban area is the physical adjustment of the area to its topography, as influenced by past events, current economic forces, and social trends.

*c. Construction.* The elements comprising an urban area may be classified according to the predominant construction and function of the buildings and other structures. Where no gaps exist between buildings, as in the business districts of larger towns and cities, this is described as block type construction. Detached and semi-detached building areas are those where the buildings are spaced relatively close together, as they are in low- and middle-cost housing areas. Isolated housing areas are found on the approaches to towns and cities where individual or small groups of homes are located in the midst of large open areas. This is typical of the suburbs of the average city.

*d. Functional Areas.* Normally a city includes separate areas largely devoted to one type of use. The major functional areas may be distinguished as follows:

(1) Industrial areas comprise a grouping of individual plants and loft buildings, with associated storage and transportation facilities, devoted to manufacturing activities.

(2) Commercial areas are composed of a concentration of retail and wholesale establishments, financial institutions, office buildings, hotels, garages, public buildings, and light manufacturing plants.

(3) Residential areas consist predominantly of dwellings with interspersed shopping centers; churches; schools; and fire, police, telephone, and power stations.

(4) Transportation and storage areas contain the terminal, transshipment, storage and repair facilities and service buildings associated with general movement by rail, water, road, pipeline, or railway.

(5) Governmental-institutional areas include the grounds, structures, and facilities related to governmental administrative offices, hospitals, schools, colleges, homes for the aged or orphans, sanitariums, monasteries, penal or research institutions and similar establishments which usually

form distinctive and generally extensive areas.

(6) Military areas contain structures and facilities for billeting, quartering, defense, hospitalization, storage, and repair, which are devoted exclusively to military use.

(7) Open areas comprise land not occupied by buildings and not assigned to any industrial, transportation, business or residential activity. Developed open areas include cultivated land, parks, recreation areas, and cemeteries. Undeveloped open areas include swamps, woods, beaches, and other vacant land.

## 123. Military Considerations

*a. Use of Urban Area.* The decision to bypass or to seize and occupy an urban area depends upon the mission of the unit concerned. Cities and towns may be important objectives because they represent centers of population, transportation, manufacture, and supply. Port cities and railroad centers are given a priority status as targets and objectives in both tactical and strategical planning. Unless the mission requires otherwise, a city or town usually is bypassed and isolated, since it is an obstacle that canalizes and impedes both attacking and counterattacking forces. Urban areas are vulnerable to destruction by air or artillery bombardment and may be neutralized by chemical, biological, or radiological contamination. Fires started by nuclear weapons or incendiaries may make them untenable. Combat within built-up areas is described in detail in FM 31–50.

*b. Limited Observation and Fields of Fire.* Because the opposing troops usually are close to each other, effective close support by artillery and combat aviation is limited. The available cover is rigid and set in straight lines, so that all movement in the open usually can be observed unless it is concealed by smoke, dust, or darkness. Smoke may be used to provide concealment, limit observation, and achieve deception and surprise. In a built-up area, smoke remains effective longer than in open areas. It is usually difficult to observe and locate enemy weapon positions because of the dust caused by the impact of projectiles and explosive charges and the smoke from explosions and fires.

*c. Increased Cover and Concealment.* Weapons and troops may be concealed in built-up areas, and ample cover is usually available against small-arms fire. Cover from air and artillery bombardment, however, is provided only in buildings of particularly substantial construction.

*d. Movement.* The mobility and maneuverability of infantry, artillery, and armor are greatly limited in built-up areas. Vehicular traffic is canalized, and extremely vulnerable to ambush and the close-range direct fires of enemy weapons.

*e. Communications.* It is difficult to maintain efficient communications in built-up areas. Normally control must be decentralized to small-unit commanders. Tall buildings and those with steel frames may interfere with radio communication. Reliance usually must be placed upon wire and foot messengers.

*f. Attack.* Detailed information concerning the enemy, his defenses, the terrain surrounding the urban area that is under his control, and the layout of the built-up area is essential to the commander in making plans and decisions for an attack. Particular emphasis is placed upon determining the location of covered approaches to the urban area, the location of public utility plants and their security measures and the location and nature of all obstacles. The objective of the attacking force is to seize the entire urban area. Within the area the objectives for individual units include key installations such as railroad stations, telephone exchanges, and the public utility plants, which are often organized as centers of enemy resistance. The attack on an urban area begins with the seizure or terrain features which dominate approaches to the city, followed by the seizure of buildings on the near edge to reduce or eliminate the defender's observation and direct fire upon the approaches. The last phase is a systematic advance through the area until it is fully secured.

*g. Defense.* Urban areas favor the defense. Whether or not a city or town is organized for defense depends upon its size, relation to the general defensive position, and the amount of cover it offers for occupying forces. Cities, towns, and villages constructed of flammable materials provide little protection and may become a hazard to the defender, and buildings of solid masonry can be developed into well-fortified defensive positions or centers of resistance. Cellars, sewers, subway tunnels, thick masonry walls, and reinforced concrete floors and roofs provide cover for the defender during heavy bombardments. A heavy aerial or artillery bombardment of a city before an attack actually may serve to strengthen its defenses. The fallen rubble may give the defender increased protection, and may make the streets impassable for armor.

## 124. Information Requirements—Urban Areas

Information about an urban area requires the compilation of many factors, each devoted to a particular aspect of the area, such as the transportation services, utilities, billeting facilities, or industries. A terrain study should include annotated maps, plans, and photographs, with an accompanying text giving that which cannot be shown graphically. Information that should be included under each category is outlined below. The scope of the information that is presented is limited by the purpose for which the study is being prepared. The text should include information in the following categories, as pertinent:

*a. Description.*

(1) Name and location (geographic and grid coordinates).

(2) Population (number and trend, significant ethnic and religious segments).

(3) Principal function (communications and industry).

*b. Physical Characteristics.*

(1) Topography and geology of area and environs.

(2) General cross-country movement of environs.

(3) Climate (mean temperatures and rainfall).

(4) Landmarks (natural and manmade).

(5) Extent of built-up areas (present boundaries, recent additions, probable future expansion).

(6) Functional areas.

*c. Structures.*

(1) Characteristics of predominant types of buildings (height, number of stories, principal construction materials).

(2) Structure density (ratio of roof coverage to gross ground area; as warranted, ratio of roof coverage to ground area within each of the functional areas).

(3) Principal buildings.

*d. Susceptibility to Fire and Shock.*

*e. Damaged or Destroyed Areas* (delineation and general character).

*f. Significant Ethnic and Religious Groupings* (delineation and general character of the areas occupied).

*g. Streets.*

(1) Surface, condition, and pattern.

(2) Prevailing widths (to curb and building to building).

(3) Names and alinement of through routes and principal streets.

(4) Location and characteristics of bridges, tunnels, and ferries.

*h. External Communications.*

(1) *Roads.* Identification of the roads that enter the urban area, the routes that bypass it, and the road distances to the nearest important town on each route should be shown on maps. In the text, the importance of the roads as avenues of movement to and from the town should be discussed. Annotations on city maps should locate and identify highway structures, ferries, and road service facilities.

(2) *Railways.* Maps should show the railways that enter or bypass the urban area, with distances to the nearest

important towns. Text should discuss the importance of the railways as transportation arteries. Annotations on city maps should locate and identify railway structures and crossings (bridges, tunnels, and ferries) and such railway structures as passenger and freight stations, yards and sidings, repair shops, turntables, and "y" track.

(3) *Inland waterways.* Identification of each navigable water route (river, lake or canal) which borders or passes through the urban area and the waterway distance to the nearest upstream or downstream port should appear on maps. The importance of the waterway should be discussed in the text. Annotations on city maps should locate and identify important waterway structures. Information on shipyards is included with that on the industries of the urban area.

(4) *Airfields.* The location of each airfield and seaplane station which serves the urban area should be shown on city maps or, if beyond the limits of the city, on topographic maps. Text should indicate the adequacy of the existing air service, list each commercial airline which serves the area, and provide information on the frequency of service. Information about airfield classification is presented in TM 5-330.

*i. Urban Services and Facilities.*

(1) Water supply.

(*a*) Sources (name, location, type, capacity).

(*b*) Treatment plants (number, type, capacity, and location).

(*c*) Storage (name, location, type, capacity).

(*d*) Method of distribution.

(*e*) Consumption (in terms of minimum and average requirements per person per day, whether any rationing is practiced and during what periods, annual consumption).

(2) Sewage disposal (sanitary, storm, industrial waste).

(*a*) Collection methods (type, adequacy).

(*b*) Treatment plants (type, location).

(*c*) Disposal methods (including location of dumps or incinerating plants).

(3) Garbage and trash disposal.

(*a*) Collection methods.

(*b*) Treatment plants (type, location).

(*c*) Disposal methods (including location of dumps, incinerators, and processing plants producing fertilizer).

(4) Major hospitals.

(*a*) Name, location, and specialization, if any.

(*b*) Bed capacity.

(*c*) Age and condition.

(5) Electricity.

(*a*) Sources (name, type, location, installed capacity).

(*b*) Substations (name, type, location, capacity).

(*c*) Distribution current characteristics.

(*d*) Number of consumers.

(*e*) Yearly consumption.

(6) Gas.

(*a*) Type.

(*b*) Sources (name, location, capacity).

(*c*) Storage (type, location, capacity).

(*d*) Extent of distribution.

(*e*) Number of consumers.

(*f*) Yearly consumption.

(7) Storage.

(*a*) Open (large open areas within or adjoining the town suitable for use as open storage and supply dumps).

(*b*) Covered (warehouses and sheds).

(*c*) Cold (refrigerated storage; ice plants with cold-storage facilities).

(*d*) POL (number of tanks or reservoirs at each location; capacities in U. S. barrels).

(e) Explosives (magazine and bulk-storage facilities; types and quantities of explosives stored).

(8) Ice-manufacturing plants (name, location, capacity).

(9) Billeting and accommodation. (Total capacity for billeting and accommodation in military barracks, hotels, public buildings, school and institutional buildings, and other structures; total capacity of bakery and laundry establishments; availability of baths and swimming pools suitable for troop use. Location, capacity, and type of each structure.)

(10) Internal transit system (type, extent, location of main terminal, and maintenance facilities).

(11) Fire protection (organization and manpower of fire department; quantity and type of equipment).

(12) City government (type, personalities, location of facilities).

(13) Civil defense (organization and manpower; quantity and type of equipment).

(14) Industry.

(a) Major industrial activity (for each industry, the type, number of plants, number of employees, and importance).

(b) Significant manufacturing plants.

## 125. Buildings

*a. Construction.* The design and construction of buildings are influenced by climate, available materials, function, and the cultural development of the native inhabitants. In areas with a tropical climate and primitive agriculture, for example, buildings usually are only crude huts made of woven grass, sticks, and mud. Buildings in desert oases are made of clay with thick walls, so that they are cool in summer and fairly warm in winter. In dry climates, where suitable timber is scarce, a wooden structure is a rarity and buildings are constructed from stone, adobe clay, or turf. Where there are cold winters, buildings will be solidly constructed of stone and wood.

*b. Military Considerations.* The military significance of a building or group of buildings depends upon the purposes of the study. A building may have value as an obstacle, a defensive strongpoint, or as a possible storage, headquarters, medical, or maintenance installation. The structural features of buildings comprise the predominant materials used, size and height, fire resistance, and architectural design. Brick, stone, and masonry buildings, when demolished, create rubble that may make formidable obstacles, or may provide concealment and cover for troops. Flimsy wooden buildings are highly flammable and may be remunerative targets for incendiary shells and bombs. Since the fires are an obstacle to an attacker, they may be employed as a weapon by the defender. The height and number of stories in a building are significant features when selecting observation points. Buildings used in the community may be adapted for military uses. These include garages and other repair facilities, stadiums, theaters, auditoriums, warehouses, transportation terminals, and schools. Wherever possible, structures of religious or artistic importance are usually designated before an operation by civil affairs/military government agencies, and their employment for military purposes is prohibited. Buildings made of solid masonry, concrete, and steel may be organized into defensive strongpoints. Substantial structures with deep basements provide varying degrees of cover from air or artillery attack. The protection against nuclear effects offered by buildings varies according to the type of construction, flammability, distance from ground zero, and many other factors. Personnel in buildings will be protected from the thermal radiation effects of a nuclear weapon and will receive some degree of protection from nuclear radiation effects. Casualties from secondary blast effects are caused largely by falling walls and ceilings and flying glass.

## 126. Information Requirements—Buildings

*a.* Location and function (residence, store, warehouse, factory, school, government headquarters, and communication center).

*b.* Structural features (materials, foundations, roof, bearing capacity of floors, exits, and basement).

*c.* Layout and capacity (floor plans, areas, cubages).

*d.* Utilities.

*e.* Possible military uses.

*f.* Security features (estimated capability for withstanding bombardment by conventional and nuclear weapons).

*g.* Needed repairs or improvements for military use.

## 127. Utilities

*a. Special Studies.* Detailed intelligence about the utilities of an urban area is necessary in order to plan its utilization for military purposes. In addition, civil affairs may require specific, detailed information and intelligence for special purposes. Special studies by technical personnel should be prepared covering each of the following:

(1) Water supply.
(2) Sewage disposal.
(3) Electric power.
(4) Illuminating gas.
(5) Public transportation system
(6) Communications.
(7) Fire protection.
(8) Trash and garbage disposal.

*b. Use of Special Studies.* Intelligence studies covering utilities form the basis for estimating requirements for operating and maintenance personnel, the equipment and replacement parts needed for repairs and operation, and the amount of military equipment that must be provided to supplement the existing utility installations. These studies also furnish a guide to selecting the most profitable targets for air attack. The destruction of key utilities is given a high priority in planning aerial bombardments, since a breakdown in these services results in disorganization of the enemy defenses and is highly damaging to civilian morale.

## 128. Information Requirements—Utilities

The amount and type of information about the utilities of an urban area that is required will depend upon the purpose for which the area is being considered. If it is intended to develop a city into a major logistical base, complete information concerning the capacity, state of repair, and operating methods of each utility will be nceessary. The capability to supply minimum civilian needs as well as military requirements must be evaluated. General surveys of utilities should include the following information about each service or installation—

*a.* Physical condition.

*b.* Adequacy for normal load.

*c.* Portion of present capacity that could be diverted to military use.

*d.* Repairs, essential for military utilization.

*e.* Safety and security provisions.

*f.* Availability of skilled, reliable, civilian personnel.

*g.* General efficiency and dependability of the plant or system.

# Section IX. NONURBAN AREAS

## 129. Types

*a. Farmstead.* Populated areas outside towns and cities usually consist of farmsteads and small settlements. A farmstead is the dwelling and adjacent buildings associated with an individual farm. The characteristics of a farmstead reflect the climate of the area and the type of agriculture.

*b. Tropical Climate.* In rainy tropical climates, most of the inhabitants dwell along streams and waterways, the settlements being located on the bluffs, which are well-drained and exposed to the river breezes. The large rubber, coconut, or banana plantations are usually near the ocean or on the banks of navigable rivers, since roads and railways are few and difficult to maintain. Nonurban areas in dry subtropical climates are dominated by large cattle and sheep ranches, with individual farmsteads separated by miles of grazing land. In semiarid tropical climates, the native agriculture is largely pastoral, and the relatively few settlements consists of huts surrounded by mud walls or fences of thorny brush. Subarctic villages seldom consist of more than a dozen dwellings, with as much as 50 to 65 kilometers (30 to 40 miles) between settled areas.

*c. Temperate Climate.* In temperate climates, the buildings of a farmstead are detached from each other, while in areas with extremely cold winters the house, barn, and other outbuildings commonly are under one roof. The outbuildings of a farmstead in the tropics normally are few and small, because the animals remain outdoors all year. Small villages in the middle latitudes often consist of houses built in rows along the sides of a road or clustered around an open square, and in tropical climates the houses of a village usually are dispersed without any regular pattern.

## 130. Military Significance

*a.* In general, the same considerations that are pertinent to an urban area also apply to nonurban areas. Small settlements may be critical when they dominate routes of communication at fords, bridges, railway lines, or defiles (fig. 52). Villages that are small in size may have considerable military significance because of a particular industry, mine, or other unique economic feature. They may be local markets and distribution centers serving a wide area and representing an important enemy source of foodstuffs and other supplies. A village with a small local population may be a resort area or the site of a university or similar large institution, capable of providing quarters and other facilities for large numbers of troops.

*b.* In tactical operations, it is occasionally necessary to secure or destroy small villages that have no direct military value but are used to provide concealment, supplies, and other support to guerrillas. The civilian inhabitants may have to be relocated in other settlements under military control. The buildings of a farmstead furnish quarters for troops and shelter for storage and maintenance facilities. Stone buildings may be suitable for weapons emplacements and defensive strongpoints. Nearly all rural dwellings are within a short distance of a reliable source of water. Cross-country movement frequently is hampered by obstacles such as stone fences, retaining walls, irrigation ditches, and paddy fields. Features such as high fences, hedgerows, embankments, and ditches may offer limited cover and concealment to individuals and small groups.

## 131. Information Requirements—Nonurban Areas

The particular information about a farmstead or small village that is required will depend largely upon the mission of the unit concerned. Basic information requirements should include—

*a.* Location; relation to local terrain features.

*b.* Size (area, population, pattern of streets or roads).

*c.* Facilities for quarters, maintenance and repair installations.

*d.* Predominant construction materials.

*e.* Utilities.

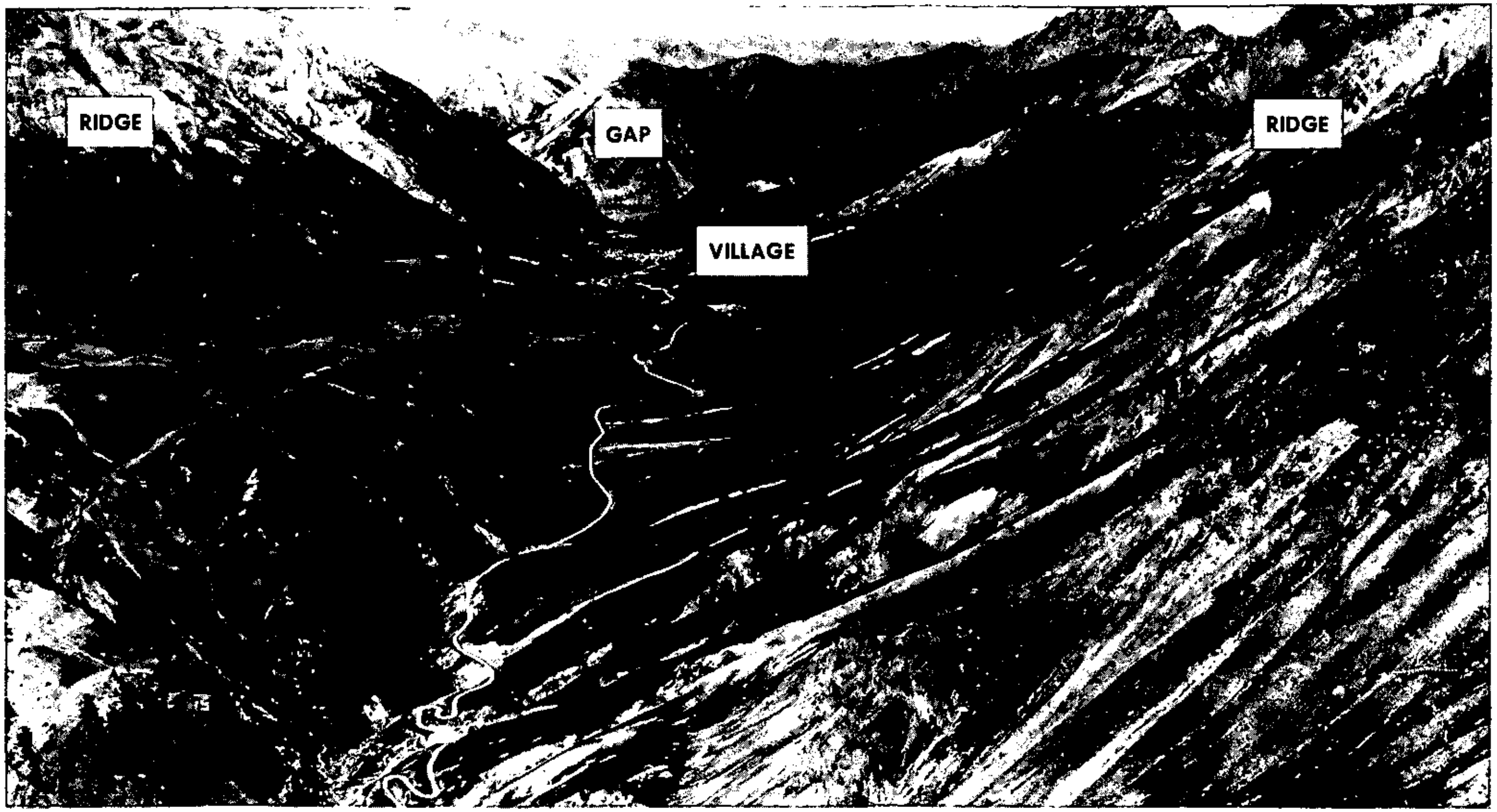



*Figure 52. Small settlement dominating a main route of communication.*

# CHAPTER 7

# MILITARY ASPECTS OF THE TERRAIN

## Section I. MILITARY USE OF TERRAIN

### 132. Commander's Considerations

In conducting an operation, the commander must determine how the terrain can be used most effectively by his forces, how it may affect the enemy's capabilities, and how it may be exploited to interfere with the enemy. With the assistance of his staff, he considers the weather conditions, relief and drainage, vegetation, surface materials, and manmade features and their effects upon—

*a.* Key terrain.

*b.* Observation and fields of fire.

*c.* Cover and concealment.

*d.* Obstacles.

*e.* Avenues of approach.

*f.* Communications.

### 133. Key Terrain

The relative importance of various aspects of the terrain varies with the mission, the type of operation, the size and composition of the forces involved, and their weapons and equipment. Detailed intelligence concerning terrain features normally increases as the size of the unit diminishes. The commander of a field army, for example, may be concerned about the effects that an extensive mountain range will have upon a proposed campaign. A corps commander might be interested only in one mountain of the range, while the commander of a brigade would concentrate upon a particular group of foothills in his area. When making a systematic study of the military aspects of an area, it is sometimes divided into natural subareas, or, if there are no suitable natural boundaries, into subareas based upon the tactical plan. The military aspects of the terrain then are evaluated by each subarea from both the friendly and enemy points of view.

### 134. Observation and Fields of Fire

*a. Observation.* Observation is the direct examination of terrain and military activities. It includes examination from ground and air by unaided vision or assisted by optical and infrared devices and detection by photographs, radar, and sonic devices. In general, observation refers to the ability of a force to see the enemy under specified conditions of weather and terrain. The best terrain for observation is that which permits both long-range observation into enemy-held areas and close-in observation of the hostile forward elements. Usually long-range observation is found near the topographical crest and close-in observation is obtained from a location near the military crest. Fog, smoke, precipitation, heat refraction, darkness, manmade and natural features, and vegetation may limit or deny observation. They must be evaluated in determining the extent and type of observation that will be available to enemy and friendly forces. The highest point on the terrain does not always provide the best observation, since variations in relief often create blind spots in the field of vision. The selection of observation points should be based upon reconnaissance, topographic profiles, or examination of aerial photographs.

*b. Fields of Fire.* A field of fire is an area that a weapon or group of weapons can cover effectively with fire from a given position. The natural terrain must be evaluated according to its suitability for flat-trajectory weapons, high-trajectory weapons, rockets, and guided missiles, including those with nuclear capabilities. The ideal field of fire for flat-trajectory weapons is flat or gently sloping terrain on which an enemy can be seen with no protection for him within the effective ranges of the waepons. Broken terrain creates dead spots and furnishes cover and concealment for the enemy. Open terrain providing good fields of fire permits a unit to defend a wide front. Broken terrain makes it necessary to provide more troops and weapons to defend a given frontage. The field of fire of high-trajectory weapons is limited only by very steep reverse slopes that the weapons cannot reach and by masks which permit the enemy to occupy positions in defilade. Fields of fire can be improved by cutting or burning vegetation, demolishing buildings, and cutting lanes through woods.

