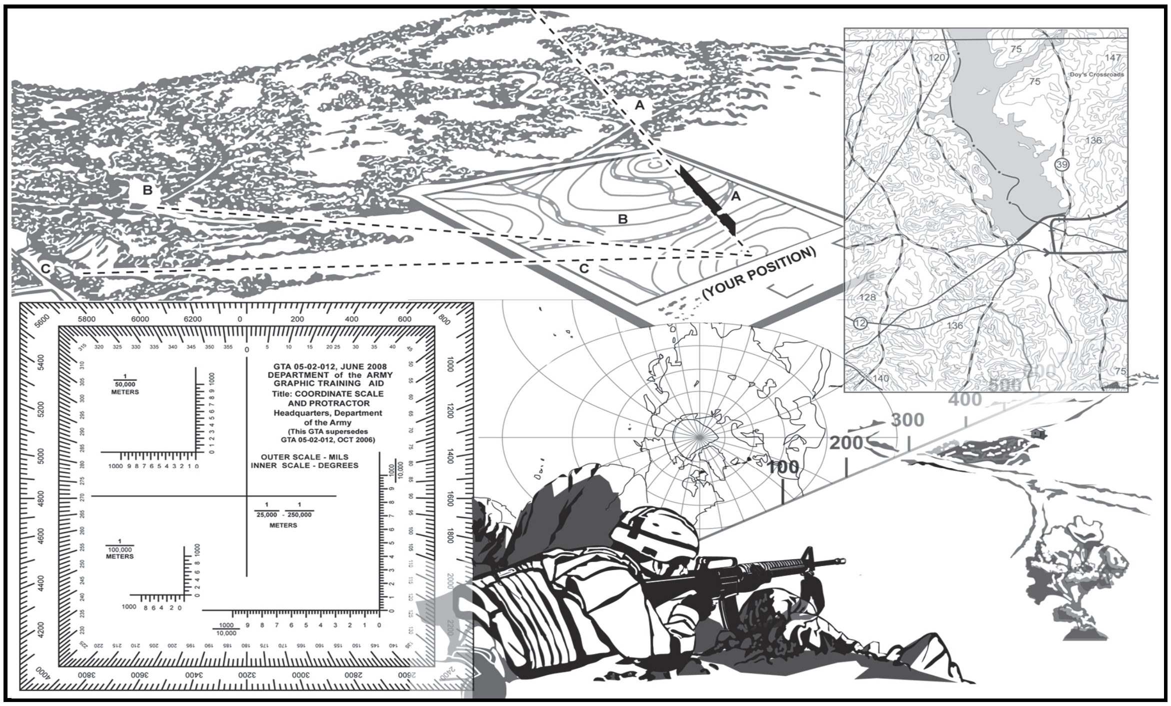
TC 3-25.26 (FM 3-25.26)

Map Reading and Land Navigation



November 2013

Headquarters, Department of the Army

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Training Circular
No. 3-25.26

Headquarters
Department of the Army
Washington, DC 15 November 2013

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Contents

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***This publication supersedes FM 3-25.26, 18 January 2005.**

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Preface

Training Circular (TC) 3-25.26 contains doctrine and training guidance on map reading and land navigation. Part One addresses map reading and Part Two, land navigation. The appendixes include an introduction to orienteering and a discussion of several devices that can assist the Soldier in land navigation. This TC provides a standardized source document for Armywide reference on map reading and land navigation. It applies to every Soldier in the Army regardless of service branch, MOS, or rank.

The primary target audience for this publication is the platoon leader and other leaders within a reconnaissance platoon. The secondary audience includes training developers involved in developing training support materials for professional military education (PME).

This TC applies to the Active Army, the Army National Guard (ARNG)/Army National Guard of the United States (ARNGUS), and the United States Army Reserve (USAR) unless otherwise stated.

The proponent for this publication is the United States Army Training and Doctrine Command (TRADOC). The preparing agency is the Maneuver Center of Excellence (MCoE). Send comments and recommendations by any means: U.S. mail, email, fax, or telephone, following the format of DA Form 2028 (*Recommended Changes to Publications and Blank Forms*). You may phone for more information. Point of contact information is as follows:

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Unless this publication states otherwise, masculine nouns and pronouns do not refer exclusively to men.

PART ONE

MAP READING

Chapter 1
Training Strategy

This manual responds to an Armywide need for a new map reading and land navigation training strategy based upon updated doctrine. This chapter describes and illustrates this approach for teaching these skills.

BUILDING BLOCK APPROACH

1-1. Institution courses are designed to prepare the Soldier for a more advanced duty position in the unit. The critical soldiering skills of move, shoot, and communicate require training, practice, and sustainment at every level in the schools and in the unit. Map reading and land navigation skills are critical to the duty position for which Soldiers are being trained, and a prerequisite for critical skills at a more advanced level. This includes:

- A Soldier completing initial-entry training prepares to become a team member proficient in basic map reading and dead reckoning skills.
- After completing the Warrior Leader Course, a Soldier should be ready to be a team leader. This duty position requires expertise in map reading, dead reckoning, and terrain association.
- A Soldier completing the Advanced Leader Course receives training for the squad leader position. Soldiers at skill level 3 are expected to be proficient in map reading and land navigation, and have developed the knowledge and skills to support route selection and squad tactical movement.
- The Senior Leader Course prepares skill level 4 Soldiers to assume the duty position of platoon sergeant or operations noncommissioned officer (NCO). Soldiers at this level are expected to have the knowledge and skills required to plan and lead tactical movements.
- Officers follow a similar progression. A new second lieutenant masters map reading and land navigation skills, and has an aptitude for dead reckoning and terrain association.
  - The Basic Officer Leader Course prepares officers to assume the duties and responsibilities of a platoon leader. Commanders require leaders to execute their orders and operations. Map reading and land navigation at this level require development of the problem-solving skills of route selection and tactical movement.
  - Completion of the Captain's Career Course prepares officers to assume the duties and responsibilities of a company commander or primary staff officer. The commander plans and executes operations with full consideration for all aspects of navigation. The staff officer recommends battlefield placement of all administrative, logistical, and personnel resources. These recommendations are tactically sound when the estimate process includes a detailed analysis of the area of operations. This ability requires expertise in all map reading and navigation skills, including the use of nonmilitary maps, digitized terrain, and terrain analysis (with respect to friendly and enemy forces). The commander/staff officer plans and executes a program to develop the unit's train-the-trainer program for land navigation.

- A program of demonstrated proficiency of all the preceding skill levels is a prerequisite for the successful implementation of a building-block training approach. This approach reflects duty position responsibilities in map reading and land navigation. An understanding of the fundamental techniques of dead reckoning or field-expedient methods is a basic survival skill that each Soldier develops at the initial-entry level. This skill provides a support foundation for more interpretive analysis at intermediate skill levels 2 and 3, with final progression to level 4. Mastery of all map reading and land navigation tasks required in previous duty positions is essential for the sequential development of increasing proficiency levels.

ARMYWIDE IMPLEMENTATION

1-2. The United States Army Training and Doctrine Command service schools and United States Army Forces Command professional development schools receive a mandatory core of critical map reading, land navigation tasks, and a list of electives. Standardization is achieved through the mandatory core requirements.

SAFETY

1-3. Unit leaders brief and enforce all safety regulations established by local range operations. They coordinate the mode of evacuation of casualties through the appropriate channels and review all installation safety regulations. Unit leaders complete a thorough terrain reconnaissance looking for dangerous terrain, heavily trafficked roads, water obstacles, wildlife, and training debris before using an area for land navigation training.

MOBILE ELECTRONIC DEVICES

1-4. Units should consider current mobile applications (apps) and those under development to supplement individual land navigation training. Mobile electronic devices may allow Soldiers to download and use training apps to learn and practice basic task steps, such as plotting a grid, determining a distance, or finding the location of map data. Some apps may have a Global Positioning System (GPS) mode that allows use of the mobile device as a navigation tool.

CAUTION

This TC does not produce or support current approved apps or interactive multimedia programs. The Army has several official online sites to access apps and multimedia training programs. However, the navigational aid or training information provided by these apps and programs may not be accurate or relevant for the intended unit training.

CAUTION

When using the GPS mode of an approved app, the mobile electronic device being used needs additional verification checks by the training unit to ensure applicable changes in data are correct (such as change the Universal Transverse Mercator [UTM] coordinate system to the military grid reference system [MGRS]).

SIMULATORS

1-5. No individual land navigation simulation trainers are currently being fielded, but there are a multitude of virtual ground vehicle and air mobile training platforms available. The scope of training depends upon the system and software packages available.

1-6. Simulators are standard training platforms, providing Soldiers the opportunity to replicate training with vehicles such as the—

- M1 Abrams tank.
- M2 Bradley fighting vehicle.
- M3 cavalry fighting vehicle.
- Bradley fire support team vehicle.
- M113 armored personnel carrier heavy expanded mobility tactical truck.
- High mobility multipurpose wheeled vehicle.

1-7. To maximize the training effort, units should consider including land navigation skills in training. Simulation programs including the Virtual Combat Convoy Trainer, AH64A Combat Missions Simulator, and the Close Combat Tactical Trainer, allow the possibility of leaders to designate routes and control movement in the virtual environment. .

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Chapter 2
Maps

Cartography is the art and science of expressing the known physical features of the earth graphically by maps and charts. No one knows who drew, molded, laced together, or scratched the first map in the dirt, but an historical study reveals that the most pressing demands for mapping accuracy and detail are a result of military needs. Today, due to the complexities of tactical operations and deployment of troops, it is essential for all Soldiers to be able to read and interpret their maps in order to move quickly and effectively on the battlefield. This chapter includes the definition and purpose of a map and describes map security, types, categories, and scales.

General George Washington

"The want of accurate maps of the Country which has hitherto been the Scene of War, has been a great disadvantage to me. I have in vain endeavored to procure them and have been obliged to make shift with such sketches as I could trace from my own Observations…"

General George Washington, according to John C. Fitzpatrick,
Writings of George Washington from the Original Manuscript Sources, 1745-1799

DEFINITION OF MAPS

2-1. A map is a graphic representation of a portion of the earth's surface drawn to scale, as seen from above. It uses colors, symbols, and labels to represent features found on the ground. The ideal representation shows the true shape of every feature in the area being mapped. Obviously this is unfeasible, and an attempt to plot each feature true-to-scale would result in a product impossible to read even with the aid of a magnifying glass.

2-2. To be understandable, features are represented by conventional signs and symbols. To be legible, many of these are exaggerated in size, often far beyond the actual ground limits of the feature represented. On a 1:250,000-scale map, the prescribed symbol for a building covers an area about 500 square feet on the ground; a road symbol is equivalent to a road about 520 feet wide on the ground; the symbol for a single-track railroad (the length of a cross-tie) is equivalent to a railroad cross-tie about 1,000 feet on the ground.

2-3. The portrayal of many features requires similar exaggeration. Therefore, the selection of features shown, as well as their portrayal, is according to the guidance established by the National Geospatial-Intelligence Agency (NGA).

PURPOSE

2-4. A map provides information on the existence of the location and the distance between ground features, such as populated places and routes of travel, and communication. It also indicates variations in terrain, heights of natural features, and the extent of vegetation cover. With our military forces dispersed throughout the world, it is necessary to rely on maps that provide information to our combat elements and resolve logistical operations far from our shores. Planning using maps allows units to transport, store, and place Soldiers and materiel into operation at the proper time and location. All operations require maps; however, the finest maps available are worthless unless the map user knows how to read them.

PROCUREMENT

2-5. Military units are authorized a basic load of maps. Local command supplements to Army Regulation (AR) 115-11 provide tables of these initial allowances. Routine ordering of NGA maps and products are made through the Defense Logistics Agency's mapping customer operations. All Department of Defense activities and federal agencies submit electronic orders via military/federal standard requisitioning and issue procedures through the Defense Automatic Addressing System Center. The mapping customer operations website, http://www.aviation.dla.mil/rmf/ Division G-2 section is responsible for maps:

- To order a map, refer to the NGA catalog located in the intelligence/G-2 shop. Part 3 of this catalog, Topographic Maps, has five volumes. Use the delineated map index to find map information needed based upon the location of the nearest city. With this information, order maps using the following forms:
  - Department of Defense (DD) Form 1348 (*DOD Single Line Item Requisition System Document [Manual]*). Order only one map sheet on each form.
  - DD Form 1348M (*Single Line Item Requisition System Document, DOD [Mechanical]*). This is a punch card form for ordering via the Automatic Digital Network.
- The numbered sections of all forms are the same. For example, in block 1, Soldiers stationed in the continental United States (CONUS), enter "AOD;" those stationed overseas, enter "AO4." In block 2, use one of the following codes depending upon location. The supply section can help with the rest of the form.

LOCATION	CODE
Europe	CS7
Hawaii	HM9
Korea	WM4
Alaska	WC1
Panama	HMJ
CONUS	HM8

- Stock numbers are also listed in map catalogs, which are available at division and higher levels (and occasionally in smaller units). A map catalog consists of small-scale maps with delineated outlines of the individual sheets of a map series. Another document that is an aid to the map user is the gazetteer. This lists all the names appearing on a map series of a geographical area, a designation that identifies anything located at that place name, a grid reference, a sheet number of the map upon which the name appeared, and the latitude and longitude of the named features. Gazetteers are prepared only for maps of foreign areas.

SECURITY

2-6. All maps are considered to be documents that require special handling. If a map falls into unauthorized hands, it could easily endanger military operations by providing information of friendly plans or areas of interest to the enemy. Even more important is a map marked which shows the movements or positions of friendly Soldiers. It is possible to determine marking and information on maps even after they have been erased. *Maps are documents that must not fall into unauthorized hands.*

- When maps are no longer needed, they are given to the proper authority. Maps that are in danger of being captured are destroyed. The best method of destruction is burning it and scattering the ashes. If burning is not possible, the map can be torn into small pieces and scattered over a wide area.
- Maps of some areas of the world are subject to third party limitations. These are agreements that permit the U.S. to make and use maps of another country provided these maps are not released to a third party without permission of the country concerned. Such maps require special handling.
- Care and handle classified maps according to AR 380-5. If applicable, follow other local security directives.

CARE

2-7. Maps are documents printed on paper that requires protection from water, mud, and tearing. Whenever possible, carry maps in a waterproof case, pocket, or some other place where it is handy for use but still protected. (Appendix A shows two ways to fold a map.) Other considerations include:

- Take care when using a map since it may have to last a long time. Use a pencil if marking a map becomes necessary. Use light lines to make erasing easier without smearing, smudging, or leaving marks that may cause confusion later. If trimming map margins is necessary, it is essential to note marginal information such as grid data and magnetic declination for possible future use.
- Take special care when using a map in a tactical mission, especially in small units; the mission may depend on that map. All members of such units should know the map's location at all times.

CATEGORIES OF MAPS

2-8. The NGAs mission is to provide mapping, charting, and all geodesy support to the armed forces, and all other national security operations. NGA produces four categories of products and services: hydrographic, topographic, aeronautical, and digital. Military maps are categorized by scale and type.

2-9. Knowing the mathematical scale used is important to the user. The scale determines the ground distance between objects or locations on the map, the size of the area covered, and the amount of detail being shown. The mathematical scale of a map is the ratio or fraction between the distance on a map and the corresponding distance on the surface of the earth. The representative fraction (RF) is the scale, with the map distance as the numerator and the ground distance as the denominator.

$$\textbf{Representative fraction (scale)} = \frac{\textbf{map distance}}{\textbf{ground distance}}$$

2-10. As the denominator of the representative fraction gets larger and the ratio gets smaller, the scale of the map decreases. NGA maps are classified by scale into three categories: small-, medium-, and large-scale maps. (See Figure 2-1.) The terms *small scale*, *medium scale*, and *large scale* may be confusing when read in conjunction with the number. However, when viewing the number as a fraction, it quickly becomes apparent that 1:600,000 of something is smaller than 1:75,000 of the same thing. Therefore, the larger the number after 1, the smaller the scale of the map. Maps can be categorized as—

- **Small**. Maps with scales of 1:1,000,000 and smaller are used for general planning and for strategic studies (bottom map in Figure 2-1). The standard small-scale map is 1:1,000,000. This map covers a large land area at the expense of detail.
- **Medium**. Maps with scales between 1:1,000,000 and 1:75,000 are used for operational planning (center map in Figure 2-1). They contain a moderate amount of detail, but terrain analysis is best done with the large-scale maps. The standard medium-scale map is 1:250,000. Medium-scale maps of 1:100,000 are encountered frequently.
- **Large**. Maps with scales of 1:75,000 and larger are used for tactical, administrative, and logistical planning (top map in Figure 2-1). These are the maps a Soldier or junior leader are most likely to encounter. The standard large-scale map is 1:50,000; however, many areas have been mapped at a scale of 1:25,000.

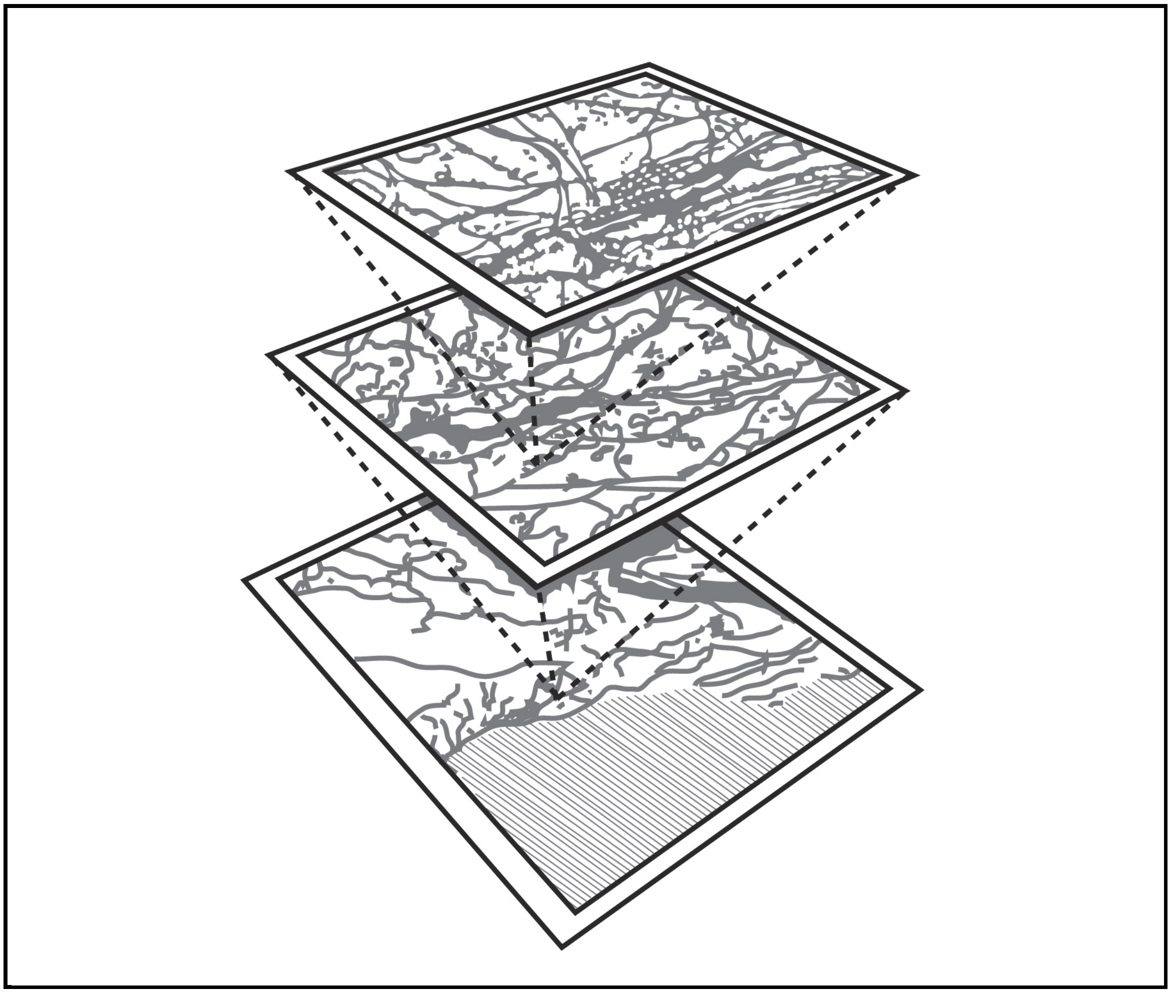

Figure 2-1. Scale classifications

- **Types**. The map of choice for land navigators is the 1:50,000-scale military topographic map. When operating in foreign places, some NGA map products may not cover a particular area of operations due to a lack of production, or may not be available to a unit when required. Therefore, units may find it necessary to use maps produced by foreign governments that may or may not meet the standards for accuracy set by NGA. These maps often use symbols that resemble those found on NGA maps but have completely different meanings. There may be other times units use obtained maps such as tourist maps or other commercially produced maps. (In Grenada, many of our troops used a British tourist map.) It is also important to know how to use the many other products available from the NGA:
  - **Planimetric map.** A planimetric map presents only the horizontal positions for the features represented. It is distinguished from a topographic map by the omission of relief, normally represented by contour lines. Sometimes it is called a line map.
  - **Topographic map.** A topographic map portrays terrain features in a measurable way, as well as the horizontal positions of the features represented. The vertical positions, or relief, are normally represented by contour lines on military topographic maps. On maps showing relief, the elevations and contours are measured from a specific vertical datum plane, usually mean sea level.
  - **Digital maps.** A digital map (also called digital cartography) is the visual representation of a point on the earth as depicted by electronic data that is compiled and formatted into a virtual image. Early digital maps had the same basic functionality as paper maps, providing a virtual view based on scanned images of paper maps already in use. Virtual views of topographic maps are only part of the current digital mapping capabilities. In many cases,

Soldiers can choose from virtual maps, satellite images, and hybrid views (with or without mission command overlays). Often, displays may be layered, and the Soldier can choose from one or multiple layers using a dropdown menu.

- **Digital city graphic.** The features of a digital city graphic include important buildings, airfields, military installations, industrial complexes, embassies, government buildings, hospitals, schools, utilities, and places of worship. A guide to numbered buildings and an index to street names are provided in the margin. Contour lines are in sufficient detail to identify spurs, draws, saddles, hill tops, and concave/convex slopes. Digital city graphic maps can be used for mission planning and navigation, and are often used in military operations in urban terrain, noncombatant evacuation operations, attaché support, and civil disturbance missions.
- **Controlled image base.** A controlled image base is an unclassified seamless dataset of geometrically corrected orthophotos, or aerial images, made from rectified grayscale images. It supports various weapons, mission command theater battle management, mission planning, digital moving map, terrain analysis, simulation, and intelligence systems. Controlled image base data are produced from digital source images, and are compressed and reformatted to conform to the national imagery transmission format. It may be derived from a grayscale image, one band of a multispectral product, or from a combination of several multispectral bands. Applications for the controlled image base include rapid overview of areas of operations, map substitutes for emergencies and crisis, metric foundation for anchoring other data in mission command systems or image exploitation, correct positional images for draping in terrain visualization, and image backgrounds for mission planning and rehearsal.
- **Compressed arc digitized raster graphic.** This is a joint services' standard map background product produced in multiple scales that support systems with map background display, coordinates selection, and provides perspective view generation capabilities. It is a common compression of arc digitized raster graphic for use in any application requiring rapid display of a map image, manipulation of the image, or manipulation of the image of a map in raster form.
- **Digital terrain elevation data.** The digital terrain elevation data (DTED) is a uniform matrix of terrain elevation values providing basic quantitative data for all military systems that require terrain elevation, slope, and gross surface roughness information. Data density depends on the level produced. DTED0 post spacing is 30 arc seconds (approximately 1000 meters). This corresponds to a small scale hardcopy map product. DTED1 post spacing is three arc seconds (approximately 100 meters). This corresponds to a medium scale hardcopy product. DTED2 post spacing is one arc second (approximately 30 meters), corresponding to large scale hardcopy products.
- **TalonView.** The National Geospatial-Intelligence Agency uses the TalonView, a computer-based mapping application that displays various types of maps and geographically referenced overlays. Many types of maps and imagery files are supported, but the primary ones of interest to most users are aeronautical, hydrographic, topographic maps and charts, satellite images, and elevation maps. TalonView supports the GeoPDF format with a large number of overlay types that can be displayed and printed over any map background. It does not include flight mission planning components and threat analysis capabilities. TalonView was designed to be distributed to other federal agencies, first responders, and foreign partners so they have a software program that utilizes NGA digital mapping and imagery products, along with applications for geospatial intelligence data interpretation, scene visualization, and situational awareness. NGA also provides the TalonView software on the SECRET Internet Protocol Router Network and Joint Worldwide Intelligence Communications System.
- **Vector maps.** A vector map (VMap) Level 0 is the low resolution component of the VMap family of products and has a comprehensive 1:1,000,000-scale vector base map of the world. It consists of geographic, attribute, and textual data stored on CD-ROMs. VMap Level 1 contains medium resolution data at the 1:250,000 scale. The data is separated into ten thematic layers consistent throughout the VMap program. The VMap Level 2 program

is designed to provide vector-based geospatial data at high resolution. It is separated into ten thematic layers, with each layer containing thematically consistent data.

- **Photomap.** A photomap is a reproduction of an aerial photograph upon which grid lines, marginal data, place names, route numbers, important elevations, boundaries, approximate scale, and direction have been added.
- **Joint operations graphics.** Joint operations graphics are typically based upon the format of standard 1:250,000 medium-scale military topographic maps, but they contain additional information needed in joint air-ground operations. Along the north and east edges of the graphic, detail is extended beyond the standard map sheet to provide overlap with adjacent sheets. The map is identified in the lower margin as joint operations graphic (ground) or joint operations graphic (air). The topographic information is identical on both, but the ground version shows elevations and contours in meters and the air version shows them in feet. Layer (elevation) tinting and relief shading are added as an aid to interpolating relief. Both versions emphasize air-landing facilities (shown in purple), but the air version has additional symbols to identify aids and obstructions to air navigation. (See Appendix B for additional information.)
- **Photomosaic.** This is an assembly of aerial photographs that is commonly called a mosaic in topographic usage. Mosaics are useful when time does not permit the compilation of a more accurate map. The accuracy of a mosaic depends upon the method employed in its preparation, and may vary from a good pictorial effect of the ground to that of a planimetric map.
- **Terrain model.** A terrain model is a scale model of the terrain showing features. Large-scale models also depict industrial and cultural shapes. It provides a means to visualize the terrain for planning or indoctrination purposes, and for briefing on assault landings.
- **Military city map.** A military city map is a topographic map (usually at 1:12,550-scale, and sometimes up to 1:5,000-scale) showing the details of a city. It delineates streets and shows street names, important buildings, and other elements of the landscape significant to navigation and military operations in urban terrain. The scale of a military city map depends upon the importance and size of the city, density of detail, and available intelligence information.
- **Special maps.** Special maps are for special purposes such as trafficability, communications, and assaults. They are usually in the form of an overprint in scales larger than 1:1,000,000 but smaller than 1:100,000. A special purpose map is one that has been designed or modified to give information not covered on a standard map. The wide range of subjects covered under the heading of special purpose maps prohibits (within the scope of this manual) more than a brief mention of a few important subjects, such as—
  - Terrain features.
  - Drainage characteristics.
  - Vegetation.
  - Climate.
  - Coasts and landing beaches.
  - Roads and bridges.
  - Railroads.
  - Airfields.
  - Urban areas.
  - Electric power.
  - Fuels.
  - Surface water resources.
  - Ground water resources.
  - Natural construction materials.

- Cross-country movements.
- Suitability for airfield construction.
- Airborne operations.

MILITARY MAP SUBSTITUTES

2-11. If military maps are not available, use substitute maps. These can range from foreign military or commercial maps, to field sketches. The NGA can provide black and white reproductions of many foreign maps, and produce its own maps based upon intelligence.