### 135. Cover and Concealment

*a. Evaluation of Terrain.* Terrain is evaluated to insure the maximum use of concealment and cover. Terrain under enemy control is also studied, to determine how his concealment and cover can be destroyed. In the attack, concealed and covered routes into the enemy position are sought to gain surprise and to reduce casualties. In the defense, concealment and cover are utilized not only to protect individual positions, but also to hide the general trace of the defenses, so that the attacking troops may be vulnerable to surprise by the location of defense positions and weapons fires. When evaluating terrain for the cover that it will provide, the characteristics of all the weapons used by the enemy must be considered. This includes their ranges, types of fire, and the relative quantities of each type of weapon available to him.

*b. Cover.* Topography is the major factor influencing cover. Valleys, mountains, gullies, ravines, hills, and similar features provide cover from flat-trajectory weapons. Individuals and small units may secure cover from such terrain features as ditches, riverbanks, folds in the ground, shell craters, buildings, walls, railroad embankments and cuts, and highway fills. Cover from high-angle weapons usually is difficult to obtain. Caves, buildings of exceptionally strong construction, and the steep slopes of hills and mountains may offer some degree of cover, depending upon the capabilities of the weapons employed by the enemy. Nuclear thermal radiation travels by line of sight, so that it will be masked by hills, banks of ravines, and gullies. The extent of protection thus provided will depend upon the height of the explosion. A nuclear blast wave curves around obstacles and is less affected by relief features.

*c. Concealment.* Terrain features that offer cover also provide concealment. The greater the irregularity of the terrain, the more concealment it will furnish from ground observation. Lower echelons are concerned with the concealment of men, vehicles, weapons, and emplacements; higher echelons, with the concealment of headquarters, supply dumps, airfields, and other major installations.

### 136. Obstacles

*a. Types.* According to their effects, obstacles may be classified as antipersonnel obstacles, antimechanized obstacles, underwater obstacles, and obstacles to the landing of aircraft. Natural obstacles comprise such features as unfordable streams, swamps, deep snow, cliffs, steep slopes, thick woods and undergrowth, flooded areas, boulder-strewn areas, lakes, mountains, and nontrafficable soils. Artificial obstacles include those prepared to delay or stop military movement, such as contaminated areas, minefields, trenches, antitank ditches or barriers, roadblocks, blown bridges, road craters, deliberately flooded areas, wire entanglements, and various types of beach and underwater obstacles. They also include manmade features that were not originally designed as obstacles to military movement, such as canals, levees, quarries, or reservoirs.

*b. Employment.* The employment of obstacles is integrated with the overall scheme of maneuver and fire support. Both natural and artificial obstacles are utilized to channel, direct, restrict, delay, or stop an opposing force. Instructions for the employment of obstacles usually are included as a barrier annex to the operation order of divisions or higher echelons.

FM 31–10 discusses the use of obstacles and the requirements of barrier plans.

*c. Barriers.* A barrier plan provides for the most effective employment of obstacles to impede enemy movement along favorable routes of approach, divert advancing enemy forces towards routes favorable to defense or compel the enemy to concentrate or disperse. Artificial obstacles must not be located where they would interfere with the proposed movements of friendly forces or with counterattack plans. They may be placed in considerable depth, so as to provide time for counterattacking troops to meet an enemy threat, and to force the enemy to expend time and strength at each barrier. To be fully effective, artificial obstacles must be kept under observation at all times, and must be augmented by fire or explosives. Whenever possible, obstacles are sited so that they are under friendly observation but defiladed from enemy observation. Local unit commanders are responsible for constructing obstacles for the close-in defense of their positions. Advice and technical assistance is provided by engineers, who also construct and install obstacles which require special skill and equipment. The use of toxic chemical and biological agents and radiological contamination to supplement barriers or as obstacles, makes it possible to deny or restrict areas by contamination, to canalize enemy maneuver, or to contaminate enemy field fortifications so that they are untenable. Additional information about the employment of these agents is contained in FM 3–5, FM 21–40, and FM 100–5.

*d. Effects.* The effects of natural terrain features as obstacles to military movement are discussed in chapter 6. Artificial obstacles are described in FM 5–15 and FM 31–10. The location and extent of both natural and artificial obstacles must be considered by a commander in making his plans. He must decide how they will affect his mission. The tactical effect of an obstacle depends upon the type of operation, the weapons and equipment employed, and the size of the forces involved. A terrain feature that is a major obstacle for a company may be a minor obstacle to a brigade and no obstacle at all to a division.

*e. Location.* Obstacles may either help or hinder a unit, depending upon their location and nature. For example, a deep creek lying across the axis of advance will slow up an attacker, but will provide defending forces with an advantage, since it delays advancing troops and exposes them to fire. Similarly, heavy woods in front of a position may provide infantry with a concealed route of approach but act as an obstacle to the movement of supporting tanks. In general, obstacles perpendicular to the axis of advance favor a defending force, while those parallel to the axis may give the attacker an advantage by protecting his flanks, although they will also limit lateral movement and his ability to maneuver.

*f. Offense.* In offensive operations, obstacles influence the choice of objectives, the avenues of approach to an objective, and the time and formation of an attack. Obstacles may be employed to contribute to flank security, impede counterattack, provide additional protection for a section of the front that is not strongly manned, or assist in enemy entrapment.

*g. Defense.* Obstacles are employed in the defense to channel, direct, delay, or stop the movement of an approaching force. They may be used to delay the initial enemy advance toward the front and flanks of a position, delay the movements of enemy penetrating or enveloping forces, or canalize enemy penetrations into avenues of approach where they can be defeated, or destroyed.

## 137. Avenues of Approach

*a. To a Terrain Feature or an Objective.* This is an area of terrain which provides a suitable, relatively easy route of movement for a force of a particular size and type. An avenue of approach should provide—

(1) Ease of movement toward the objective.

(2) Concealment and cover from the defender's observation and fire.

(3) Favorable observation and fields of fire for the attacker.

(4) Adequate maneuver room for the attacking force.

*b. Suitability and Ease of Movement.* The suitability and ease of movement of an avenue of approach depend upon—

(1) The routes of communication.
(2) Soil trafficability.
(3) Concealment and cover.
(4) Observation and fields of fire.
(5) Obstacles.
(6) Relationship of terrain corridors and cross compartments.

*c. Multiple Use.* In some types of operations, in which maneuver is very limited by either weather or terrain, an avenue of approach may in itself be a key terrain feature. For example, in rugged mountainous terrain, one road along a valley may be the only route of supply and at the same time the most favorable avenue for approach for the major element of the attacking force. A river in the jungle may be the only transportation route, and thus a key terrain feature, an avenue of approach, and an obstacle.

*d. In Attack.* Usually an attack is directed toward securing dominating terrain early in the action. The avenue of approach that is most favorable for accomplishing this mission normally is assigned to the forces making the main attack. Whenever possible, the avenues of approach that are selected are those that avoid areas most strongly held by the enemy. In planning an attack, a study is made of the avenues of approach that might be used by the enemy for counterattacks and for reinforcing and supplying his forces. These avenues can be determined by an analysis of the terrain in its relation to the location of enemy reserves and supply routes.

*e. In Defense.* In planning the organization of defense positions, the terrain is evaluated to determine the avenues of approach that are most likely to be used by the enemy. These normally will be the avenues that lead toward key terrain features, provide good observation, fields of fire, concealment and cover, and either avoid or exploit obstacles. Defense positions are sited to deny such avenues of approach to the enemy. The avenues of approach that can be used by friendly forces in counterattacks also are evaluated.

## 138. Compartments

The effects of relief and drainage upon avenues of approach are considered in terms of compartments. A terrain compartment is an area bounded on at least two opposite sides by terrain features such as woods, ridges, or villages that limit observation and observed fire into the area from points outside the area. A terrain compartment includes not only the area enclosed but the limiting features as well. Delimiting lines are imaginary lines drawn along limiting features from which ground observation into a compartment is limited. In compartments formed by woods and villages, these lines run at some point within the edge of the woods or village, depending upon the density of the woods, or the number and density of the buildings. Compartments are classified according to the direction of movement of the forces operating in them. They are termed corridors (fig. 53) when the longer dimension of the compartment lies generally in the direction of movement, or leads toward the objective, and cross compartments (fig. 54) when the longer axis is perpendicular or oblique to the direction of movement. Compartments are also classified as simple or complex (figs. 55 and 56). A complex compartment is one having a smaller compartment or compartments lying within it. This is the type most often encountered.

## 139. Corridors

Corridors, or ridges that form their limiting features, provide favorable routes of approach for an advancing force because the defender's lateral organization and fields of flat-trajectory fire are obstructed by the limiting features, which also decrease his ability to obtain mutual support between units and limit his observation. To the attacker, a corridor offers two types of approach: valley approach and ridge approach.

*a. Valley Approach.* Although a valley approach may provide concealment and cover, the military crest of the limiting features on each side must be controlled to deny enemy observation and direct fire into the valley. The best axis of advance is the one that offers the most favorable conditions of observation, cross-country movement, fields of fire, concealment, and cover. Often the most favorable route is along the slopes of a ridge below the military crest rather than along the valley floor. A valley approach should never be used when the enemy controls dominant flank ob-

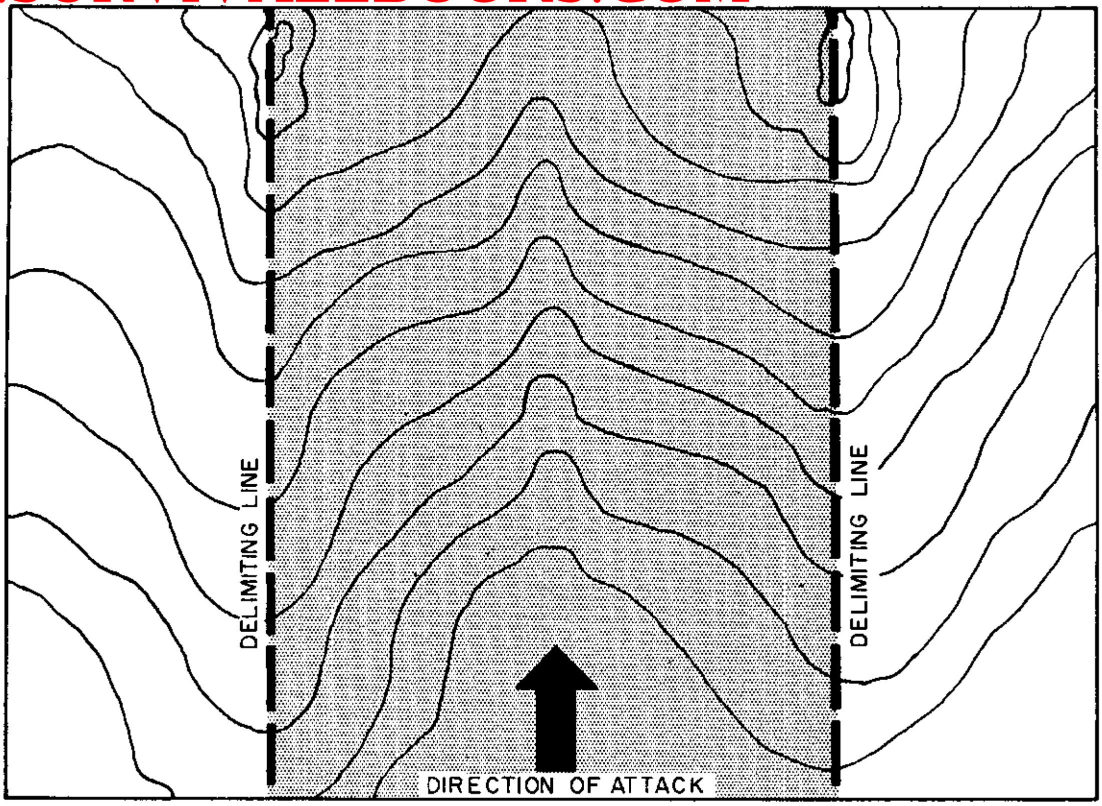



*Figure 53. Terrain corridor.*

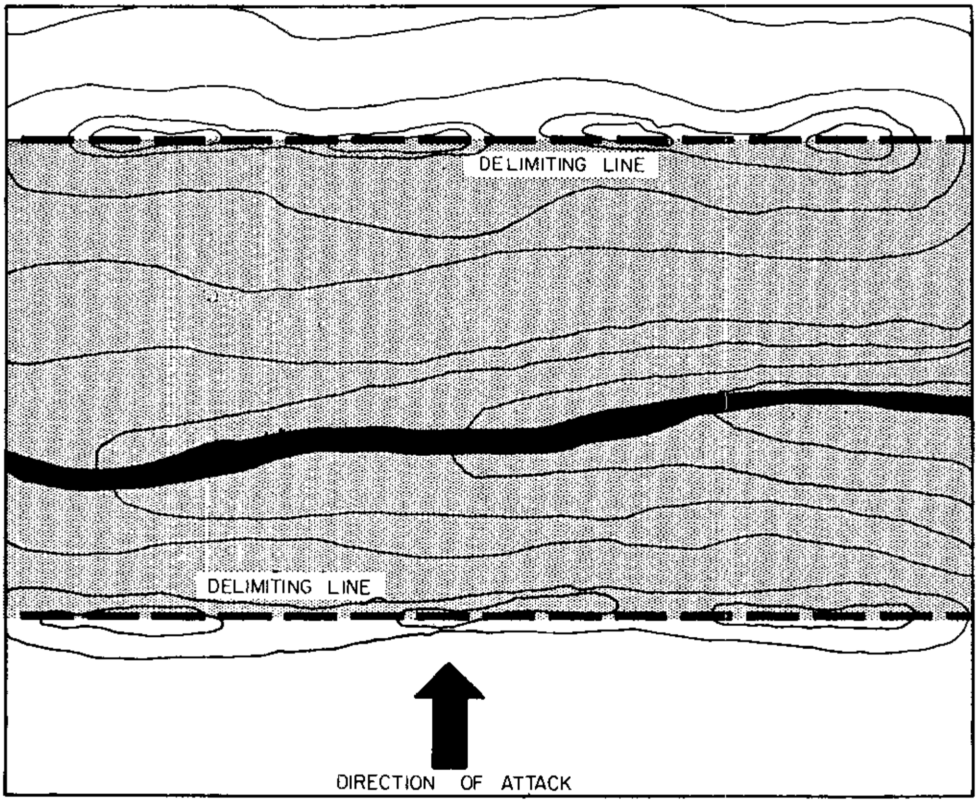



*Figure 54. Cross compartment.*

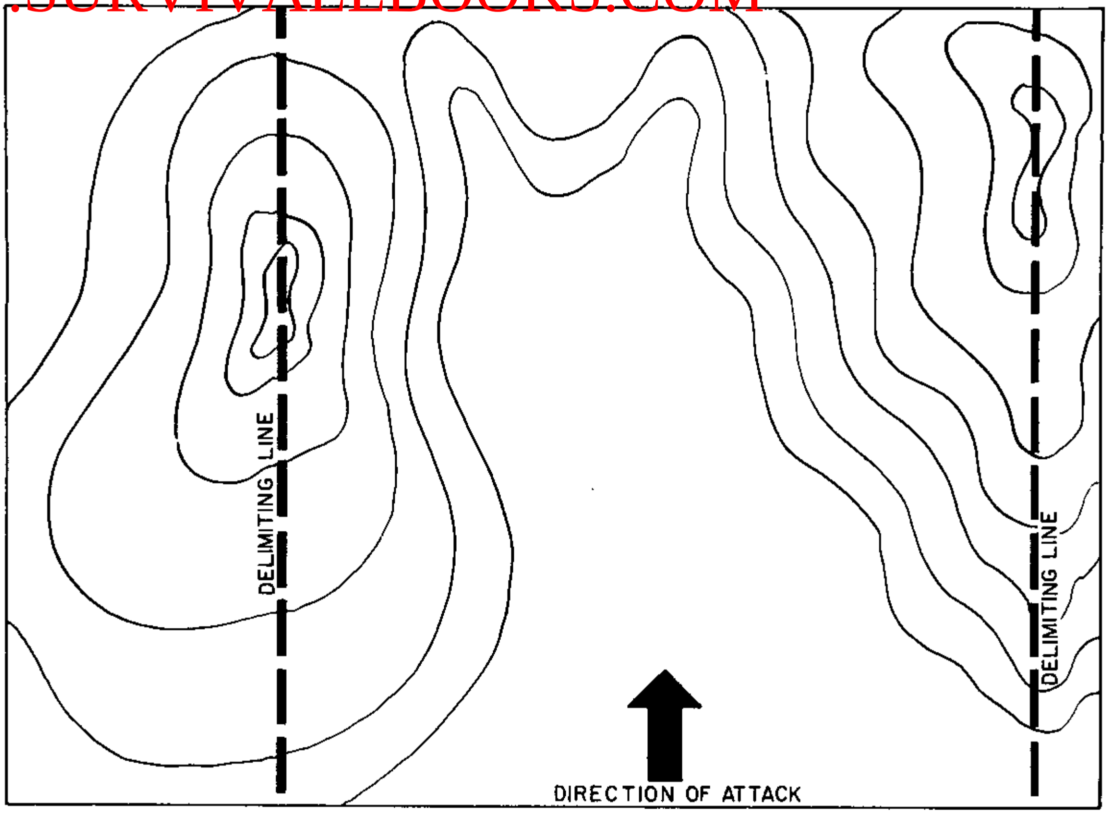



*Figure 55. Simple compartment.*

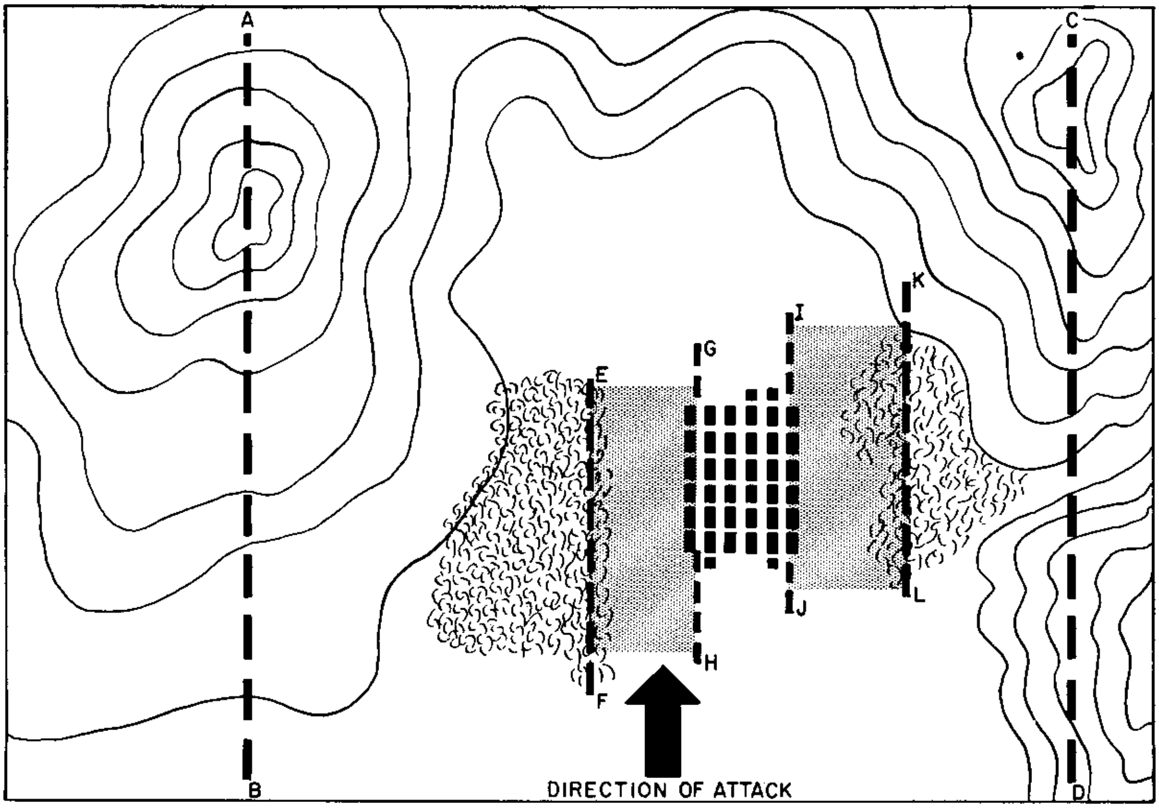



*Figure 56. Complex compartments.*

servation into the valley, where there are numerous obstacles, and the soils have poor trafficability characteristics.

*b. Ridge Approach.* The suitability of a ridge for an avenue of approach depends upon its width and shape, the size and frontage of the unit concerned, the distance to adjacent ridges and their elevations, and the capabilities of the enemy weapons. A ridge approach places the axis of advance along dominant observation, but offers little protection from enemy fire directed at the ridge. Usually the best axis of advance in a ridge approach is slightly below the topographical crest, with sufficient forces deployed to control the crest.

*c. Cross Compartments.* Cross compartments provide the defender with the most favorable terrain for obtaining maximum observation and fields of fire. Mutual support between units, both laterally and in depth, is available and cross compartments also provide the defender with successive defensive or delaying positions. The concealment or cover provided by each limiting feature permits the defender to shift his reserves to meet or to counter threats to his position.

## Section II. SPECIAL OPERATIONS

### 140. Amphibious Operations

*a. Detailed Studies.* Amphibious operations require detailed studies of hydrography, weather, and terrain. A technical discussion of the requirements and preparation of these studies is beyond the scope of this manual. They are covered in FM 60–30, FM 110–101, and FM 110–115, which also describe the characteristics, tactics, and techniques of amphibious operations. The discussion in this paragraph supplements information in paragraphs 70 through 75.

*b. Weather Effects.* All phases of an amphibious operation are directly influenced by weather conditions. Weather affects the tides, beaching and unloading conditions, speeds of vessels, air support, and visibility. Poor weather conditions may provide cover for the amphibious force, but favorable weather is essential for the actual landing and during the initial buildup that follows, because excessive sea and swell jeopardize the entire operation.

*c. Location.* The ideal beach for an amphibious landing is one near a strategic location, with no obstructions seaward; deep water close nearshore; a firm bottom; minimum variation in tides, currents, or surf. The beach terrain should be gently rising, relatively clear, with a firm surface that has adequate drainage. Adequate exits from the beach area should be available. Flat or gently rising terrain, backed by a coastal range high enough to mask the landing area, is the most desirable for landing operations. Ideal conditions are rarely found, and so suitable areas must be evaluated to determine those that come nearest to the optimum requirements.

*d. Coastal Plain.* A landing on a wide coastal plain provides unrestricted maneuver room usually free from enemy observation and a subsequent advance from the beach can be made in any direction. Boundaries and objectives are hard to locate on this type of terrain, however, and there are few prominent registration points for artillery, naval gunfire, and aerial bombardment. Usually there is no good defensive terrain on the flanks of the beachhead, so that more troops are required to protect the flanks.

*e. Coastal Ridge.* Terrain which rises evenly to a considerable distance back from the beach gives the defender excellent observation and fields of fire. More commonly, the coastal area remains flat for some distance and then rises abruptly to a coastal ridge.

*f. Sand Dunes.* Ground that is sharply broken by extensive sand dunes or a low coastal plateau provides the attacker with concealment from enemy observation. The small compartments and corridors limit the range of defensive fires. Direction and control may be extremely difficult.