- **Foreign maps.** Foreign maps have been compiled by nations other than our own. When used, change the marginal information and grids to conform to U.S. standards, if time permits. The scales may differ from our maps, but they do express the ratio of map distance to ground distance and are used in the same way. Use the legend since the map symbols almost always differ from ours. Before issuing to the troops, foreign maps are usually evaluated in regard to established accuracy standards, because their accuracy varies considerably. (See Appendix C for additional information.)
- **Atlases.** Atlases are collections of maps of regions, countries, continents, or the world. Such maps are accurate only to a small degree and are used for general information only.
- **Geographic maps.** Geographic maps provide an overall idea of the mapped area in relation to climate, population, relief, vegetation, and hydrography. They also show the general location of major urban areas.
- **Tourist road maps.** Tourist road maps are maps of a region where the main means of transportation and areas of interest are shown. Some of these maps depict secondary networks of roads, historic sites, museums, and beaches in detail. They may contain road and time distance between points. Carefully consider the scale when using these maps.
- **City/Utility maps**. City/utility maps are maps of urban areas showing streets, water ducts, electricity and telephone lines, and sewers.
- **Field sketches.** Field sketches are preliminary drawings of an area or piece of terrain. (See Appendix D.)

STANDARDS OF ACCURACY

2-12. Accuracy is the degree of conformity that horizontal positions and vertical values are clearly represented on a map in relation to an established standard. The NGA determines the standard based upon user requirements. Unless otherwise specified in the marginal information, consider maps to meet accuracy requirements.

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Chapter 3

Marginal Information and Symbols

It is important that Soldiers know how to read maps, and the place to begin is the marginal information and symbols, where useful information about the map is located and explained. All maps are not the same, so it is necessary to examine the marginal information carefully each time a different map is used.

MARGINAL INFORMATION ON A MILITARY MAP

3-1. Figure 3-1 shows a reduced version of a large-scale topographic map. The circled numbers indicate the items of marginal information that the map user needs to know. These circled numbers correspond to the following:

- **Sheet name (1).** The sheet name is found in bold print at the center of the top and in the lower left area of the map margin. A map is generally named for the largest settlement contained within the area covered by the sheet, or for the largest natural feature located within the area at the time the map was drawn.
- **Sheet number (2).** The sheet number is found in bold print in the upper right and lower left areas of the margin, and in the center box of the adjoining sheets diagram found in the lower right margin. To link specific maps to overlays, operations orders, and plans, use the sheet number as reference. For maps at 1:100,000-scale and larger, the sheet numbering system is arbitrary and makes possible the ready orientation of maps at scales of 1:100,000, 1:50,000, and 1:25,000.
- **Series name (3).** The map series name is found in bold print in the upper left corner of the margin. The name given to the series is generally that of a major political subdivision such as a state within the United States or a European nation. A map series usually includes a group of similar maps at the same scale and on the same sheet lines or format. They are designed to cover a particular geographic area and may be a group of maps that serve a common purpose, such as military city maps.
- **Scale (4).** The scale is found in the upper left margin after the series name and in the center of the lower margin. The scale note is a representative fraction that gives the ratio of a map distance to the corresponding distance on the earth's surface. For example, the scale note 1:50,000 indicates that one unit of measure on the map equals 50,000 units of the same measure on the ground.
- **Series number (5).** The series number is found in the upper right margin and the lower left margin. It is a sequence reference expressed either as a four-digit numeral (1125) or as a letter followed by a three- or four-digit numeral (M661, T7110).
- **Edition number (6)**. The edition number is found in bold print in the upper right area of the top margin and the lower left area of the bottom margin. Editions are numbered consecutively; if there is more than one edition, the highest numbered sheet is the most recent. Most military maps are now published by the NGA, but older editions of maps may have been produced by the U.S. Army Map Service. Still others may have been drawn, at least in part, by the U.S. Army Corps of Engineers, the U.S. Geological Survey, or other agencies affiliated or not with the United States or allied governments. The credit line, revealing who produced the map, is just above the legend. The map information date is found immediately below the word "LEGEND" in the lower left margin of the map. This date is important when determining how accurately the map data might be expected to match what is encountered on the ground
- **Index to boundaries (7).** The index to boundaries diagram appears in the lower or right margin of all sheets. This diagram, which is a miniature of the map, shows the boundaries that occur within the map area such as county lines and state boundaries.

- **Adjoining sheets diagram (8).** Maps at all standard scales contain a diagram that illustrates the adjoining sheets. On maps at 1:100,000 and larger scales and at 1:1,000,000-scale and smaller, the diagram is called the index to adjoining sheets. It consists of as many rectangles representing the adjoining sheets as are necessary to surround the rectangle that represents the sheet under consideration. The diagram usually contains nine rectangles, but the number may vary depending on the locations of the adjoining sheets. All represented sheets are identified by their sheet numbers. Sheets of an adjoining series, whether published or planned, that are at the same scale are represented by dashed lines. The series number of the adjoining series is indicated along the appropriate side of the division line between the series.
- **Elevation guide (9).** The elevation guide is normally found in the lower right margin. It is a miniature characterization of the terrain shown. The terrain is represented by bands of elevation, spot elevations, and major drainage features. The elevation guide provides the map reader with a means of quick recognition of major landforms.
- **Declination diagram (10).** The declination diagram is located in the lower margin of large-scale maps and indicates the angular relationships of true north, grid north, and magnetic north. On maps at 1:250,000-scale, this information is expressed as a note in the lower margin. In recent edition maps, there is a note indicating the conversion of azimuths from grid to magnetic and from magnetic to grid next to the declination diagram.
- **Bar scales (11).** Bar scales are located in the center of the lower margin. They are rulers used to convert map distance to ground distance. Maps have three or more bar scales, each in a different unit of measure. Care should be exercised when using the scales, especially in the selection of the unit of measure that is needed.
- **Contour interval note (12)**. The contour interval note is found in the center of the lower margin normally below the bar scales. It states the vertical distance between adjacent contour lines of the map. When supplementary contours are used, the interval is indicated. In recent edition maps, the contour interval is given in meters instead of feet.
- **Spheroid note (13).** The spheroid note is located in the center of the lower margin. Spheroids (ellipsoids) have specific parameters that define the X Y Z axis of the earth. The spheroid is an integral part of the datum.
- **Grid note (14).** The grid note is located in the center of the lower margin. It gives information pertaining to the grid system used and the interval between grid lines, and it identifies the UTM grid zone number.
- **Projection note (15).** The projection system is the framework of the map. For military maps, this framework is of the conformal type; small areas of the surface of the earth retain their true shapes on the projection; measured angles closely approximate true values; and the scale factor is the same in all directions from a point. The projection note is located in the center of the lower margin. (Refer to NGA for the development characteristics of the conformal-type projection systems.) The three types of projection notes are:
  - Between 80 degrees south and 84 degrees north, maps at scales larger than 1:500,000 are based on the transverse Mercator projection. The note reads TRANSVERSE MERCATOR PROJECTION.
  - Between 80 degrees south and 84 degrees north, maps at 1:1,000,000 scale and smaller are based on standard parallels of the Lambert conformal conic projection. The note reads, for example, LAMBERT CONFORMAL CONIC PROJECTIONS 36 DEGREES 40 MINUTES NORTH AND 39 DEGREES 20 MINUTES NORTH.
  - Maps of the polar regions (south of 80 degrees south and north of 84 degrees north) at 1:1,000,000 and larger scales are based on the polar stereographic projection. The note reads POLAR STEREOGRAPHIC PROJECTION.
- **Vertical datum note (16).** The vertical datum note is located in the center of the lower margin. The vertical datum or vertical-control datum is defined as a level surface taken as a surface of reference from which to determine elevations. In the United States, Canada, and Europe, the vertical datum refers to the mean sea level surface. However, in parts of Asia and Africa, the vertical-control datum may vary locally and is based on an assumed elevation that has no connection to the sea level surface. Map readers should habitually check the vertical datum note

on maps, particularly if the map is used for low-level aircraft navigation, naval gunfire support, or missile target acquisition.

- **Horizontal datum note (17).** The horizontal datum note is located in the center of the lower margin. The horizontal datum or horizontal-control datum is defined as a geodetic reference point (of which five quantities are known: latitude, longitude, azimuth of a line from this point, and two constants, which are the parameters of reference ellipsoid). These are the basis for horizontal-control surveys. The horizontal-control datum may extend over a continent or be limited to a small local area. Maps and charts produced by NGA are produced on 32 different horizontal-control data. Map readers should habitually check the horizontal datum note on every map or chart, especially adjacent map sheets, to ensure the products are based on the same horizontal datum. If products are based on different horizontal-control data, coordinate transformations to a common datum is performed. UTM coordinates from the same point computed on different data may differ as much as 900 meters (m).
- **Control note (18).** The control note is located in the center of the lower margin. It indicates the special agencies involved in the control of the technical aspects of all the information that is disseminated on the map.
- **Preparation note (19).** The preparation note is located in the center of the lower margin. It indicates the agency responsible for preparing the map.
- **Printing note (20).** The printing note is also located in the center of the lower margin. It indicates the agency responsible for printing the map and the date the map was printed. The printing data should not be used to determine when the map information was obtained.
- **Grid reference box (21).** The grid reference box is normally located in the center of the lower margin. It contains instructions for composing a grid reference.
- **Unit imprint and symbol (22).** The unit imprint and symbol is on the left side of the lower margin identifies the agency that prepared and printed the map and its respective symbol. This information is important to the map user in evaluating the reliability of the map.
- **Legend (23).** The legend is located in the lower left margin. It illustrates and identifies the topographic symbols used to depict some of the more prominent features on the map. The symbols are not always the same on every map. Always refer to the legend to avoid errors when reading a map.

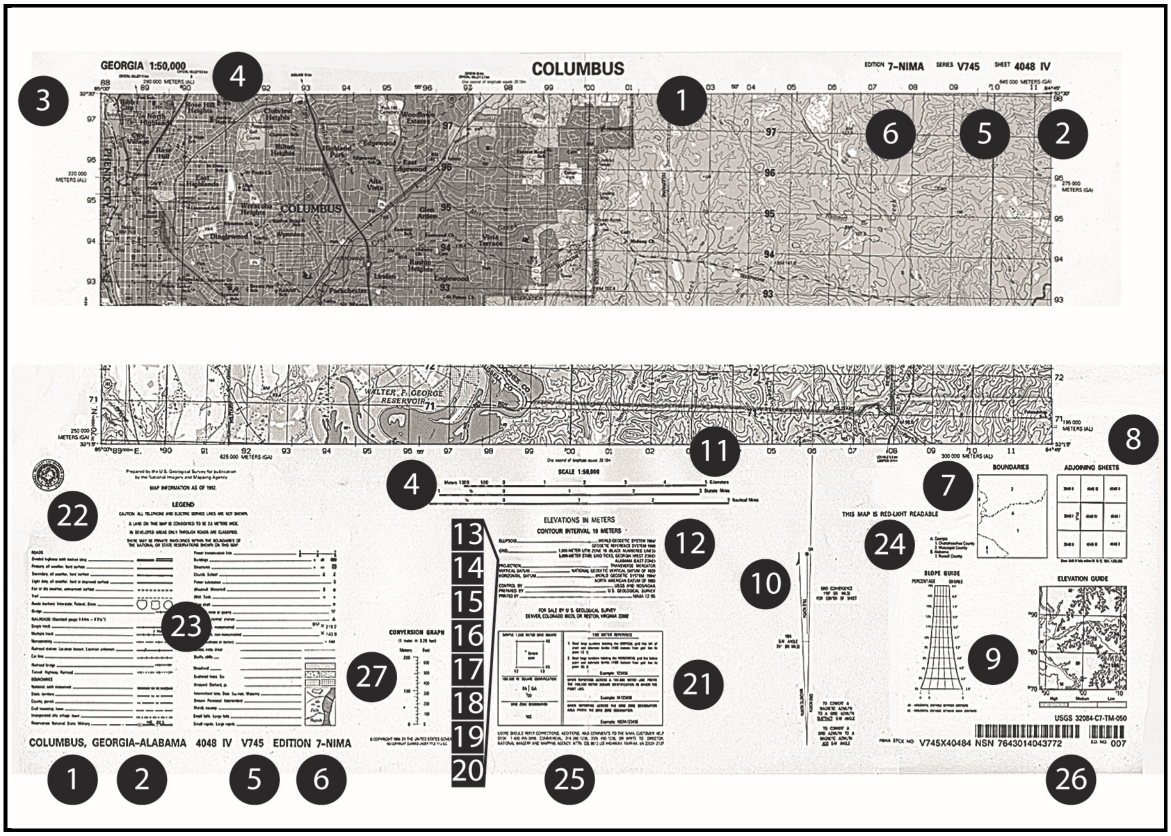


Figure 3-1. Topographical map

ADDITIONAL NOTES

3-2. Not all maps contain the same items of marginal information. Under certain conditions, special notes and scales may be added to aid the map user.

- **Glossary.** The glossary is an explanation of technical terms or a translation of terms on maps of foreign areas where the native language is other than English.
- **Classification.** Certain maps require a note indicating the security classification. This is shown in the upper and lower margins.
- **Protractor scale**. The protractor scale may appear in the upper margin on some maps. It is used to lay out the magnetic-grid declination for the map, which, in turn, is used to orient the map sheet with the aid of the lensatic compass.
- **Coverage diagram**. On maps at scales of 1:100,000 and larger, a coverage diagram may be used. It is normally in the lower or right margin and indicates the methods by which the map was made, dates of photography, and reliability of the sources. On maps at 1:250,000-scale, the coverage diagram is replaced by a reliability diagram.
- **Special notes (24).** A special note is a statement of general information that relates to the mapped area. It is normally found in the lower right margin. For example, a particular note could be “this map is red-light readable.”
- **User’s note (25).** The user’s note is normally located in the lower right-hand margin. It requests cooperation in correcting errors or omissions on the map. Errors should be marked and the map forwarded to the agency identified in the note.
- **Stock number identification (26).** All maps published by the NGA that are in the Department of the Army map supply system contain stock number identifications that are used in requisitioning map supplies. The identification consists of the words “STOCK NO” followed by a unique designation that is composed of the series number, the sheet number of the individual map, and on recently printed sheets, the edition number. The designation is limited to 15 units

(letters and numbers). The first 5 units are allotted to the series number; when the series number is less than 5 units, the letter "X" is substituted as the fifth unit. The sheet number is the next component; however, Roman numerals, which are part of the sheet number, are converted to Arabic numerals in the stock number. The last 2 units are the edition number; the first digit of the edition number is a zero if the number is less than 10. If the current edition number is unknown, the number 01 is used. The latest available edition is furnished. Asterisks are placed between the sheet number and the edition number when necessary to ensure there are at least 11 units in the stock number.

- **Conversion graph (27).** Normally found in the right margin, the conversion graph indicates the conversion of different units of measure used on the map.

TOPOGRAPHIC MAP SYMBOLS

3-3. The purpose of a map is to visualize an area of the earth's surface with pertinent features properly positioned. The map's legend contains the symbols most commonly used in a particular series or on that specific topographic map sheet. The legend should be referred to each time a new map is used. Every effort is made to design standard symbols that resemble the features they represent. If this is not possible, symbols are selected that logically imply the features they portray. For example, an open-pit mining operation is represented by a small black drawing of a crossed hammer and pickax.

3-4. Ideally, all the features within an area would appear on a map in their true proportion, position, and shape. This is not practical because many of the features would be unimportant and others would be unrecognizable because of their reduction in size.

3-5. The mapmaker (known professionally as a cartographer) is forced to use symbols to represent the natural and man-made features of the earth's surface. These symbols resemble the actual features as viewed from above. They are positioned in such a manner that the center of the symbol remains in its true location. An exception to this would be the position of a feature adjacent to a major road. If the width of the road has been exaggerated, then the feature is moved from its true position to preserve its relation to the road.

MILITARY SYMBOLS

3-6. In addition to the topographic symbols used to represent the natural and man-made features of the earth, military personnel require some method for showing identity, size, location, or movement of Soldiers, military activities, and installations. These are known as military symbols and are not normally printed on maps because the features and units they represent are constantly moving or changing; military security is also a consideration. They do appear in special maps and overlays. The map user draws them in, according to proper security precautions. (Refer to FM 1-02 for more information.)

COLORS ON A MILITARY MAP

3-7. By the fifteenth century, most European maps were carefully colored. Profile drawings of mountains and hills were shown in brown, rivers and lakes in blue, vegetation in green, roads in yellow, and special information in red. A look at the legend of a modern map confirms that the use of colors has not changed much over the past several hundred years. To facilitate the identification of features on a map, the topographical and cultural information is usually printed in different colors. These colors may vary from map to map. On a standard large-scale topographic map, the colors used and the features they represent are:

- **Black.** Black indicates cultural (man-made) features such as buildings and roads, surveyed spot elevations, and all labels.
- **Red-Brown**. The colors red and brown are combined to identify cultural features, all relief features, non-surveyed spot elevations, and elevation such as contour lines on red-light readable maps.
- **Blue**. Blue identifies hydrography or water features such as lakes, swamps, rivers, and drainage.
- **Green.** Green identifies vegetation with military significance such as woods, orchards, and vineyards.
- **Brown.** Brown identifies all relief features and elevation such as contours on older edition maps, and cultivated land on red-light readable maps.

- **Red.** Red classifies cultural features such as populated areas, main roads, and boundaries on older maps.
- **Other**. Occasionally, other colors may be used to show special information. As a rule, these are indicated in the marginal information.

Chapter 4
Grids

This chapter covers how to determine and report positions on the ground in terms of locations on a map. Knowing where one is (position fixing) and being able to communicate that knowledge is crucial for successful land navigation, effective employment of direct and indirect fire, tactical air support, and medical evacuation. It is essential for valid target acquisition; accurate reporting of various danger areas, and nuclear, biological, and chemical contamination areas; and obtaining emergency resupply. Few factors contribute as much to the survivability of troops and equipment, and to the successful accomplishment of a mission, as always knowing one's location. This chapter includes explanations of geographical coordinates, Universal Transverse Mercator (UTM) grids, the military grid reference system, and the use of grid coordinates.

REFERENCE SYSTEM

4-1. In a city, it is quite simple to find a location; the streets are named and the buildings have numbers. The only thing needed is the address. However, finding locations in undeveloped areas or in unfamiliar parts of the world can be a problem. To cope with this difficulty, a uniform and precise system of referencing has been developed.

GEOGRAPHIC COORDINATES

4-2. One of the oldest systematic methods of location is based upon the geographic coordinate system. By drawing a set of east-west rings around the globe (parallel to the equator), and a set of north-south rings crossing the equator at right angles and converging at the poles, a network of reference lines is formed from which a point on the earth's surface can be located.

- The distance of a point north or south of the equator is known as its latitude. The rings around the earth parallel to the equator are called parallels of latitude, or simply parallels. Lines of latitude run east-west but north-south distances are measured between them.
- A second set of rings that run around the globe at right angles to the lines of latitude and passing through the poles are known as meridians of longitude, or simply meridians. One meridian is established as the prime meridian. The prime meridian of the system we use runs through Greenwich, England and is known as the Greenwich Meridian. The distance east or west of a prime meridian to a point is known as its longitude. Lines of longitude (meridians) run north-south but east-west distances are measured between them. (See Figures 4-1 and 4-2.)

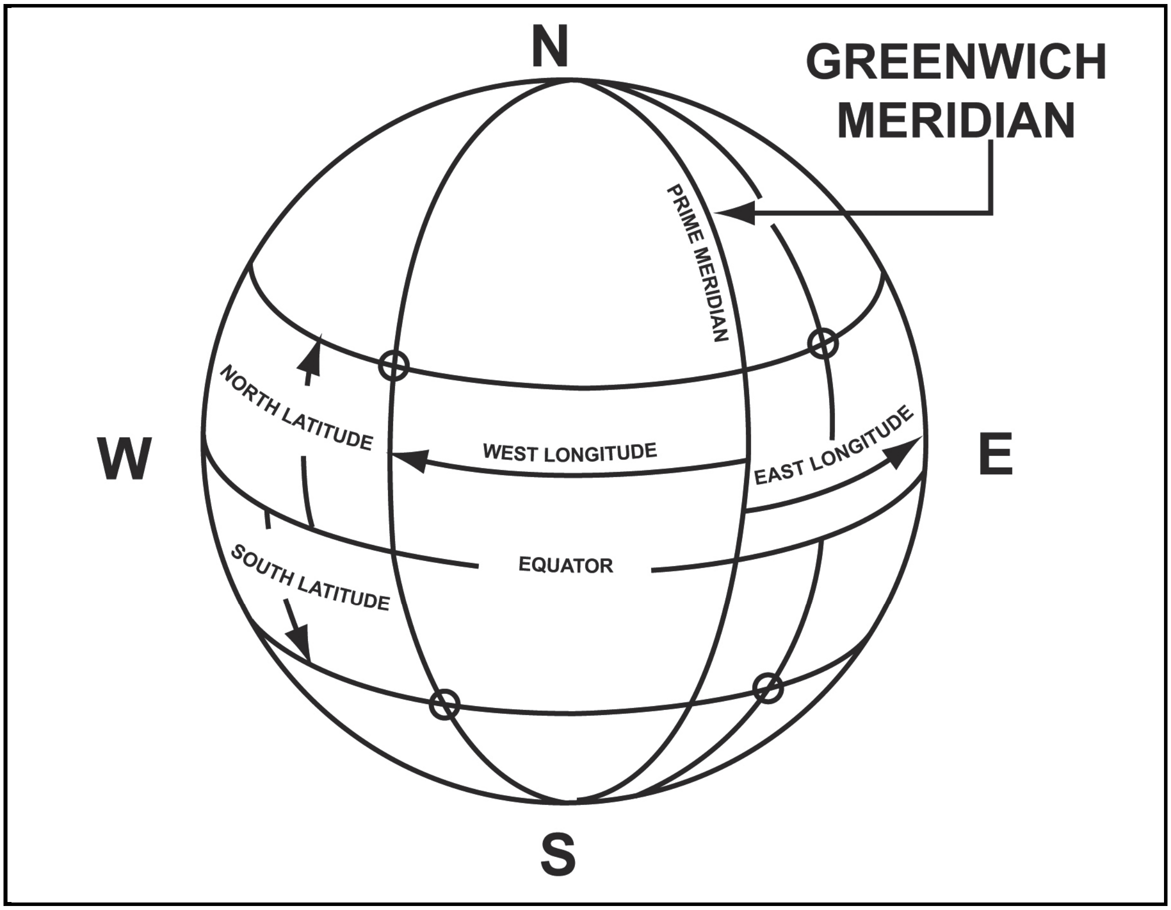


Figure 4-1. Prime meridian and equator

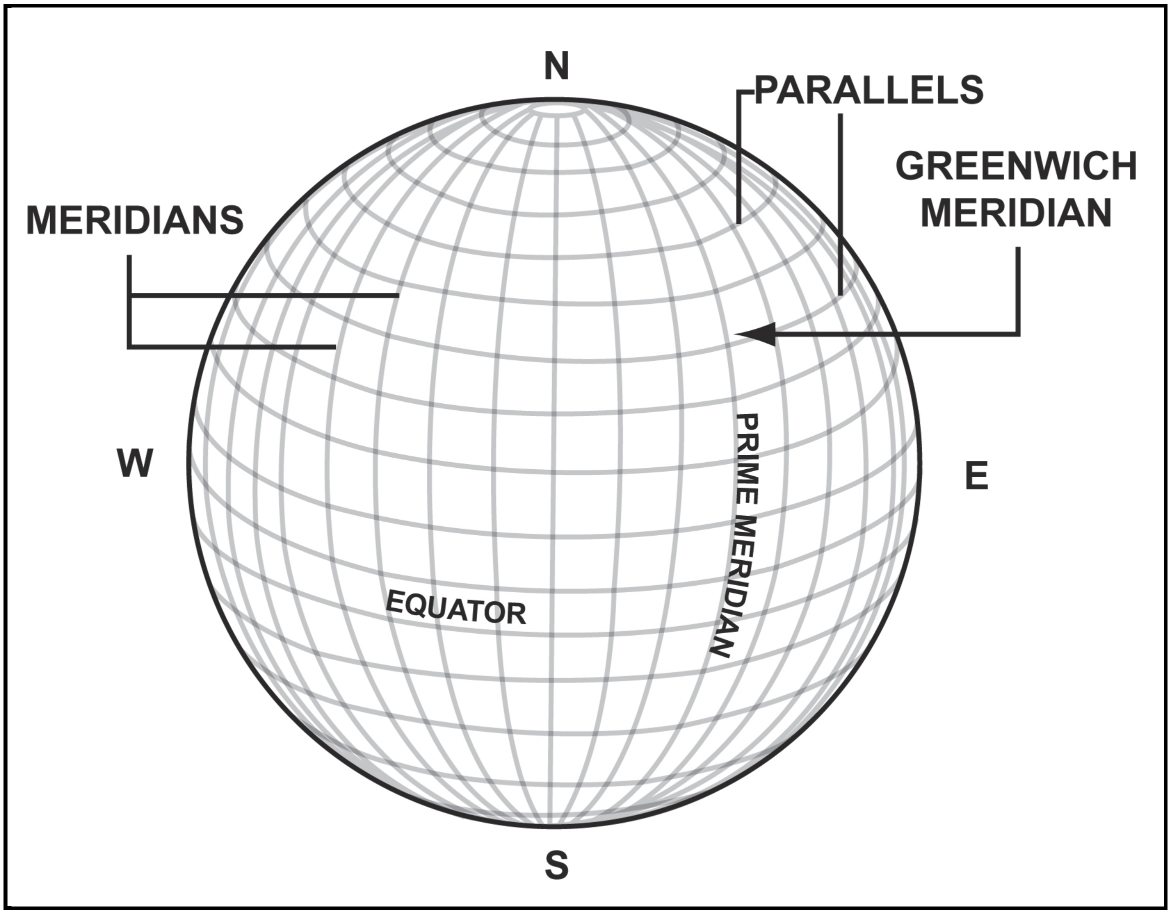


Figure 4-2. Reference lines

- Geographic coordinates are expressed in angular measurement. Each circle is divided into 360 degrees, each degree into 60 minutes, and each minute into 60 seconds. The degree is symbolized by °, the minute by ′, and the second by ″.
  - Starting with 0° at the equator, the parallels of latitude are numbered to 90° both north and south. The extremities are the North Pole at 90° north latitude and the South Pole at 90° south latitude. Latitude can have the same numerical value north (N) or south (S) of the equator, so the direction N or S is always given.
  - Starting with 0° at the prime meridian, longitude is measured both east (E) and west (W) around the world. Lines east of the prime meridian are numbered to 180° and identified as east longitude; lines west of the prime meridian are numbered to 180° and identified as west longitude. The direction E or W is always given. The line directly opposite the prime meridian, 180°, may be referred to as either east or west longitude.
  - The values of geographic coordinates, being in units of angular measure, mean more if they are compared with more familiar units of measure. At any point on the earth, the ground distance covered by one degree of latitude is about 111 kilometers (km) or 69 miles; one second is equal to about 30 m (or 100 feet). The ground distance covered by one degree of longitude at the equator is also about 111 km, but decreases as one moves north or south, until it becomes zero at the poles. For example, one second of longitude represents about 30 m at the equator; but at the latitude of Washington, D.C., one second of longitude is about 24 m (78 feet). Latitude and longitude are illustrated in Figure 4-3.

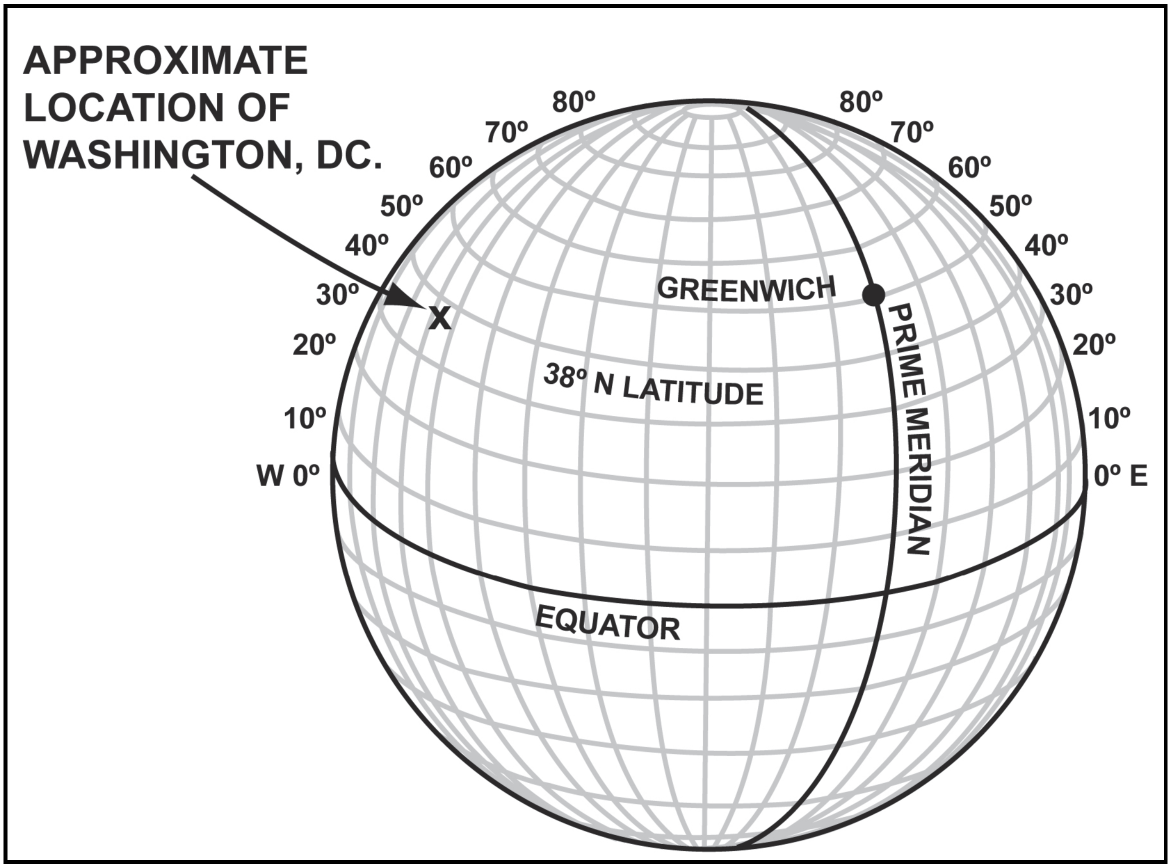


Figure 4-3. Latitude and longitude

- Geographic coordinates appear on all standard military maps; on some they may be the only method for locating and referencing the location of a point. The four lines that enclose the body of the map (neatlines) are latitude and longitude lines. Their values are given in degrees and minutes at each of the four corners.
  - On a portion of the Columbus, Georgia, map (see Figure 4-4), the figures 32°15' and 84°45' appear at the lower right corner. The bottom line of this map is latitude 32°15'00"N, and the line running up the right side is longitude 84°45'00"W.
  - In addition to the latitude and longitude given for the four corners, there are small tick marks at regularly spaced intervals along the sides of the map, extending into the body of the map. Each of these tick marks is identified by its latitude or longitude value.
  - Near the top of the right side of the map is a tick mark with the number 20'. The full value for this tick marks is 32°20'00" of latitude. At one-third and two-thirds of the distance across the map from the 20' tick mark is found a cross tick mark (grid squares GL 0379 and FL 9679) and at the far side another 20' tick mark. By connecting the tick marks and crosses with straight lines, a 32°20'00" line of latitude can be added to the map. This procedure is also used to locate the 32°25'00" line of latitude. For lines of longitude, the same procedure is followed using the tick marks along the top and bottom edges of the map.
- After the parallels and meridians have been drawn, the geographic interval (angular distance between two adjacent lines) is determined. Examination of the values given at the tick marks gives the interval. For most maps of scale 1:25,000, the interval is 2'30". For the Columbus map and most maps of scale 1:50,000, it is 5'00". The geographic coordinates of a point are found by dividing the sides of the geographic square in which the point is located into the required number of equal parts. If the geographic interval is 5'00" and the location of a point is required to the nearest second, each side of the geographic square is divided into 300 equal parts

(5’00” = 300”), each of which would have a value of one second. Any scale or ruler that has 300 equal divisions and is as long (or longer) than the spacing between the lines may be used.

- The following steps determine the geographic coordinates of Wilkinson Cemetery (northwest of the town of Cusseta) on the Columbus map:
  - Draw on the map the parallels and meridians that enclose the area around the cemetery.
  - Determine the values of the parallels and meridians where the point falls.

    Latitude 32°15’00” and 32°20’00”.
    Longitude 84°45’00” and 84°50’00”.

  - Determine the geographic interval (5’00” = 300”).
  - Select a scale that has 300 small divisions or multiples thereof (300 divisions, one second each; 150 divisions, two seconds each; 75 divisions, four seconds each, and so forth).
  - Using Figure 4-4 to determine the latitude:
    - Place the 0 of the scale on the latitude of the lowest number value (32°15’00”) and the 300 of the scale on the highest numbered line (32°20’00”) (labeled 1).
    - Keeping the 0 and 300 on the two lines, slide the scale (labeled 2) along the parallels until the Wilkinson Cemetery symbol is along the edge of the numbered scale.
    - Read the number of seconds from the scale (labeled 3). This is about 246.
    - Convert the number of seconds to minutes and seconds (246” = 4’06”) and add to the value of the lower numbered line (32°15’00” + 4’06” = 32°19’06”) (labeled 4).
    - The latitude is 32°19’06”, but this information alone is not enough. The latitude 32°19’06” could be either north or south of the equator, so the letter N or S is added to the latitude. To determine whether it is N or S, look at the latitude values at the edge of the map and find the direction in which they become larger. If they are larger going north, use N; if they are larger going south, use S. The latitude for the cemetery is 32°19’06”N.
  - To determine the longitude, repeat the same steps but measure between lines of longitude and use E and W. The geographic coordinates of Wilkinson Cemetery should be about 32°19’06”N and 84°47’32”W. (See Figure 4-5.)
- Many of the same steps are followed to locate a point on the Columbus map when knowing the geographic coordinates. (See Figure 4-6.) To locate 32°25’28”N and 84°50’56”W, first find the geographic lines within which the point falls: latitude 32°25’00” and 32°30’0”; and longitude 84°50’00” and 84°55’00”. Subtract the lower latitude or longitude from the higher latitude or longitude.
  - Place the 0 of the scale on the 32°25’00” line and the 300 on the 32°30’00”. Make a mark at the number 28 on the scale (the difference between the lower and higher latitude).
  - Place the 0 of the scale on the 84°50’00” line and the 300 on the 84°50’55”. Make a mark at the number 56 on the scale (the difference between the lower and higher longitude).
  - Draw a vertical line from the mark at 56 and a horizontal line from the mark at 28; they intersect at 32 25’28”N and 84 50’56”W.

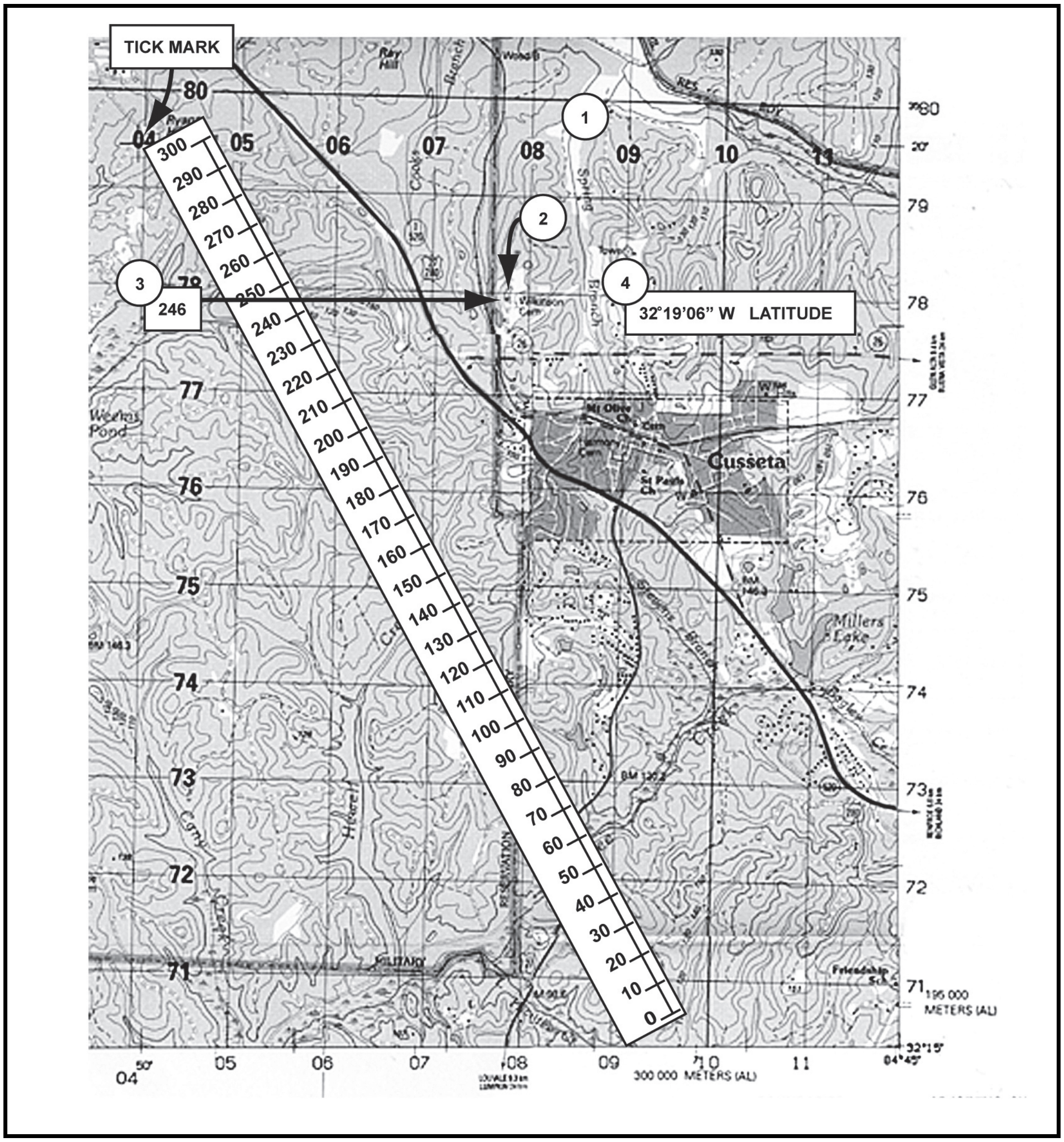


Figure 4-4. Determining latitude

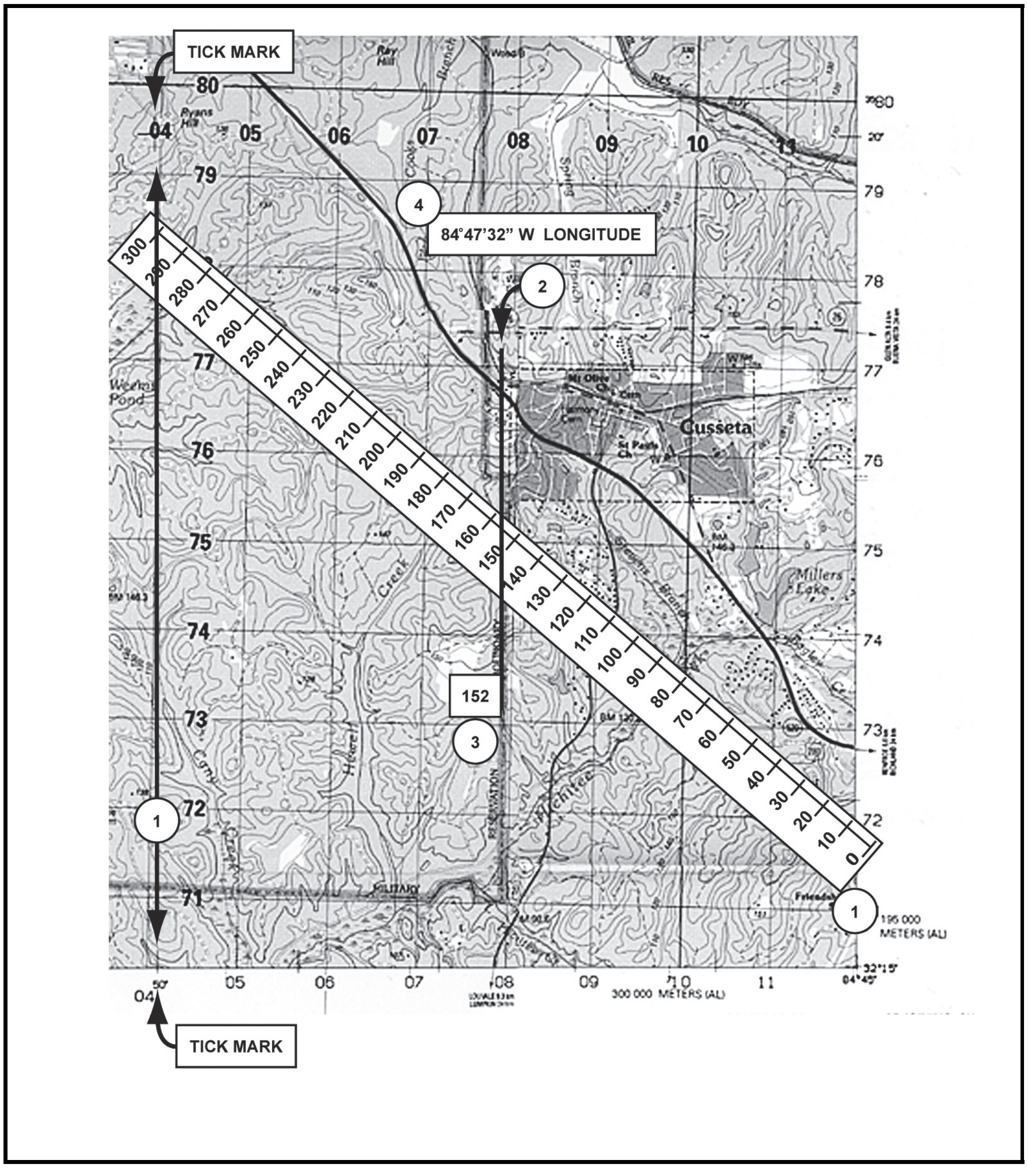


Figure 4-5. Determining longitude

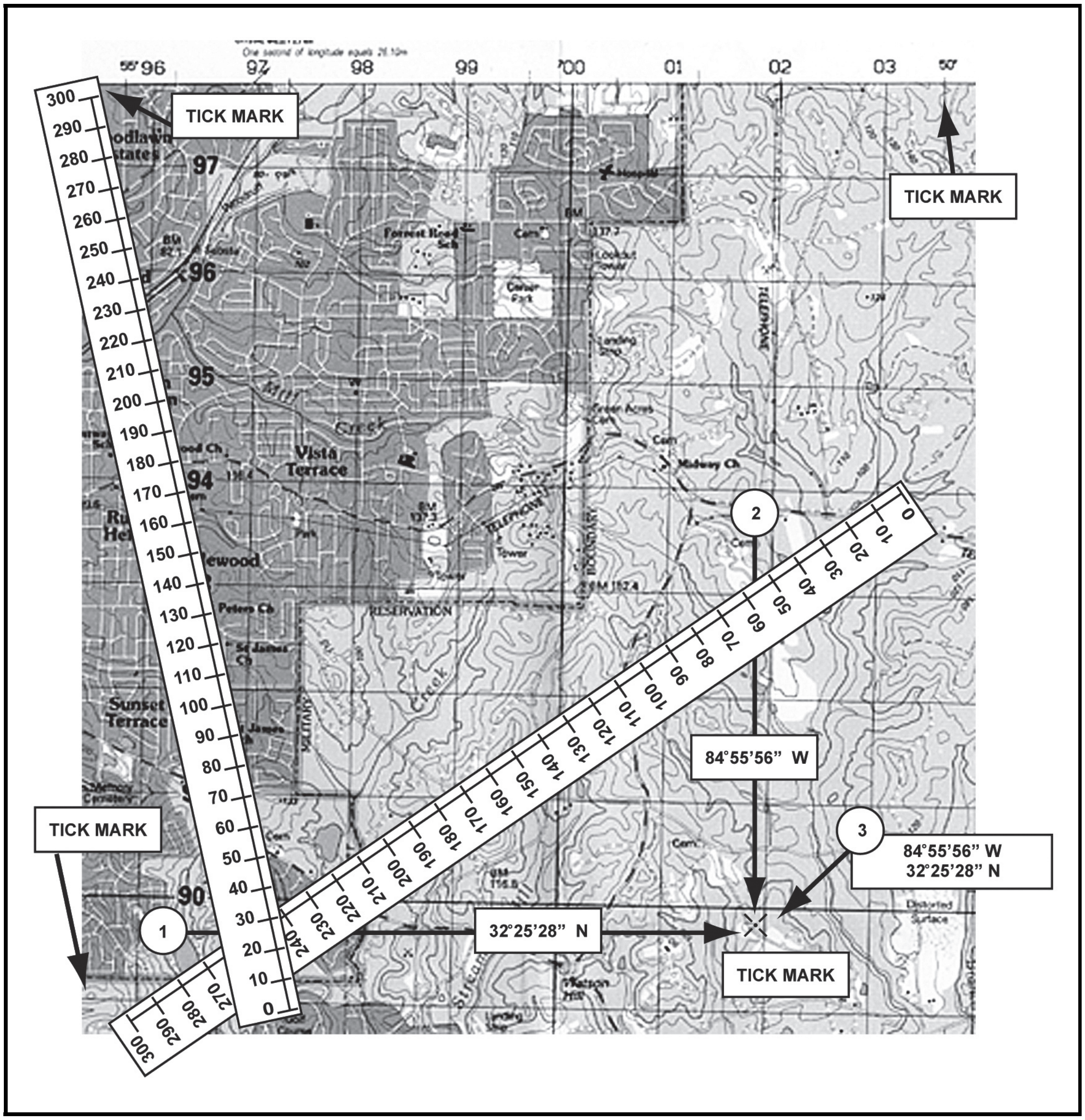


Figure 4-6. Determining geographic coordinates

- If there is no scale or ruler with 300 equal divisions or a map whose interval is other than 5'00", use the proportional parts method. The following steps determine the geographic coordinates of horizontal control station 141:
  - Locate horizontal control station 141 in grid square (GL0784). (See Figure 4-7.)
  - Find a cross in grid square GL0388 and a tick mark in grid square GL1188 with 25'.
  - Find another cross in grid square GL0379 and a tick mark in grid square GL1179 with 20'.
  - Enclose the control station by connecting the crosses and tick marks. The control station is between 20' and 25'.
  - With a boxwood scale, measure the distance from the bottom line to the top line that encloses the area around the control station on the map (total distance).

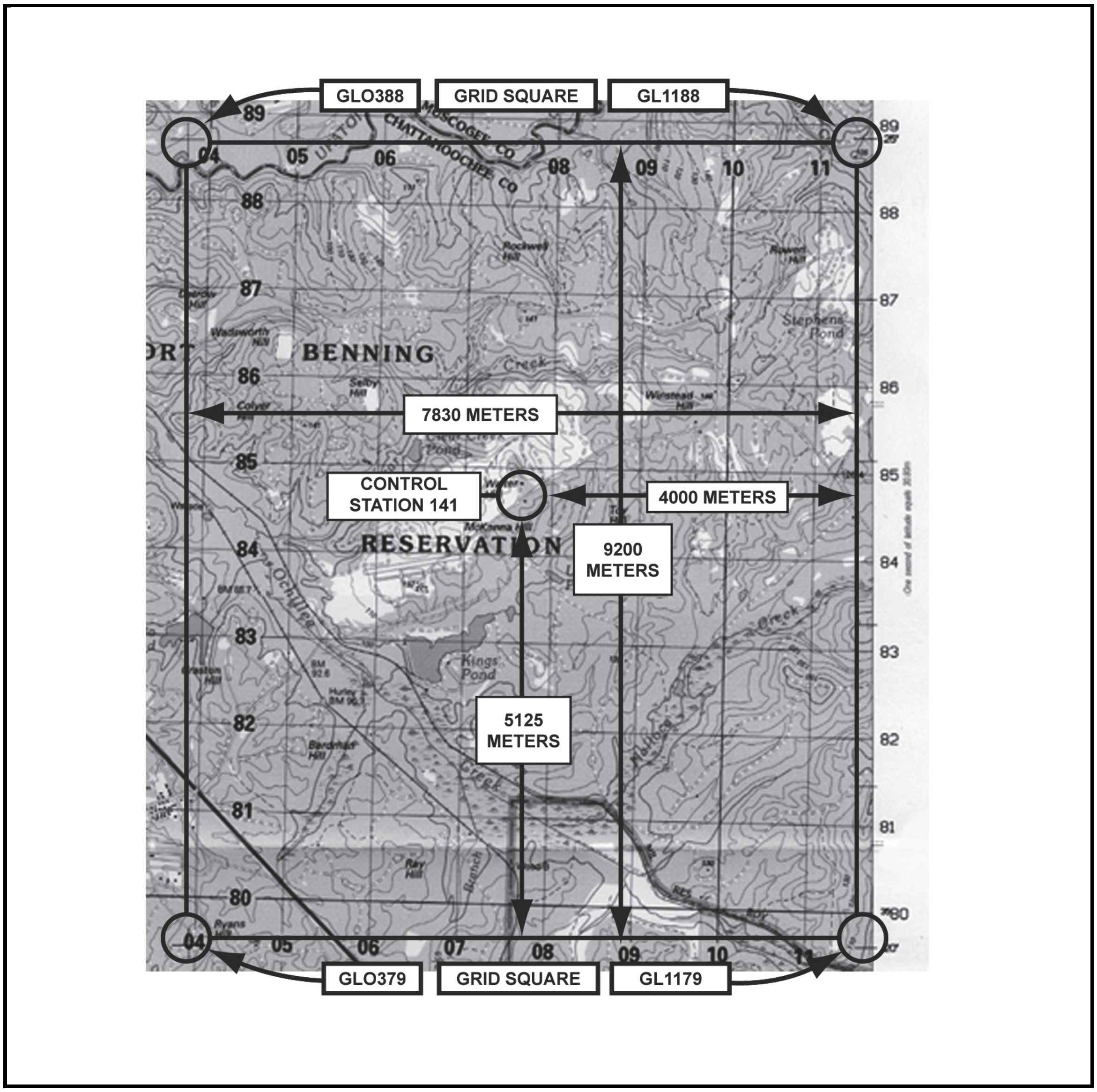


Figure 4-7. Using the proportional parts method

- Measure the partial distance from the bottom line to the center of the control station. These straight-line distances are in direct proportion to the minutes and seconds of latitude and are used to set up a ratio.
- The total distance is 9200 m, and the partial distance is 5125 m.
- With the two distances and the five-minute interval converted to seconds (300”), determine the minutes and seconds of latitude using the following formula:
  - 5125 x 300 = 1,537,500
  - 1,537,500 ÷ 9200 = 167
  - 167 ÷ 60 = 2.78 convert fraction (see note below) = 2’47”
  - Add 2’47” to 32°20’00” = 32°22’47”
- Follow the same procedures to determine minutes and seconds of longitude.

- The total distance is 7830 m, and the partial distance is 4000 m.
  - 4000 x 300 = 1,200,000
  - 1,200,000 ÷ 7830 = 153
  - 153 ÷ 60 = 2.55 convert fraction (see note below) = 2’33”
  - Add 2’33” to 84°45’ = 84°47’33”N
- The geographic coordinates of horizontal control station 141 in grid square GL0784 are 32°22’47”N latitude and 84°47’33”W longitude.

Note. When computing formulas, round off totals to the nearest whole number in step 2. In step 3, convert the fraction to seconds by multiplying the fraction by 60 and rounding off if the total is not a whole number.

- The maps made by some nations do not have their longitude values based on the UTM prime meridian that passes through Greenwich, England. Table 4-1 shows the prime meridians that may be used by other nations. When these maps are issued to our Soldiers, a note usually appears in the marginal information giving the difference between our prime meridian and the one used on the map.

Table 4-1. Table of prime meridians.

City, Country	*Prime Meridian*
Amsterdam, Netherlands	4°53’01”E
Athens, Greece	23°42’59”E
Batavia (Djakarta), Indonesia	106°48’28”E
Bern, Switzerland	7°26’22”E
Brussels, Belgium	4°22’06”E
Copenhagen, Denmark	12°34’40”E
Ferro (Hierro), Canary Islands	17°39’46”W
Helsinki, Finland	24°53’17”E
Istanbul, Turkey	28°58’50”E
Lisbon, Portugal	9°07’55”W
Madrid, Spain	3°41’15”W
Oslo, Norway	10°43’23”E
Paris, France	2°20’14”E
Pulkovo, Russia	30°19’39”E
Rome, Italy	12°27’08”E
Stockholm, Sweden	18°03’30”E
Tirane, Albania	19°46’45”E

MILITARY GRIDS

4-3. Gerardus Mercator developed the Mercator projection (see Figure 4-8) in 1569 as an aid for naval navigators. The straight lines of the Mercator projection are loxodromes, or rhumb lines, that represent the lines of a constant compass bearing, which is perfect for determining "true" direction. Mercator projection is a poor projection for world maps, but its rectangular grid and shape make it an appealing choice for wall maps, atlas maps, and other maps in books and newspapers published by nongeographers. Its popularity caused it to become the most identifiable map projection for most Americans.

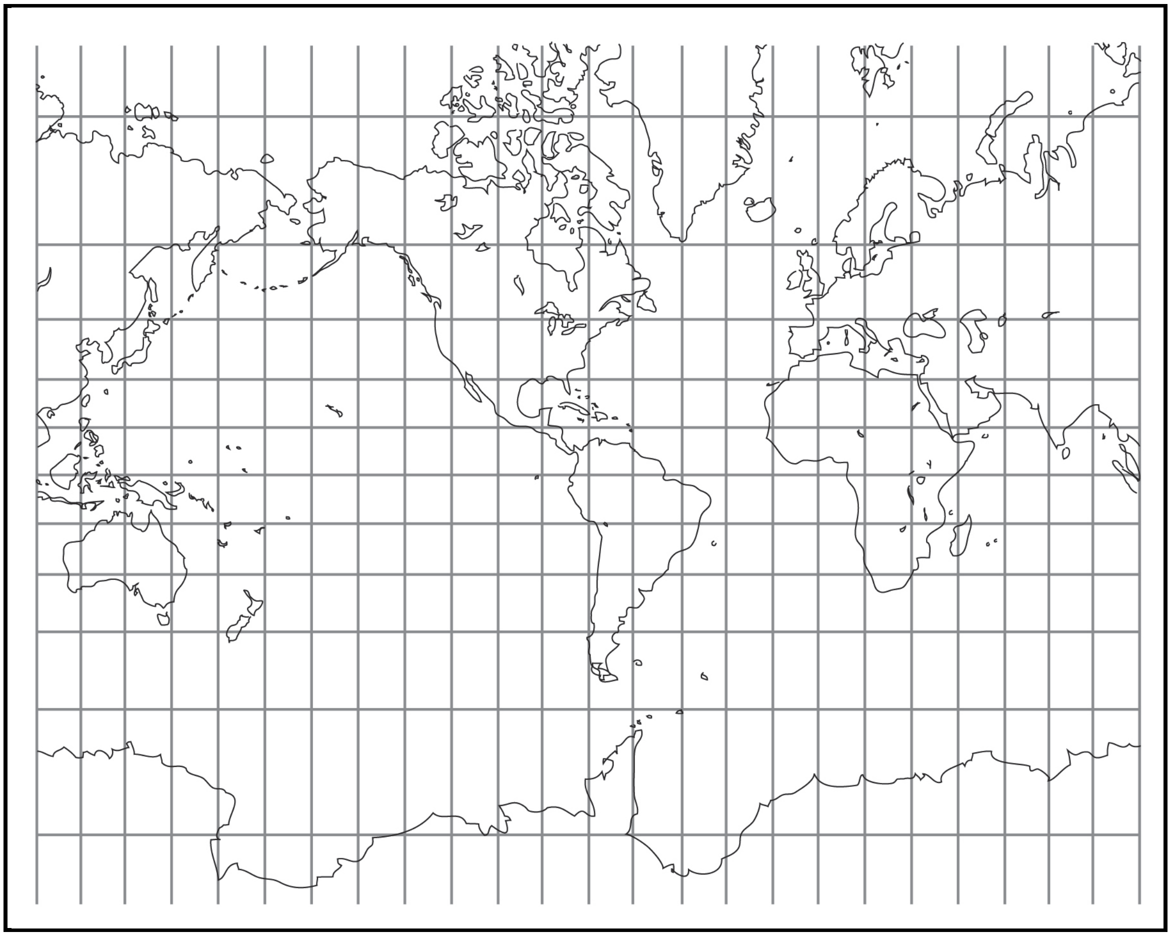


Figure 4-8 Regular Mercator projection.