*g. Mountains.* Mountains located directly on the sea usually limit the number of beaches large enough to accommodate a landing force of effective size. Where steep ground is lightly defended or neglected by the enemy, a lightly equipped force may seize it and gain surprise. Airborne or airmobile troops may be used to block the movement of enemy reserves to the landing area, or to secure passes through the mountains and thus prevent the enemy from interfering with the amphibious landing.

### 141. Airborne-Airmobile Operations

*a. Basic Factors.* The characteristics, tactics, and techniques of airborne operations are discussed in FM 17–36 and FM 57–10. Airborne forces are capable of crossing such terrain barriers as inland seas, mountains, and jungles that represent serious obstacles to the movement of other troops. Usually airborne assaults are made on terrain that is relatively undefended, to secure initial surprise. Weather has greater restrictive effects upon airborne operations than upon ground operations. Adverse weather may cause postponement or delay in initiating an operation, and prevent adequate reinforcement or supply by air. In addition to terrain studies covering landing and drop-zone areas, special studies may be required to determine the most favorable routes for linkup between airborne forces and friendly ground units.

*b. Terrain Requirements.* One of the principal factors influencing the selection of a landing area for airborne forces is the terrain. The area chosen must provide adequate space to permit defense in depth; room for maneuver; a safe landing for troops, supplies, and equipment; and protection for critical installations. Airborne troops can land on any terrain that is relatively free from obstacles. Unobstructed areas are required for the landing and recovery of heavy equipment dropped by parachute. Assault aircraft can land on any relatively level and unobstructed terrain that has suitable trafficability. Other fixed-wing transport aircraft require suitable airfields or prepared landing strips. Rotary-wing and other aircraft with vertical takeoff and landing characteristics can land in areas that are otherwise accessible only to parachute units.

*c. Drop Areas.* The selection of drop areas for the delivery of supplies by parachute requires a consideration of the following:

(1) *Length.* The required length of the area depends upon the type of plane being used. Normally an area 460 meters (500 yards) long is a minimum requirement.

(2) *Width.* A width of 180 meters (200 yards) is minimum. The pilot must have a reasonable amount of room so that he may fly to the right or left of the center of the area, allowing for the drift of his plane under the influence of surface winds.

(3) *Surface conditions.* The type of soil must be considered in relation to the effect that it will have upon the falling loads. A hard surface may cause the bundles to break open upon landing. Soil that is muddy or swampy may cause the dropped loads to bury themselves upon landing, making recovery difficult or impossible.

(4) *Topography.* A clear and level area is desirable. Drop zones on a steep slope or mountainside cause the bundles to scatter, tumble, and break open. A mountain or hill top usually has turbulent winds that reduce drop accuracy and make the drift of bundles unpredictable.

(5) *Access.* A desirable drop zone has an adjacent road, or terrain adjoining the area, that offers good access for vehicles, so that the dropped supplies can be recovered and transported conveniently.

## Section III. WATER SUPPLY

### 142. Importance

An adequate supply of water for drinking, sanitation, construction, and vehicle operation is one of the fundamental needs. In arid and semiarid regions, water supply affects plans and operations. Entire campaigns in desert lands may be conducted solely to secure water sources or to deny them to an enemy. All feasible sources and methods for developing them must be considered when making plans for the water supply of troops and installations. Development data are obtained from reconnaissance, map study, reports or runoff and rainfall average, and geological surveys. Water sources are located by a study of maps, aerial photographs, water resources data, and intelligence reports, then verified by field reconnaissance if feasible. Detailed information concerning water supply is contained in TM 5–700.

### 143. Sources

*a. Basic Considerations.*Water may be obtained from wells, streams, springs, lakes, and municipal or other supplies that are already developed. Water for permanent and semipermanent installations also may be secured from the distillation of sea water or the drainage from building roofs. Investigations to select a water source must consider the quantity and quality of the water, and the conditions at the proposed sites from which the water supply would be secured.

*b. Quantity.* The quantity of water available in an area depends chiefly upon the climate. In temperate and tropical regions with less than 60 centimeters (25 inches) of annual precipitation, most streams become dry in drought periods. Streams usually flow throughout the year in temperate regions with more than 60 centimeters (25 inches) of annual rainfall and in tropical regions where the rainfall exceeds 90 to 100 centimeters (35 to 40 inches). Seasonal variations may reduce the flow of water below the required amount or result in water points being flooded by seasonal high water periods. The seasonal characteristics of water sources should be obtained from local inhabitants. Terrain studies usually indicate alternate water sources for use in case the primary sources dry up, become flooded, or cannot be used because of enemy action.

*c. Quality.* Color, turbidity, odor, taste, mineral content, and contamination determine the quality of water. TM 5–700 gives methods for estimating these characteristics and describes the use of standard test kits. The quality of water will vary according to the source and the season, the kind and amount of bacteria present, and the presence of dissolved matter or sediment. Streams in inhabited regions commonly are polluted, with the sediment greatest during flood stages. Streams fed by lakes and springs, with a uniform flow, are usually clear and vary less in the quality of water than do those fed mainly by surface runoff. Water in large lakes generally is of excellent quality, the purity increasing with the distance from shore. Very shallow lakes and small ponds are usually polluted.

*d. Site Requirements.* The ease with which a water source can be developed, operated, and maintained is determined largely by the location and the routes of communication. The design of the collecting system and the difficulties of development, operations, and maintenance are partially influenced by site conditions, topography, soils and vegetation. A military water point should be located as close as possible to a main route without interfering with traffic. An all-weather access road should lead to the place of storage, with a turnaround or separate exit, and an all-weather off-road parking area for trucks waiting to be filled. In locating the water point, attention is given to concealment and cover, possible nearby targets which may attract enemy fire, drainage, road connections, condition of the banks and the bed if surface water is being drawn, and the means required to develop the source. Existing water supply systems are used when carefully checked by engineers and medical authorities. Purification units may have to be installed. The possibility of contamination by enemy agents also must be considered.

### 144. Surface Water

*a. Regional Variations.* Surface water sources are generally more accessible and adequate in plains and plateaus than in mountains. Large amounts of good quality water normally can be obtained in coastal, valley, or alluvial and glacial plains. Although large quantities also can be secured in delta plains, the water may be brackish or salty. Supplies of water are scarce and difficult to obtain on lacustrine, loess, volcanic, and karst plains. In the plains of arid regions, water usually cannot be obtained in the quantities required by a modern army. Much of the water that is available is highly mineralized. In the plains and plateaus of humid tropical regions, surface water is abundant, but it is generally polluted by bacteria and requires treatment. Perennial surface water supplies are difficult to obtain in Arctic regions. In summer, water is abundant but often polluted. In winter it can be obtained from beneath the ice in the larger lakes and streams, but its quality is poor because of a high organic content.

*b. Springs and Seeps.* There are two types of springs or seeps: those originating at the base of steep slopes where the topography breaks abruptly, and those caused by faulting. The first type is found along the edges of a valley, and has a perennial flow and fresh, cold water. The second type is caused by the fracture or displacement of confining clay or rock layers above an artesian water-bearing formation (aquifer), thus forcing the water in the artesian zone to the surface. Springs of this type often are thermal, and may contain excessive amounts of minerals. Frequently the depth of a source of water can be estimated by the temperature of the water; the hotter the water, the deeper the source. Spring water is generally clear, cool, and low in organic impurities, but may be hard because of a high dissolved mineral content. In regions where seasonal rainfall varies greatly, the spring flow often decreases during long periods of dry weather. The heavy infiltration of surface water causes some springs to become turbid, and may produce contamination.

*c. Streams.* Streams are the most common source of surface water supply. Streamflow may vary with precipitation, temperature, and the amount of vegetation. Turbidity and mineral content vary with the flow and with watershed conditions. Since large flows produce high dilution, many such streams may be suitable sources of water supply although they receive raw or partially treated sewage. However, water from such streams must be settled, filtered, and chlorinated before use.

*d. Lakes.* Ordinarily, lakes are a satisfactory source of water supply. The water level and average yield in small lakes may vary. Many lakes receive sewage flow, have a high content of dissolved minerals, and may have considerable vegetative growth or contain vegetable or animal organisms. These can usually be removed by purification processes.

### 145. Ground Water

*a. Source.* Ground water is obtained without difficulty from unconsolidated or poorly consolidated materials in alluvial valleys and plains, streams and coastal terraces, alluvial fans, glacial outwash plains, and alluvial basins in mountainous regions. Areas of sedimentary and permeable igneous rocks also may have fair to excellent aquifers, although they do not usually provide as much ground water as areas composed of unconsolidated materials. Aquifers of this type underlie coastal plains, inland sedimentary plains and basins, karst and volcanic plains and plateaus. Large amounts of good-quality ground water may be obtained at shallow depths from the alluvial plains of valleys and coasts, and in somewhat greater depths in their terraces. Large quantities may also be secured from shallow wells in delta plains, although it is apt to be brackish or salty. Aquifers underlying the surface of inland sedimentary plains and basins also provide adequate amounts of water. Often these formations lie with a few hundred feet of the surface. Those at greater depths yield very hard water which may be too highly mineralized to be drinkable. Abundant quantities of good-quality water generally can be obtained from shallow to deep wells in glacial plains. In loess plains and plateaus, small amounts of water may be secured from shallow wells, but these supplies are apt to fluctuate seasonally. Water from wells usually is clear and low in organic impurity, but it may be high in dissolved mineral content.

*b. Plains.* Large springs are the best sources of water in karst plains and plateaus. Wells may produce large amounts if they tap underground streams. To estimate the possible yield of proposed wells, information is sought about existing wells that tap similar water-bearing formations in the vicinity. The siting and drilling of wells is difficult because the areas of permeability and the solution cavities in limestone cannot be easily predicted. Shallow wells in low-lying lava plains normally produce large quantities of ground water. In lava uplands, where water is more difficult to find and wells are harder to develop, careful prospecting is necessary to obtain adequate supplies. In wells near the seacoast, excessive withdrawal of fresh water may lower the water table, allowing infiltration of salt water which ruins the well and the surrounding aquifer. Springs and wells near the base of volcanic cones may yield fair quantities of water, but elsewhere in volcanic cones the ground water is too far below the surface for drilling to be practicable.

*c. Climate.* Plains and plateaus in arid climates generally yield small, highly mineralized quantities of ground water. In semiarid climates, following a severe drought, there frequently is a flow of subsurface water under an apparently dry streambed that may yield considerable amounts of excellent water. Ground water is abundant in the plains of humid tropical regions, but usually it is polluted by bacteria. In arctic and subarctic plains, wells and springs fed by ground water above the permafrost are dependable only in summer; some of the sources freeze in winter, and subterranean channels and outlets may shift in location during the seasons. Wells that penetrate aquifers within or below the permafrost, however, are good sources of perennial supply.

*d. Hills.* Adequate supplies of ground water are hard to obtain in hills and mountains composed of gneiss, granite, and granitelike rocks. They may contain springs and shallow wells that will yield water in small amounts.

*e. Military Use.* Both large- and small-diameter wells are used for military installations. Large-diameter wells usually are dug by hand, in diameters up to 15 meters (50 feet). They may be used as reservoirs, the water level falling during periods of withdrawal and being replenished from subterranean flow during periods of light demand. Small-diameter wells, normally, made by driving, jetting, boring, or drilling, do not provide storage. Deep wells are drilled by percussion rigs or rotary equipment. The amount of water obtained from deep wells will depend upon local conditions. They are less subject than shallow wells to seasonal fluctuation, contamination, and pollution. Information about wells and well-drilling is in TM 5–297.

## 146. Water Supply Systems

*a. Types.* There are 3 basic types of water supply and distribution systems—

(1) *Gravity.* The storage reservoirs of gravity distribution systems usually are located high enough to develop the required pressure and flow. Sometimes the storage tanks are filled by gravity from springs located at a higher level, but ordinarily they are filled by pumps.

(2) *Direct pumping.* In direct pumping systems, ordinarily there are no elevated storage tanks. The water is pumped into the distribution system from ground storage reservoirs or wells at a rate depending on demand.

(3) *Combination.* Primary mains are supplied by both gravity and direct pumping in combination systems.

*b. Parts.* The essential parts of a water supply system are—

(1) *Headworks,* usually a reservoir formed by a dam.

(2) *Conduit,* sometimes an open canal or an aqueduct, but more commonly made of wood, iron, or steel that is watertight to prevent contamination and losses by evaporation, absorption, and changes in temperature.

(3) *Distributing* system, which connects with the plumbing in buildings. Large mains carry the water from the source to service pipes, which take it to individual buildings and other outlets.

## 147. Information Requirements — Water Supply

Special water supply studies are made by engineers, assisted by geologists and hydrologists. The information required in terrain intelligence studies includes the following—

*a. General.*

(1) Normal level of water table and variations.

(2) Yield of springs and wells, and variations.

(3) Potability and contaminations.

(4) Underground flow in dry watercourses.

*b. Surface Supplies.*

(1) Total drainage area.

(2) Rainfall and runoff data.

(3) Sources and kinds of possible contamination, including sewage or industrial wastes.

(4) Chemical and bacteriological analyses.

*c. Wells.*

(1) Rainfall data.

(2) Reports of available well logs and test data.

(3) Physical, chemical, and bacteriological analyses.

*d. Existing Water Supply System.*

(1) Source of supply.

(2) Quantity provided; ultimate capacity.

(3) Treatment methods.

(4) Distance from supply to proposed military user point.

(5) Pressures.

(6) Chemical and bacteriological analyses.

# CHAPTER 8

# TERRAIN STUDIES

## Section I. BASIC FEATURES

### 148. Description

*a. Preparation.* A terrain study is an intelligence product which presents an analysis and interpretation of the natural and manmade characteristics of an area and their effects on military operations. It is a compilation of only that information which has a direct bearing on some existing requirement. This study is prepared at all echelons to provide the intelligence officer with an analysis of the terrain for use in preparing the analysis of area of operations that forms part of his overall intelligence estimate for the commander, and for use by other staff elements for planning and conduct of operations. The preparation of an analysis of area of operations is discussed in FM 30–5. Above army level, terrain studies are prepared primarily, to assist the commander and his staff. At lower levels, terrain studies are intended chiefly for use in tactical operations and include more details of the terrain and its effects.

*b. Topics.* Special studies devoted exclusively to certain terrain features or effects may be prepared to meet the requirements of a particular plan or operation. These are produced by technical personnel or teams, and include, but are not limited to, studies concerning—

(1) Construction problems.
(2) Movement.
(3) State of ground.
(4) Water resources.
(5) Lines of communication.
(6) Site selection.
(7) Coast and landing beaches.
(8) Inundation.
(9) Urban areas.
(10) Barriers.
(11) Defenses.
(12) Airborne landing areas.
(13) Soils.
(14) Rock types.
(15) Drainage.
(16) Climate.
(17) Surface configuration.
(18) Inland waterways.
(19) Other military aspects.

### 149. Prerequisite Information

Before initiating the study, one must know the area to be covered, the mission and type of operation, the specific information required, and the time period to be considered. Terrain intelligence is produced continuously at all echelons. The preparing unit maintains a file of intelligence data, drawing upon it for pertinent matter when he is directed to make a terrain study. Additional information is obtained from the sources and agencies discussed in chapter 3.

### 150. Format

*a. Content.* A specific terrain study will not cover every item in outline, but only those items applicable to the operation being planned. Used in this manner, the terrain study form insures uniformity of presentation yet permits the flexibility imposed by terrain analysis.

*b. Primary Requirement.* The primary requirement for a terrain study at army, corps, or division level is that it must present the intelligence in a form that can be easily utilized by field units. The study must be concise, presenting only pertinent information. Written description should be kept to a minimum. Intelligence should be presented graphically whenever possible.

*c. Automation.* The intelligence portion of the Tactical Operations System (TOS) automatic data systems within the Army in the field (ADSAF–75) is an information processing system which uses automatic data processing equipment as a tool for battlefield commanders to help them exercise command and control of their forces and make effective and timely decisions. The computer center accepts information from various sources, including that from forward observers as well as from other computer centers. This information is automatically assembled, sorted, evaluated, and stored by the computer. This computer drives an automatic, constantly up-dated map display which provides the commander with a view of his entire operation. The map includes symbols representing the size, type, and location of all forces, both friendly and enemy, as well as the terrain features, supply dumps, and other intelligence information necessary for the effective evaluation and direction of the operation. This computer center consists of a central processor, memory units, and auxiliary equipment. It also has an automatic communications switching capability which permits contact with all units having an organic intelligence section and a primary intelligence collection mission. In addition, it has operating and monitoring controls for the system.

## 151. Compilation

*a. Format.* The format suggested for the terrain study consists of three parts: text, a terrain study map, and a regional description section. A fourth major paragraph, "Analysis of Area of Operations," is prepared by the intelligence officer. The scope of this paragraph is described in FM 30–5. The text follows the sequence of the sample terrain study (app. C). It presents the terrain intelligence called for in the applicable section of the form Tables and charts are used to simplify, amplify, and clarify the presentation. The text should be as concise as possible.

*b. Map.* Wherever possible, terrain intelligence should be presented on a terrain study map, based on a topographic map of appropriate scale. A map scale of 1:50,000 is usually utilized for brigades and divisions. Corps and army headquarters usually do not require a scale larger than 1:250,000. The terrain intelligence is overprinted on the topographic map (printed in gray monochrome) or is an overlay to the map. Appropriate symbols are used to present items of terrain intelligence. Conditions for movement are portrayed by designated movement colors.

*c. Regions.* Terrain features exist in certain patterns or combinations, which create distinctive terrain regions. Usually the area of study encompasses several terrain regions. The regional description section of the terrain study gives the user an understanding of the terrain by explaining the combined effect of the terrain features in the regions. This section consists of a sketch map delineating the terrain regions and of brief descriptions summarizing the terrain intelligence for each region. It may be printed on the back of the terrain study map. The information presented in the regional description section enables the user to evaluate the factors influencing movement and to interpret changes in movement which might be caused by changes in weather.

## 152. Reproduction

Reproduction of terrain studies should be done by the fastest, cheapest, and easiest method. Only as many as necessary for primary users should be made. The engineer topographic battalion assigned to army has the capabilities for map reproduction. The battalion can draft and reproduce in bulk the terrain study map mentioned in paragraph 151. It can also perform the other printing and drafting necessary for the reproduction of terrain studies. The engineer topographic company assigned to corps has basically the same capabilities as the topographic battalion in the type of work it can do, but is limited in volume and equipment. A division has no organic topographic units. Terrain studies are produced by means of duplicators which can produce a map-size paper. The type and quality of terrain studies are limited only by the degree of skill and imagination on the part of the personnel who are responsible for this function.

## 153. Dissemination

The Engineer or Engineer Terrain Detachment, or G2 Staff Engineer Officer, disseminates the completed terrain study to the G2 and other interested staff elements. The G2 utilizes the terrain study according to the tactical situation and presents the resulting terrain estimate to the commander. If necessary, the terrain study is disseminated to subordinate and adjacent units. The terrain study is also disseminated through engineer channels. Copies are sent to lower echelons to assist them in planning and preparing their own terrain studies. A copy is sent to higher engineer headquarters, and another is sent through enginner channels to the Office of the Chief of Engineers.

## Section II. TERRAIN AND CLIMATE

### 154. Basic Factors Affecting Terrain

The basic factors for a terrain analysis are discussed under item 2 of the terrain study (app C). The factors discussed are climate, topography, and when applicable, coastal hydrography. Although climate and oceanographic aspects of coastal hydrography are not elements of terrain, they have a direct influence on the usefulness of an area for military activities. Appendix C compiles the terrain intelligence that is pertinent to the area of the planned operation. The extent of the area will vary with the echelon performing the compilation. Terrain studies at higher echelons may present fairly extensive descriptions for planning purposes, but terrain studies at lower echelons, having a more definite direction and limit as to area, time, and purpose, restrict their descriptions to the intelligence applicable to the operation planned.

### 155. Climate

*a. Elements.* The elements of the climate discussed in a terrain study include visibility, temperature, precipitation, humidity, winds, clouds, and electrical disturbances. Not all must be discussed in every terrain study, because the factors selected depend on the area, time, and type of operation planned. The area of operations influences the description of the climate. The climate of a large area may be described in general terms, whereas a description of a small area will be quite specific. The importance of certain elements of climate depends upon the area. The time that an operation commences determines the type of intelligence presented. Climatic data must be used if the starting date is more than a week or two in the future. (Weather forecasts will be used in the terrain estimate for 5 days or less.) The type of operations planned determines the pertinent elements of climatic information to be furnished. Planning of airborne operations, amphibious operations, and other special operations requires knowledge of weather elements not usually required in normal ground operations. These considerations are discussed in greater detail in manuals pertaining to airborne and amphibious operations.

*b. Factors.* The methods of describing various factors of climate are discussed below.

(1) *Visibility.* Certain fixed data are best presented graphically. Times of sunrise, sunset, moonrise, moonset, BMNT, EENT, and phases of the moon are best presented on a chart to indicate periods of degree of visibility. Such a chart is included in the sample terrain study. Where pertinent, tide movements can also be presented on this chart. Other deterring influences on visibility, such as fog, smoke, dust, or snowstorms, are discussed in the text.

(2) *Temperature.* This information is generally presented in tabular form. Temperature predictions based solely on climatic studies cannot forecast the expected temperatures, but can describe the range of temperatures that can be expected in a particular location by either of two methods. By the first method, the mean temperature, the mean maximum and mean minimum, and the absolute maximum and absolute minimum temperatures which can be expected for the period can be indicated. The mean temperature alone has little significance since it gives no indication of the range of the temperature variation. The second method is to tabulate the number of days of the period that the temperature can be expected to exceed or

fall below stated temperatures. Temperature effects on other terrain features should be described adequately when significant, such as effect on soil trafficability and freezing or thawing of water bodies.

(3) *Precipitation.* This information, based on climatic studies, can state the type and amount of precipitation encountered during a particular period; the number of days within that period on which certain amounts of precipitation can be expected; and the variability of precipitation from year to year. A statement of the total amount of precipitation that can be expected over a period of time has little significance in itself, since a 3-inch rainfall means one thing when spread over 30 days and a totally different thing when concentrated in 1 day during the 30-day period. The effect of precipitation on other terrain features, particularly water bodies and the trafficability of soils, should be described.

(4) *Winds.* Wind data based on climatic research present the direction, intensities, and duration that can be expected over a period of time. These facts are best expressed graphically by means of a wind rose or may be referenced to the Weather Map Scale of Wind Velocity. Wind rose data may be secured from AWS when specifically required by a commander. The effect of wind on surface materials and on waves is described when pertinent.

(5) *Humidity.* Exact descriptions of humidity are not usually necessary, but the effects of humidity on operations is described when significant. The description should consider fog conditions and the effect of humidity in reducing the efficiency of personnel or in creating problems of storage and maintenance of supplies and equipment.

(6) *Clouds.* Data based on climatic records signify the approximate number of days during a specific period that a certain degree of cloud cover can be expected. There is also a statement as to what time of the day or night certain cloud coverage can be expected. Related conditions such as storms and fog are also described when applicable.

(7) *Electrical disturbances.* This subject is discussed only when it has an important effect on proposed operations. The type of disturbance, its period of occurrence and duration, and its effect on planned operations are described in the text when pertinent.

## 156. Natural and Manmade Features

*a. Relief.* Relief is described in the text and symbolized on the map to highlight significant relief features, but not to repeat the detail of a topographic map. The general picture of the relief of an area may be indicated by ridge and stream lining, which accentuates the major ridges and drainage patterns. This consists of emphasizing the streams by drawing over them with a blue pencil and emphasizing ridges with brown pencil. Ridge lining or stream lining can be used separately, if desired, but the combination of the two is more effective. Ridge and stream lining emphasizes the compartmentation of an area, but does not show relative elevations or slope (fig. 57). Another method is to emphasize the principal contours of an area. This is done by tracing over certain critical contour lines with a heavy black pencil or by using different colored pencils to indicate different elevations. This method has the advantage of not obscuring details on the map (fig. 58). Sharp slopes, such as embankments, steep riverbanks, and cliffs are indicated by a red movement symbol when traverse appears to be impracticable. In certain cases, an area may be cut by numerous draws and gullies which are significant but are not shown on topographic maps because their depths are less than the contour interval. These draws and gullies are symbolized on the map. The effect on movement is discussed under "movement" and illustrated graphically by movement symbols.

*b. Drainage and Hydrography.* Since drain-

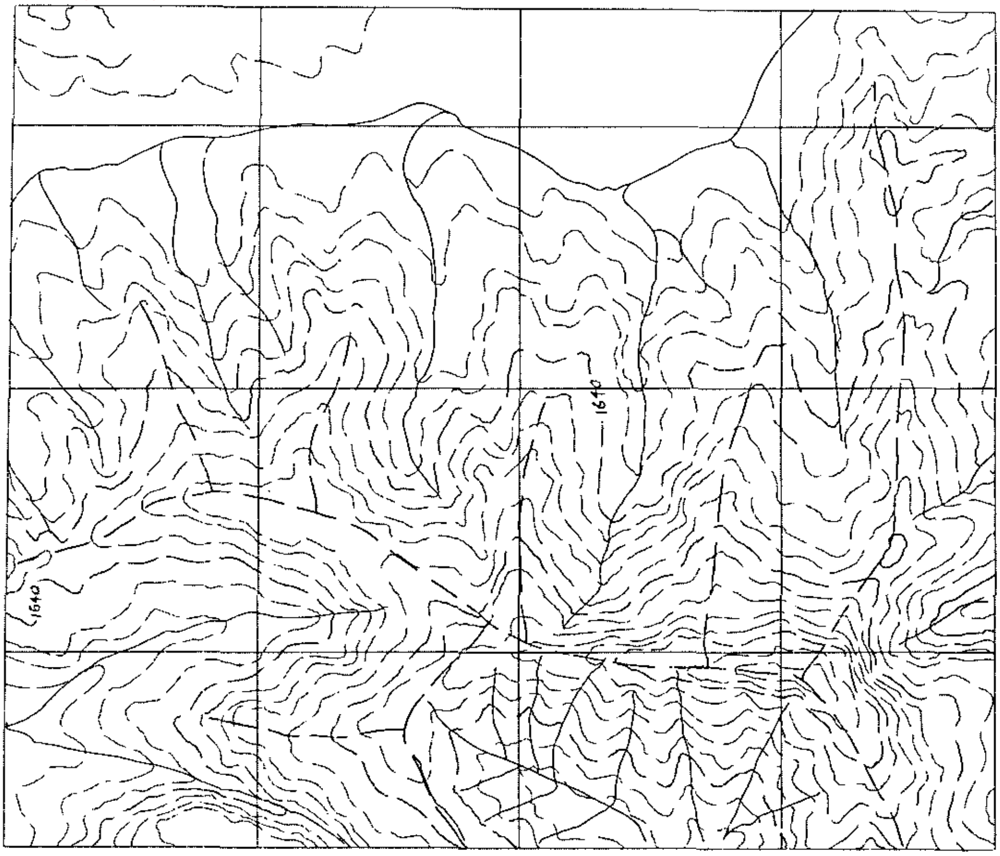



*Figure 57. Ridge and stream lining.*

age features are subject to change at least seasonally, it is important that the terrain study describe the present condition of the drainage features. The degree of detail in the description is usually determined by the echelon at which the study is prepared and the primary purpose of the study itself. A higher echelon indicates only the major features on the terrain study map, but lower echelon study covering a smaller area can indicate the minor drainage features and give detailed descriptions of them.

c. *Vegetation.* Forests are indicated graphically. The type of trees, deciduous and evergreen, the density of the forest, and the range of trunk diameters are noted on the map. The text describes other significant vegetation in the area and the effect of weather on the vegetation. Vegetation may be discussed under concealment, fields of fire, obstacles, and any other pertinent aspects of the terrain.

d. *Surface Materials.* Higher echelon terrain studies usually include a soils map. At army and lower headquarters, this will not usually be feasible. A description of the types of surface materials is included in the surface material section of the study. The effect of surface materials on cross-country movement is an important factor of the terrain study and is described graphically in that section. Surface materials are also discussed in the sections on construction sites and construction materials.

e. *Manmade Features.* The terrain study describes those manmade terrain features which have particular significance or which require more detailed description to be of value. The more common manmade features are discussed below.

(1) The road-bridge-bypass system is described because of its influence on vehicular movement. A higher echelon study may describe graphically only the primary roads whereas a division study usually describes the secondary

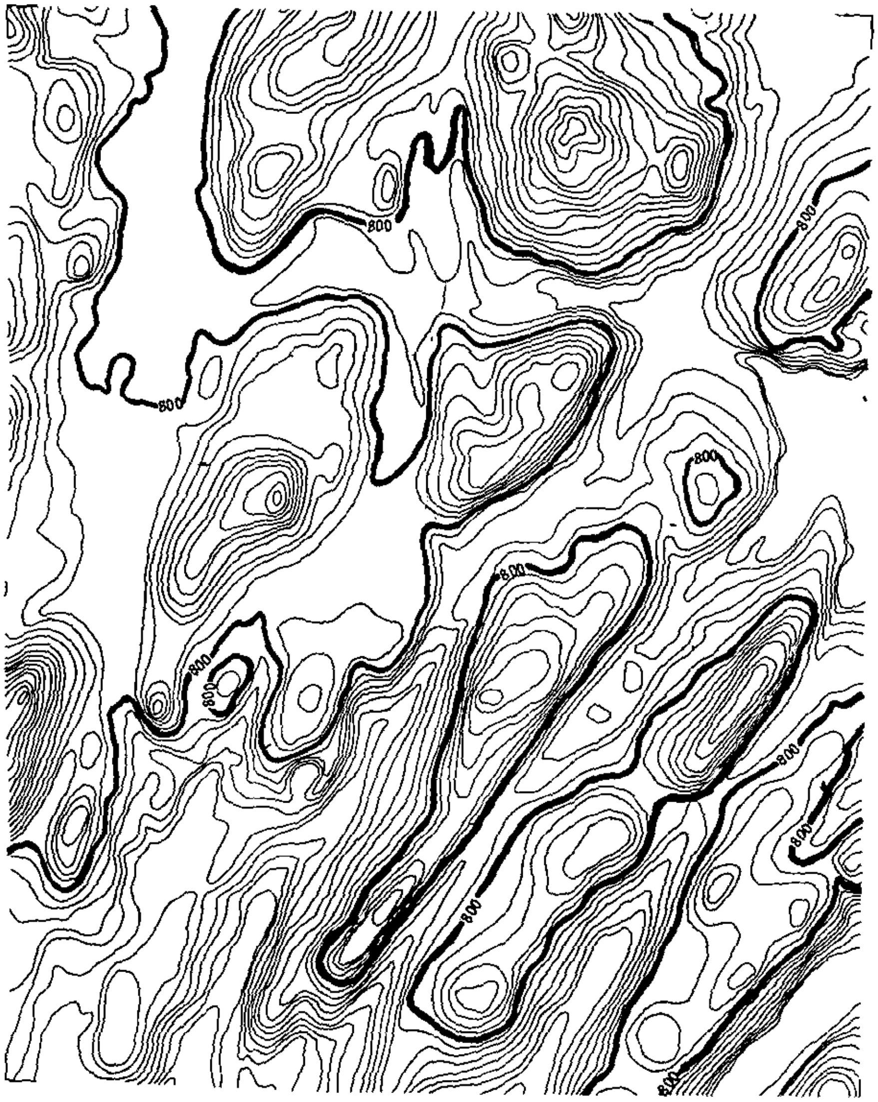



*Figure 58. Contour emphasis.*

and tertiary systems as well. Important bridges and bypass sites are indicated. (See DIA, AP-1-335-3-1-65-ADMIN and DIAM 57-5 for route classification symbols.)

(2) Airfields of all types are described. Their locations are shown on the map by standard topographic symbols and an indication is given as to their size and condition. Further details are given in a table.

(3) Principal cities and towns are indicated on the terrain study map, and are listed further in a table.

(4) Railroads are shown on the terrain study map, with detailed information in a table.

(5) Hydrologic structures of all types are described, with detailed information in a table.

## Section III. MILITARY ASPECTS

### 157. Operations

Determining the military aspects of the terrain for an operation requires a knowledge of the terrain and of the operation planned.

Not having complete knowledge of any specific military operation, the person preparing the terrain study should describe the military aspects in terms of generalized operations. The intelligence officer using the study will interpret them in terms of the operation being planned. This is particularly true of key terrain features and avenues of approach. Descriptions of the aspects of terrain vary with the echelon. At army level, descriptions are general; at division level they are more detailed and specific.

## 158. Key Terrain Features

The determination of key terrain features requires a knowledge of the terrain, the objective, and the plan of operations. As a rule the person making this study may not have a complete knowledge of the plan of operations, and therefore, he must determine those features that have a controlling effect on the surrounding terrain and list them as probable key terrain features for consideration by the user. The description of these features includes a discussion of their significance.

## 159. Observation and Fields of Fire

*a. Observation.* The description of observation includes an evaluation of the ground and air observation in the area, and a brief discussion of the terrain features in that area that affect observation. Periods of visibility are described by a visibility chart in the weather and climate section. The effect of the terrain on observation by special devices such as radar, infared equipment, and sound-ranging devices is described when applicable. The description of observation is generally included in the text. A lower echelon study map may indicate the location of individual observation points.

*b. Fields of Fire.* The description of fields of fire in the terrain study is included in the text, and is primarily concerned with flat-trajectory fire. The description includes a general evaluation and a discussion of the terrain features that affect fields of fire. Features which limit or restrict fields of fire are described in detail. Terrain features that create special problems in the use of high-trajectory weapons are described when they exist. (Areas of marsh or volcanic ash that smother explosive shells are examples of such features.) The possible effect of terrain on nuclear actions is described when pertinent.

## 160. Cover and Concealment

This includes a discussion of the problem of constructing installations to provide cover, such as foxholes, bunkers, and underground installations. The means available for providing cover from nuclear action is discussed when applicable. Concealment is described in the text with reference to pertinent terrain features such as forests which are portrayed graphically. The amount of concealment and to what extent various type units can utilize it are discussed.

## 161. Obstacles

The description of obstacles includes a description of the general hindering characteristics of the terrain and a description of specific obstacles. The explanation of the general obstructive elements of the terrain is an overall description and includes terrain features which are unimportant singly, but which constitute obstacles cumulatively, such as systems of irrigation or drainage ditches, terraces, and hedgerows. These are described in the text and indicated graphically by movement symbols. Specific obstacles, such as rivers or escarpments, are described individually. Obstacles that are known to be impracticable for crossing by personnel or equipment are outlined by red hachuring.

## 162. Avenues of Approach

The determination of avenues of approach involves a summation of all other military aspects as they affect the mission of a particular force. Fixing the avenue of approach involves a tactical decision which is beyond the scope of the engineer intelligence officer. His role in the preparation of a terrain study is to present information on the available avenues of approach for consideration by the G2 and the commander. This information is included in the text. It includes a description of the avenues of approach and a brief discussion of their advantages and disadvantages.

## 163. Movement

The description of cross-country movement conditions is the most important and detailed of the descriptions of military aspects of the terrain. The description of movement in the text is devoted to a general evaluation of conditions for movement in the area and a discussion of the terrain features and weather conditions which affect movement. Movement is shown graphically on the terrain study map by color symbols which represent an evaluation of movement conditions. The effect of all terrain features is considered in the text on movement evaluation. The specific meaning of symbols as applied to the area of study is explained in the margin of appropriate classification symbols. A more complete discussion of areas of poor or doubtful movement than is possible on the terrain study map is contained in the regional description section, to enable the commander to determine conditions under which movement is possible through the area.

### 164. Construction Materials

The description of construction materials presents information on the availability of construction materials in the area of operations. It includes data on the presence of developed and undeveloped sources of rock, sand, gravel, and aggregate, and of stocks of lumber, steel, and other construction materials. It is not a detailed report, but presents general data on the availability of materials for construction in the area. Availability of building materials is discussed generally under military aspects of the terrain. Detailed reports on the sources of construction materials are prepared separately as required by engineer units.

### 165. Suitability of Sites for Construction

The description of construction sites includes a discussion of sites for roads, airfields, and other surface and underground installations. This description should be suited to the needs of the echelon for which the study is prepared. The description does not indicate specific sites, but describes the general suitability of the area for various types of construction. Building sites are discussed generally in the text. Detailed reports on appropriate sites for specific construction projects are prepared separately as required.

### 166. Water Supply

The description of water supply enumerates the sources of water available in the area and evaluates their suitability for use by the troops. It includes a discussion of natural water sources and water supply systems. When pertinent, the water requirements of the civilian population are discussed. Water supply is discussed in the text.

## Section IV. COASTAL HYDROGRAPHY

### 167. Describing Coastal Hydrography

*a. Presentation.* Descriptions of coastal hydrography are of interest primarily for amphibious operations. They differ from overland operations only in the method of transportation and types of routes by which they arrive at the area of operations. The terrain study for an amphibious operation includes: text, terrain study map, and tables. These are the same elements which are in the land-operation study, but the terrain study for an amphibious operation must also include a means for presenting detailed intelligence about the landing area. This is done by extending the three elements of presentation mentioned above to include descriptions of the landing area, and by use of a fourth element, the beach profile diagram. Application of this method of description to coastal hydrography is discussed below.

*b. Text.* The text describes the features of coastal hydrography, such as sea approaches, beach area, sea and surf, and tides. The description is coordinated with the graphic presentation. The effect of other terrain features on coastal hydrographic conditions is also described, and includes the effect of inland surface materials on beach composition.

*c. Terrain Study Map.* The terrain study map shows potential amphibious landing areas. Since the terrain study map may be of too small a scale to be of value as a description of the landing area, it is generally used to depict the configuration of the coast line, location and length of the beaches, and location of exits from the beaches.

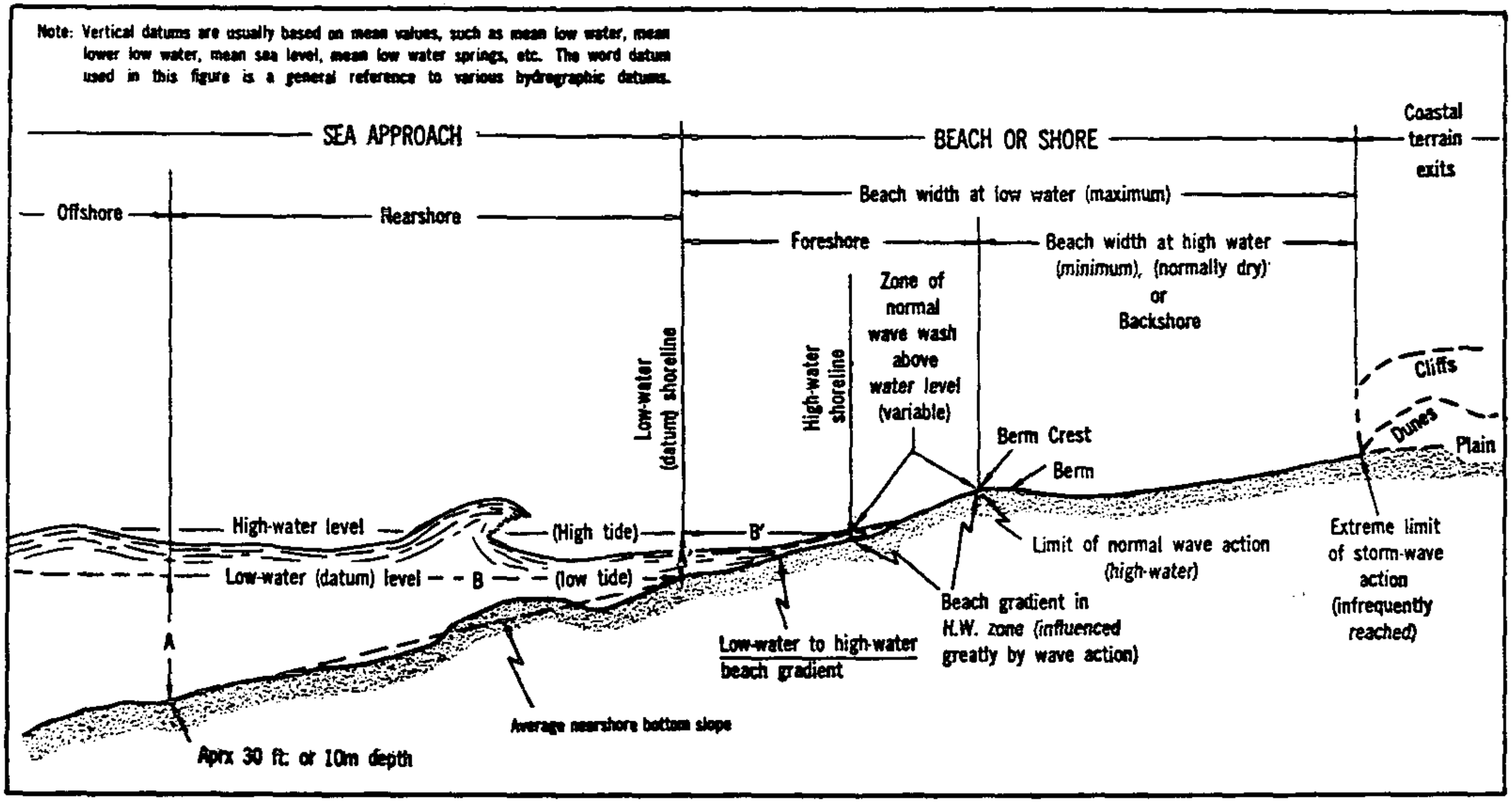



*Figure 59. General beach profile diagram (tidal sea).*

*d. Description.* A description of both the hydrographic and terrain conditions for each landing area is included in a table.

*e. Beach Profile Diagram.* The beach profile diagram (fig. 59) is a large scale sketch of the offshore and nearshore area, the shore, and the coastal terrain (hinterland). The water levels at high tide and low tide are shown in the offshore, nearshore, and foreshore areas. In addition, the beach widths at high water level and low water level and some of the coastal terrain are shown. A profile of the area to the rear of the beach, showing landmarks visible from the sea, is included if deemed necessary as a navigation aid for landing craft. Other data may be included if it is pertinent to the operation.

## 168. Sea Approaches

*a. Offshore Approaches.* The offshore approaches are usually of interest only to naval forces and therefore are not described in the terrain study. When description is necessary, a hydrographic chart may be utilized.

*b. Nearshore Approaches.* The nearshore approaches are of primary interest to landing forces and, as such, require a detailed description. The description should present a general evaluation of the nearshore area, and describe bottom conditions and the effect of sea, swell, breakers, surf, tides and currents. Also described are any special phenomena such as sea vegetation thick enough to be classed as an obstacle, ice conditions, unusual or tricky currents. The landing area map presents a graphic description of the nearshore area. The general relief of the area is described by contours based on the hydrographic chart datum plane. Obstacles are located on the map and any special features are identified by special symbols. Representative profiles, as necessary, describe the gradient of the nearshore area.

*c. Beaches and Beach Exits.* The text presents a general description of the beach area, covering such items as the capacity of the beach, its composition and trafficability, and the capacity of beach exits. The terrain study map describes the general configuration of the coast, the location and length of the beaches, and the beach exits. The regional description deals with the beaches as part of topographic regions. The landing-area map presents a detailed graphic description of the beaches. It portrays the dimensions of the beaches and the location of obstacles areas, and describes the beach exits. The colors used in the landing-area map conform to the color key used in all movement maps. The water tint usually extends to the high water shoreline, or at time to mean sea level, depending upon the mapping agency. One or more profiles are used to describe the beach gradient. If necessary, the area to the rear of the beach is included to indicate the position of landmarks as seen from seaward.

*d. Sea and Swell.* Sea is defined as waves caused by local winds, whereas swell refers to wind-generated waves that have advanced beyond the region of generation. The direction of sea is that of the local wind, whereas the direction of swell is independent of, but may coincide with the local wind. Both sea and swell may be present at the same time. Sea and swell must be described in the text, with roses that show the frequency of various height categories by direction.

*e. Breakers and Surf.* Surf is the disturbed water area extending from the outer breaker line to the limit of uprush on the beach. Breakers are waves that shoal over a reef or on a shore. Hazards to landing increase with increasing breaker height, and vary with period of waves, type of breakers, and the direction of breaker approach onto the beach. Breakers and surf are described by the text, and breaker roses show frequency by direction of specified breaker height ranges.

*f. Tides.* Tide information is presented graphically. Curves portray times of high and low tides, and can be incorporated into the visibility chart. A chart showing the tides during the period of the study is included in the margin of the landing-area map for predicting the heights of the water at any given time. Special tidal conditions and tidal currents are described in the study text.

# CHAPTER 9

# TRAFFICABILITY

## 169. Estimating Soils Trafficability

The purpose of this chapter is to assist intelligence and reconnaissance personnel to determine the trafficability of soils to support cross-country movement of military vehicles. Increased emphasis on the military concept of dispersion, which requires cross-country movement has increased the requirement for information on soil trafficability. Most information on trafficability pertains to military vehicles operating on various unfrozen soils in the temperate zones. The procedures for measurement of soil trafficability can also be applied to unfrozen soils that have been subjected to freeze-thaw cycles. An estimate of trafficability can be made with the aid of this chapter if something is known of the general weather conditions, the topography and the soils of the area.

## 170. Weather and Climate

Information about the weather and climate is available from meteorological records, and climatology textbooks, and by interrogation of prisoners. Only two general conditions of weather apply to trafficability estimates, the dry period and the wet period.

*a. Trafficability During Dry Period.* During a dry period all soils usually are passable unless the area is low-lying and poorly drained or is kept wet by underground springs. Sand in a dry state is less trafficable than in a wetter condition (with the exception of quicksand).

*b. Trafficability During Wet Period.* When moisture is added to a soil its strength is changed. Different soils are affected differently by moisture. During a wet period, all soils with the exception of clean sands and gravels provide poor trafficability. The relative trafficability ratings of soil types under set conditions are given in figure 60. This figure is explained in paragraph 178.

## 171. Topography

The effects of slopes on soil requirements for vehicle performance can be shown in quantitative units when actual measurements of the cone index (para 174*d*) can be made, but in estimates of trafficability only general statements concerning slopes are feasible. Slopes require better soil traction conditions for vehicle movement than does level terrain of a similar soil type. Other factors pertaining to trafficability that must be kept in mind are that ridges are generally more trafficable than the adjacent valley, that downhill travel is easier than uphill travel, and that low tire pressure increases traction. During the dry season, sand slopes of approximately 30 percent are impassable. Fine-grained soils and sands with fines which are poorly drained may be trafficable up to a 45 percent slope. During the wet season a 30 percent slope is the maximum that should be tried on any type soil.

## 172. Soils Maps

Two types of soils maps exist. One type classifies the soils according to the Unified Soil Classification System (USCS), as used in determining trafficability. The second type of soils map employs the agricultural system of soil classification (ASSC). This type is not used by the military. It is mentioned here to avoid confusing it with the USCS. Soils are formed by the action of the following factors: parent material, climate, age, chemical action, topography, and vegetation. A trained analyst can estimate the soil types by using a geologic map, providing he has a general knowledge of the climate, the topography, and the vegetation of the area.

## 173. Aerial Photographs

The full utilization of aerial photos in estimating trafficability is presently being studied. At present the following information pertaining to trafficability is obtained from aerial photographs.

*a. Topography.* Aerial photographs are a good source of topographic information. Estimates of elevations and slopes can be made from stereopairs by properly instructed personnel. Accurate elevations and slopes can be obtained by trained operators using mechanical equipment such as Multiplex and Kelch plotters.