4-4. In the standard Mercator projection, meridians are vertical, parallel, and equally spaced lines cut at right angles by straight horizontal parallels. The parallels have increasingly larger spaces between them as they approach the poles; these spaces are proportional to the earth's radius at a given latitude.

4-5. While the standard Mercator projection has a constant scale around the equator, the transverse Mercator projection (Figure 4-9) has a constant scale along a chosen central meridian. The meridians and parallels of the transverse Mercator projection are no longer straight lines (with the exception of the equator, the chosen central meridian, and each meridian 90 degrees away from the central meridian); instead, they are complex curves. When using the transverse Mercator projection, the scale along the chosen central meridian remains constant. This makes the projection ideal for regions extending predominantly north and south. The constant scale along the central meridian may be true to scale or deliberately reduced so that the mean scale of the entire map is more accurate.

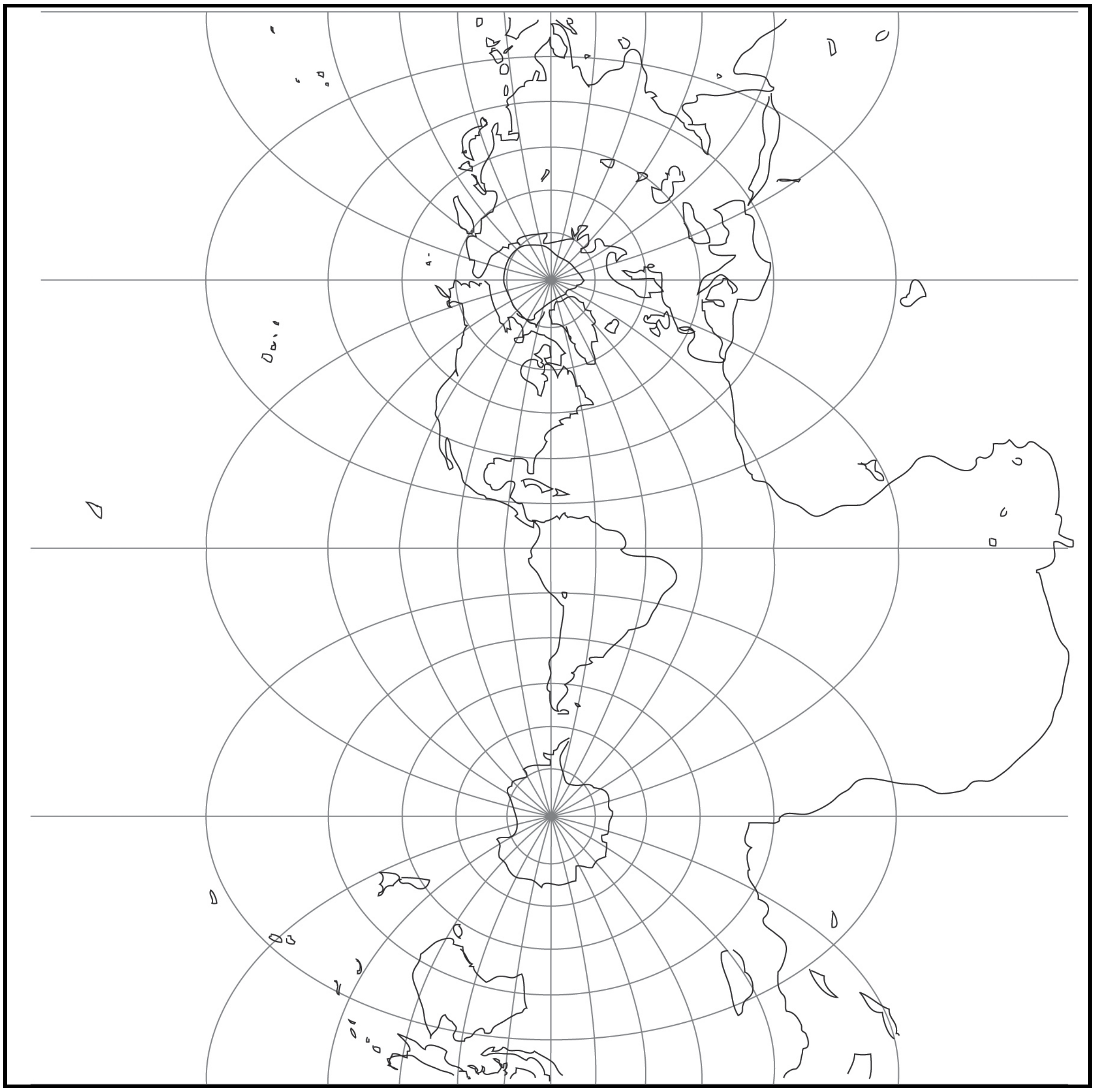


Figure 4-9. Transverse Mercator projection

4-6. An examination of the transverse Mercator projection, which is used for large-scale military maps, shows that most lines of latitude and longitude are curved lines. The quadrangles formed by the intersection of these curved parallels and meridians are of different sizes and shapes, complicating the location of points and the measurement of directions. To aid these essential operations, a rectangular grid is superimposed upon the projection. This grid (a series of straight lines intersecting at right angles) furnishes the map reader with a system of squares similar to the block system of most city streets. The dimensions and orientation of different types of grids vary, but three properties are common to all military grid systems: they are true rectangular grids; they are superimposed on the geographic projection; and they permit linear and angular measurements.

- **Universal transverse Mercator grid.** The UTM grid system was adopted by the U.S. Army in 1947 for designating rectangular coordinates on large-scale military maps. The UTM is currently used by the U.S. and North Atlantic Treaty Organization armed forces. With the advent of inexpensive GPS receivers, many other map users are adopting the UTM grid system for coordinates that are simpler to use than latitude and longitude. The UTM grid was designed to cover that part of the world between latitude 84°N and latitude 80°S, and, as its name implies, is imposed on the transverse Mercator projection. Each of the 60 zones (6-degrees wide) into which the globe is divided for the grid has its own origin at the intersection of its central meridian and the equator. (See Figure 4-10.) The grid is identical in all 60 zones. Base values (in meters) are assigned to the central meridian and the equator, and the grid lines are drawn at regular intervals parallel to these two base lines. With each grid line assigned a value denoting its distance from the origin, the problem of locating a point becomes progressively easier. Normally, it would seem logical to assign a value of zero to the two base lines and measure outward from them, but this would require that directions N, S, E, or W always be given with distances, or that all points south of the equator or west of the central meridian have negative values. This inconvenience is eliminated by assigning “false values” to the base lines, resulting in positive values for all points within each zone. Distances are always measured RIGHT and UP (east and north as the reader faces the map), and the assigned values are called “false easting” and “false northing.” (See Figure 4-11.) The false easting value for each central meridian is 500,000 m, and the false northing value for the equator is 0 m when measuring in the northern hemisphere and 10,000,000 m when measuring in the southern hemisphere.

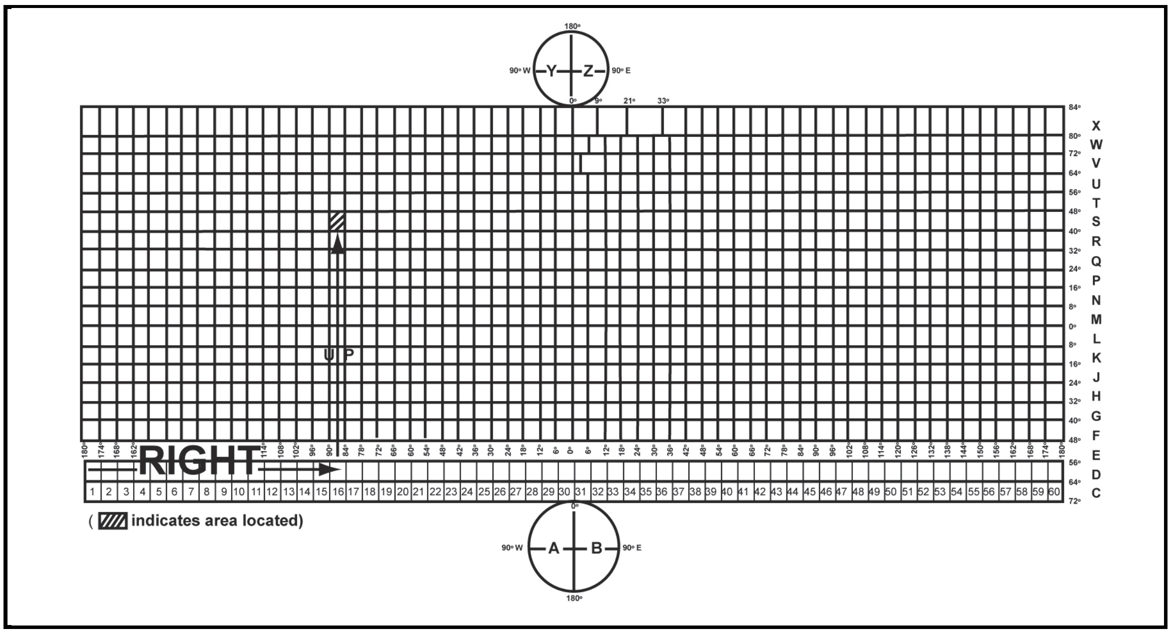


Figure 4-10. UTM grid zone location

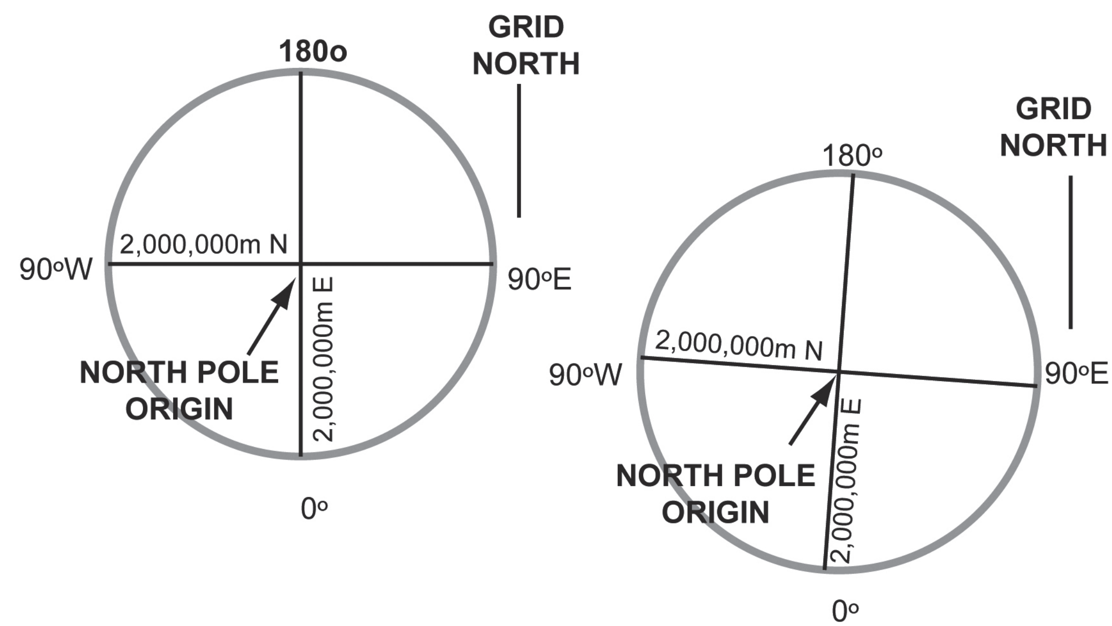


Figure 4-11. False eastings and northings for the UTM grid

- **Universal Polar Stereographic (UPS) grid**. The UPS grid is used to represent the polar regions. (See Figure 4-12.)
  - **North polar area**. The origin of the UPS grid applied to the north polar area is the North Pole. The "north-south" base line is the line formed by the 0 degree and 180-degree meridians; the "east-west" base line is formed by the two 90-degree meridians.
  - **South polar area**. The origin of the UPS grid in the south polar area is the South Pole. The base lines are similar to those of the north polar area.

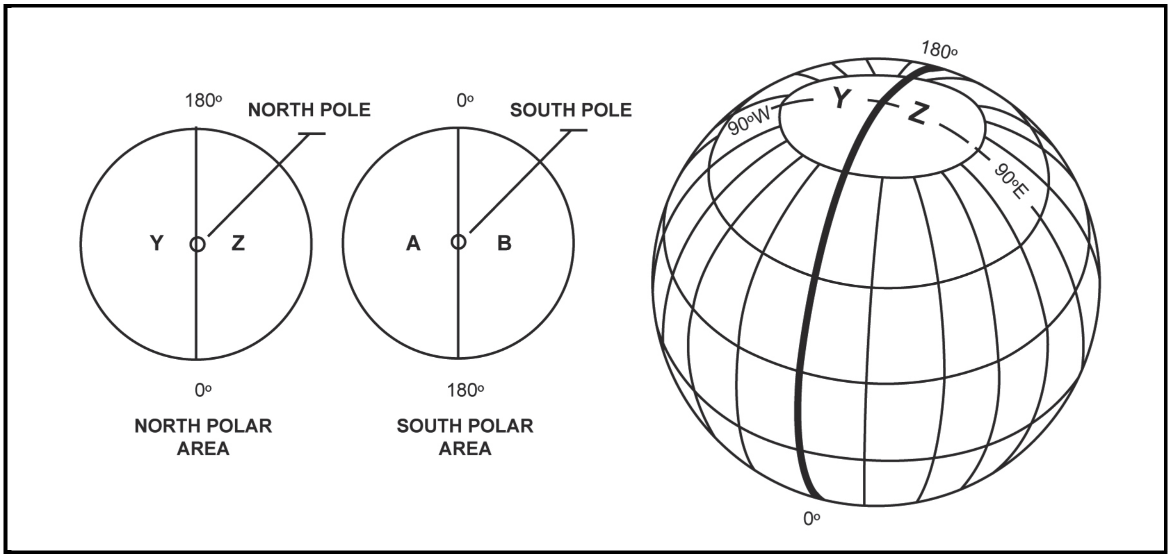


Figure 4-12. Grid zone designation for UPS grid

UNITED STATES ARMY MILITARY GRID REFERENCE SYSTEM

4-7. This grid reference system is used with the UTM and UPS grids. The coordinate value of points in these grids could contain as many as 15 digits if numerals alone were used. The U.S. military grid reference system reduces the length of written coordinates by substituting single letters for several numbers.

4-8. Using the UTM and the UPS grids, it is possible for the location of a point (identified by numbers alone) to be in many different places on the surface of the earth. With the use of the military grid reference system, there is no possibility of this happening.

4-9. The world is divided into 60 grid zones, which are large, regularly shaped geographic areas, each having a unique identification called the grid zone designation. The two grids are:

- **UTM grid.** The first major breakdown is the division of each zone into areas 6-degrees wide by 8-degrees high or 6-degrees wide by 12-degrees high. Remember, for the transverse Mercator projection, the earth's surface between 80°S and 84°N is divided into 60 north-south zones, each 6-degree wide. These zones are numbered from west to east, 1 through 60, starting at the 180-degree meridian. This surface is divided into 20 east-west rows, in which 19 are 8-degrees high and 1 row at the extreme north is 12-degrees high. These rows are then lettered, from south to north, C through X (I and O are omitted). Any 6-degrees-by-8-degrees zone or 6-degrees-by-12-degrees zone is identified by giving the number and letter of the grid zone and row in which it lies. These are read RIGHT and UP so the number is always written before the letter. This combination of zone number and row letter constitutes the grid zone designation. Columbus is in zone 16 and row S, or in grid zone designation 16S. (See Figure 4-10.)

UPS grid. The remaining letters of the alphabet—A, B, Y, and Z—are used for the UPS grids. Each polar area is divided into two zones separated by the 0 to 180-degrees meridian. In the south polar area, the letter A is the grid zone designation for the area west of the 0- to 180-degrees meridian, and B for the area to the east. In the north polar area, Y is the grid zone designation for the western area and Z for the eastern area. (See Figure 4-12.)

4-10. Between 84°N and 80°S, each 6-degrees-by-8-degrees or 6-degrees-by-12-degrees zone is covered by 100,000-m squares in each zone that are identified by the combination of two alphabetical letters. This identification is unique within the area covered by the grid zone designation. The first letter is the column designation; the second letter is the row designation. (See Figure 4-13.) The north and south polar areas are covered by 100,000-m squares in each zone by columns and rows. The 100,000-m square identification letters are located in the grid reference box in the lower margin of the map.

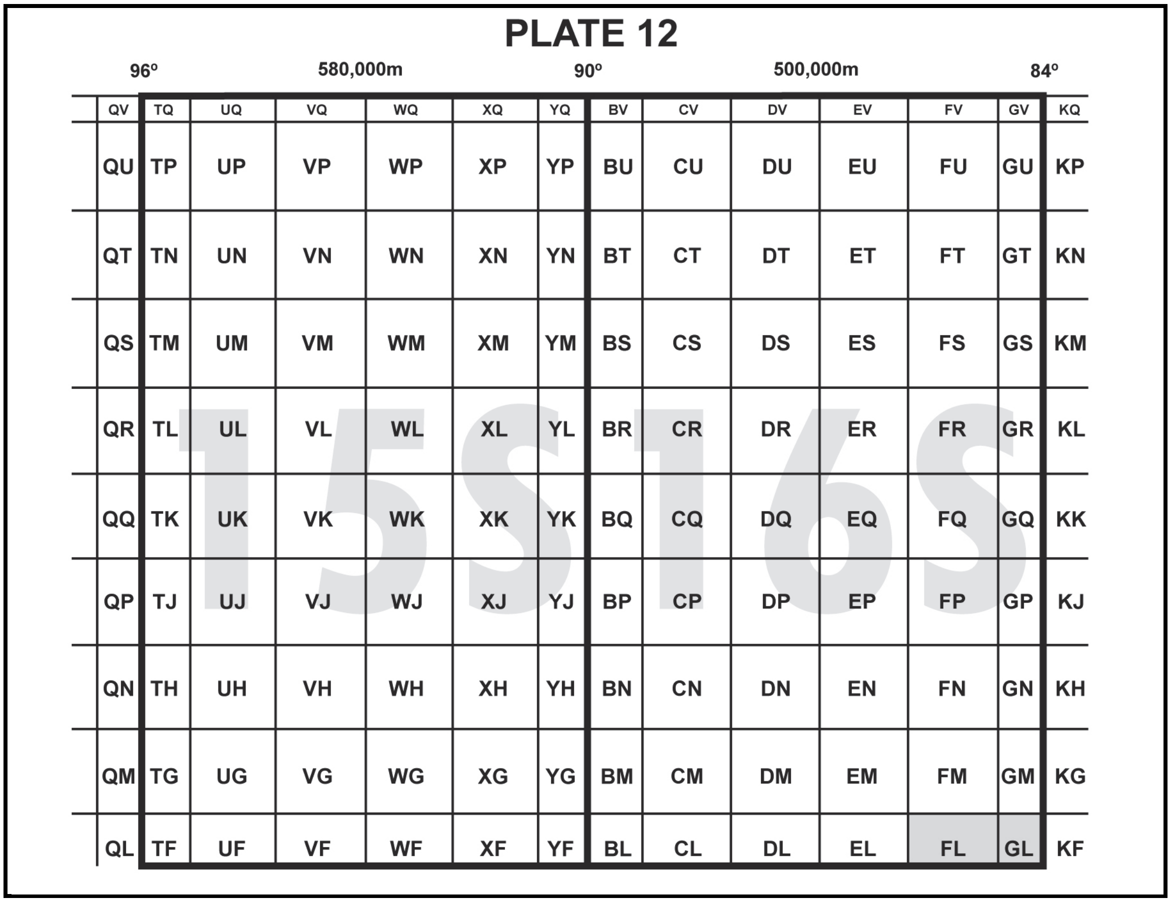


Figure 4-13. Grid zone designation and 100,000-m square identification

4-11. Grid coordinates divide the earth's surface into 6-degrees-by-8-degrees quadrangles, covered with 100,000-m squares. The military grid reference of a point consists of the numbers and letters indicating where in the 100,000-m grid zone areas the point lies, plus the coordinates locating the point to the desired position within the 100,000-m square. The next step is to tie in the coordinates of the point with the larger areas. To do this, it is important to understand—

- **Grid lines**. The regularly spaced lines that make up the UTM and UPS grid on large-scale maps are divisions of the 100,000-m square. The lines are spaced at 10,000-m or 1000-m intervals. (See Figure 4-14.) Each of these lines is labeled at both ends of the map with its false easting or false northing value, showing its relation to the origin of the zone. Two digits of the values are printed in large type, and these same two digits appear at intervals along the grid lines on the face of the map. These are called the principal digits, and represent the 10,000 and 1000 digits of the grid value. They are of major importance to the map reader because they are the numbers used most often for referencing points. The smaller digits complete the UTM grid designation.

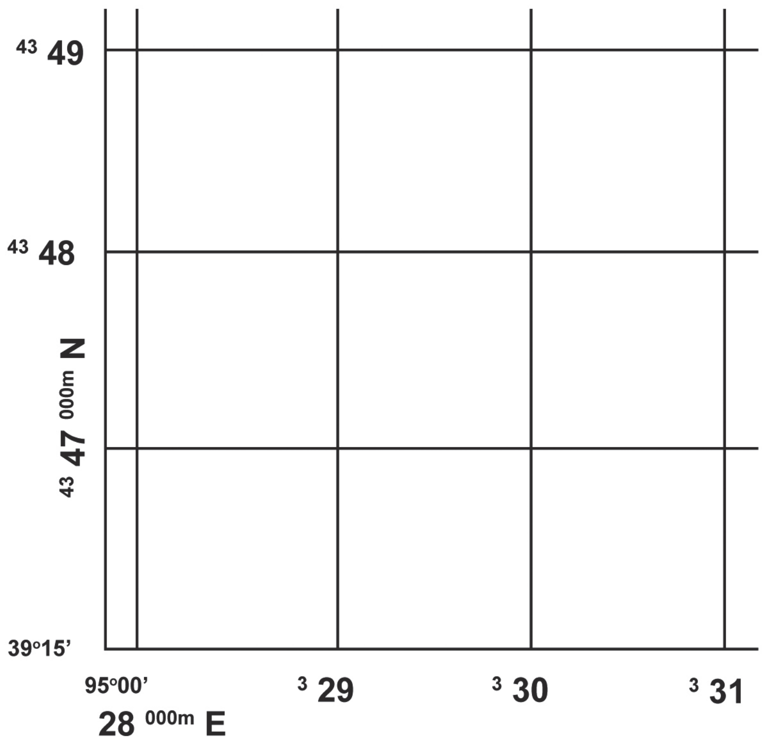


Figure 4-14. Grid lines and principle digits

Note. As an example, the first grid line north of the south-west corner of the Columbus map is labeled 3570000m N. This means its false northing (distance north of the equator) is 3,570,000 m. The principal digits, 70, identify the line for referencing points in the northerly direction. The smaller digits, 35, are part of the false coordinates and are rarely used. The last three digits, 000, of the value are omitted. Therefore, the first grid line east of the south-west corner is labeled 689000m E. The principal digits, 89, identify the line for referencing points in the easterly direction. (See Figure 4-15.)

Figure 4-15. Southwest corner of the Columbus, Georgia, map

- **Grid squares.** The north-south and east-west grid lines intersect at 90 degrees, forming grid squares. Normally, the size of one of these grid squares on large-scale maps is 1000 m (1 km).
- **Grid coordinate scales.** The primary tool for plotting grid coordinates is the grid coordinate scale. This scale divides the grid square more accurately than can be done by estimation and the results are more consistent. When used correctly, it presents less chance for making errors. GTA 5-2-12 contains four types of coordinate scales. (See Figure 4-16.)

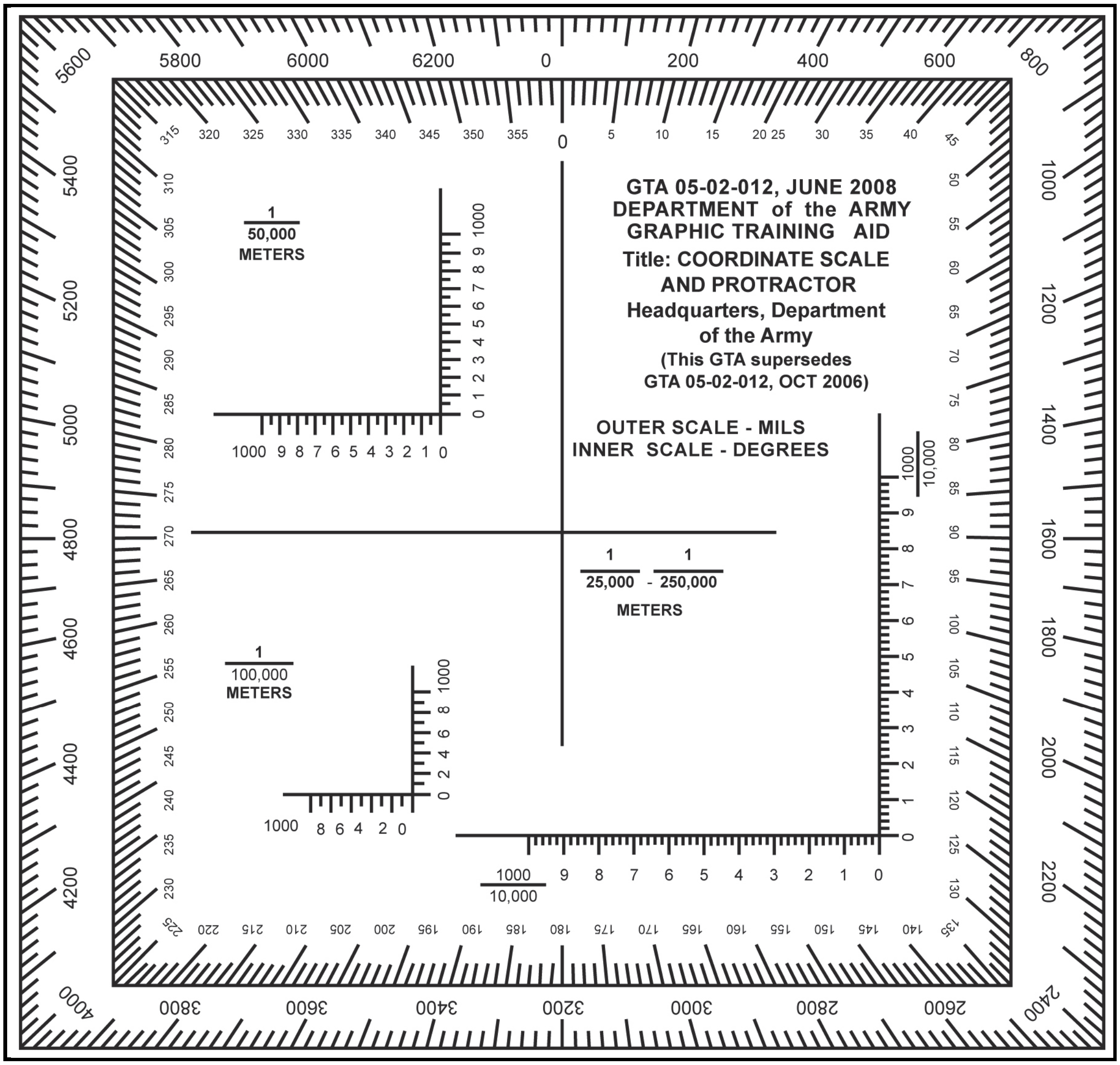


Figure 4-16. Coordinate scales

Note. The 1:50,000-scale (upper left in Figure 4-16) subdivides the 1000-m block into 10 major subdivisions, each equal to 100 m. Each 100-m block is then divided in half. Points falling between the graduations are estimated to the nearest 10 m for the fourth and eighth digits of the coordinates.