*b. Soils and Moisture Conditions.* In the present stage of development, the techniques for identifying soils from airphotos are so complex that only well-trained technicians can employ them to their fullest extent. However, certain general facts may be used to advantage by personnel with a minimum of training. For instance, orchards usually are planted in well-drained, sandy soils; vertical cuts are an evidence of deep loessial (silty) soils; tile drains in agricultural areas indicate the presence of poorly drained soils, probably silts and clays. On a given photo, light color tones generally signify higher elevations, sandier soils, and lower moisture contents than do dark color tones. The same color tone does not always indicate the same soil conditions even on the same photo. Color tone may have entirely different significance on two separate photos. Also, natural tones are apt to be obscured and modified by tones created by vegetation (natural and cultivated), plowed fields, and shadows of clouds.

*c. Vegetation.* Dense grass, especially if wet, will cause slipperiness. Tall grass will often restrict visibility. Heavier vegetation such as brush and trees will decrease trafficability if the vehicles must push aside this vegetation as they advance. The presence of vegetation in sands usually stabilizes the soil, thus increasing its trafficability. Decaying vegetation including the roots, found especially in the northern latitudes, adds to the support of the soil if the soil is weak. The limited testing that has been done shows that if the mat of partially decayed vegetation is 6 or more inches thick it will support 40 to 50 passes of very light vehicles such as the M29 amphibious cargo carrier. Heavier vehicles will break through after 2 or 3 passes.

*d. Obstacles.* A complete assessment of the trafficability of a given area must include an evaluation of obstacles such as forests, rivers, boulders, ditches, hedgerows, steep slopes and cliffs, and embankments. Aerial photographs are valuable in identifying these features.

## 174. Trafficability Terms

*a. Trafficability.* The capacity of a soil to withstand traffic of military vehicles.

*b. Bearing Capacity.* The ability of a soil to support a vehicle without excessive settlement of the vehicle. California Bearing Ratio is used in denoting design values.

*c. Traction Capacity.* Ability of a soil to resist the vehicle tread thrust required for steering and propulsion.

*d. Cone Index.* A numerical indication of the carrying ability (resistance to penetration by wheels and tracks of vehicles) of a soil. An index of the shearing resistance of soil obtained with the cone penetrometer; a dimensionless number representing resistance to penetration into the soil of a 30° cone with a ½-sq in. base area (actually load in pounds on cone base area in square inches). TM 5–530 discusses this in detail.

*e. Remolding.* The changing or working of a soil by traffic, or by a remolding test. Remolding may have a beneficial, neutral, or detrimental effect on soil strength.

*f. Remolding Index.* The ratio of remolded soil strength to original strength, determined in accordance with procedures described in TM 5–530.

*g. Rating Cone Index.* The measured cone index multiplied by the remolding index; it expresses the soil-strength rating of an area.

*h. Critical Layer.* The soil layer in which the rating cone index is considered a significant measure of trafficability, or the layer of soil which is regarded as being most pertinent to establishing relationship between soil strength and vehicle performance. Its depth varies with the weight and type of vehicle and the soil profile, but it is normally the layer lying 6 or 12 inches below the surface.

*i. Vehicle Cone Index.* The index assigned to a given vehicle that indicates the minimum soil strength in terms of rating cone index required to permit 50 passes of the vehicle.

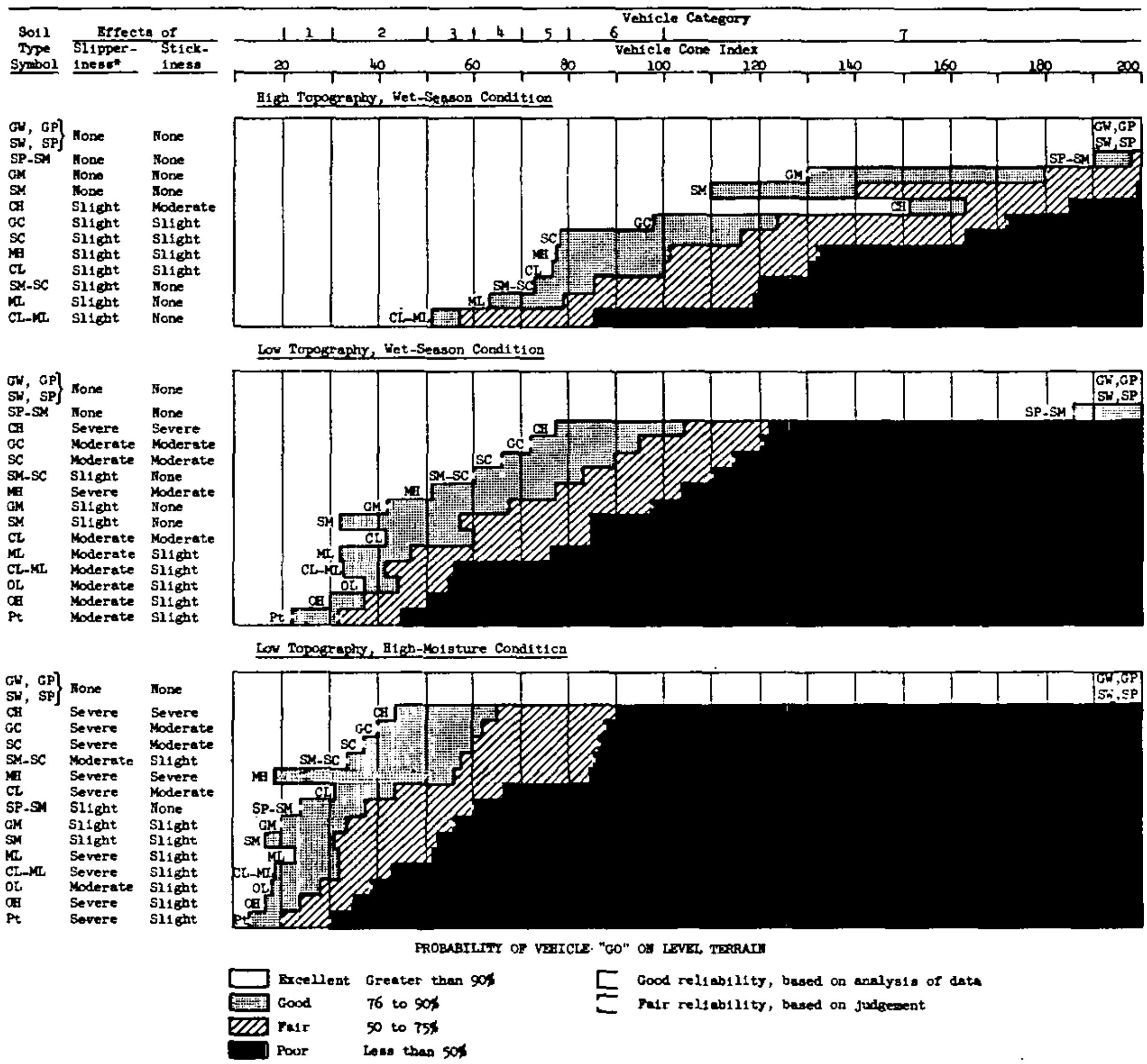
*j. Stickiness.* The ability of a soil to adhere to vehicles, wheels, and tracks.

*k. Slipperiness.* Low traction capacity of a soil's surface due to its lubrication by water or mud.

*l. Mobility Index.* A dimensionless number which results from a consideration of certain vehicle characteristics.

*m. Maximum Tractive Effort.* The maximum continuous towing force or pull a vehicle can exert expressed as a ratio or percentage of its own weight.

*n. Fine-Grained Soil.* A soil of which more than 50 percent of the grains, by weight, will pass a No. 200 sieve (Unified Soils Classification System (USCS)).




Note: Vehicle category and cone index range are given on table IX.

* Applies only to wheeled vehicles without traction devices.

*Figure 60. Soil trafficability classification (USCS).*

*o. Coarse-Grained Soil.* A soil of which 50 percent or more of the grains, by weight, will be retained on a No. 200 sieve.

*p. Sand with Fines, Poorly Drained.* A sand in which water content greatly influences the trafficability characteristics. These soils react to traffic in a manner similar to fine-grained soils. They usually contain 7 percent or more of material passing the No. 200 sieve, and little or no gravel.

## 175. Soil Trafficability Table

*a. Soil Type Symbols.* The soil type symbols used on figure 60 are those employed in the Unified Soil Classification System (USCS). The symbols are given on the extreme left of the figure and also in the graphic portion. The duplication aids in the reading of the graphs. These letter symbols are explained in table 2. Hyphenated letters indicate a mixture of types of soils.

*Table 2. Soils Symbols*

| Symbols | |
|---|---|
| GW | gravel-sand mixtures, little or no fines. |
| GP | gravel-sand mixtures, little or no fines. |
| SW | gravelly sands, little or no fines. |
| SP | gravelly sands, little or no fines. |
| CH | inorganic clays of high plasticity, fat clays. |
| GC | gravel-sand-clay mixtures. |
| SC | sand-clay mixtures. |
| CL | gravelly clays, sandy clays, inorganic clays of low to medium plasticity, lean clays, and silty clays. |
| GM | gravel-sand-silt mixtures. |
| SM | sand-silt mixtures. |
| ML | low plasticity silts. |
| MH | inorganic silts, micaceous or diatomaceous fine sandy or silty soils and elastic silts. |
| OL | organic silts and organic silty clays of low plasticity. |
| OH | organic clays of medium to high plasticity and organic silts. |

Peat, muck, and swamp soils are not classified in the above list because such soils are almost always impassible except for light amphibious-type vehicles.

*b. Strength Measurements.* The probable ranges of the cone index (CI), the remolding index (RI), the rating cone index (RCI), and the mean rating cone index are given on figure 60 for those desiring this technical information. For most trafficability purposes this information may be folded out of view to simplify the reading of the remainder of the trafficability chart. Information on the strength measurements is given in TM 5–530.

## 176. Slipperiness and Stickiness

The information on figure 60 pertaining to stickiness and slipperiness is self-explanatory. The following is general information on each of these two factors.

*a. Stickiness.* No instrument for measuring the effects of stickiness on the performance of vehicles has been devised. Stickiness will occur in all fine-grained soils when they are comparatively wet. The greater the plasticity of soil, the more severe are the effects of stickiness. In general, stickiness will have adverse effect on the speed and facility of travel and steering of all vehicles. It will immobilize small tracked vehicles like the M29 weasel, but will not stop the larger and more powerful military vehicles. Removal of fenders will reduce stickiness effects on some vehicles.

*b. Slipperiness.* Like stickiness, the effects of slipperiness cannot be measured quantitatively. Soils which are covered with water or a layer of soft plastic soil usually are slippery and often cause steering difficulty, especially to rubber-tired vehicles. They can often immobilize vehicles, especially when slipperiness is associated with low bearing capacity. Slipperiness effects assume greater significance on slopes. Sometimes slopes whose soil strength is adequate may not be passable because of slipperiness. The use of chains on rubber-tired vehicles usually will be of benefit in slippery conditions.

## 177. Vehicle Categories

Military vehicles are divided into seven categories according to a cone index range as shown in table 3. These vehicle categories, 1 through 7, are shown at the top of figure 60.

*a. Vehicle Cone Index.* This index is shown directly below the vehicle category range on figure 60. It is helpful in showing the trafficability of vehicles below category 1 and subdivides each of the seven vehicle categories, especially category 7.

*Table 3. Vehicle Categories*

| Category | Vehicle cone index range | Vehicles |
|---|---|---|
| 1 | 20–29 | The M29 weasel, M76 Otter, and Canadian snowmobile are the only known standard vehicles in this category. |
| 2 | 30–49 | Engineer and high-speed tractors with comparatively wide tracks and low contact pressures. |
| 3 | 50–59 | The tractors with average contact pressures, the tanks with comparatively low contact pressures and some trailed vehicles with very low contact pressures. |
| 4 | 60–69 | Most medium tanks, tractors with high contact pressures, and all wheel-drive trucks and trailed vehicles with low contact pressures. |
| 5 | 70–79 | Most all-wheel-drive trucks, a great number of trailed vehicles, and heavy tanks. |
| 6 | 80–99 | A great number of all-wheel-drive and rear-wheel-drive trucks, and trailed vehicles intended primarily for highway use. |
| 7 | 100 or greater | Rear-wheel-drive vehicles and others that generally are not expected to operate off roads, especially in wet soils. |

*b. Graphic Portion of Figure 60.* The legend for the shading of the three graphic portions of figure 60 is given at the bottom part of the figure. The white indicates excellent trafficability, the stippled good, the striped fair, and the black indicates poor to intrafficable soil. The topography and soil conditions are shown in the following three graphs in figure 60.

(1) High topography, (higher areas of the terrain) wet-season condition.

(2) Low topography, (low areas of the terrain) wet-season condition (saturated).

(3) Low topography, high-moisture condition (wet, but below saturation point).

## 178. Use of Figure 60

*a. Mission.* You have a rear-wheel drive truck with which to deliver supplies cross country to another area. You have the following information:

(1) Vehicle cone index: 85

(2) Topography: level high topography

(3) Type of soil: clayey sands (SC)

*b. Question.* Is this trip feasible from the standpoint of trafficability?

*c. Procedure in Determining Trafficability.*

(1) You know that the vehicle cone index of the truck is 85. Table 3 shows the vehicle to be in category 6. The vehicle cone index range (80–99) to the right of the category in table 3 and the written description under *vehicles* verify the category of your truck.

(2) Locate vehicle category 6 at the top of figure 60.

(3) Find the vehicle cone index 85. The number 85 must be interpolated on the vehicle cone index line in the space between 80 to 100.

(4) Find the soil type SC. This is given under *Soil type symbol* in the left column of the figure, and more conveniently on the graphic portion of the figure.

(5) From the 85 (interpolated) on the vehicle cone index, move downward on the high topography, wet-season condition graphic rectangle to the area marked SC. This area is stippled. Your legend at the bottom of figure shows that the trafficability for your vehicle is *good* in this area. Therefore, the trip is feasible from the standpoint of trafficability. The marking around the soil type area on the figure indicates that the trafficability interpretation on the chart has good reliability, as you may note in the legend. (Good reliability, based on analysis of data.)

*d. Trafficability for Same Truck and Soil Type on Low Topography, Wet-Season Condition.* From the 85 (interpolated) on the vehicle cone index, move downward into the *low topography, wet-season condition* graphic rectangle to soil type SC. Note that the trafficability is *good*, as indicated by the stippling. Reliability of this trafficability interpretation is fair, based on judgment.

*e. Trafficability for the Same Truck and*

*Same Soil Type on Low Topography, High Moisture Condition.* From the 85 (interpolated) on the vehicle cone index, move downward into the *low topography, high-moisture condition* graphic rectangle to soil type SC. Note that the trafficability is only *fair*. Had the vehicle cone index been a few points higher, the trafficability would have been *poor*. The black on this graphic chart indicates poor trafficability and is a warning to "stay off."

# APPENDIX A

## REFERENCES

### 1. Field Manuals

| | |
|---|---|
| FM 3–10 | Employment of Chemical and Biological Agents. |
| FM 3–12 | Operational Aspects of Radiological Defense. |
| FM 5–15 | Field Fortifications. |
| FM 5–20 | Camouflage, Basic Principles and Field Camouflage. |
| FM 5–29 | Passage of Mass Obstacles. |
| FM 5–30 | Engineer Intelligence. |
| FM 5–35 | Engineer's Reference and Logistical Data. |
| FM 5–36 | Route Reconnaissance and Classification. |
| FM 17–36 | Divisional Armored and Air Cavalry Units. |
| FM 21–40 | Small Unit Procedures in Chemical, Biological and Radiological (CBR) Operations. |
| FM 30–5 | Combat Intelligence, C–1. |
| (C)FM 30–10A | Special Applications of Terrain Intelligence (U). |
| (C)FM 30–15 | Intelligence Interrogations (U). |
| FM 30–16 | Technical Intelligence. |
| FM 31–10 | Barriers and Denial Operations. |
| FM 31–25 | Desert Operations. |
| FM 31–30 | Jungle Training and Operations. |
| FM 31–50 | Combat in Fortified and Built-Up Areas. |
| FM 31–60 | River-Crossing Operations. |
| FM 31–70 | Basic Cold Weather Manual. |
| FM 31–71 | Northern Operations. |
| FM 31–72 | Mountain Operations. |
| FM 55–8 | Transportation Intelligence. |
| FM 57–10 | Army Forces in Joint Airborne Operations. |
| FM 57–35 | Airmobile Operations. |
| FM 60–30 | Embarkation and Loading—Amphibious. |
| FM 100–5 | Field Service Regulation—Operations, C–1. |
| FM 100–15 | Field Service Regulations—Larger Units. |
| FM 101–5 | Staff Officers' Field Manual—Staff Organization and Procedure. |
| FM 101–10–1 | Staff Officers' Field Manual—Organization, Technical, and Logistical Data. |

### 2. Technical Manuals

| | |
|---|---|
| TM 3–240 | Field Behavior of Chemical, Biological and Radiological Agents. |
| TM 5–248 | Foreign Maps. |
| TM 5–249 | Terrain Models and Relief Map Making. |
| TM 5–297 | Well Drilling Operations. |
| TM 5–312 | Military Fixed Bridges. |
| TM 5–330 | Planning, Site Selection and Design of Roads, Airfields and Heliports in the Theater of Operations. |

| | |
|---|---|
| TM 5–332 | Pits and Quarries. |
| TM 5–343 | Military Petroleum Pipeline Systems. |
| TM 5–530 | Materials Testing. |
| TM 5–541 | Control of Soils in Military Construction. |
| TM 5–545 | Geology. |
| TM 5–700 | Field Water Supply. |
| TM 30–245 | Photographic Interpretation Handbook. |
| TM 30–246 | Tactical Interpretation of Air Photos. |

### 3. Army Regulations

| | |
|---|---|
| AR 117–5 | Military Mapping and Geodesy. |
| AR 320–50 | Authorized Abbreviations and Brevity Codes. |

# APPENDIX B

# OUTLINE FOR TERRAIN STUDIES

## 1. Purpose and Limiting Considerations

State the purpose and limiting considerations under which the study is being prepared. This statement should include the scope of the study in area, time, and subject matter, and any information on the tactical situation, mission, or method of operations that is pertinent to the study.

## 2. General Description of the Terrain

*a. Synopsis.* State briefly the impact of the terrain on military operations.

*b. Climatic Conditions.* Describe predicted meteorological conditions for the period, based on climatic data. Present climatic data graphically whenever possible. The requirements of the study will determine the exact information presented and the manner of presentation.

(1) *Temperature.* Climatic data—give frequency of occurrence of temperatures during period.

(2) *Precipitation.* Climatic data—state frequency of occurrence of precipitation by type and amount.

(3) *Winds.* Climatic data—give frequency of occurrence of winds of certain velocities and direction. Use wind rose.

(4) *Visibility.* Present graphically data on times of sunrise, sunset, twilight, moonrise, and moonset. Describe effect of fogs, mist, haze, and other influences on visibility. State expected visibility by distance when applicable.

(5) *Cloudiness.* Describe when applicable and separate from precipitation and visibility. Climatic data—give data of frequency of occurrence and time of occurrence of various cloud conditions.

(6) *Humidity.* Describe only when significant. Describe effect when combined with other weather elements, such as oppressive heat or wind chill.

(7) *Electrical disturbances.* Describe only when significant.

*c. Topography.* If pertinent, describe the following characteristics by written or graphic means. Recommend the use of a topographic map overprint to emphasize particular characteristics.

(1) *Relief and drainage systems.* Use ridge and stream lining, contour emphasis, hilltopping, or relief shading to outline the ridge and valley systems. Use numbers, words, or standard symbols to indicate critical relief or drainage conditions.

(2) *Vegetation.* Indicate location, type, and size of trees, density of planting, existence of undergrowth, and the location, type, and density of other significant vegetation.

(3) *Surface materials.* Indicate the type and distribution of soils, subsoils, and bare rock in the area. Indicate their trafficability under various weather conditions.

(4) *Manmade features.* Describe fully the significant manmade features. Include roads, railroads, bridges, tunnels, towns, important buildings, fortifications, or airfields when pertinent.

(5) *Special features.* Describe significant special features such as earthquake zones or active volcanoes.

*d. Coastal Hydrography.* Describe when applicable. Use graphic means whenever possible.

(1) *Sea approaches.* Describe nature of approaches, bottom conditions, ob-

stacles, gradients, and coastal structures. Use landing-area map to present information graphically.

(2) *Beaches.* Describe dimensions, trafficability, and beach exits. Use land-area map to present information graphically.

(3) *Tides and currents.* Describe expected time of occurrence and stage of tides. Present graphically. Describe currents by direction, velocity and duration.

(4) *Sea and surf.* Describe height of sea. Describe type of surf, width of surf band, height of surf, and expected duration.

## 3. Military Aspects of the Terrain

From an analysis of the factors of climate, topography, and coastal hydrography, determine the following military aspects and describe them by written or graphic means. Use of an overlay to the basic topographic map is recommended.

*a. Tactical Aspects of the Terrain.* The following aspects are those basic to all tactical operations.

(1) *Observation.* Determine the effect of the terrain factors on observation from the ground, from the air, and by means of electric or sonic devices when applicable.

(2) *Fields of fire.* Determine the effect of the terrain factors on the ability of flat- and high-trajectory weapons to deliver projectiles to a target. Consider nuclear weapons when applicable.

(3) *Concealment.* Determine the capability of the terrain to provide concealment for men, equipment, and installations. Consider the effect of terrain on concealment by artificial means.

(4) *Cover.* Determine the capability of the terrain to provide cover for men, equipment, and installations. Consider the problem of cover from flat-trajectory, high-trajectory, and nuclear weapons when applicable.

(5) *Obstacles.* Determine the capability of the terrain to delay the advance of military forces or impede military operations. Consider both natural and manmade obstacles.

(6) *Movement.* From an analysis of soils trafficability, natural and manmade obstacles, and existing routes of movement, determine the ability of troops and equipment to move through an area. Use standard color code to describe movement conditions. Use specific terms of movement whenever possible; i.e.—vehicular, cross-country, and foot.

(7) *Key terrain features.* From an analysis of the terrain and of friendly and enemy methods of operations, indicate those terrain features which appear to be critical, such as a dominant height, a highway, a communication center, or an airfield.

(8) *Avenues of approach.* From an analysis of all terrain factors affecting capabilities to move men and materiel, determine the avenues of approach to the objective. Consider existing routes of movement, possibilities of cross-country movement, and amphibious or airborne or airmobile operations when applicable.

*b. Engineering Aspects of the Terrain.* Determination of the following military aspects is essential to planning the engineer phase of operations. Include these items in written or graphic form as overprints or overlays.

(1) *Construction sites.* From an analysis of surface material and other terrain factors, determine areas suitable for construction of roads, airfields, buildings, underground installations, surface defensive installations, or others.

(2) *Construction materials.* From an analysis of surface materials and other terrain factors, determine the probable location of rock, gravel, sand, or other natural construction material.

(3) *Water supply.* From an analysis of the drainage system and subsurface formations, determine the probable location of potable water and water suitable for construction use.

**4. Maps and Charts (as appropriate)**

*a. Topographic.*

*b. Trafficability.*

*c. Landing* (where applicable).

*d. Special maps* (when needed).

(1) *Geological.*

(2) *Soils.*

(3) *Hydrographic charts.*

(4) *Town plans.*

(5) *Road.*

(6) *Joint operations graphic.*

# APPENDIX C

## SAMPLE TERRAIN STUDY

Headquarters 15th Army
Western Germany
January 1945

1. PURPOSE AND LIMITING CONSIDERATIONS

*a. Purpose.* This terrain study considers the area to the south and east of COLOGNE, Germany, for February and March. General boundaries for the zone are the towns of JULICH on the ROER RIVER (3145) and ZULPICH (3418), and the RHINE RIVER north and south of COLOGNE as shown on inclosure 1 (fig. 61). Elements of Fifteenth Army, consisting of armored and infantry units, are located west of the ROER RIVER and presumably will operate in the area with the general mission of advancing northeastward to the RHINE RIVER.

*b. Limiting Consideration.* Information presented is based on data obtained from maps, intelligence documents, climatic study, and interrogation. Ground reconnaissance has not been made, nor have the effects of bombing been considered.

2. GENERAL DESCRIPTION OF THE TERRAIN

*a. Synopsis.* The area during this period of the year provides favorable conditions for military operations. It is highly populated mixed farm and industrial region. Construction sites and materials are available and the communication system is excellent. Movement across the RHINE RIVER is canalized at BONN and COLOGNE. Obstacles are the ROER and ERFT RIVERS and the VILLE RIDGE. Conditions influencing movement are sensitive to precipitation.

*b. Climate Conditions.* See inclosures 2, 3, and 4 (figs. 61-64).

(1) *Temperatures* will present problems to the effective operation of troops in the field. Inclosures 2, 3, and 4 give compiled temperature data.

(2) *Precipitation* in some form normally occurs every second day. Wet soils are common. Snowfalls ordinarily do not exceed 9 to 11 centimeters (6 or 7 inches). Ice, if present, is thin and will not support a man.

(3) *Wind* direction and velocity are given by the wind roses in inclosures 3 and 4. Winds from the east are usually accompanied by severe temperature drops.

(4) *Visibility* factors are listed in inclosures 2, 3, 4 and 5. Fog occurs rarely at this time of year, despite the high relative humidity. The high frequency of moderate to fresh winds favors the formation of low clouds rather than fog.

*c. Topography.*

(1) *Relief* is low and gently rolling with only two exceptions: the southwestern portion of the map (HOHE VENN) has steep wooded hills and highlands dissected by deep valleys; and a low hilly ridge, hereafter known as the VILLE RIDGE, exists between the ERFT RIVER and the RHINE RIVER. This area is discussed in detail on the back of the map and later in this study.

(2) *Drainage.* Streams cross the region generally from southeast to northwest. The ROER RIVER is approximately 80 feet wide, with no fords, and *can be flooded by release of water impounded in dams to the south.* The ERFT RIVER, or canal, meanders through several channels in its flood plain. These channels average 6 to 9 meters (20 to 30 feet) in width and .6 to 1.5 meters (2 to 5 feet) in depth. In many places, the river channels are flanked by marshy flats which are drained through numerous deep ditches.

(3) *Vegetation.* The area is largely devoted to agriculture and pasture but scattered forests do exist, and these are delineated on the map with notes as to density, type, and approximate boll size. Trails and unimproved roads allow restricted passage even through the dense forests. At this period of the year, the ground will be fallow or in low cover crop which will increase its trafficability. Trees are scattered throughout the numerous mine pits in the area.

(4) *Surface materials.* The region is generally covered by a loamy soil tending toward sandy soil in the south. In the VILLE RIDGE area, the original soils have been stripped off during mining, exposing sandstone and shale. Stream valleys are composed of fine grained silts in the northern reaches and change to sandy material upstream to the south. The soil immediately west of the RHINE RIVER is composed of sandy well-drained material. Surface materials are discussed further on the back of the movement map.

(5) *Manmade features.* The manmade features studied include roads, railways, bridges, airfields, towns, and strip mines.

(*a*) An excellent network of roads exists. Only the primary system, that with a route classification (FM 5–36) of X is shown on the map. In addition, secondary roads of general route classification connect many of the villages. Free egress from roads for cross-country movement is possible in most places.

(*b*) Rail communication, as shown on the map, is very good. As a a supplement to the standard-gage system, considerable narrow-gage lines exist, particularly in the VILLE RIDGE region. Marshalling yards are located at DUREN, BONN, and COLOGNE. The tunnel on the double-tracked route between DUREN and COLOGNE is a vulnerable point, but may be bypassed through alternate routes.

(*c*) The classification of bridges along the primary-road system is 65. Important bridges are indicated on the map with the classification noted if lower than the general class. Bridges on the secondary-road system have a general classification of 55.

(*d*) This area contains a large municipal airfield capable of handling heavy-cargo aircraft. These have been marked on the map. Also shown are three landing strips which can be used by assault aircraft. Sections of primary roads and autobahns may be utilized for light Army aircraft strips.

(*e*) Most urban areas are well built-up with stone and masonry buildings. Streets, except for boulevards or freeways, are narrow, and may permit only one-way traffic to trucks and tanks. All but the larger cities may be bypassed easily.

3. MILITARY ASPECTS OF THE TERRAIN

*a. Tactical Aspects.*

(1) *Observation.* Observation throughout the area is generally good, although there are small areas of defilade. The VILLE RIDGE affords excellent observation of the lowlands to the east and west. The HOHE VENN area provides good points for observation of the ROER RIVER valley. Small hills afford tactical observation in the plains section. Aerial observation will be excellent, except where woods obscure the ground.

(2) *Fields of fire.* The area provides generally good fields of fire for all weapons with two exceptions. The broken terrain of the VILLE RIDGE and the HOHE VENN limits fields of fire for flat-trajectory weapons within the ridge masses themselves. However, flat-trajectory weapons situated on these ridges can command their lowland approaches very effectively.

(3) *Concealment.* The mixed forested areas give good concealment from both air and ground observation. The broadleaf forests are bare of leaves during February and March and offer only limited concealment. Farming practices in this part of Germany are such that little concealment is possible in the winter cover crops, but the many farm buildings and small villages afford good concealment for small units.

(4) *Cover.* Principal cover is offered by the stone structures that make up the cities and farm communities. In the VILLE RIDGE area, some cover can be found in the mine tunnels.

(5) *Obstacles.*

(*a*) The ROER RIVER under normal conditions will offer only minor problems to an assault crossing. Opening or destroying the ROER DAM will flood the ROER VALLEY. If this is done, it will take at least a week for the ROER RIVER to recede, and 2 to 3 weeks for soils trafficability to return to normal.

(*b*) The ERFT VALLEY, with its drained swamps and many canals, will restrict movement to roads in most areas. The river channels themselves are not a serious obstacle to infantry; however, a long thaw, which is quite possible in March, or an unseasonal rain can make them unfordable to foot troops. There are also lignite pits west of Koln along Erft River.

(*c*) Wooded areas may restrict vehicular movement to narrow unimproved roads but are passable for infantry under normal conditions.

(*d*) The VILLE RIDGE forms an obstacle of major importance to vehicular and foot movement. It may be easily defended against a superior force, affording the defender excellent observation and concealment in its woods and extensive mine workings.

(6) *Movement.* This is indicated on the movement map (fig. 61). The area as a whole provides very good movement during dry weather, and fair to doubtful movement during periods of heavy precipitation.

(7) *Key terrain features.*

(*a*) The VILLE RIDGE dominates the lowlands to the east and west of the hill mass. Routes crossing the VILLE RIDGE are restricted to the roads because of the extensive pits, quarries, and spoil heaps left by coal-mining operations.

(*b*) The HOHE VENN highlands southwest of DUREN overlook the adjacent ROER RIVER valley. In this region heavy forests and steep slopes restrict vehicular traffic to the roads.

(8) *Avenues of approach.* The main highways from the ROER RIVER toward COLOGNE offer good avenues af approach from the southwest, and represent the bet routes for breaching the VILLE RIDGE. The *best* avenues of approach would be to the north of JULICH-COLOGNE highway where the VILLE RIDGE may be flanked and cut off. The secondary road and rail net is adequate for support of an armored attack. The VILLE RIDGE may be flanked from the south in the vicinity of BONN, but here armored operations will be somewhat restricted and canalized by dense forests, and by the constriction of the corridor between the VILLE RIDGE and the RHINE RIVER.

*b. Engineering Aspects of the Terrain.*

(1) *Construction sites.* With the exception of the mining dumps, the southwestern highlands, and the river flood plains, the area is well suited for the construction of roads, airfields, cantonments, depots, and other military surface structures. The land is level and open, the communication net is excellent, and the soil has good stability and bearing capacity. The HOHE VENN highland is better suited for underground facilities than the plains area. Solid sandstone layers are useful as floors and roofs here, and ground water will not be as troublesome as in the flatlands.

(2) *Construction materials.*

(*a*) *Natural materials.* Quarries and gravel banks are available for stone and aggregate at many places. The terraces along the RHINE and ROER RIVERS are good sources of gravel and sand, while sandstone suitable for construction purposes can be quarried west of ZULPICH. Broken rock consisting of sandstone, shale, and soil is piled in the VILLE RIDGE dumps, and west of DUREN. Forests supply adequate quantities of standing timber to cover any foreseeable needs. Small local sawmills may be useful in cutting the timber for use.

(*b*) *Manufactured materials.* The heavy industrial buildings in the VILLE RIDGE and COLOGNE areas are good sources of construction steel, lumber, and similar materials needed by engineers. In addition, a large network of mine railroads exists throughout the pits and may be utilized for material.

(3) *Water supply.* An adequate field water supply may be obtained from the streams and wells of the area. Civilian water supply on farms is obtained from wells, and in cities through municipal distribution plants and systems which draw water from the major rivers. Emergency water supplies may be drawn from these sources.

5 Inclosures:

Inclosure 1. Movement map of Cologne area (fig. 61).
Inclosure 2. Climate conditions Cologne, Germany, for February and March.
Inclosure 3. Climatic data for Cologne area for February (fig. 62).
Inclosure 4. Climatic data for Cologne area for March (fig. 63).
Inclosure 5. Ephemeris for Cologne area for February and March (fig. 64).

*Figure 61. Movement map of Cologne area.*

*Figure 61*—Reverse.

**(Located in back of manual)**

CLIMATIC DATA FOR COLOGNE AREA, GERMANY
FEBRUARY

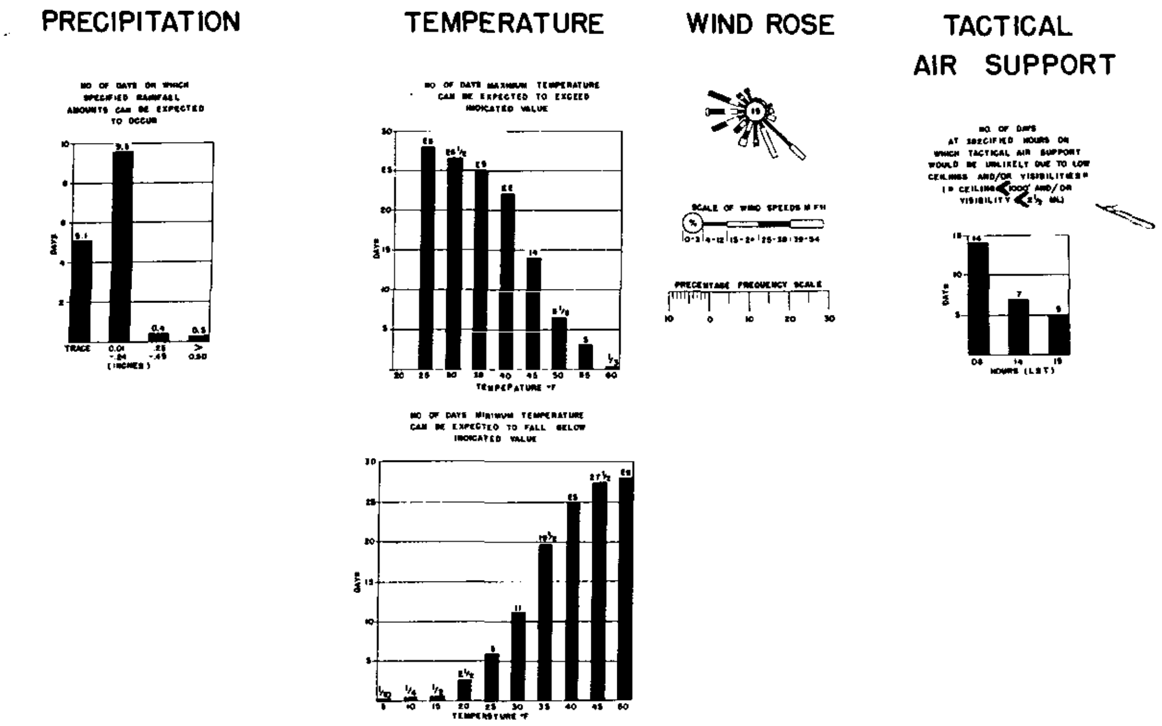



*Figure 62. Climatic data for Cologne area for February (Inclosure 3 to app D).*

CLIMATIC DATA FOR COLOGNE AREA, GERMANY
MARCH

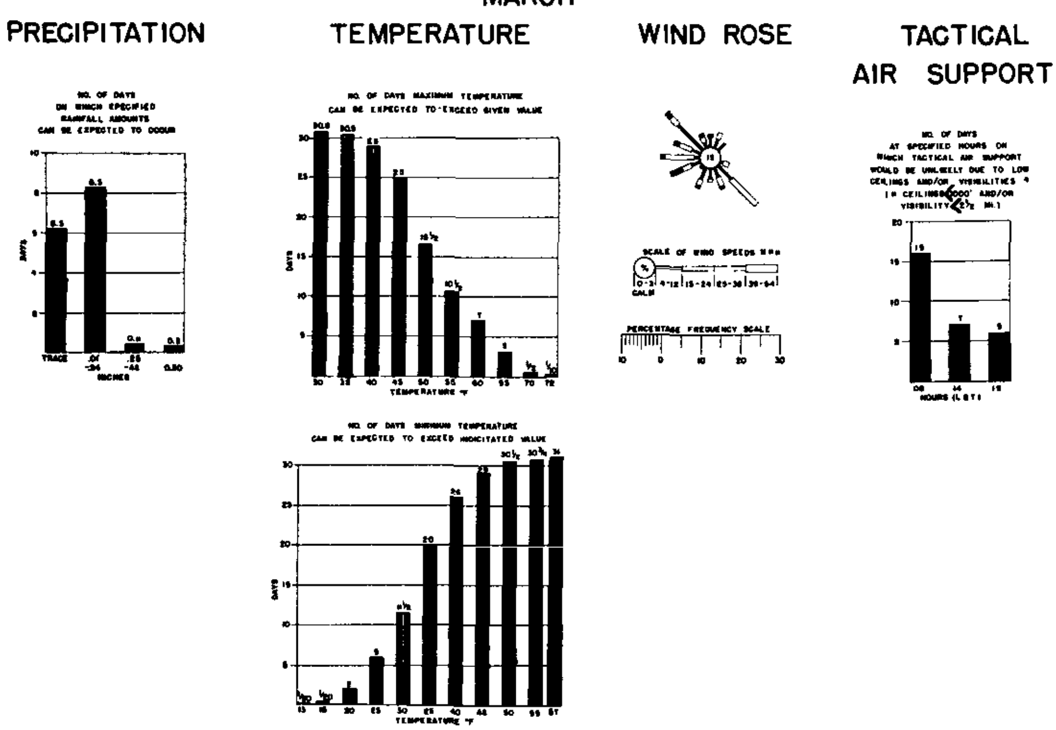



*Figure 63. Climatic data for Cologne area for March (Inclosure 4 to app D).*

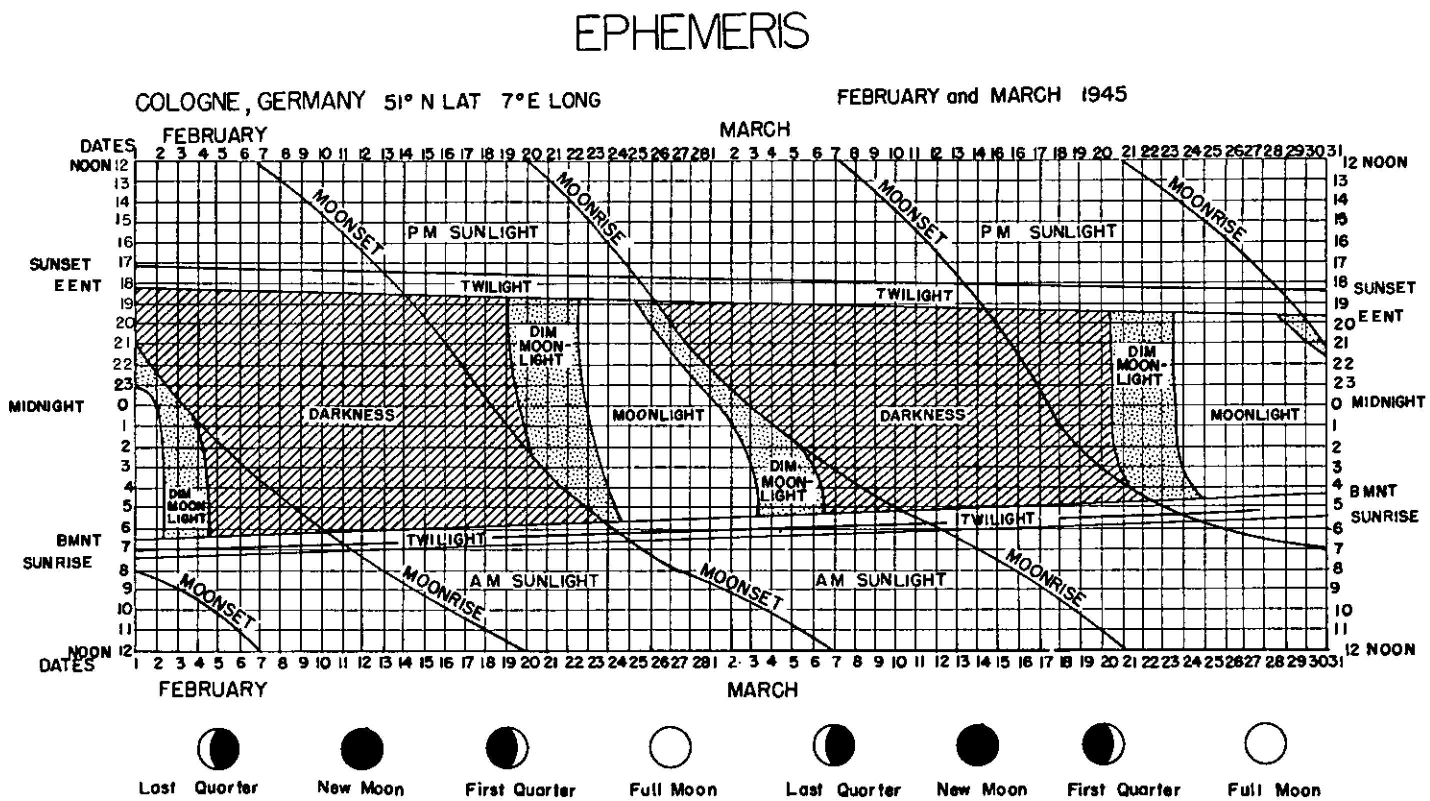



*Figure 64. Ephemeris for Cologne for February and March (Inclosure 5 to app D).*

*Inclosure 2. Climatic Conditions, Cologne, Germany, for February and March*

| | Feb | Mar |
|---|---|---|
| Temperature (°F.): | | |
| Mean maximum | 43 | 49 |
| Mean minimum | 33 | 37 |
| Absolute maximum | 66 | 72 |
| Absolute minimum | 0 | 13 |
| Number of days with: | | |
| Minimum—32°F | 10 | 6 |
| Maximum—32°F | 2 | 0.4 |
| Precipitation (CM): | | |
| Mean | 4.09 | 4.39 |
| Maximum | 11.88 | 10.31 |
| Minimum | 0.4 | .7 |
| Maximum in 24 hours | 3.15 | 2.06 |
| Mean number of days with: | | |
| Snowfall 0.01CM | 6.4 | 5.9 |
| Snow on ground | 5.3 | 2.0 |
| Fog | 1.2 | 1.4 |
| Wet soil | 14.2 | 13.2 |
| Clear skies | 3.2 | 3.1 |
| Partly cloudy skies | 14.7 | 19.1 |
| Cloudy skies | 10.3 | 8.8 |
| Mean relative humidity (%): | | |
| 0700 LST | 84 | 82. |
| 1400 LST | 74 | 67. |
| 1900 LST | 82 | 76 |

# APPENDIX D

## SAMPLE CLIMATIC STUDY

### General

This study is divided into four parts, each having a different operational aspect: amphibious, airborne, airmobile, and overland in two differing climatic regions. The studies and accompanying data do not refer to any exact geographic locations, but are offered only as a guide for format and content.

*a. Information Sources.* Source material for such studies is usually drawn from climatic summaries on file at the Climatic Center, Headquarters Air Weather Service, from the National Intelligence Survey (NIS) sources, and from weather summaries on file at the U.S. Weather Bureau or Congressional Libraries. In the field, information of a climatic nature may be obtained from local Air Weather Service detachments or a national meteorological service office. The climatic study is designed to provide a first estimate of weather factors affecting military operations and should not be regarded as an operational forecast which normally is supplied by other Air Weather Service detachments.

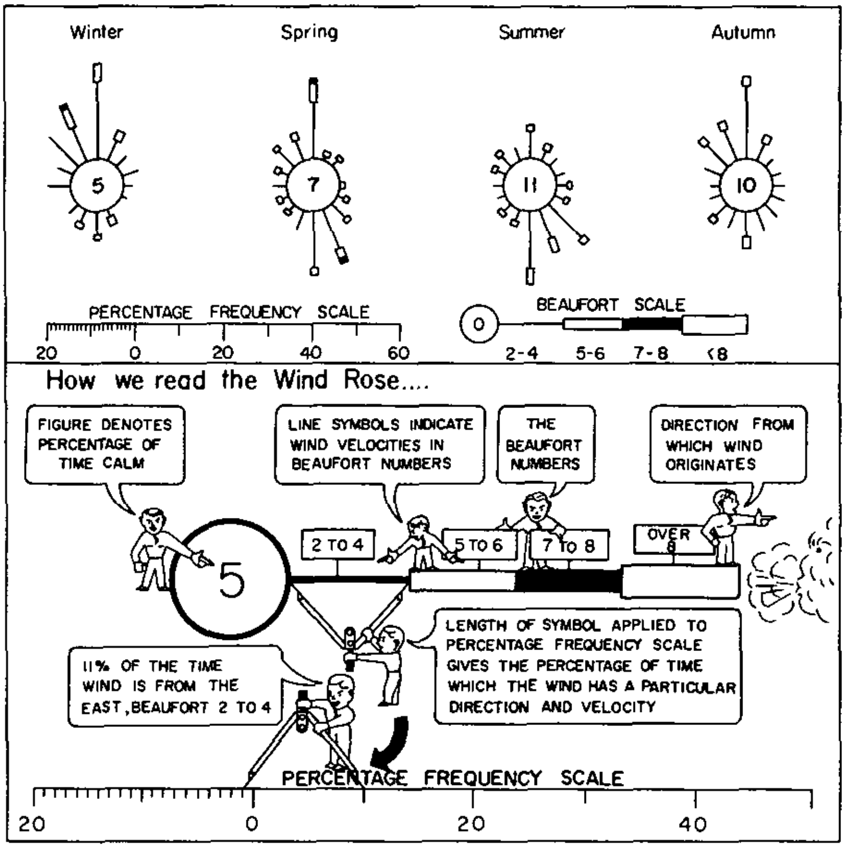



*Figure 65. How to read a wind rose.*

*b. Wind Rose.* The agency requesting climatic data from Air Weather Service should specify whether the wind speed data is desired in kilometers, miles, or knots per hour. Wind speed data is shown in compact form by means of a wind rose. The method used to read a wind rose is shown in figure 65. The wind rose makes use of the Beaufort scale, which is a wind scale in which the force of the wind is indicated by numbers with corresponding descriptive terms. These terms are commonly used by the U.S. Weather Bureau (table 1, chap. 4).