The 1:100,000-scale (lower left in Figure 4-16) subdivides the 1000-m grid block into five major subdivisions of 200 m each. Each 200-m block is then divided in half at 100-m intervals.

The 1:25,000/1:250,000 (center, lower right in Figure 4-16) can be used in two different scale maps; 1:25,000 or 1:250,000. The 1:25,000-scale subdivides the 1000-m grid block into 10 major subdivisions, each equal to 100 m. Each 100-m block has five graduations; each equal to 20 m. Points falling between the two graduations can be read accurately by using estimation. These values are the fourth and eighth digits of the coordinates. The 1:250,000-scale is subdivided into 10 major subdivisions, each equal to 1000 m. Each 1000-m block has five graduations; each equal to 200 m. Points falling between two graduations can be read approximately by using estimation.

LOCATING A POINT USING GRID COORDINATES

4-12. Based on the military principle for reading maps RIGHT and UP, locations on the map can be determined by grid coordinates. The number of digits represents the degree of precision to which a point has been located and measured on a map. More digits mean the measurement is more precise.

DETERMINE GRIDS WITHOUT A COORDINATE SCALE

4-13. In order to determine grids without a coordinate scale, the reader refers to the north-south grid lines numbered at the bottom margin of a map. Then read RIGHT to the north-south grid line that precedes the desired point (this first set of two digits is the RIGHT reading). Then, by referring to the east-west grid lines numbered at either side of the map, the map reader moves UP to the east-west grid line that precedes the desired point (these two digits are the UP reading). In Figure 4-17, coordinates 1484 locate the 1000-m grid square in which point X is located; the next square to the right would be 1584; the next square up would be 1485, and so forth. To locate the point to the nearest 100 m, use estimation. By mentally dividing the grid square in tenths, estimate the distance from the grid line to the point in the same order (RIGHT and UP). Give complete coordinate RIGHT, then complete coordinate UP. Point X is about two-tenths or 200 m to the RIGHT into the grid square and about seven-tenths or 700 m UP. The coordinates to the nearest 100 m are 142847.

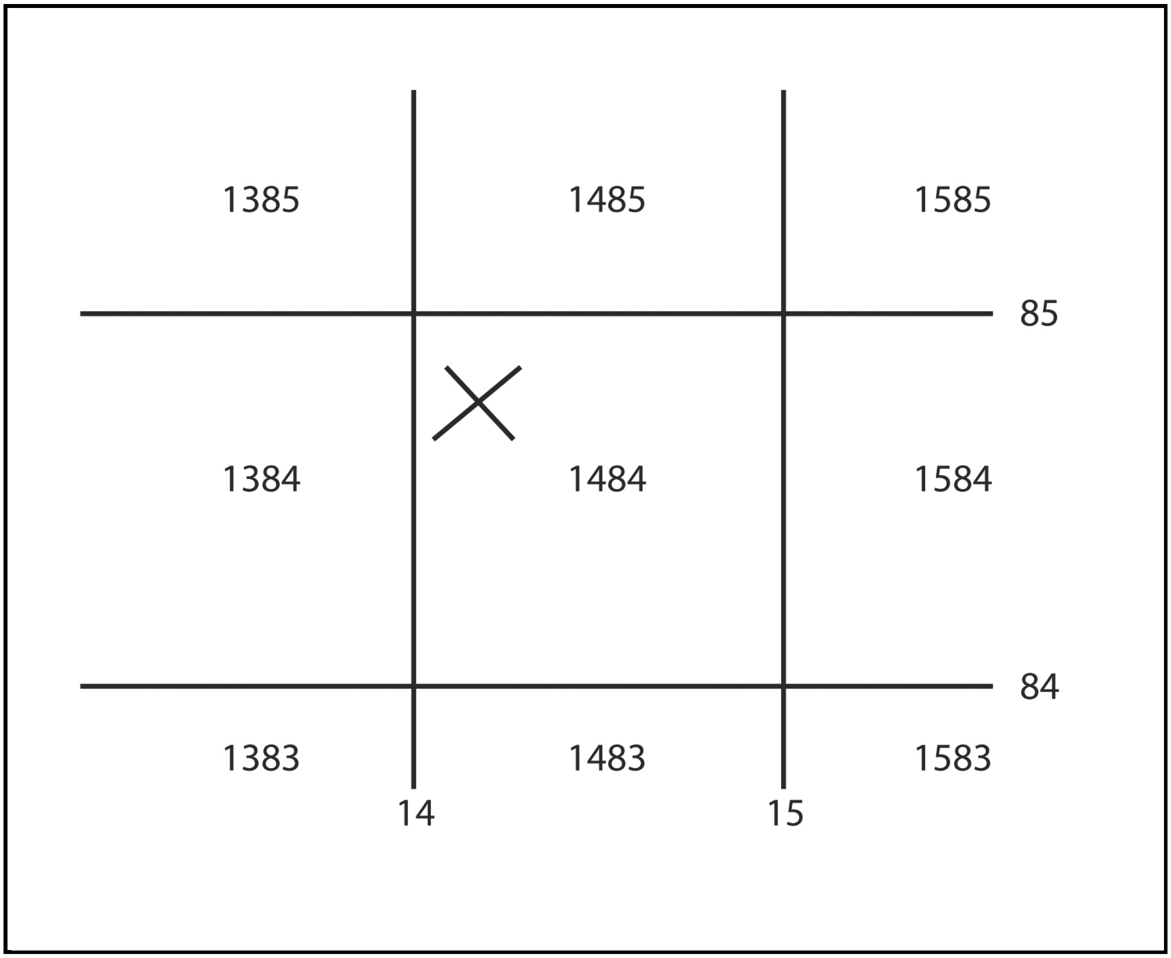


Figure 4-17. Determining grids without coordinate point

DETERMINE GRIDS WITH A COORDINATE SCALE

4-14. In order to use the coordinate scale for determining grid coordinates, the map user has to make sure that the appropriate scale is being used on the corresponding map, and that the scale is right side up. To ensure the scale is correctly aligned, place it with the zero-zero point at the lower left corner of the grid square. Keeping the horizontal line of the scale directly on top of the east-west grid line, slide it to the right until the vertical line of the scale touches the point for which the coordinates are desired. (See Figure 4-18.) When reading coordinates, examine the two sides of the coordinate scale to ensure that the horizontal line of the scale is aligned with the east-west grid line, and the vertical line of the scale is parallel with the north-south grid line. The scale is used when precision of more than 100 m is required. To locate the point to the nearest 10 m, measure the hundredths of a grid square RIGHT and UP from the grid lines to the point. Point X is about 21-hundredths or 210 m RIGHT and 73-hundredths or 730 m UP. The coordinates to the nearest 10 m are 14218473.

RECORDING AND REPORTING GRID COORDINATES

4-15. Coordinates are written as one continuous number without spaces, parentheses, dashes, or decimal points; they always contain an even number of digits. Therefore, whoever is to use the written coordinates knows where to make the split between the RIGHT and UP readings. It is a military requirement that the 100,000-m square identification letters be included in a point designation. Normally, grid coordinates are determined to the nearest 100 m (six digits) for reporting locations. With practice, this can be done without using plotting scales. The location of targets and other point locations for fire support are determined to the nearest 10 m (eight digits).

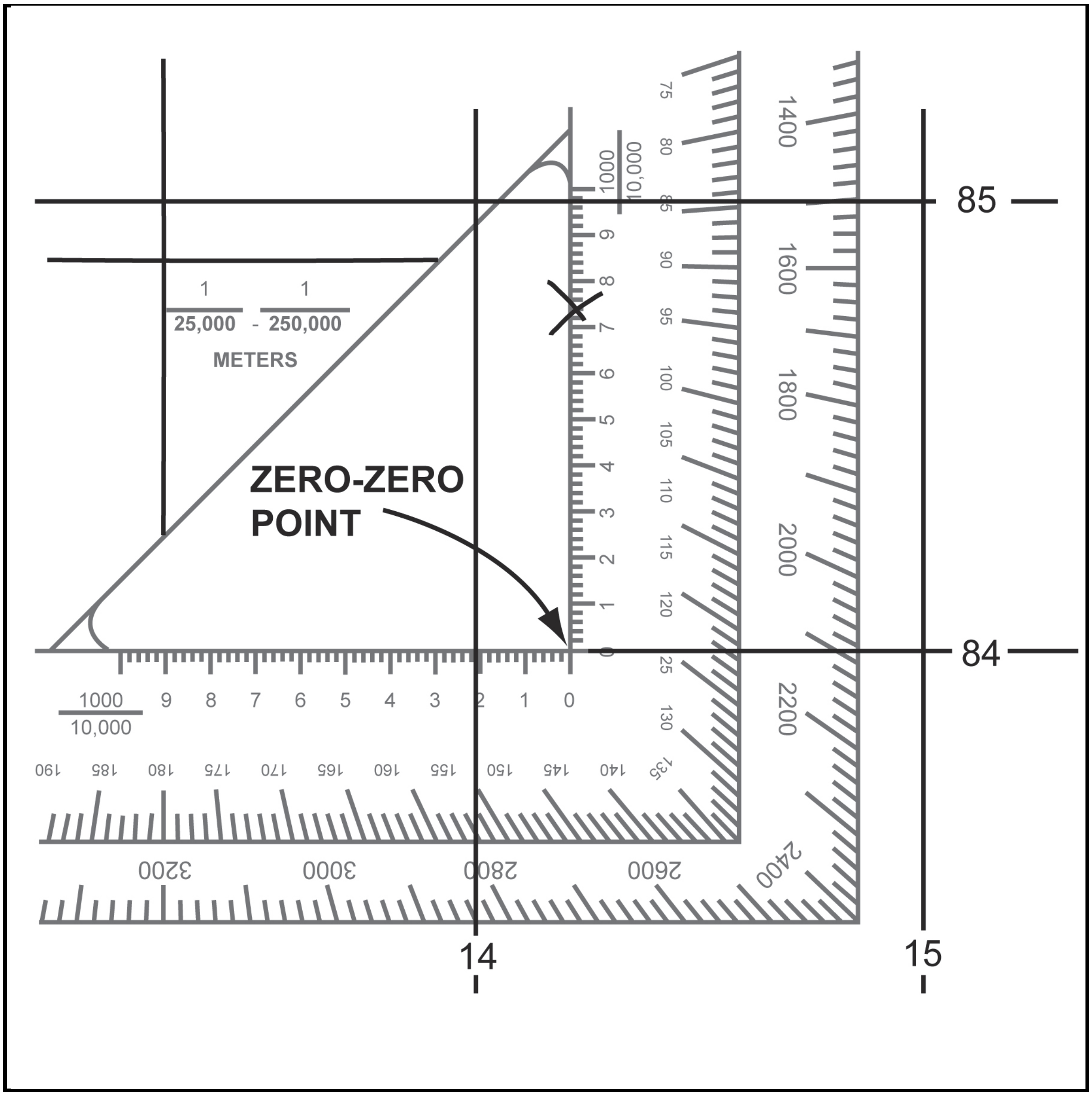


Figure 4-18. Placing a coordinate scale on a grid

Note. Care should be exercised by the map reader using the coordinate scale when the desired point is located within the zero-zero point and the number 1 on the scale. Always prefix a zero if the hundredths reading is less than 10. In Figure 4-19, the desired point should be reported as 14838425.

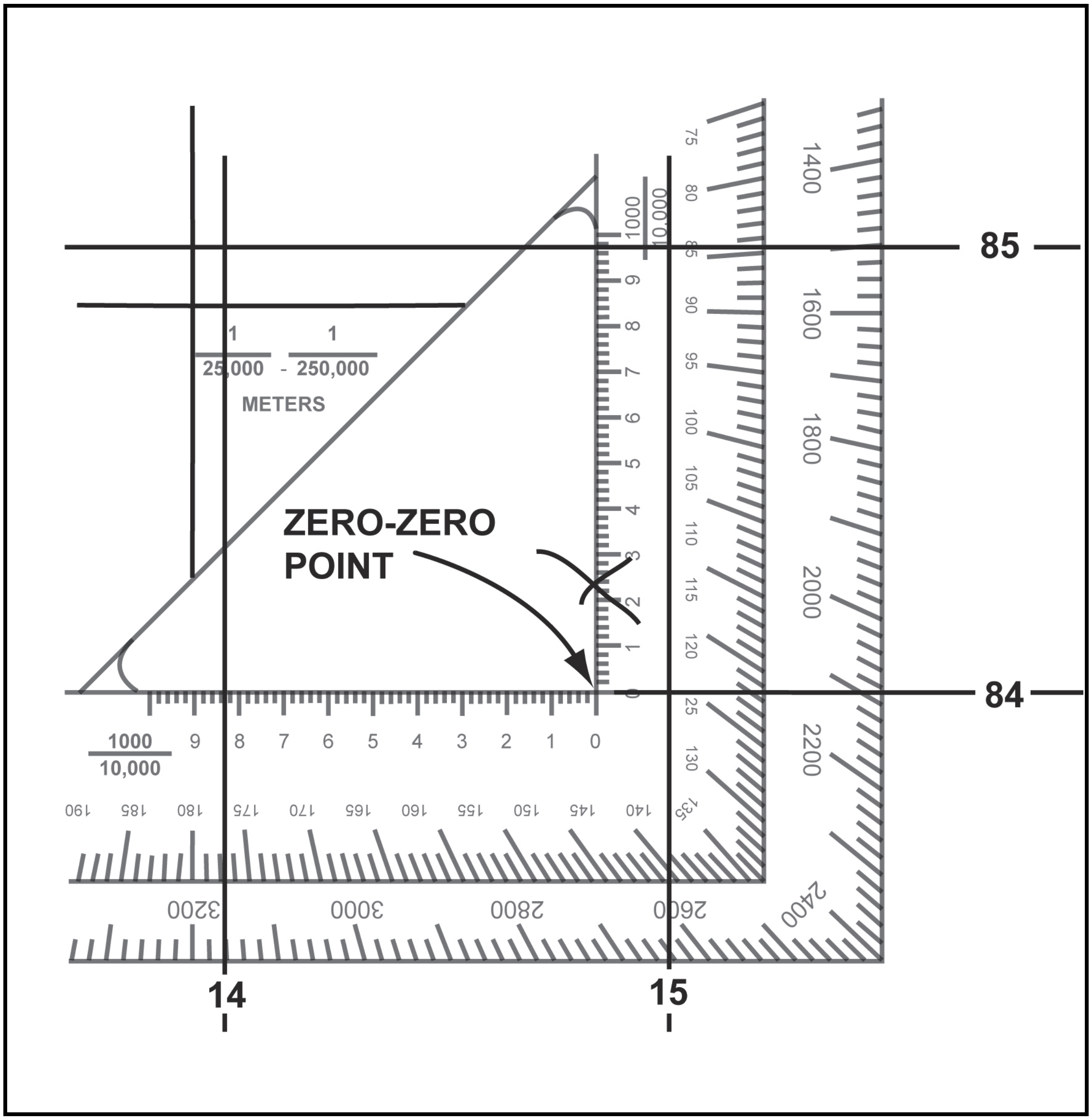


Figure 4-19. Zero-zero point

> ***Note.*** Special care should be exercised when recording and reporting coordinates. Transposing numbers or making errors could be detrimental to military operations.

LOCATING A POINT USING THE U.S. ARMY MILITARY GRID REFERENCE SYSTEM

4-16. There is only one rule to remember when reading or reporting grid coordinates—always read to the RIGHT and then UP. The first half of the reported set of coordinate digits represents the left-to-right (easting) grid label, and the second half represents the label as read from the bottom-to-top (northing). The grid coordinates may represent the location to the nearest 10-m, 100-m, or 1000-m increment. These coordinates are found by taking the following steps:

- **Grid zone**. The number 16 locates a point within zone 16, which is an area 6-degrees wide and extends between 80°S latitude and 84°N latitude. (See Figure 4-10.)
- **Grid zone designation**. The number and letter combination 16S, further locates a point within the grid zone designation 16S, which is a quadrangle 6-degrees wide by 8-degrees high. There are 19 of these quads in zone 16. Quad X, which is located between 72°N and 84°N latitude, is 12-degrees high. (See Figure 4-10.)

- **100,000-m square identification**. The addition of two more letters locates a point within the 100,000-m grid square. The coordinates 16SGL (see Figure 4-13) locates the point within the 100,000-m square GL in the grid zone designation 16S. (Refer to the Defense Mapping Agency Technical Manual 8358.1 for more information.)
- **10,000-m square**. The breakdown of the U.S. Army military grid reference system continues as each side of the 100,000-m square is divided into 10 equal parts. This division produces lines that are 10,000 m apart. The coordinates 16SGL08 would locate a point as shown in Figure 4-20. The 10,000-m grid lines appear as index (heavier) grid lines on maps at 1:100,000 and larger.

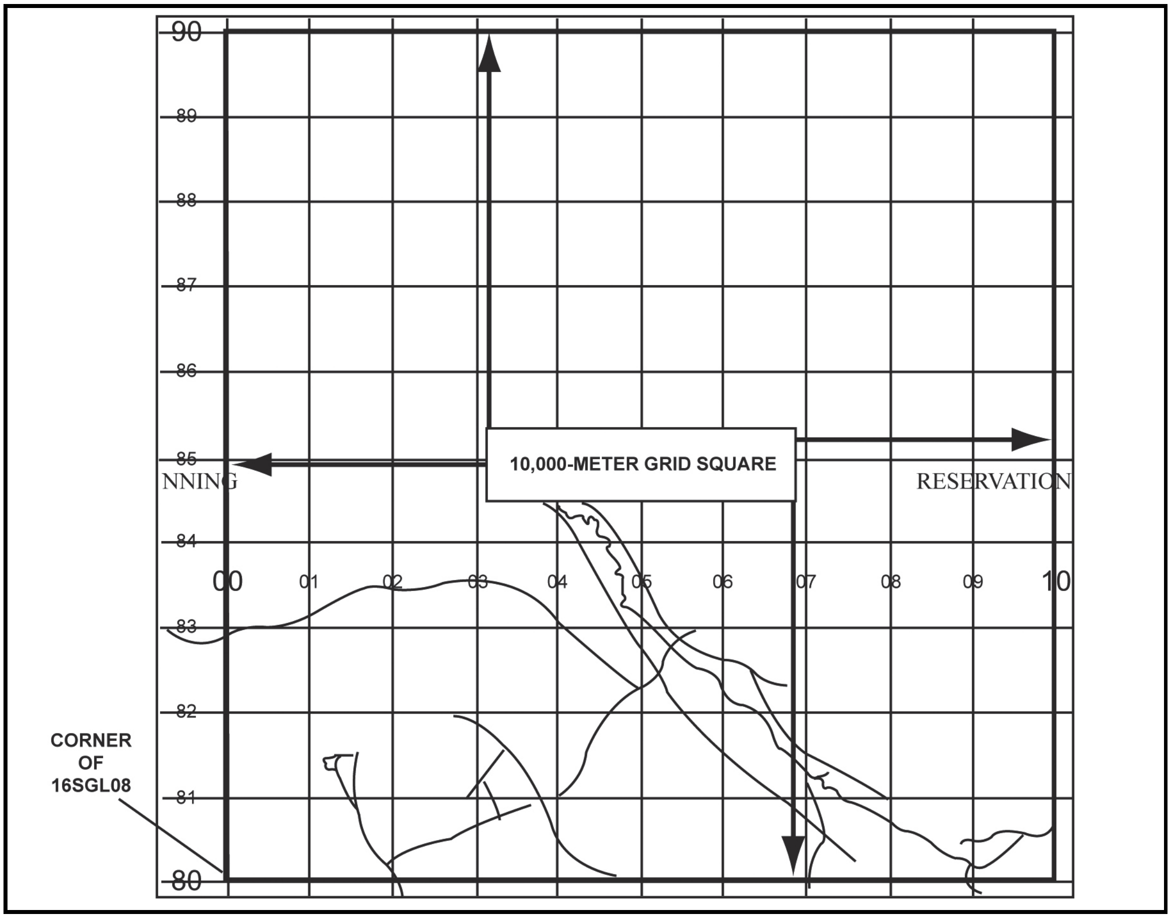


Figure 4-20. The 10,000-meter grid square

- **1000-meter grid square**. To obtain the 1000-m grid squares, each side of the 10000-m square is divided into 10 equal parts. This division appears on large-scale maps as the actual grid lines; they are 1000 meters apart (1 km). (See Figure 4-21.)

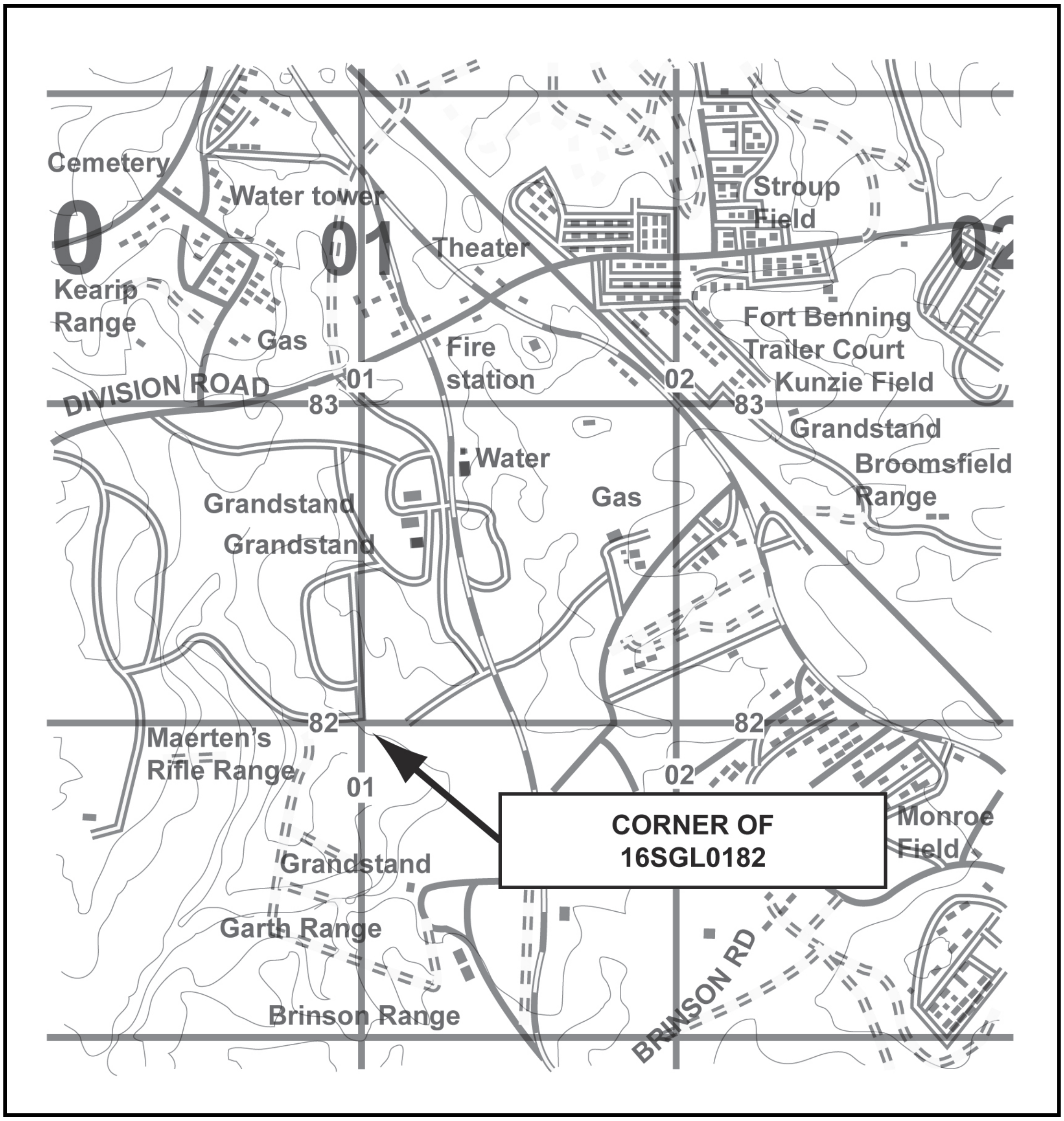


Figure 4-21. The 1000-meter grid square

- **100-meter identification**. To locate to the nearest 100 meters, the grid coordinate scale can be used to divide the 1000-m grid squares into 10 equal parts. (See Figure 4-22.)
- **10-meter identification**. The grid coordinate scale has divisions every 50 m on the 1:50,000-scale, and every 20 m on the 1:25,000-scale. These can be used to estimate to the nearest 10 m and give the location of one point on the earth's surface to the nearest 10 m**.** For example, 16SGL01948253 is a gas tank.

- **Precision.** The precision of a point's location is shown by the number of digits in the coordinates; the more digits, the more precise the location. (See Figure 4-22, insert.)

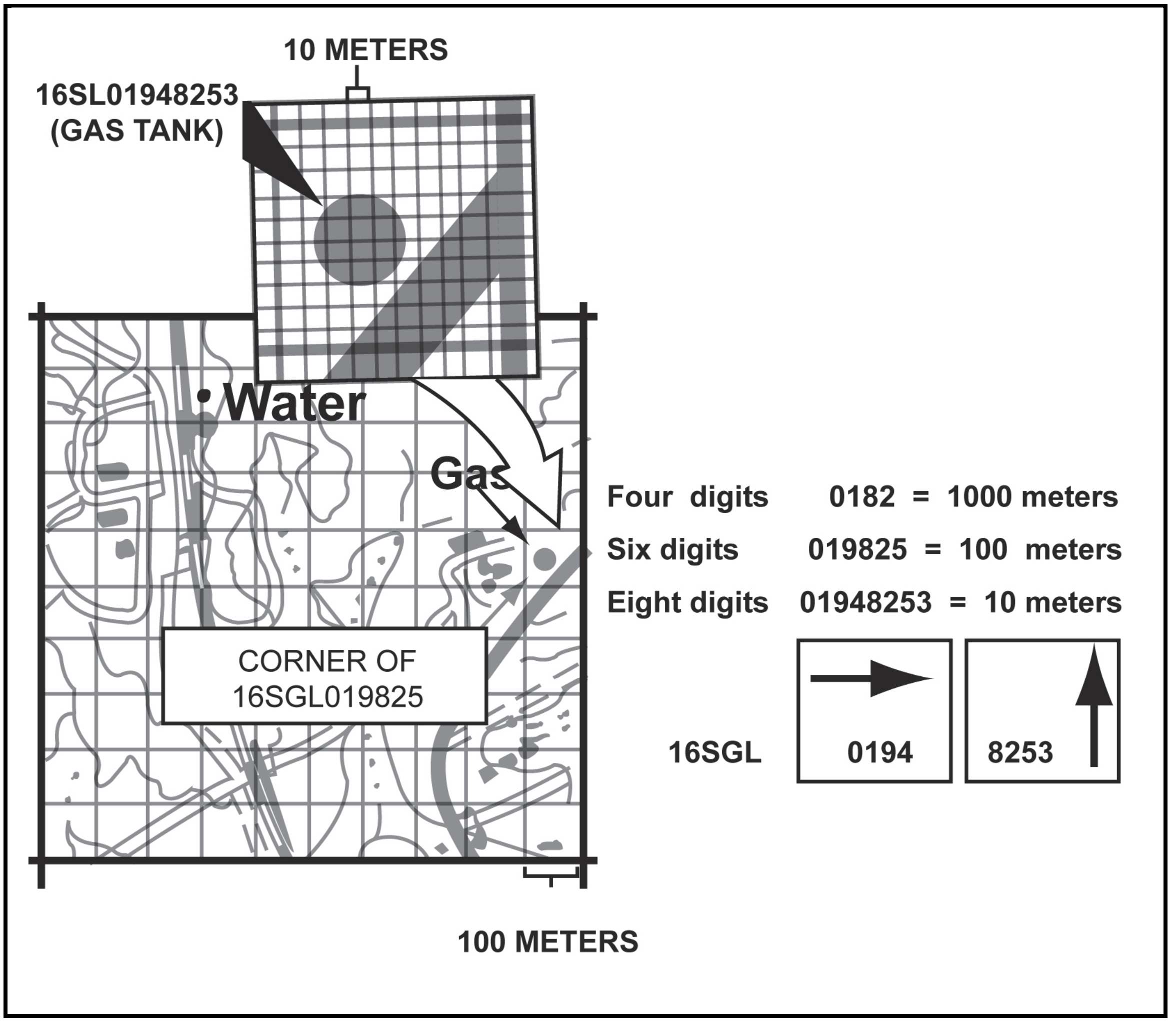


Figure 4-22. The 100-meter and 10-meter grid squares

GRID REFERENCE BOX

A grid reference box (see Figure 4-23) appears in the marginal information of each map sheet. It contains step-by-step instructions for using the grid and the U.S. Army military grid reference system. The grid reference box is divided into two parts. The left portion identifies the grid zone designation and the 100,000-m square. If the sheet falls in more than one 100,000-m square, the grid lines that separate the squares are shown in the diagram and the letters identifying the 100,000-m squares are given. For example, on the Columbus map sheet, the vertical line labeled 00 is the grid line that separates the two 100,000-m squares, FL and GL. The left portion also shows a sample for the 1000-m square with its respective labeled grid coordinate numbers and a sample point within the 1000-m square.

4-17. The right portion of the grid reference box explains how to use the grid and is keyed on the sample 1000-meter square of the left side. The following is an example of the military grid reference:

EXAMPLE: 16S locates the 6-degrees-by-8-degrees area (grid zone designation).

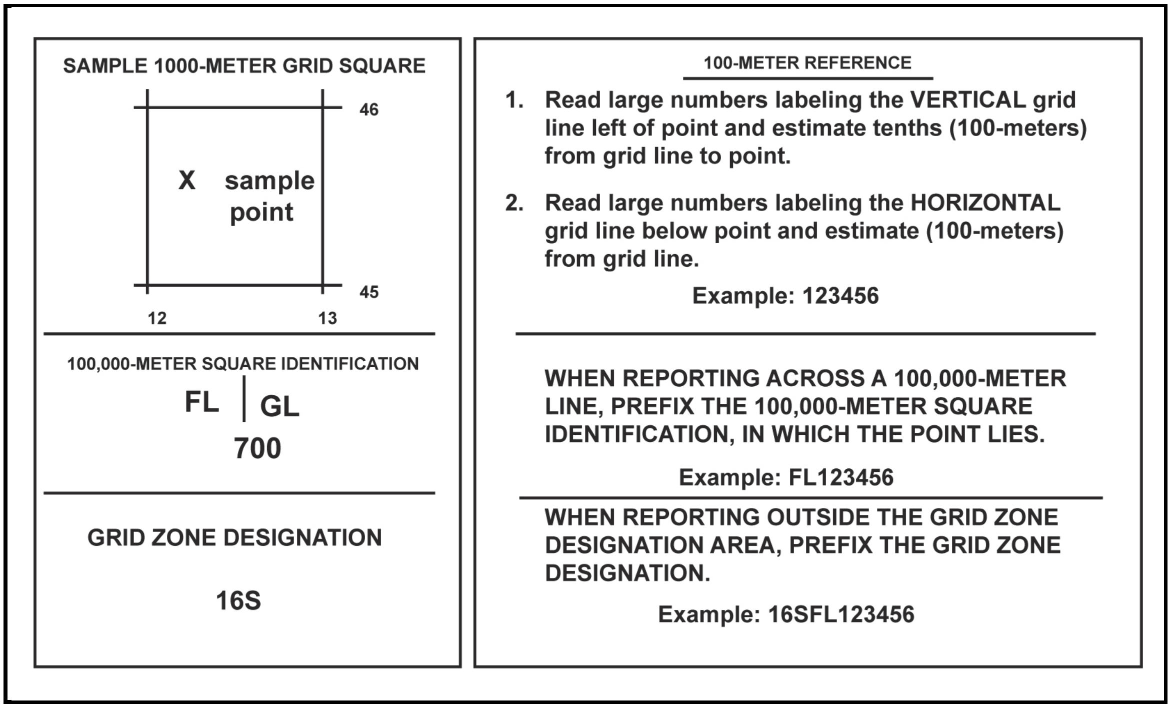


Figure 4-23. Grid reference box

OTHER GRID SYSTEMS

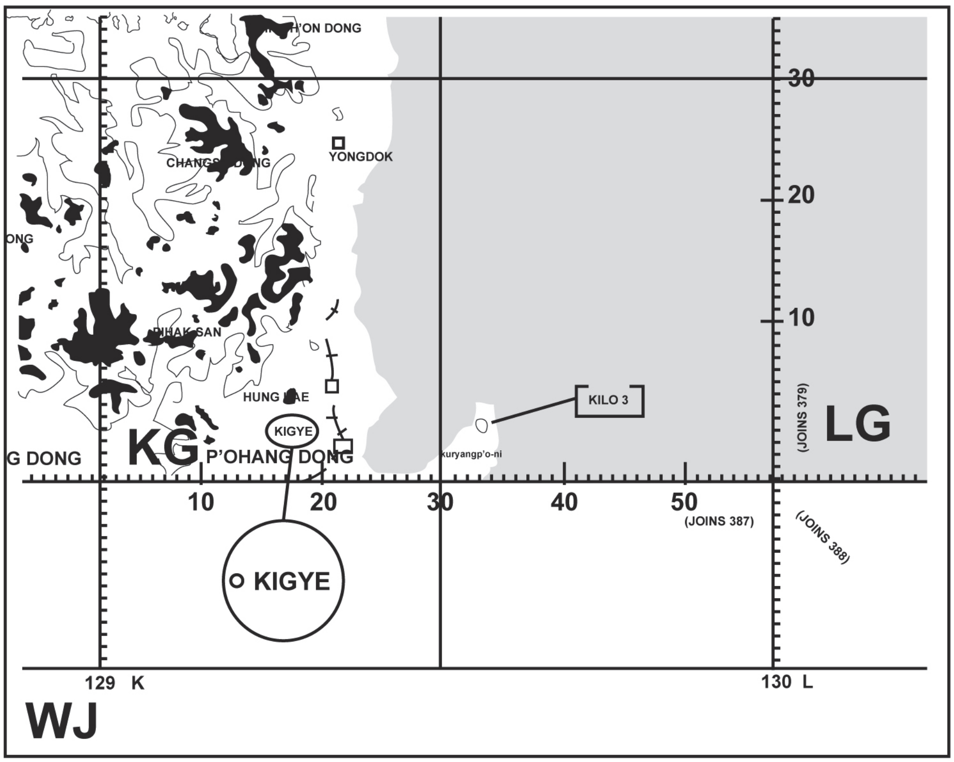
4-18. The military grid reference system is not universally used. Soldiers are prepared to interpret and use other grid systems, depending upon the area of operations or the personnel working together.

4-19. **British grids.** In a few areas of the world, British grids are still shown on military maps. However, the British grid systems are being phased out. Eventually all military mapping will be converted to the UTM grid.

4-20. **World Geographic Reference System (GEOREF).** This is a worldwide position reference system used primarily by the U.S. Air Force. It may be used with a map or chart that has latitude and longitude printed on it. Instructions for using GEOREF data are printed in blue and are found in the margin of aeronautical charts. This system is based upon a division of the earth's surface into quadrangles of latitude and longitude having a systematic identification code. It is a method of expressing latitude and longitude in a form suitable for rapid reporting and plotting. Figure 4-24 illustrates a sample grid reference box using GEOREF. The GEOREF System uses an identification code that has three main divisions:

- **First division.** There are 24 north-south (longitudinal) zones, each 15-degree wide. These zones, starting at 180 degrees and progressing eastward, are lettered A through Z (omitting I and O). The first letter of a GEOREF coordinate identifies the north-south zone in which the point is located. There are 12 east-west (latitudinal) bands, each 15-degrees wide. These bands are lettered A through M (omitting I) northward from the South Pole. The second letter of a GEOREF coordinate identifies the east-west band in which the point is located. The zones and bands divide the earth's surface into 288 quadrangles, each identified by two letters.
- **Second division.** Each 15° quadrangle is further divided into 225 quadrangles of 1 degree each (15-degrees-by-15-degrees). This division is effected by dividing a basic 15-degree quadrangle into 15 north-south zones and 15 east-west bands. The north-south zones are lettered A through Q (omitting I and O) from west to east. The third letter of a GEOREF coordinate identifies the 1-degree north-south zone within a 15-degree quadrangle. The east-west bands are lettered A through Q (I and O omitted) from south to north. The fourth letter of a GEOREF coordinate identifies the 1-degree east-west band within a 15-degree quadrangle. Four letters identify any 1-degree quadrangle in the world.

- **Third division.** Each of the 1-degree quadrangles is divided into 3,600 1” quadrangles. These 1” quadrangles are formed by dividing the 1-degree quadrangles into 60 1” north-south zones numbered 0 through 59 from west to east, and 60 east-west bands numbered 0 to 59 from south to north. To designate one of the 3,600 1” quadrangles requires four letters and four numbers. The rule READ RIGHT AND UP is always followed. Numbers 1 through 9 are written as 01, 02, and so forth. Each of the 1” quadrangles may be further divided into 10 smaller divisions both north-south and east-west, permitting the identification of 0.1” quadrangles. The GEOREF coordinate for a 0.1”quadrangle consists of four letters and six numbers. (See Figure 4-24.)



TO REFERENCE BY GEOREF(SHOWN IN BLUE) TO MINUTES

Select nearest intersection south and west of point.

Sample point: KIGYE

1. **WJ identifies basic 15° quadrangle.**
2. **KG identifies 1° quadrangle.**
3. **15 identifies GEOREF minute of longitude.**
4. **03 identifies GEOREF minute of latitude.**
5. **Sample reference: WJKG 1503.**

Figure 4-24. Sample reference using GEOREF

PROTECTION OF MAP COORDINATES AND LOCATIONS

4-21. A disadvantage of a standard system of location is that if the enemy intercepts a friendly message using the system, they can interpret the message and find our location. This possibility can be eliminated by using an authorized low-level numerical code to express locations. AR 380-40 outlines the procedures for obtaining authorized codes.

Chapter 5

Scale and Distance

A map is a scaled graphic representation of a portion of the earth's surface. The scale of the map permits the user to convert distance on the map to distance on the ground, or vice versa. The ability to determine distance on a map, as well as on the earth's surface, is an important factor in planning and executing military missions.

REPRESENTATIVE FRACTION

5-1. The numerical scale of a map indicates the relationship of distance measured on a map and the corresponding distance on the ground. This scale is usually written as a fraction and is called the representative fraction. The RF is always written with the map distance as 1, and is independent of a unit of measure. (It could be yards, meters, inches, or something else.) An RF of 1/50,000 or 1:50,000 means that one unit of measure on the map is equal to 50,000 units of the same measure on the ground.

5-2. The ground distance between two points is determined by measuring between the same two points on the map and then multiplying the map measurement by the denominator of the RF or scale. (See Figure 5-1.)

EXAMPLE: The map scale is 1:50,000 making RF = 1/50,000. The map distance from point A to point B is 5 units. 5 x 50,000 = 250,000 units of ground distance.

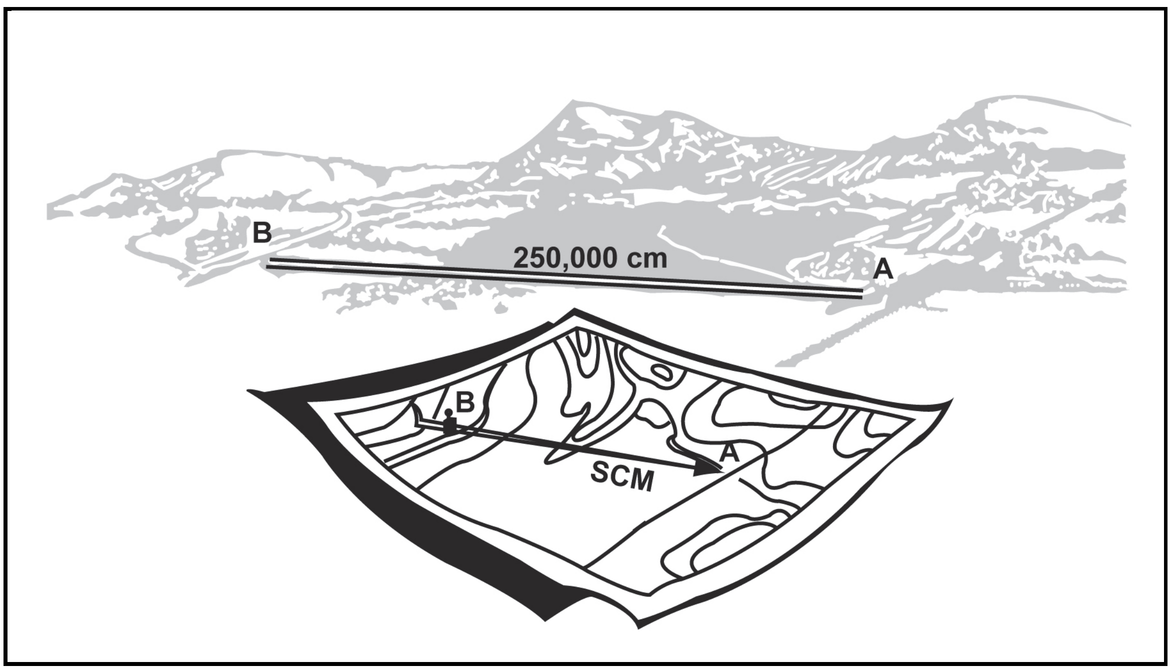


Figure 5-1. Converting map distance to ground distance

5-3. Since the distance on most maps is marked in meters and the RF is expressed in this unit of measurement, in most cases a brief description of the metric system is needed. In the metric system, the standard unit of measurement is the meter. It is multiplied this way:

- 1 m contains 100 centimeters (cm).
- 100 m is a regular football field plus 10 m.

- 1000 m is 1 km.
- 10,000 m is 10 km.

Note. Appendix E contains the units of measure conversion tables.

5-4. The situation may arise when a map or sketch has no RF or scale. To be able to determine ground distance on such a map, the RF is determined. There are two ways to do this:

- **Comparison with ground distance.** Measure the distance between two points on the map—map distance (MD). Determine the horizontal distance between these same two points on the ground—ground distance (GD). Use the RF formula and remember that RF is in the general form:

$$\textbf{RF} = \frac{1}{X} = \frac{MD}{GD}$$

Both the MD and the GD is in the same unit of measure, and the MD is reduced to 1.

EXAMPLE: MD = 4.32 cm

GD = 2.16 km (216,000 cm)

$$\textbf{RF} = \frac{1}{X} = \frac{4.32}{216{,}000} \quad \textit{or} \quad \frac{216{,}000}{4.32} = 50{,}000$$

***therefore* RF = 1⁄50,000 *or* 1:50,000**

- **Comparison with another map of the same area that has an RF.** Select two points on the map with the unknown RF, and measure the MD between them. Locate those same two points on the map that has the known RF, and measure the MD between them. Using the RF for this map, determine GD, which is the same for both maps. Using the GD and the MD from the first map, determine the RF using the formula:

$$\textbf{RF} = \frac{1}{X} = \frac{MD}{GD}$$

5-5. Occasionally, it may be necessary to determine map distance from a known ground distance and the RF:

$$\textbf{MD} = \frac{GD}{\text{Denominator or RF}}$$

Ground distance = 2200 m
RF = 1:50,000

$$\textbf{MD} = \frac{2200\text{ m}}{50{,}000} = 0.044\text{ m}$$

MD = 0.044 m X 100 (cm per meter)
MD = 4.4 cm

5-6. When determining ground distance from a map, the scale of the map affects the accuracy. As the scale becomes smaller, the accuracy of measurement decreases because some of the features on the map are exaggerated so that they may be readily identified.

GRAPHIC (BAR) SCALES

5-7. A graphic scale is a ruler printed on the map that is used to convert distances on the map to actual ground distances. The graphic scale is divided into two parts. To the right of the zero, the scale is marked in full units of measure and is called the primary scale. To the left of the zero, the scale is divided into tenths and is called the extension scale. Most maps have three or more graphic scales, each using a different unit of measure. (See Figure 5-2.) When using the graphic scale, be sure to use the correct scale for the unit of measure desired.

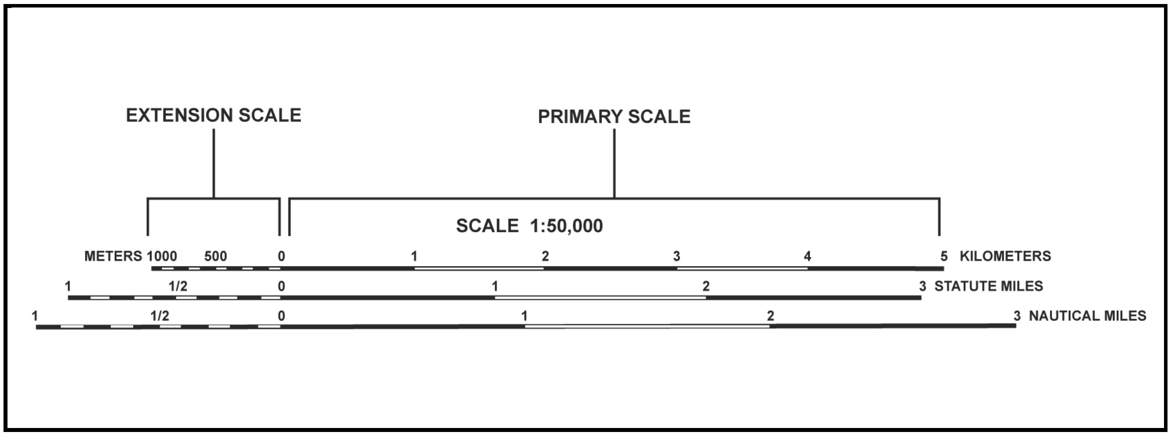


Figure 5-2. Using a graphic (bar) scale

5-8. To determine the straight-line distance between two points on a map, lay a straight-edged piece of paper on the map so that the edge of the paper touches both points and extends past them. Make a tick mark on the edge of the paper at each point. (See Figure 5-3.)

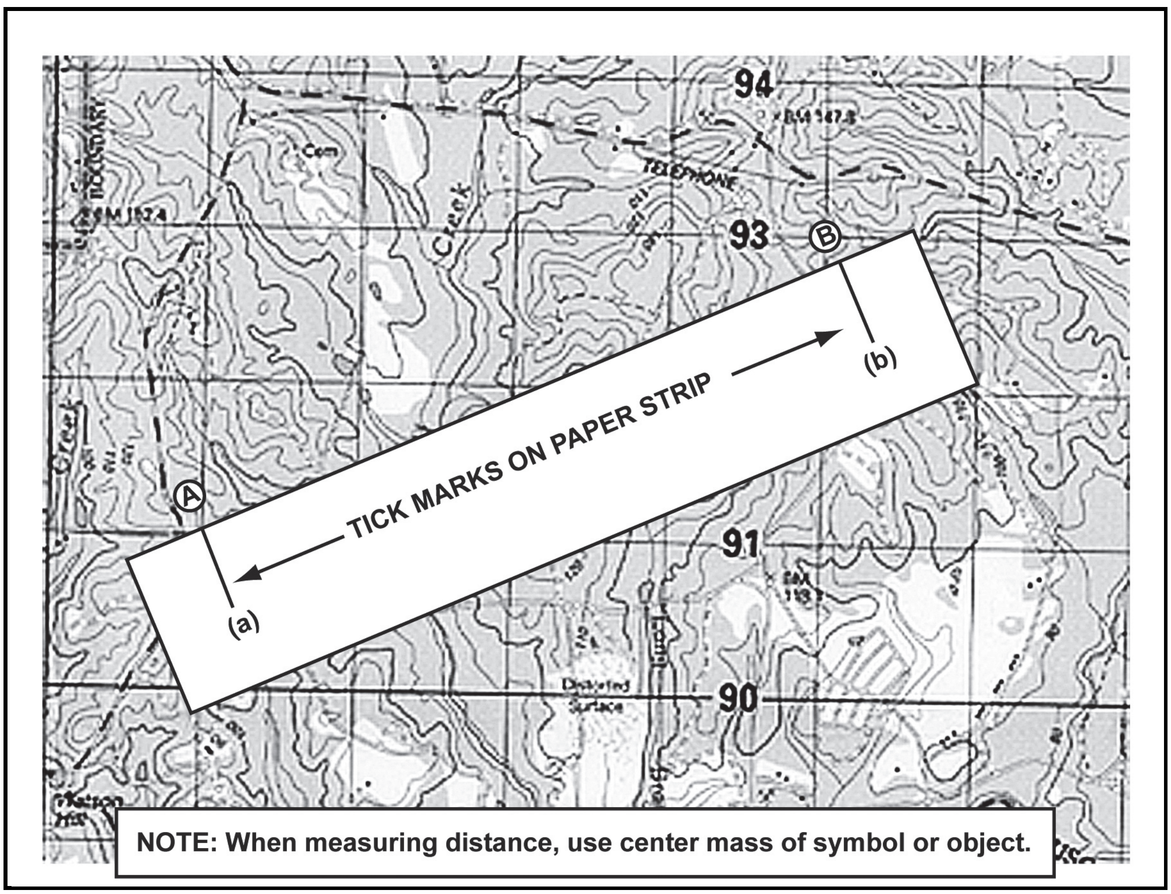


Figure 5-3. Transferring map distance to a paper strip

5-9. To convert the map distance to a measured ground distance, move the paper down to the graphic bar scale, and align the right tick mark (b) with a printed number in the primary scale so that the left tick mark (a) is in the extension scale. (See Figure 5-4.) The primary scale provides the whole unit distance, while the extension scale provides the divided scale used to determine smaller increments of measure.

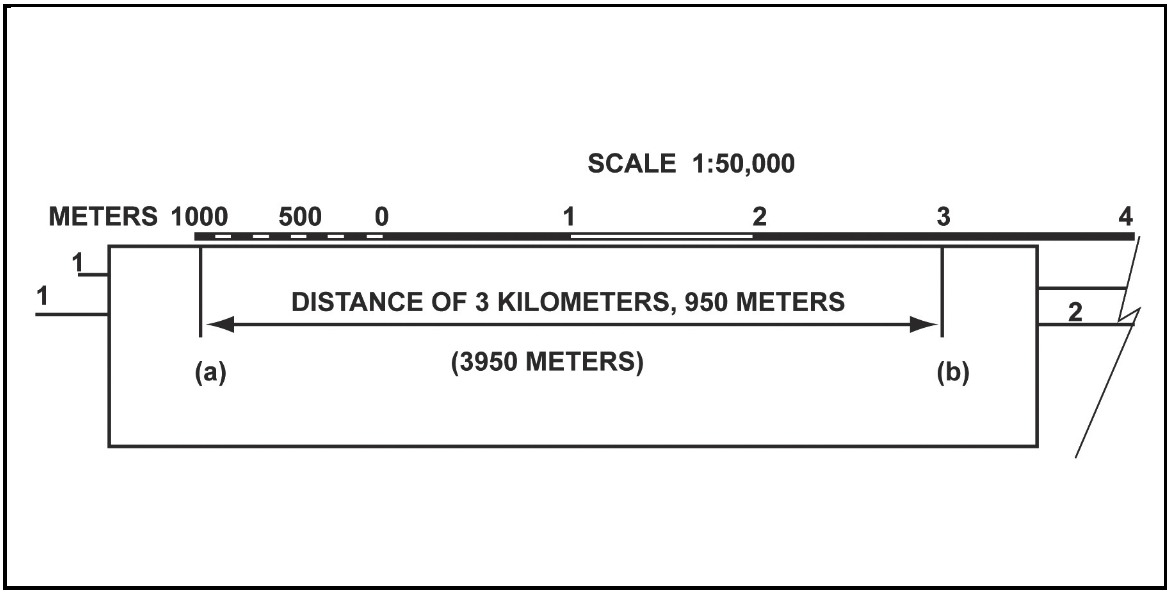


Figure 5-4. Measuring straight-line map distance

5-10. The primary scale is read from the zero mark to the right. Figure 5-4 shows the right tick mark (b) is aligned with the 3000-m mark in the primary scale with the left tick mark (a) in the extension scale, so the distance is at least 3000 m. To determine the distance between the two points to the nearest 100 m, look at the extension scale. The extension scale is numbered with zero at the right and increases to the left. (See Figure 5-4.) The first area on the extension scale represents 0 to 100 m. The second represents 100 to 200 m. Remember, the distance in the extension scale increases from right to left.

5-11. To determine the distance between the two points to the nearest 10 m, divide the distance inside the extension scale into tenths. In Figure 5-4, tick mark (a) falls within the 900 to 1000-m scale area. The location is approximate 5 tenths to the left of the 900 m start point. This is read as 950 m. Adding the distance of 3000 m determined in the primary scale to the 950 m determined by using the extension scale, the total distance between points (a) and (b) is 3950 m.

5-12. To measure distance along a road, stream, or other curved line, the straight edge of a piece of paper is used. In order to avoid confusion concerning the point to begin measuring from and the ending point, an eight-digit coordinate should be given for both the starting and ending points. Place a tick mark on the paper and map at the beginning point from which the curved line is to be measured. Align the edge of the paper along a straight portion and make a tick mark on both map and paper when the edge of the paper leaves the straight portion of the line being measured. (See A, Figure 5-5.)

5-13. Keeping both tick marks together (on paper and map), place the point of the pencil close to the edge of the paper on the tick mark to hold it in place. Then, pivot the paper until another straight portion of the curved line is aligned with the edge of the paper. Continue in this manner until the measurement is completed. (See B, Figure 5-5.)

5-14. When the distance is completely measured, move the paper to the graphic scale to determine the ground distance. The only tick marks being measured are (a) and (b). The tick marks in between are not used. (See C, Figure 5-5.)