## Part I

### Climatic Factors Affecting an Overland Operation in the Region Surrounding OBJECTIVE ONE During May

In terms of general climate, OBJECTIVE ONE area has a maritime-type climate, characterized by cool, humid winters and mild, comparatively dry summers. The month of May represents a portion of the transition period between these two characteristic seasons.

In the absence of meteorological information for the exact location involved, combined data from adjacent areas, both north and south, were considered to be representative of the climate of OBJECTIVE ONE area and are presented as appendix material in tabular (table D–1) and graphical (fig. 66) form.

*Table D-1. Overland Operation OBJECTIVE ONE—May*

| | |
|---|---|
| Temperature (°F.): | |
| Mean Maximum | 62 |
| Mean | 50 |
| Mean minimum | 38 |
| Recorded Extremes | 77 to 31 |
| Mean Number of Days with: | |
| Fog | 1 |
| Thunderstorms | 0 |
| Rain | 8 |

*Temperature* during May is usually conducive to moderate to strenuous activity. Normally, temperature averages approximately 50° F., with a moderate diurnal and monthly range. Minimum temperatures, especially during the first portion of the month, in valley areas or close to the ground surface are frequently in the mid 30's during early morning hours.

*Rainfall* is light, averaging 5 to 6 centimeters (2 to 2½ inches) for the month. This amount, well distributed in time (the maximum reported for any 24-hour period is 2.5 centimeters (1½ inches)), should not create problems associated with soil moisture and would be sufficient to minimize dust conditions. Snow accumulations on the mountains and passes east of the area melt at this time and provide a source of fresh water for the local streams. Flooding of these streams is unusual.

*Relative Humidity* is high throughout the day, averaging 80 percent to 85 percent. Diurnally, the variation is relatively small, 10 percent to 20 percent. Although relative humidities average quite high, the incidence of fog and other forms of restricted visibilities is quite low; about 5 percent of the time the visibility is less than 4 kilometers (2½ miles).

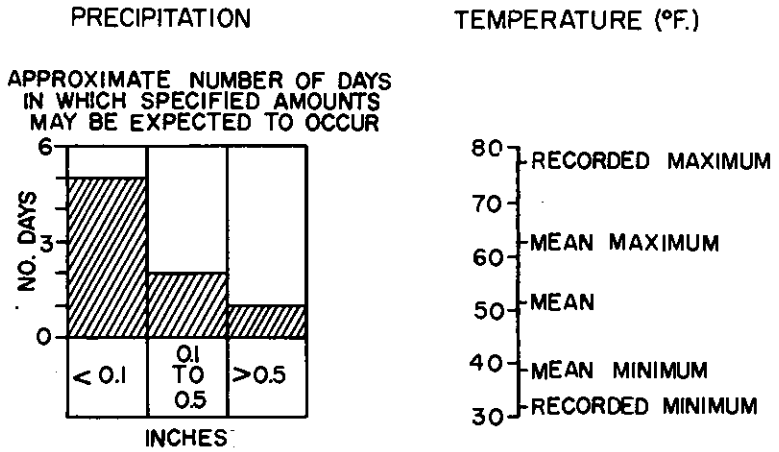
Cloud cover and visibilities are well suited for tactical air support.*

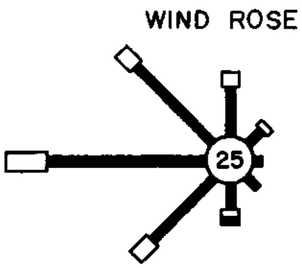
Winds are primarily from a westerly direction, southwest through northwest, with an average speed of 7 to 10 knots. Approximately 25 percent of the time the winds are less than 3 knots.

* Minimum ceiling and visibility requirements depend upon the type of support and the equipment involved, and upon the type of terrain over which this support must operate.

CLIMATIC DATA FOR OBJECTIVE ONE

MAY



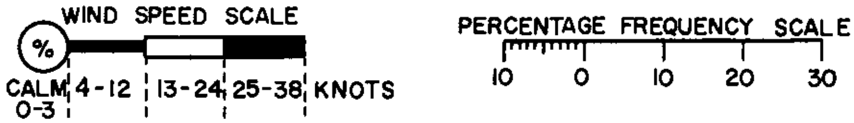




*Figure 66. Climatic data for OBJECTIVE ONE—May.*

## Part II

### Climatic Factors Affecting an Amphibious Landing on OBJECTIVE TWO During May or June

Complete meteorological observations on the island were made only during a brief period during World War II. Plantation records for longer periods of record have been used in arriving at precipitation estimates. Climatic data are presented as appendix material (table D–2 and figs. 67 and 68).

*Table D–2. Amphibious Operations OBJECTIVE TWO Island—May and June*

| | May | June |
|---|---|---|
| Temperature (°F.): | | |
| Mean Maximum | 88 | 90 |
| Mean | 81 | 82 |
| Mean Minimum | 75 | 76 |
| Recorded Extremes | 93 to 73 | 95 to 74 |
| Mean Number of Days with: | | |
| Thunderstorms | 8 | 6 |
| Precipitation | 17 | 12 |
| 1.3 centimeters—0.5 inch | 12 | 9 |
| 4.8 centimeters—0.6 to 1.9 inches | 4 | 2 |
| 5 centimeters—2.0 inches | 1 | 1 |

Climatically, OBJECTIVE TWO Island has all the typical tropical characteristics with heavy, shower-type rainfall and a small diurnal and seasonal temperature range. Since the island is affected by the monsoon wind, the May-June period is one of transition, during which winds are normally light and variable.

*Temperature* conditions are not conducive to human activity, and the daily range of temperatures is insufficient to alleviate this human discomfort at night. The mean temperature is approximately 80° F., with a maximum daily range of about 20 Fahrenheit degrees.

*Humidity* is constantly high and coupled with the warm temperatures creates problems of material storage and supply, in addition to adding to human discomfort. Mean relative humidity is approximately 80 percent, with only slight variation diurnally.

*Visibility* is seldom restricted by weather factors except during brief periods of heavy shower activity; however, dense vegetation limits ground visibility severely unless some form of clearing has taken place.

*Precipitation* is of the brief, heavy shower-type that usually occurs during the afternoon on an average of 1 out of 2 days. Thunderstorms are quite frequent, with an average of 8 storms per month. Although total precipitation is highly variable from year to year, it is more than adequate to keep soils moist, support heavy vegetation, and present vehicular transport problems. Maximum precipitation in 24 hours reported for the island during this period was 18 centimeters (7.2 inches) during May.

*Winds* are light and variable, except during heavy showers; however, during June the southeast monsoon is being established and southeast winds become more predominant. In the forested areas, winds are usually very light or calm, but along coastal strips they average about 5 knots. Typhoon winds are not considered a threat to operations this early in the season.

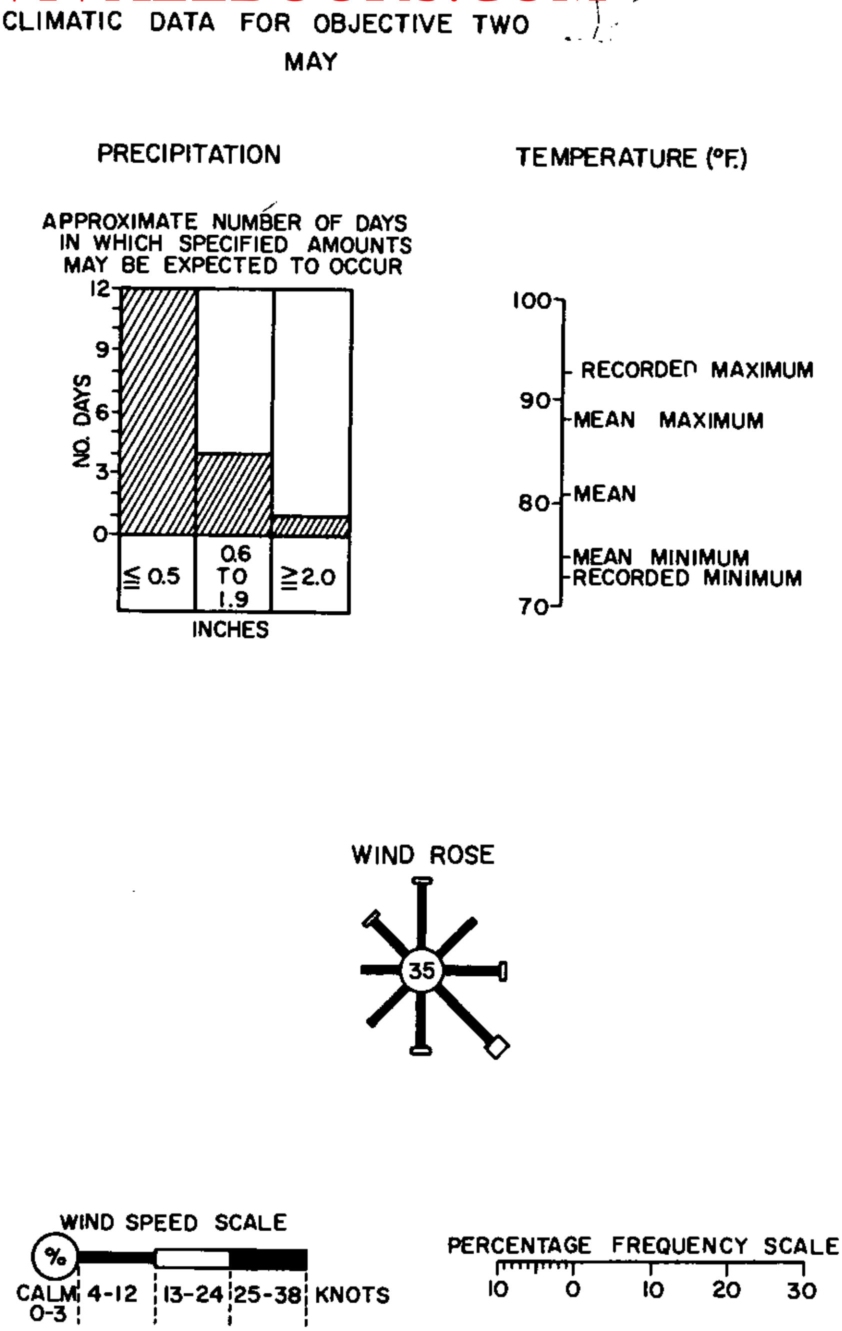



*Figure 67. Climatic data for OBJECTIVE TWO—May.*

## Part III

### Climatic Factors Affecting an Airborne-Airmobile Operation in the Vicinity of OBJECTIVE THREE During September

For the purposes of this report, it was assumed that paratroop operations would be carried out only with a ceiling value equal to or greater than 305 meters (1,000 feet), visibility equal to or greater than 4 kilometers (2½ miles), and wind speed less than 13 knots. On this basis, favorable weather occurs most frequently during the midafternoon. Unfavorable

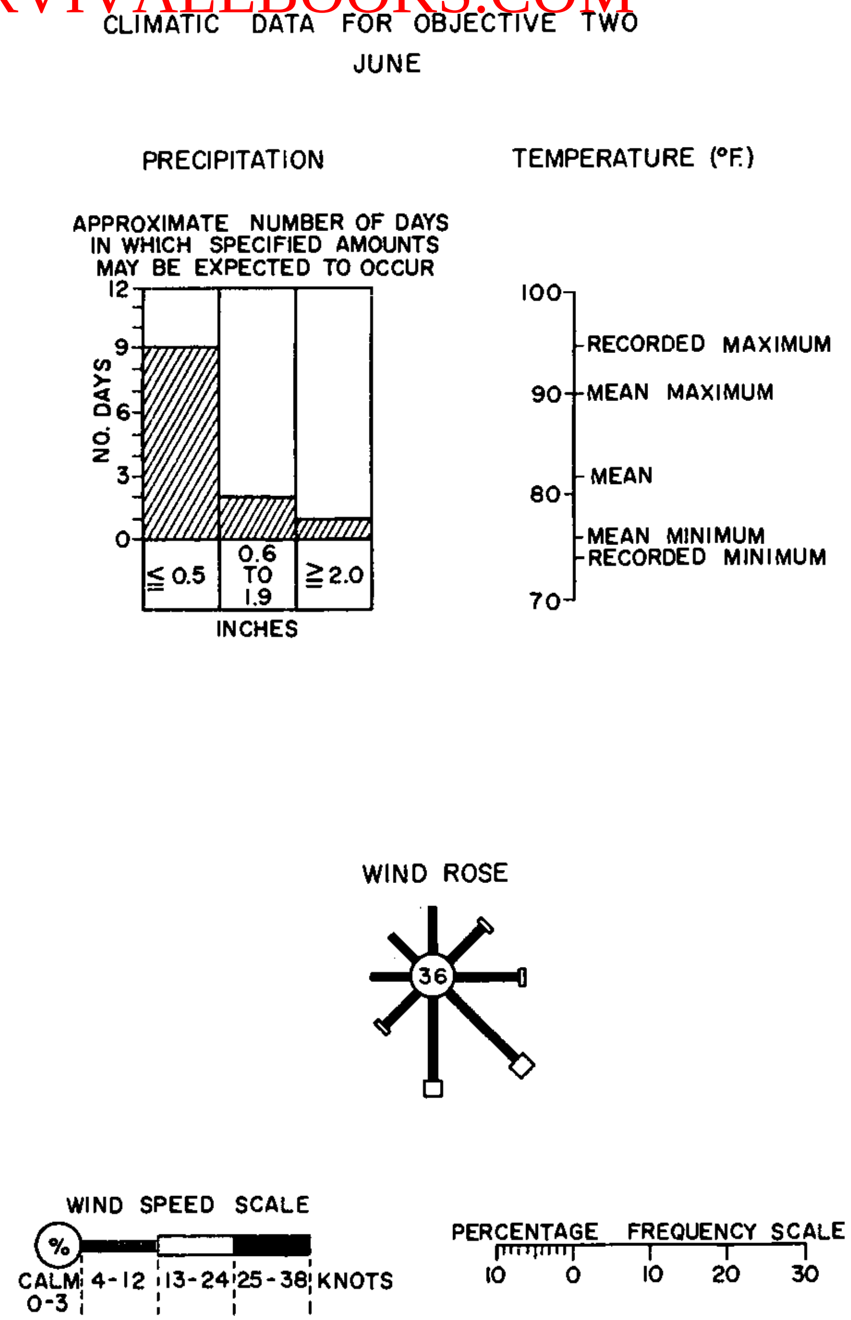



*Figure 68. Climatic data for OBJECTIVE TWO—June.*

conditions increase gradually until early morning hours when adverse weather occurs approximately 25 percent of the time. Tactical air support, depending upon the type needed and equipment utilized, should be able to operate 70 percent to 80 percent of the daylight hours (table D–3 and fig. 69) .

*Table D–3. Airborne Operation OBJECTIVE THREE—September*

| Temperature (°F.): | September |
|---|---|
| Mean Maximum | 67 |
| Mean | 58 |
| Mean Minimum | 50 |
| Recorded Extremes | 87 to 38 |
| Mean Number of Days with: | |
| Thunderstorms | 3 |
| Precipitation | 19 |
| 2.54 millimeters (0.1 inch) | 9 |
| 2.54 to 12.70 millimeters (0.1 to 0.5 inch) | 6 |
| 12.70 millimeters (0.5 inch) | 4 |
| Precentage Frequency, by Hour, of Weather Favorable for Paradrop Operations (Ceiling 305 meters (1,000 ft.)), Visibility 4 kilometers (2½ miles, Wind 13 ft.) | |
| 0800 LST 74% | |
| 1400 LST 96% | |
| 1900 LST 91% | |

*Temperatures* are not extreme during this period and should not present problems of human comfort. The extreme range of temperature is large, but normal temperatures are quite moderate with mean maximum of 67° F. and a mean minimum of 50° F.

*Precipitation,* in the form of drizzle, light rain, or showers, occurs on the average of 2 days out of 3, giving an average September rainfall amount of approximately 6.35 centimeters (2½ inches). Heavy rainfall is infrequent, but when it occurs, poorly drained areas become flooded and trafficability problems are intensified.

Fog restricts visibility to less than 800 meters (one-half mile) on 1 day of 10, most often during the early morning hours. During the afternoon and early evening the possibility of restricted vision caused by air pollutant is even less.

*Winds* are most frequently from the northwest (see wind rose), with about 10 percent of the observations showing wind speeds greater than 13 knots. Diurnal variations in wind strength or direction appear negligible in this particular area.

## Part IV

### Climatic Factors Affecting an Overland Operation in the Vicinity of OBJECTIVE FOUR During February

Climatically, the objective area has a marine climate, which implies mild, cloudy, and humid weather (table D–4 and fig. 70).

*Table D–4. Overland Operation OBJECTIVE FOUR—February*

| Temperature (°F.): | February |
|---|---|
| Mean Maximum | 45 |
| Mean | 38 |
| Mean Minimum | 32 |
| Recorded Extremes | 64 to 10 |
| Mean Number of Days with: | |
| Precipitation | 16 |
| 2.54 millimeters (0.1 inch) | 8 |
| 2.54 to 12.70 millimeters (0.1 to 0.5 inch) | 5 |
| 12.70 millimeters (0.5 inch) | 3 |
| Snowfall | 5 |
| Snow on ground | 5 |
| Mean Relative Humidity (%) | |
| 0700 LST | 85 |
| 1400 LST | 71 |
| 1900 LST | 80 |

*Temperatures* usually are not severe, as a result of the moderating effect of the water on the migratory air masses. However, alternate freezing and thawing of the normally water-soaked soil surface is common, creating problems of vehicular movement due to rapid deterioration of natural surfaces.

*Precipitation* in the form of rain, drizzle, and/or snow occurs on approximately one-half of the days during the month. Snowfall is usually small in amount, but is apt to be wet, heavy, and clinging; possibly resulting in destruction of overhead wires and some vegetation. Snow cover is usually shortlived, being destroyed by the frequent warmer rains. Soils are usually water soaked; only during exceptionally cold winters does the ground freeze to any depth.

*Fog* occurs on 4 to 5 days during the month and is usually quite dense, persistent, and widespread, restricting visibility to several hundred meters and precluding any tactical air support. Cloud cover is usually present, but

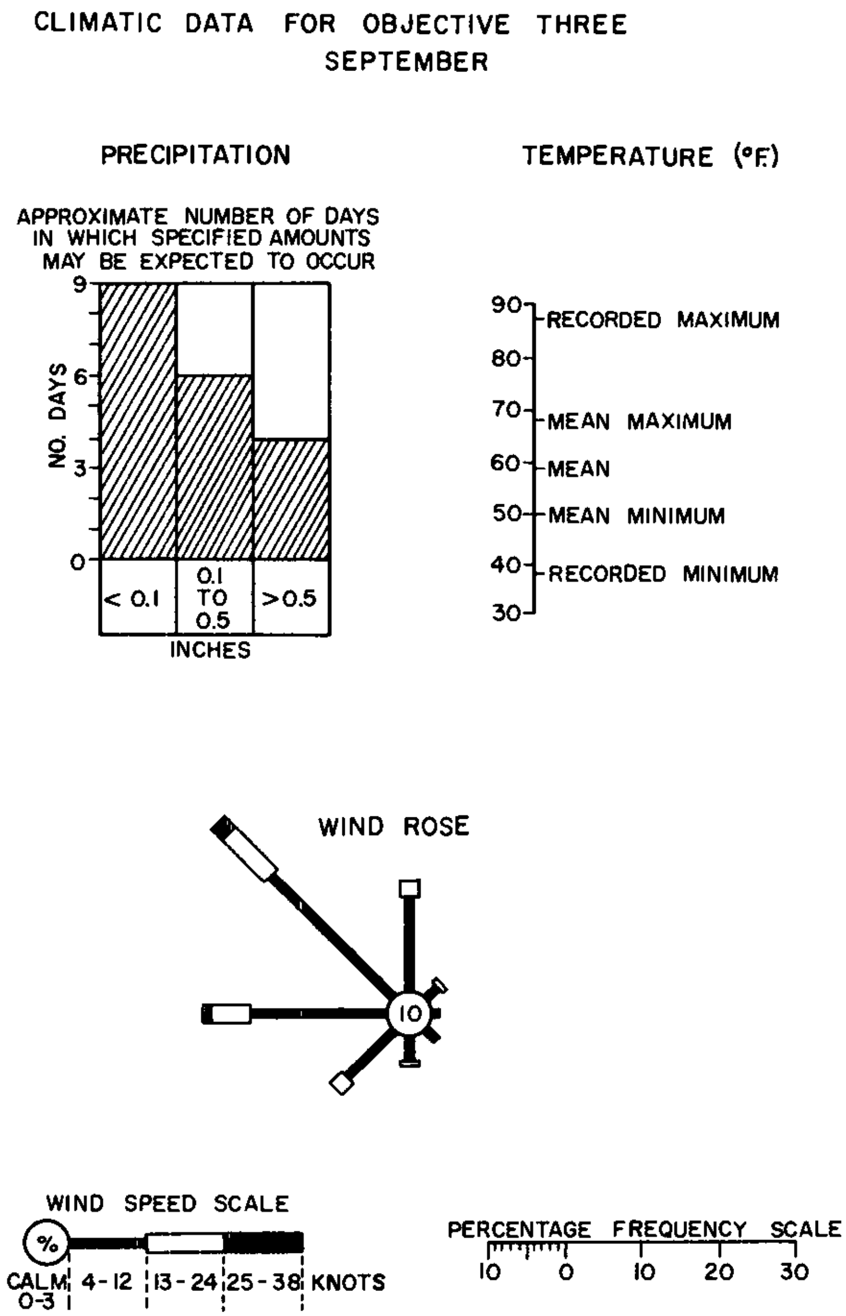



*Figure 69. Climatic data Objective Three—September.*

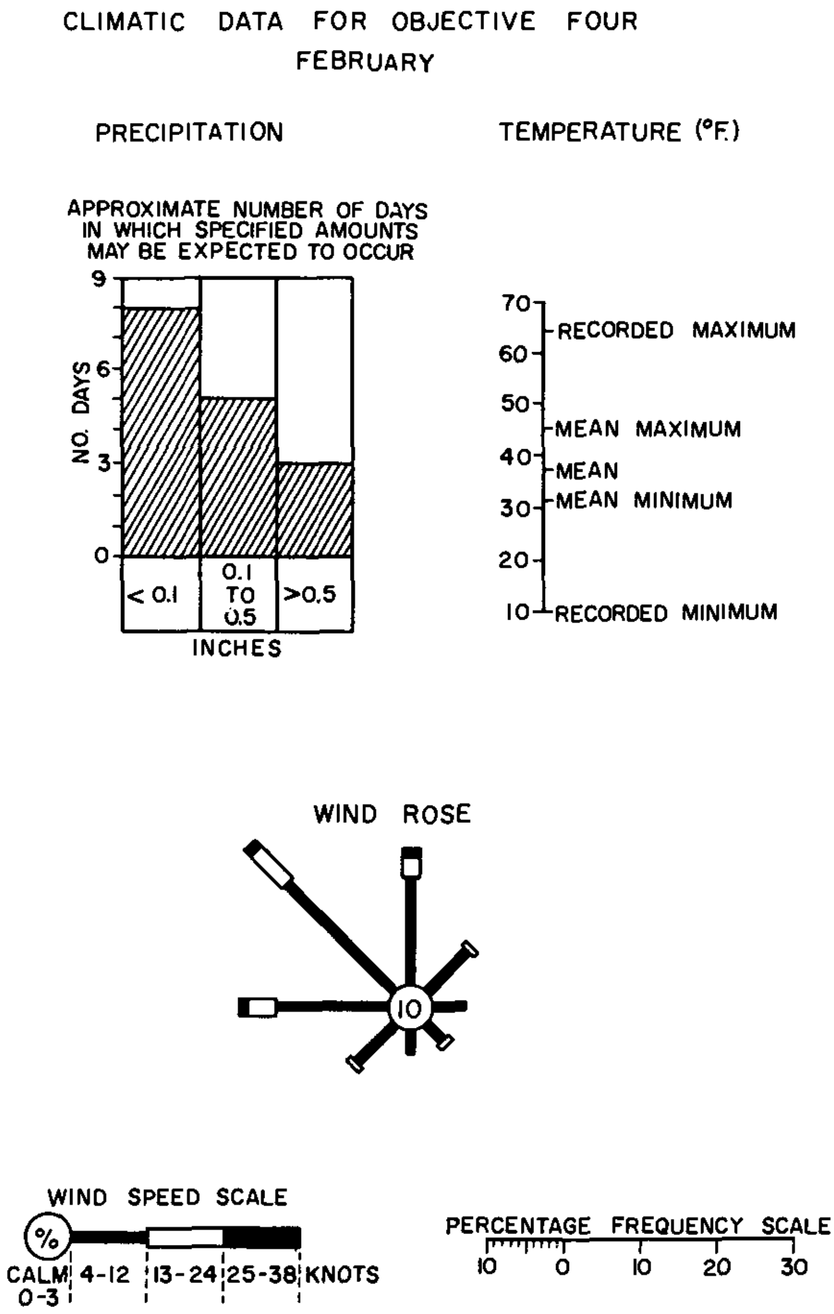



*Figure 70. Climatic data for OBJECTIVE FOUR—February.*

normally the effective ceiling is about 610 meters (2,000 feet).