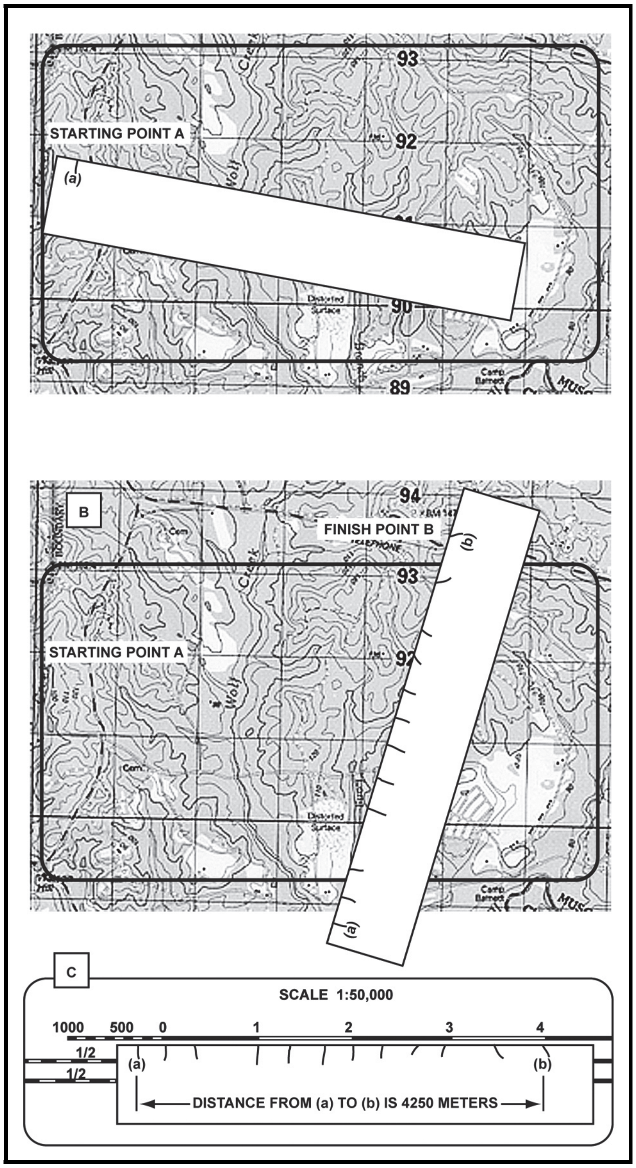


Figure 5-5. Measuring a curved line

5-15. There may be times when the distance being measured on the edge of the paper exceeds the graphic scale. In this case, there are different techniques that can be used to determine the distance:

- One technique is to align the right tick mark (b) with a printed number in the primary scale, in this case the 5. From point (a) to point (b) is more than 6000 m when the 1000 m in the extension scale is added. To determine the exact distance to the nearest 10 m, place a tick mark (c) on the edge of the paper at the end of the extension scale. (See A, Figure 5-6.) Point (b) to point (c) is 6000 m. With the tick mark (c) placed on the edge of the paper at the end of the extension scale, slide the paper to the right. (Remember the distance in the extension is always read from right to left.) Align tick mark (c) with zero and then measure the distance between tick marks (a) and (c). The distance between tick marks (a) and (c) is 420 m. The total ground distance between start and finish points is 6420 m. (See B, Figure 5-6.)

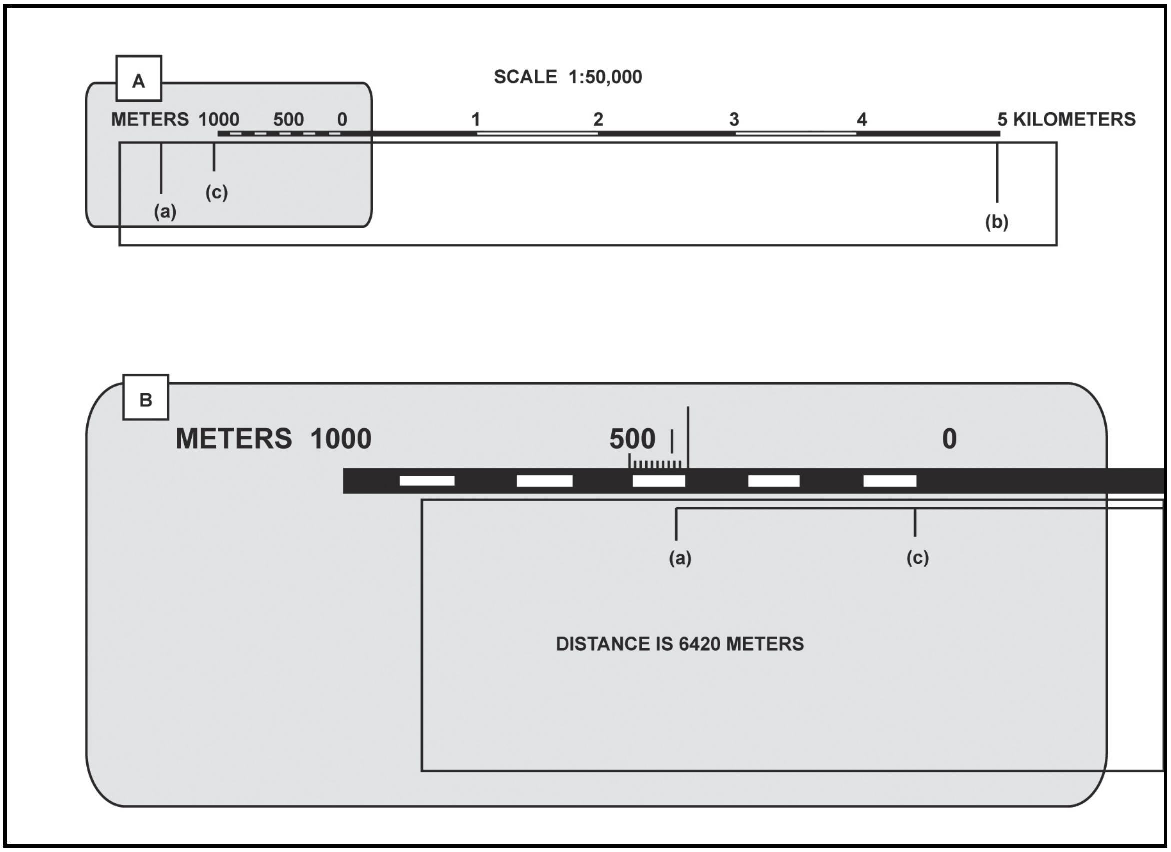


Figure 5-6. Determining the exact distance

- Another technique that may be used to determine exact distance between two points when the edge of the paper exceeds the bar scale is to slide the edge of the paper to the right until tick mark (a) is aligned with the edge of the extension scale. Make a tick mark on the paper, in line with the 2000-m mark (c). (See A, Figure 5-7.) Then slide the edge of the paper to the left until tick mark (b) is aligned with the zero. Estimate the 100-m increments into 10-m increments to determine how many meters tick mark (c) is from the zero line. (See B, Figure 5-7.) The total distance is 3030 m.
- At times it's necessary to know the distance from a point on the map to a point off the map. In order to do this, measure the distance from the start point to the edge of the map. The marginal notes give the road distance from the edge of the map to some towns, highways, or junctions off the map. To determine the total distance, add the distance measured on the map to the distance given in the marginal notes. Be sure the unit of measure is the same.
- When measuring distance in statute or nautical miles, round it off to the nearest one-tenth of a mile and make sure the appropriate bar scale is used.
- Distance measured on a map does not take into consideration the rise and fall of the land. All distances measured by using the map and graphic scales are flat distances. Therefore, the distance measured on a map increases when actually measured on the ground. This is taken into consideration when navigating across land.

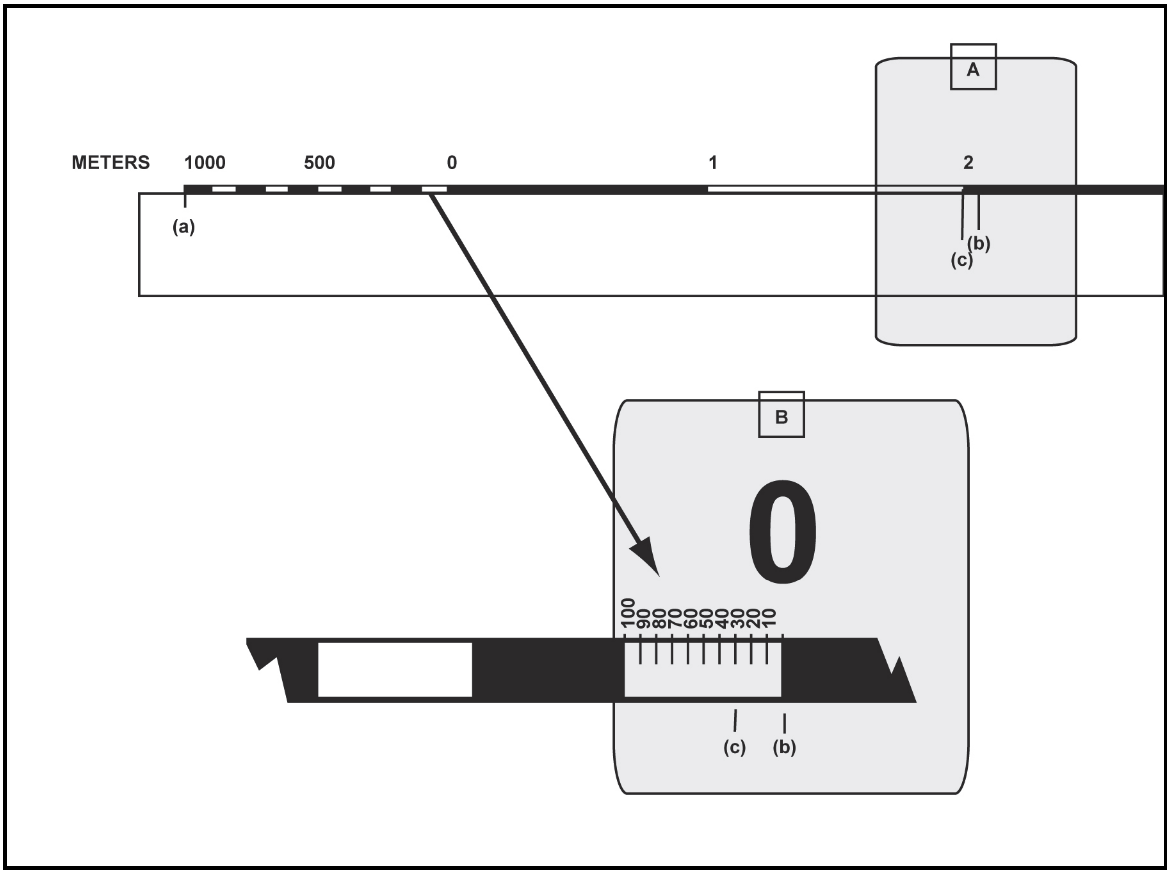


Figure 5-7. Reading the extension scale

5-16. The amount of time required to travel a certain distance on the ground is an important factor in most military operations. This can be determined if a map of the area is available and a graphic time-distance scale is constructed for use with the map as follows:

R = Rate of travel (speed)

T = Time

D = Distance (ground distance)

$$\mathbf{T = \frac{D}{R}}$$

5-17. For example, if an Infantry unit is marching at an average rate (R) of 4 kilometers per hour (kph), it takes about 3 hours of time (T) to travel the distance (D) of 12 km.

$$\mathbf{\frac{12\ (D)}{4\ (R)} = 3\ (T)}$$

5-18. To construct a time-distance scale (see A, Figure 5-8), knowing the length of march, rate of speed, and map scale (that is, 12 km at 3 km per hour on a 1:50,000-scale map), use the following process:

- Mark off the total distance on a line by referring to the graphic scale of the map or, if this is impracticable, compute the length of the line as follows:
  - Convert the ground distance to centimeters: 12 km X 100,000 (cm per km) = 1,200,000 cm.
  - Find the length of the line to represent the distance at map scale.

$$\mathbf{MD = \frac{1}{50} = \frac{1{,}200{,}000}{50{,}000} = 24\ cm}$$

- Construct a line 24 cm in length. (See A, Figure 5-8.)
  - Divide the line into equal increments of time corresponding to the rate of march. In this example, 1 hour increments representing the distance traveled in one hour (see B, Figure 5-8), and label.
  - Divide the scale extension (left portion) into the desired number of lesser time divisions.

1-minute divisions — 60
5-minute divisions — 12
10-minute divisions — 6

  - Section C, Figure 5-8, shows a 5-minute interval scale. Make these divisions in the same manner as for a graphic scale. The completed scale makes it possible to determine where the unit is located at any given time. However, it must be remembered that this scale is for one specific rate of march: only at 4 kph.

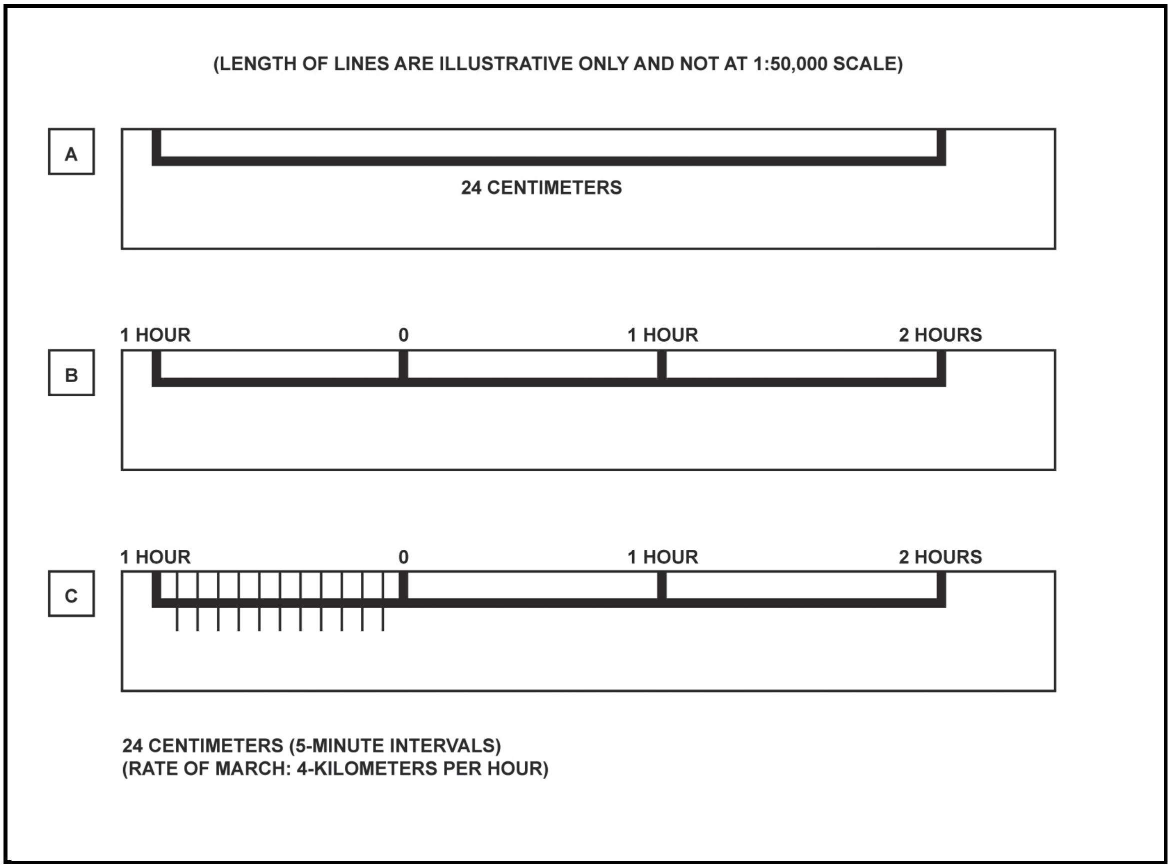


Figure 5-8. Constructing a time-distance scale

OTHER METHODS

5-19. Determining distance is a common source of error encountered while moving, either mounted or dismounted. There may be circumstances when it is not possible to determine distance using a map. It is essential to learn methods to accurately pace, measure, use subtense, or estimate distances on the ground.

PACE COUNT

5-20. A pace is equal to one natural step, about 30 inches long. To use the pace count method accurately, a Soldier knows how many paces it takes to walk 100 m. To determine this, walk an accurately-measured course and count the number of paces it takes to reach 100 m. (A pace course can be as short as 100 m or as long as 600 m.) The pace course, regardless of length, is on similar terrain as that to be walked over. It does no good to walk a course on flat terrain and then try to use that pace count on hilly terrain. To determine the pace count on a 600-m course, count the paces it takes to walk the 600 m, then divide the total paces by 6. The answer gives the average paces it takes to walk 100 m. It is important that each person who navigates while dismounted knows their pace count.

5-21. Many methods exist to keep track of the distance traveled when using the pace count. Some of these methods are to put a pebble in a pocket every time 100 m have been walked, tie knots in a string, or put marks in a notebook. Do not try to remember the count but always use one of these methods, or design another method.

5-22. Certain conditions affect the pace count in the field. Adjustments should be allowed for conditions such as—

- **Slopes.** A pace lengthens on a down slope and shortens on an upgrade. Keeping this in mind, if it normally takes an individual 120 paces to walk 100 m, the pace count may increase to 130 or more when walking up a slope.
- **Winds.** A head wind shortens the pace and a tail wind increases it.
- **Surfaces.** Sand, gravel, mud, snow, and similar surface materials tend to shorten the pace.
- **Elements.** Falling snow, rain, or ice causes the pace to be reduced in length.
- **Clothing.** Excess clothing and boots with poor traction affect the pace length.
- **Visibility.** Poor visibility such as in fog, rain, or darkness, shortens the pace.

ODOMETER

5-23. Distances can be measured by an odometer, which is standard equipment on most vehicles. Readings are recorded at the start and end of a course, and the difference is the length of the course.

To convert km to miles, multiply the number of km by 0.62.
EXAMPLE: 16 km = 16 x 0.62 = 9.92 miles

To convert miles to km, divide the number of miles by 0.62.
EXAMPLE: 10 miles = 10 divided by 0.62 = 16.12 km

SUBTENSE

5-24. Subtense is based upon a principle of visual perspective—the farther away an object is, the smaller it appears. The subtense method is a fast method for determining distance, and yields accuracy equivalent to that obtained by measuring distance with a premeasured piece of wire. An advantage is that a horizontal distance is obtained indirectly; the distance is computed rather than measured. This allows subtense to be used over terrain where obstacles such as streams, ravines, or steep slopes, may prohibit other methods for determining distance.

5-25. The principle used in determining distance by the subtense method is similar to that used in estimating distance by the mil relation formula. The mil relation formula is based upon the assumption that an angle of 1 mil subtends an arc of 1 m at a distance of 1000 m. The field artillery application of the mil relation formula involves only estimations. It is not accurate enough for survey purposes. However, the subtense method uses precise values with a trigonometric solution. The following two procedures are involved in subtense measurement:

- Establishing a base of known length.
- Measuring the angle of that base by use of the aiming circle.

5-26. The subtense base may be any desired length. However, if a 60-m base, a 2-m bar, or the length of an M16A1 or M16A2 rifle is used, precomputed subtense tables are available. The M16 or 2-m bar is held horizontal and perpendicular to the line of sight by a Soldier facing the aiming circle. The instrument operator sights on one end of the M16 or 2-m bar and measures the horizontal clockwise angle to the other end of the rifle or bar, doing this twice, and averaging the angles. Enter the appropriate subtense table with the mean angle and extract the distance. Accurate distances can be obtained with the M16 out to approximately 150 m, with the 2-m bar out to 250 m, and with the 60-m base out to 1000 m. If a base of another length is desired, a distance can be computed by using the following formula:

Distance = <u>1/2 (base in meters)/</u>
Tan (1/2) (in mils)

ESTIMATION

5-27. At times, because of the tactical situation, it may be necessary to estimate range. The two ways to estimate range or distance are: the 100-m unit-of measure and the flash-to-bang methods.

100-Meter Unit-of-Measure Method

5-28. To use this method, the Soldier visualizes a distance of 100 m on the ground. For ranges up to 500 m, determine the number of 100-m increments between the two objects to measure. Beyond 500 m, the Soldier selects a point halfway to the object(s) and determines the number of 100-m increments to the halfway point, then doubles it to find the range to the object. (See Figure 5-9.)

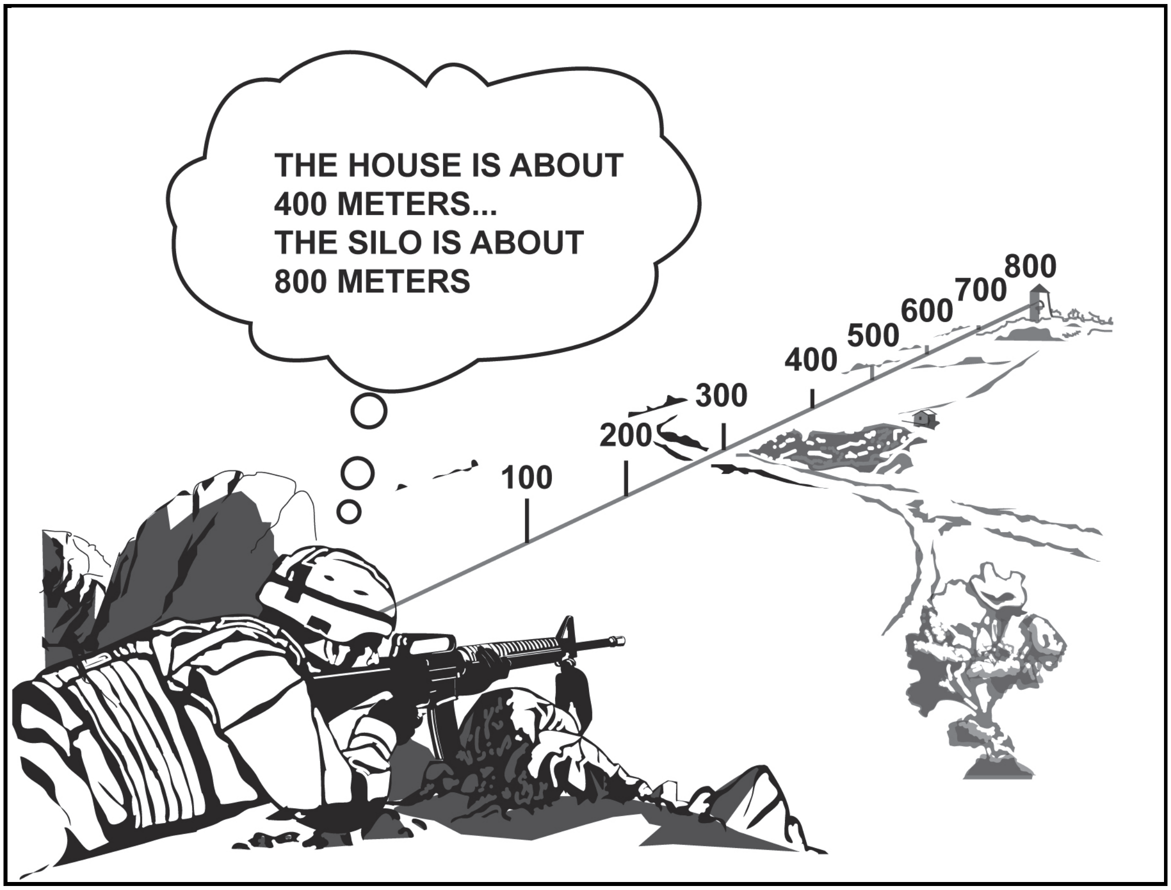


Figure 5-9. Using the 100-meter unit-of-measure method

Flash-to-Bang Method

5-29. To use this method for determining range to an explosion or enemy fire, begin to count when the flash is seen. Count the seconds until weapon fire is heard. This time interval may be measured with a stopwatch or by using a steady count, such as one-thousand-one, one-thousand-two, and so forth, for a three-second estimated count. If there is a count higher than 10 seconds, start over with one. Multiply the number of seconds by 330 m to get the approximate range.

Proficiency of Methods

5-30. The methods discussed above are used only to estimate range. (See Table 5-1.) Proficiency in both methods requires constant practice. The best training technique is requiring the Soldier to pace the range after estimating the distance. In this way, the Soldier personally discovers the actual range, which makes a greater impression than being told the answer.

Table 5-1. Factors of range estimation

Factors Affecting Range Estimation	***Factors Causing Underestimation of Range***	***Factors Causing Overestimation of Range***
Clearness of outline and details of the object.	Most of the object is visible and offers a clear outline.	When only a small part of the object can be seen or the object is small in relation to its surroundings.
Nature of terrain or position of the observer.	Looking across a depression that is mostly hidden from view or downward from high ground. Looking down a straight, open road or along a railroad. Looking over uniform surfaces like water, snow, desert, or grain fields. In bright light or when the sun is shining from behind the observer.	When looking across a depression that is totally visible. When vision is confined, as in streets, draws, or forest trails. When looking from low ground toward high ground. In poor light, such as at dawn or dusk; and in rain, snow, or fog. When the sun is in the observer's eyes.
Light and atmosphere.	When the object is in sharp contrast with the background or is silhouetted because of its size, shape, or color. When seen in the clear air of high altitudes.	When the object blends into the background or terrain.

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Chapter 6

Directions

Being in the right place at the prescribed time is necessary for successfully accomplishing military missions. Direction plays an important role in a Soldier's everyday life. It can be expressed as right, left, straight ahead, and so forth; but then the question arises, "To the right of what?" This chapter defines the word azimuth and the three different norths. It explains in detail how to determine the grid and the magnetic azimuths with the use of the protractor and the compass. It explains the use of some field-expedient methods to find directions, the declination diagram, and the conversion of azimuths from grid to magnetic, and vice versa. It also includes some advanced aspects of map reading such as intersection, resection, modified resection, and polar plots.

METHODS OF EXPRESSING DIRECTION

6-1. Military personnel need a way of expressing direction that is accurate, adaptable to any part of the world, and has a common unit of measure. Directions are expressed as units of angular measure, such as—

- **Degree.** The most common unit of measure is the degree (º) with its subdivisions of minutes (') and seconds ("). (See Chapter 4.)
- **Mil.** Another unit of measure, the mil (abbreviated m/ in graphics), is used mainly in artillery, tank, and mortar gunnery. The mil expresses the size of an angle formed when a circle is divided into 6400 angles, with the vertex of the angles at the center of the circle. A relationship can be established between degrees and mils. A circle equals 6400 mils divided by 360 degrees, or 17.78 mils per degree. To convert degrees to mils, multiply degrees by 17.78.
- **Grad.** The grad is a metric unit of measure found on some foreign maps. There are 400 grads in a circle (a 90-degree right angle equals 100 grads). The grad is divided into 100 centesimal minutes (centigrads) and the minute into 100 centesimal seconds (milligrads).

BASE LINES

6-2. To express direction as a unit of angular measure, there is a starting point or zero measure, and a point of reference. These two points designate the base, or reference line. The three base lines include true north, magnetic north, and grid north. (See Figure 6-1.) The most commonly used base lines are magnetic and grid. To explain further:

- **True north** is defined as a line from a point on the earth's surface to the North Pole. All lines of longitude are true north lines. True north is usually represented by a star.
- **Magnetic north** is the direction to the north magnetic pole, as indicated by the north-seeking needle of a magnetic instrument. The magnetic north is usually symbolized by a line ending with half of an arrowhead. Magnetic readings are obtained with instruments such as the lensatic and M2 compasses. It has been proven that the geomagnetic poles migrate over time. This means that the effect on the declination diagram varies depending on location. The declination diagram for Fort Richardson, Alaska in 1993 was 23° E, but by 2013 it was 18° E—a five degree change. The declination diagram for Fort Benning, Georgia in 1993 was 2° W, but by 2013 it was 4° W—a difference of two degrees. The National Oceanic and Atmospheric Administration (NOAA) provides a magnetic field calculator web site to calculate the declination using the current international geomagnetic reference field model. The website address is: http://www.ngdc.noaa.gov/geomag-web/?id=declinationFormId#declination.