*Winds* are predominately from a northwestern direction, light to moderate in force with infrequent gale-force winds associated with strong frontal passages.

# APPENDIX E

## NATURAL TERRAIN FEATURES

The natural terrain features shown in A, B, and C, figure 71 will serve as a guide to producers and users of terrain studies. A few of the terrain features identified on the figure may be known in some regions under different names because of local usage.

# APPENDIX F

## DEPARTMENT OF DEFENSE INTELLIGENCE INFORMATION REPORT FORMS 1396 AND 1396C

Department of Defense intelligence information will be reported on DD Form 1396 and DD Form 1396c. These forms are available through regular supply channels.

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By Order of the Secretary of the Army:

HAROLD K. JOHNSON,
*General, United States Army,*
*Chief of Staff.*

Official:
KENNETH G. WICKHAM,
*Major General, United States Army,*
*The Adjutant General.*

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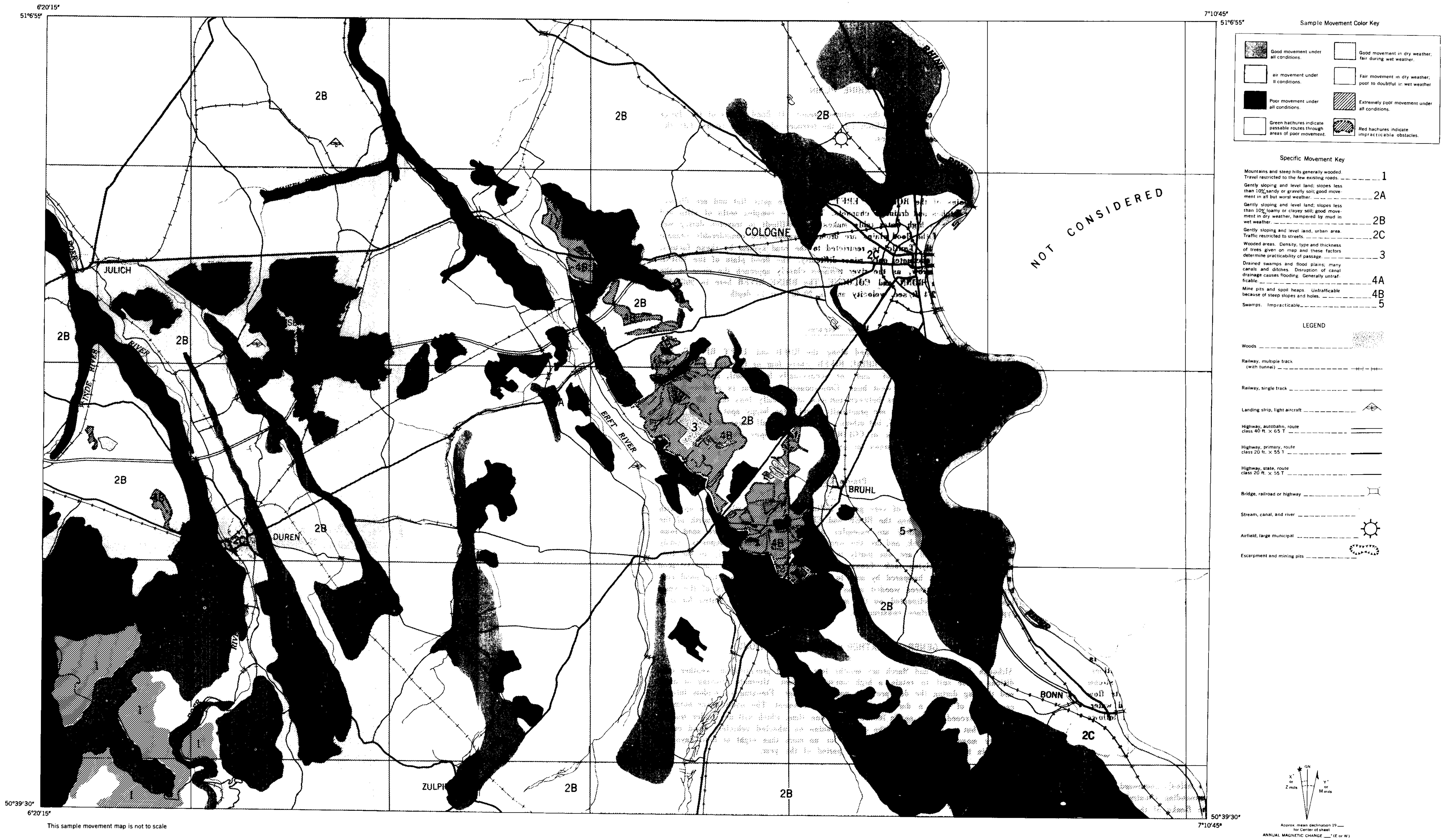
MOVEMENT MAP COLOGNE AREA

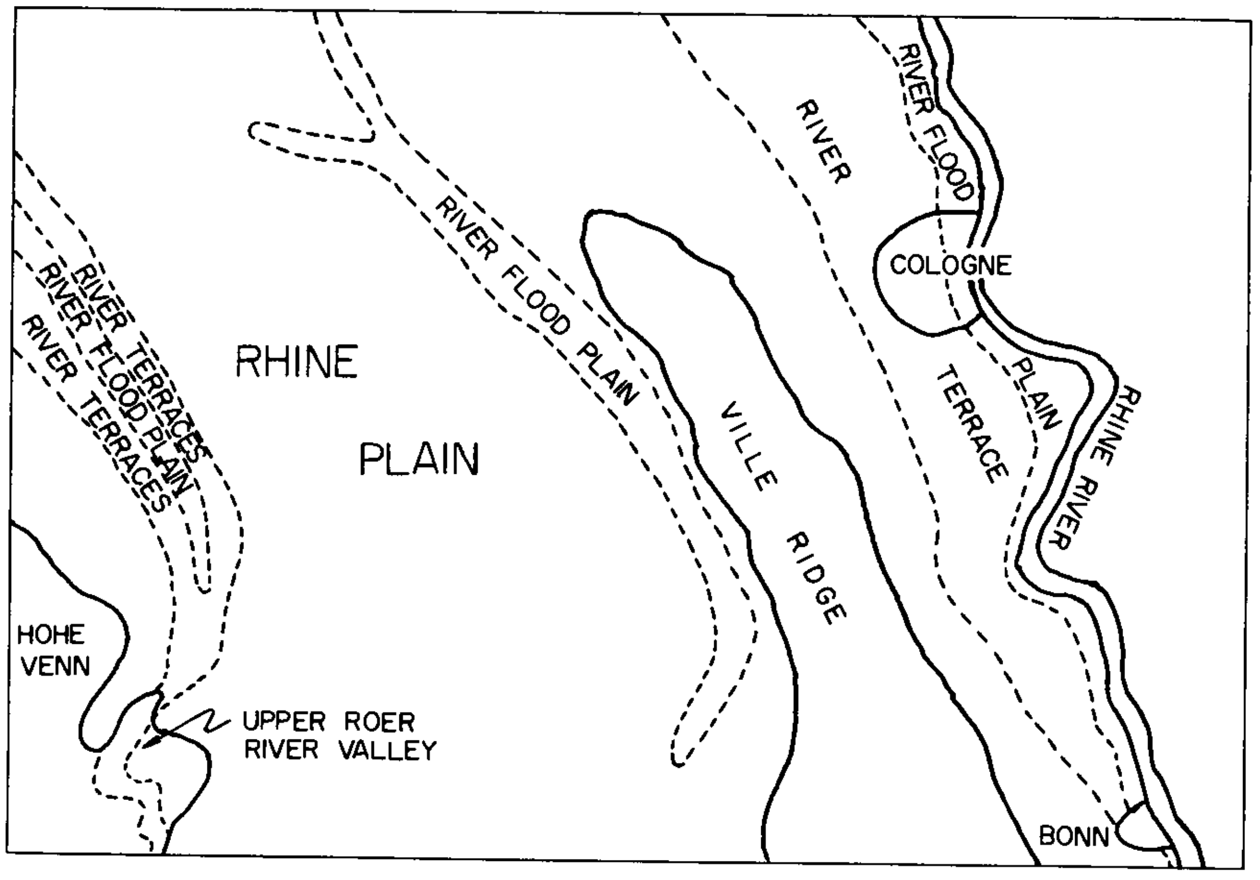



Scale 1:100,000

Contour Interval 50 Feet

Prepared by The Engineer School, Fort Belvoir, 1959. Map keyed to Germany 1:100,000 AMS, S-1 and R-1, 1952, to which reference is made for marginal information. Comments concerning field usability are requested by The Department of Training Publications, The Engineer School, Fort Belvoir, Virginia. For illustrative purposes, bridge classification information has been purposely omitted from this map. Route classification information has been added to the legend under "roads".

*Figure 61. Movement Map of Cologne area.*




## HOHE VENN HIGHLAND

The HOHE VENN HIGHLAND shown on the map is the northern tip of a much larger forested plateau to the southwest. It has two principal landforms . . . a dissected upland and the upper ROER RIVER valley system.

### Upland

This upland is made up of flattened sandstone hills 300–500 feet high with steep wooded slopes usually above 25 percent. Bluffs are common. Some of the flattened hilltops are open and are used for farming and pasturage. Principal soil type is loam. Cross-country movement is good in the open areas, but steep sandstone-shouldered ravines are frequent barriers. Trails and roads provide occasional passage from the open hilltops through defiles to the lowland valleys. In this area, sandstone may be quarried. Towns are small and scattered, and construction sites for facilities are limited. Road and rail communication is poor as compared to the lowland plains.

### Upper ROER RIVER Valley

This valley system is rather narrow with steep wooded sides and occasional escarpments. The valley floor does not exceed one-half mile in width but is made up of sandy gravel; cross-country movement is good under most conditions. The ROER RIVER is approximately 80 feet wide in this vicinity, with a stream velocity of 4-8 ft/sec. Two large dams several miles upstream control its flow and much of the valley floor may be flooded by release of the impounded water. Traffic into and out of the valley is restricted to roads, but a railroad follows the river route into the city of DUREN.

## VILLE RIDGE

The VILLE RIDGE is a long (25 miles), narrow (3-5 miles), southward rising promontory with summits 100 to 250 feet above the surrounding countryside. Surface soil type is clay loam with sand loam along the flanks of the ridge, but the overburden is rarely in sight due to extensive surface coal mining. The mine pits, dumps, and spoil heaps, and the great number of industrial buildings effectively limit vehicular movement to roads. Scattered mixed and broadleaf forests are found throughout the ridge and are indicated on the map. Crushed rock is available in the mine dumps. Several coal-driven power generating stations are located here. The ridge area is unfit for airfield sites because of mines, industrial towers, buildings, woods, and so on.

## RHINE PLAIN

The RHINE PLAIN consists of three related areas; (1) flood plains of the lower ROER, ERFT, and RHINE RIVERS; (2) the terraces along these rivers; (3) the prairie lands between the rivers.

### Flood Plains

The flood plains of the ROER and ERFT RIVERS are quite flat and are dissected by many ditches and drainage channels. They have complex soils of silts and very fine sands; a high water table makes them difficult to traverse during wet periods. Portions of the flood plains are drained swamps with considerable organic material in the soil. Traffic is restricted to the road system by these factors, but foot troops will encounter only minor difficulty. The flood plain of the RHINE RIVER is quite narrow, as the river terraces closely approach the river on the west bank between BONN and COLOGNE. The RHINE RIVER here is 900-1400 feet wide, has a 2-4 ft/sec. velocity and is 20-40 feet in depth.

### River Terraces

River terraces are poorly developed along the ROER and ERFT RIVERS, but reach a grand scale along the RHINE RIVER where four or five terraces can be found. They are composed of sandy or occasionally loamy soil, and are up to four miles wide along the west bank. Cross-country movement is good to excellent in most weather. Slopes between terraces are usually less than 10 percent, while the terraces themselves are practically level. One boggy spot (5) is shown between COLOGNE and BONN, but others, all of very small size, may be present on the southwestern outskirts of COLOGNE. Terrace slopes along the ROER and RHINE RIVERS are good sources for gravel aggregate.

### Prairie Lands

These are extensive areas of very gently rolling topography mostly taken up with farmland. The land between the ROER and ERFT RIVERS, and that north of the JULICH-COLOGNE highway are examples of prairie lands. Soils are sand loam to clay loam, rather thick, and are the weathered product of loess deposits. Sandy areas are found, and are due partly to glacial outwash, and partly to the lithology of the underlying rock. Cross-country movement over prairie land is good in fair weather, but hampered by mud to a degree dependent upon the sand content of the soil. Scattered wooded areas which usually possess soils of the same loamy nature are delineated on the map. Prairie lands are well suited for most types of military surface construction.

## GENERAL WEATHER-MOVEMENT RELATIONS

Although February and March are months low in total precipitation, weather conditions cause soil to retain a high moisture content. Alternate freezing at night and thawing during the day prevents normal drainage. Freezing is seldom intense enough or of such a duration to facilitate movement. The snow cover normally does not exceed six or seven inches at any one time, which will not hinder tracked vehicles but may necessitate the use of chains on wheeled vehicles. Good cross-country movement may be counted on for no more than eight or nine days per month in the prairie lands during this period of the year.

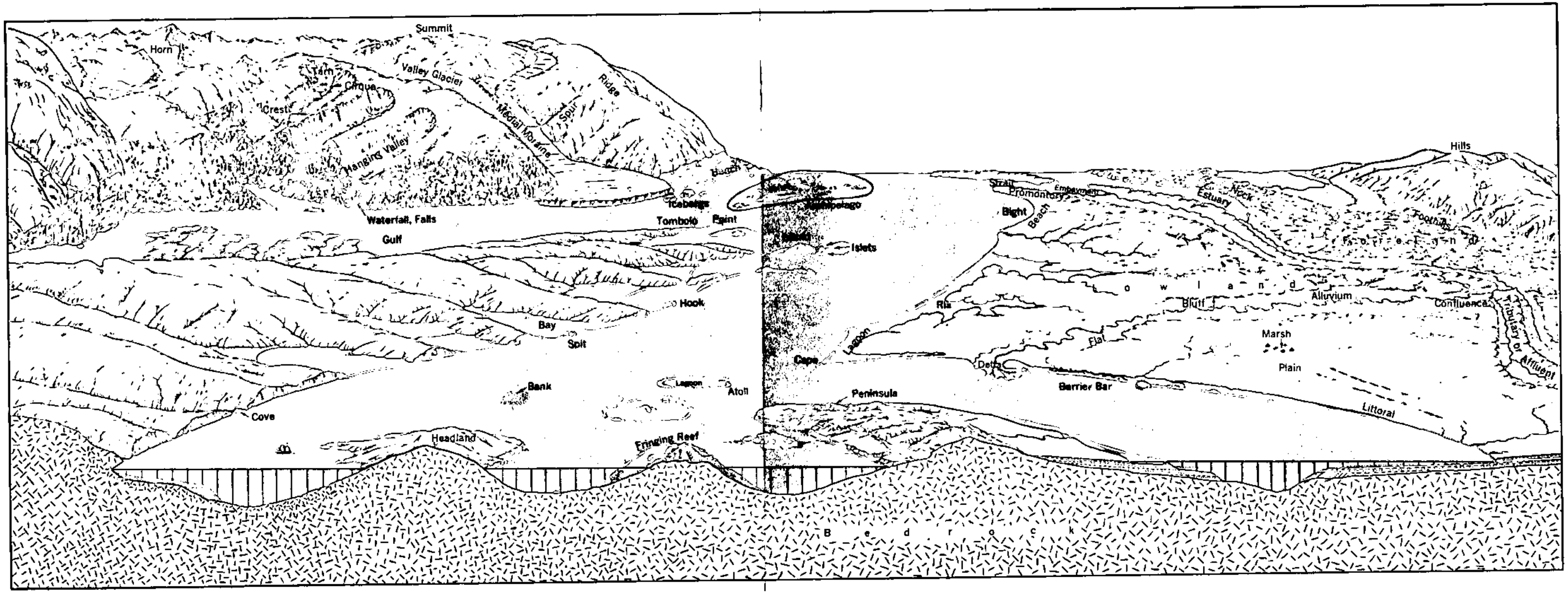



*Figure 71. Natural terrain features.*

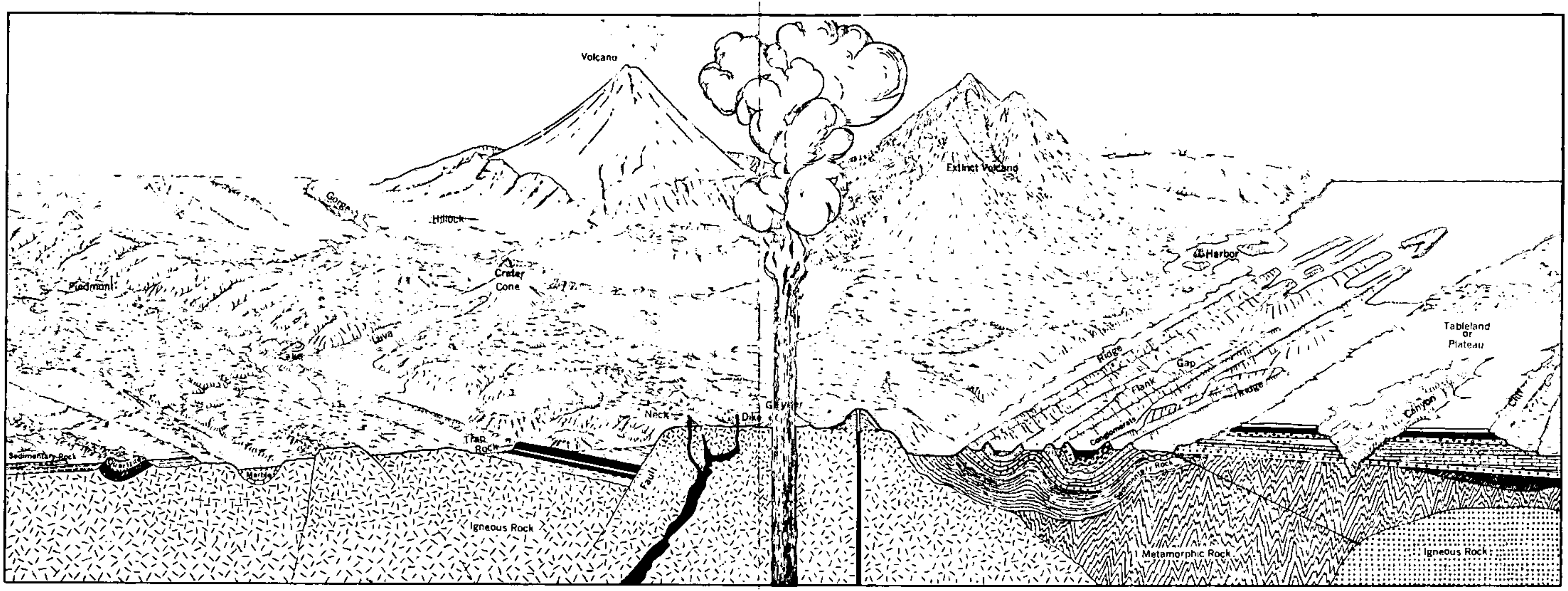



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*Figure 71.*—Continued

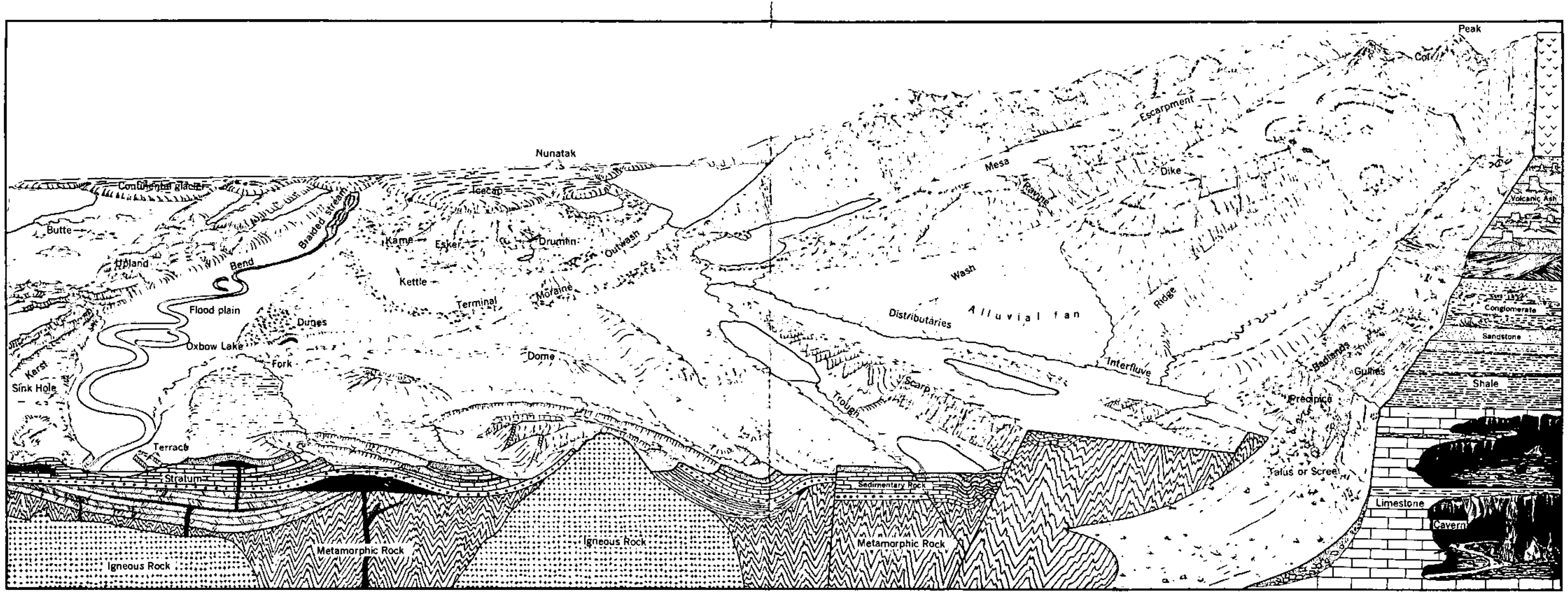


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*Figure 71.*—Continued