- **Grid north** is established by using the vertical grid lines on the map. Grid north may be symbolized by the letters GN or the letter "y."

CAUTION

Check the map for the date; see Chapter 3 for location of map information. Declination diagrams older than 20 years may provide magnetic readings which are unreliable when converting True or Grid North with the Magnetic North, or the opposite.

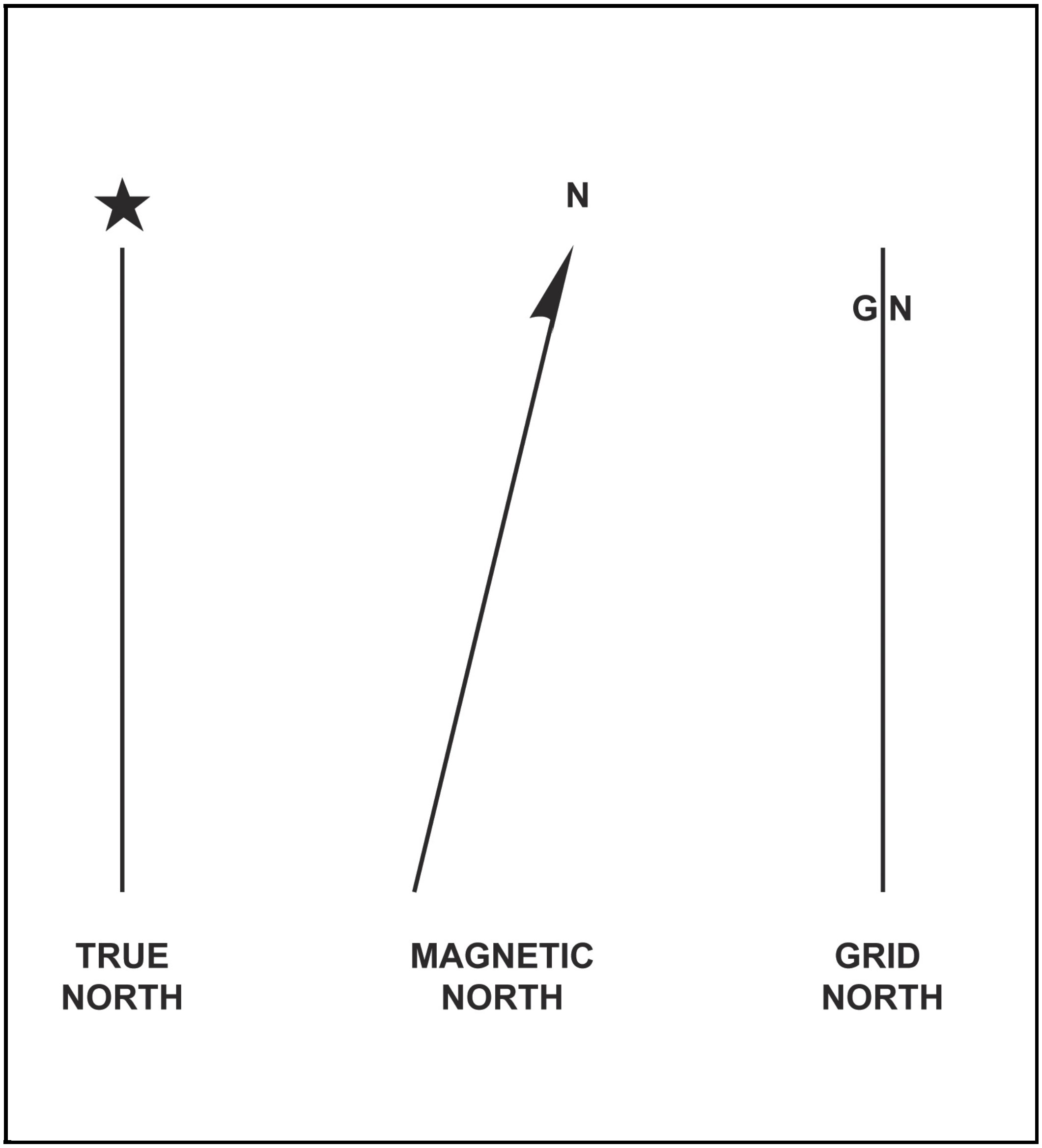

Figure 6-1. Three norths

AZIMUTHS

6-3. An azimuth is defined as a horizontal angle measured clockwise from a north base line. This north base line could be true north, magnetic north, or grid north. The azimuth is the most common military method to express direction. When using an azimuth, the point where the azimuth originates is the center of an imaginary circle. (See Figure 6-2.) This circle is divided into 360 degrees, or 6400 mils. Other azimuths are:

- **Back azimuth**. This is the opposite direction of an azimuth. It is comparable to doing an "about face." To obtain a back azimuth from an azimuth, add 180 degrees if the azimuth is 180 degrees or less; subtract 180 degrees if the azimuth is 180 degrees or more. (See Figure 6-3.) The back azimuth of 180 degrees may be stated as 0 degrees or 360 degrees. For mils, if the azimuth is less than 3200 mils, add 3200 mils; if the azimuth is more than 3200 mils, subtract 3200 mils.

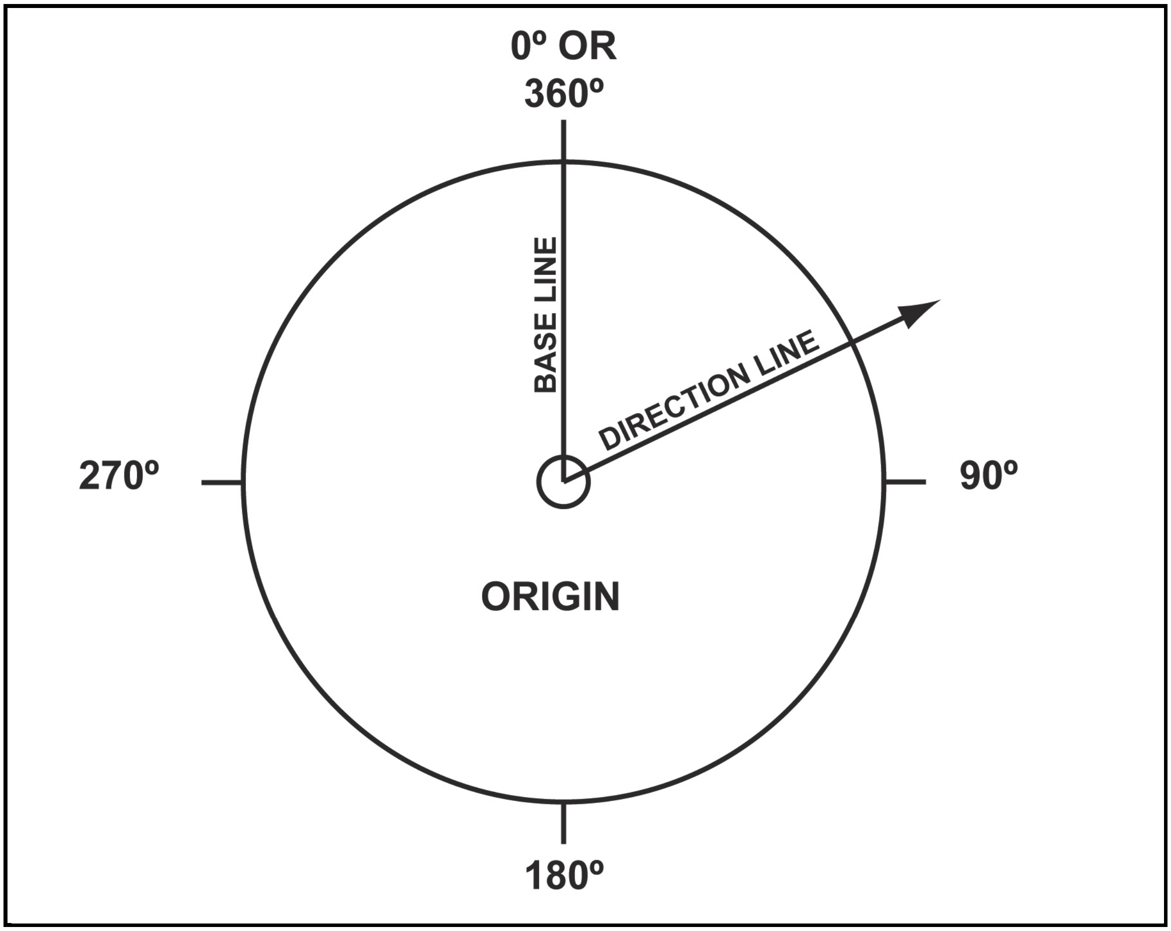

Figure 6-2. Origin of azimuth circle

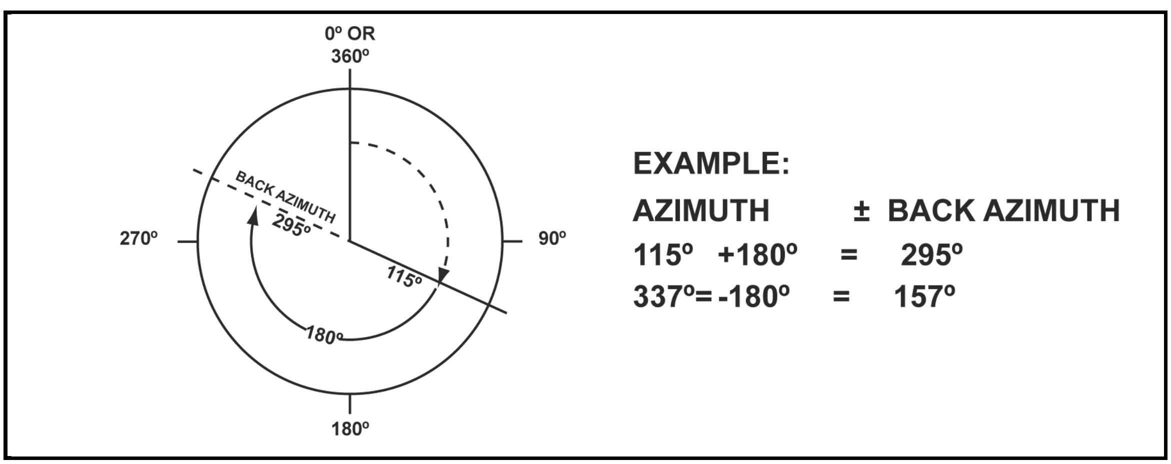

Figure 6-3. Back azimuth calculation with azimuth less than 180 degrees

WARNING

When converting azimuths into back azimuths, extreme care should be exercised when adding or subtracting the 180 degrees. A simple mathematical mistake could cause disastrous consequences.

- **Magnetic azimuth.** This is determined by using magnetic instruments such as lensatic and M2 compasses.
- **Field-expedient methods**. Several field-expedient methods to determine direction are discussed in Chapter 8.

GRID AZIMUTHS

6-4. When an azimuth is plotted on a map between point A (starting point) and point B (ending point), the points are joined by a straight line. A protractor is used to measure the angle between grid north and the drawn line, and this measured azimuth is the grid azimuth. (See Figure 6-4. The example given represents 99 degrees.)

WARNING

When measuring azimuths on a map, remember to measure from a starting point to an ending point. If a mistake is made and the reading is taken from the ending point, the grid azimuth is opposite, causing the user to go in the wrong direction.

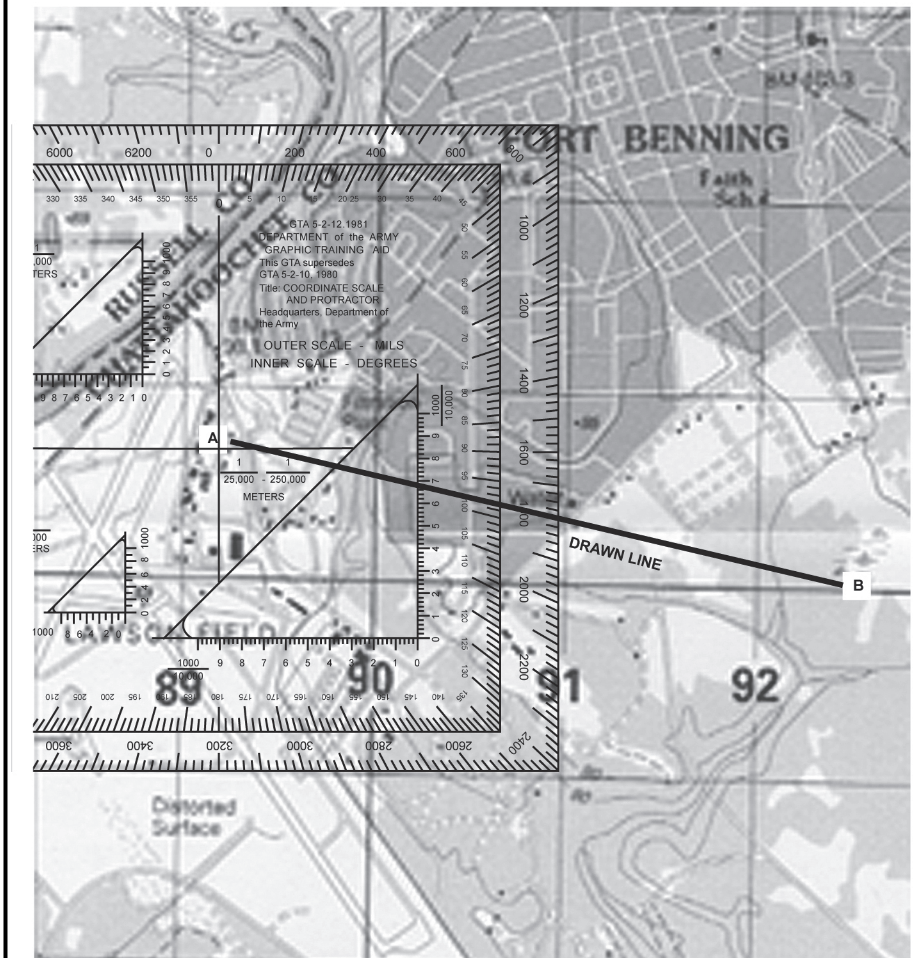

Figure 6-4. Measuring an azimuth

PROTRACTOR

6-5. The various types of protractors include: full circle, half circle, square, and rectangular. (See Figure 6-5.) All of them divide the circle into units of angular measure, and have a scale around the outer edge and an index mark. The index mark is the center of the protractor circle from which all directions are measured.

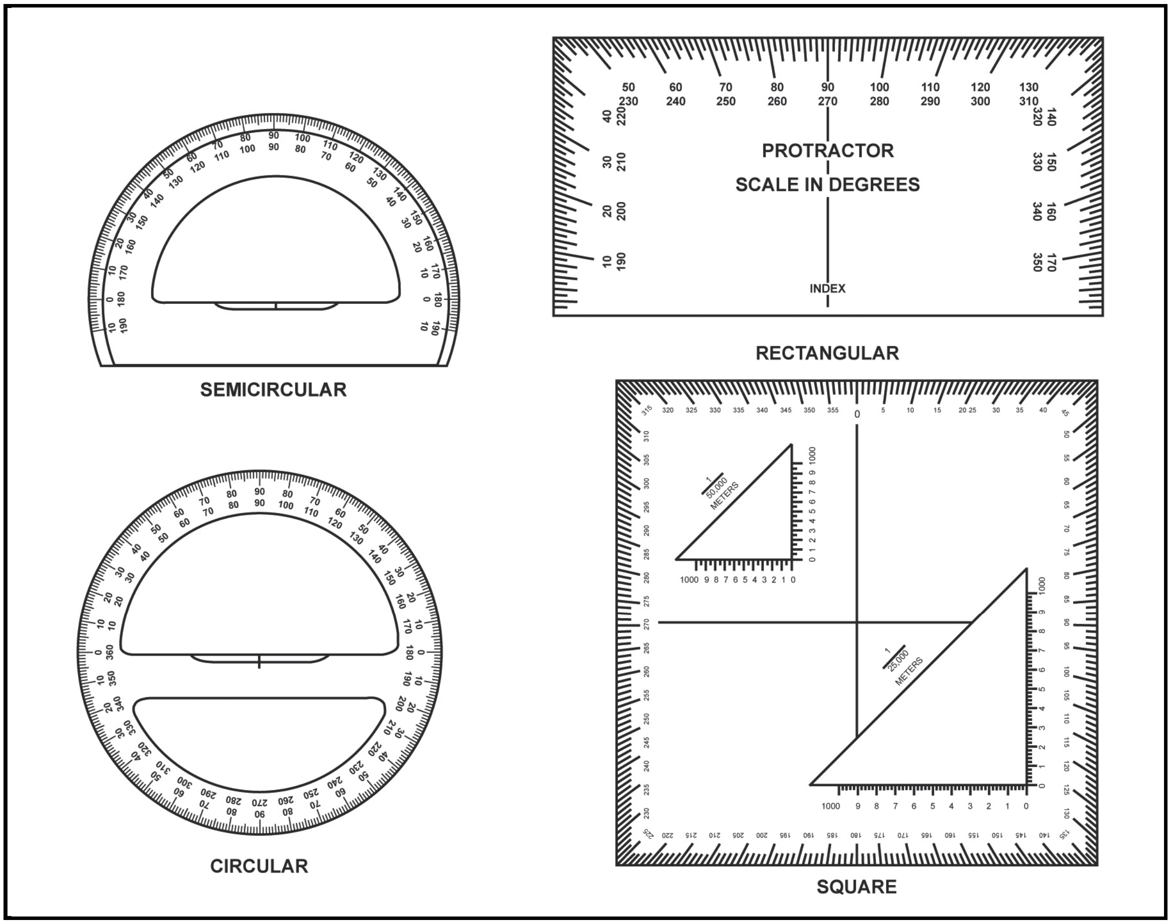

Figure 6-5. Types of protractors

6-6. The military protractor, GTA 5-2-12, contains two scales: one in degrees (inner scale) and one in mils (outer scale). This protractor represents the azimuth circle. The degree scale is graduated from 0 to 360 degrees, with each tick mark representing one degree. A line from 0 to 180 degrees is called the base line of the protractor. The index (or center) of the protractor is where the base line intersects the horizontal line, between 90 and 270 degrees. (See Figure 6-6.)

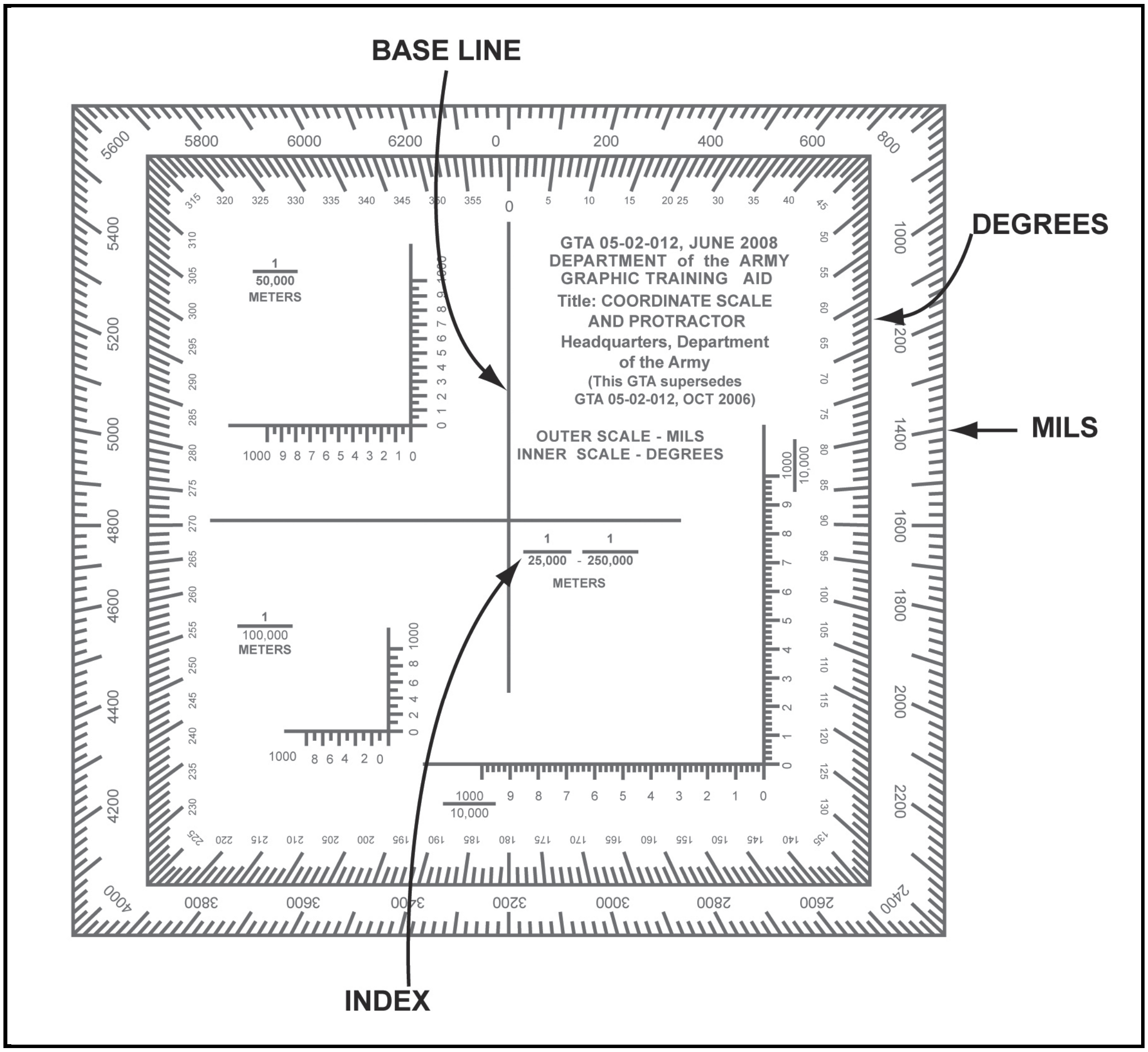

Figure 6-6. Military protractor

6-7. When using the protractor, the base line is always oriented parallel to a north-south grid line. The 0- or 360-degree mark is always toward the top or north on the map and the 90-degree mark is to the right. To determine the grid azimuth:

- Draw a line connecting the two points (A and B).
- Place the index of the protractor at the point where the drawn line crosses a vertical (north-south) grid line.
- Keeping the index at this point, align the 0- to 180-degree line of the protractor on the vertical grid line.
- Read the value of the angle from the scale; this is the grid azimuth from point A to point B. (See Figure 6-4.)

6-8. Figure 6-7 shows how to plot an azimuth from a known point on a map:

- Convert the azimuth from magnetic to grid, if necessary.

- Place the protractor on the map with the index mark at the center of mass of the known point, and the base line parallel to a north-south grid line.
- Make a mark on the map at the desired azimuth.
- Remove the protractor and draw a line connecting the known point and the mark on the map. This is the grid direction line (azimuth).

Note. When measuring an azimuth, the reading is always to the nearest degree or 10 mils. Distance does not change an accurately measured azimuth.

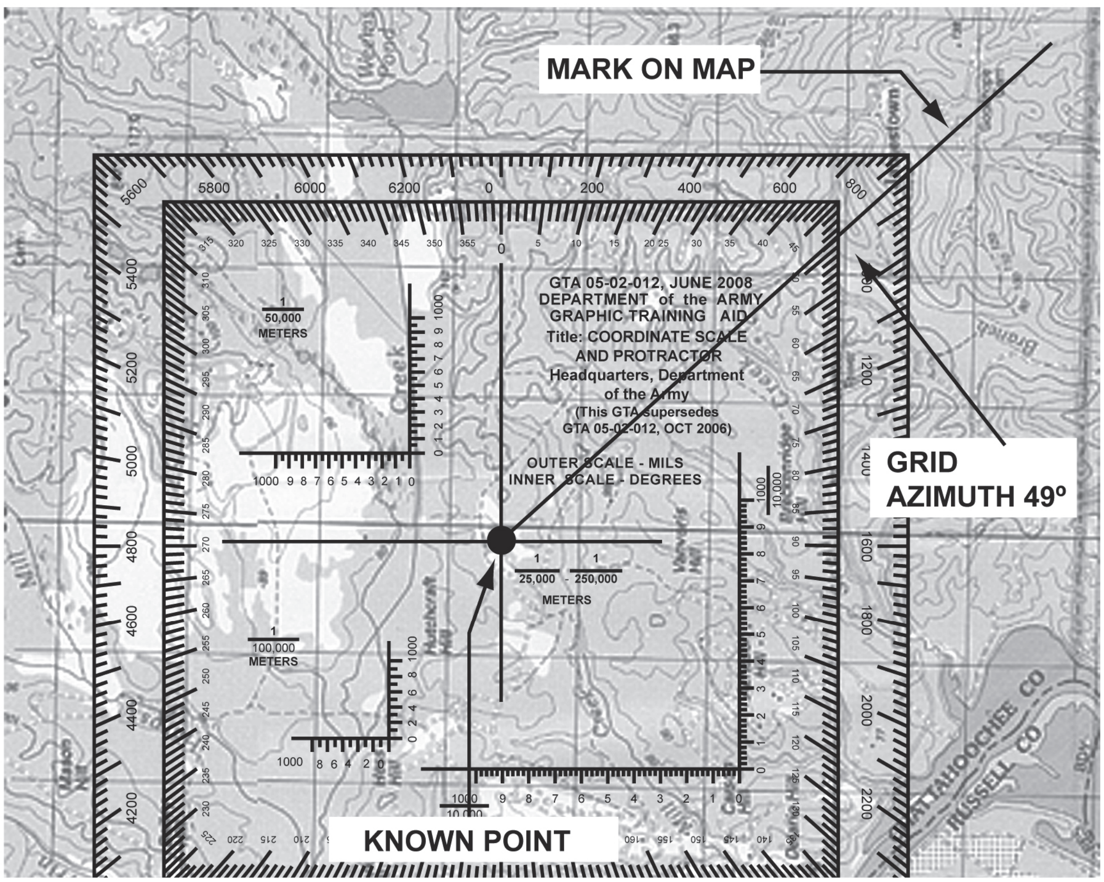

Figure 6-7. Plotting an azimuth on the map

6-9. To obtain an accurate reading with the protractor (to the nearest degree or 10 mils), there are two techniques to check that the base line of the protractor is parallel to a north-south grid line:

- Place the protractor index where the azimuth line cuts a north-south grid line, aligning the base line of the protractor directly over the intersection of the azimuth line with the north-south grid line. The user should be able to determine whether the initial azimuth reading was correct. The user should re-read the azimuth between the azimuth and north-south grid line to check the initial azimuth.
- Note that the protractor is cut at both the top and bottom by the same north-south grid line. Count the number of degrees from the 0-degree mark at the top of the protractor to this

north-south grid line and then count the number of degrees from the 180-degree mark at the bottom of the protractor to this same grid line. If the two counts are equal, the protractor is properly aligned.

DECLINATION DIAGRAM

6-10. Declination is the angular difference between two norths. Having a map and a compass, the declination of most interest is between magnetic and grid north. Soldiers primarily receive information based on a magnetic north or grid north azimuth. The declination diagram shows the angular relationship, represented by prongs among the grid, magnetic, and true norths. While the relative positions of the prongs are correct, they are seldom plotted to scale. Do not use the diagram to measure a numerical value. This value is written in the map margin (in degrees and mils) beside the diagram.

Note. Magnetic azimuths are generally used by Soldiers while navigating with a compass or dead reckoning (land navigation). The grid azimuth is generally used by planners and leaders when writing orders, controlling movement, or looking at graphic control measures.

6-11. A declination diagram is part of the information in the lower margin on most larger maps. On medium-scale maps, the declination information is shown by a note in the map margin. Other map information includes:

- **Grid-magnetic (G-M) angle.** The G-M angle value is the angular size that exists between grid north and magnetic north. It is an arc, indicated by a dashed line that connects the grid-north and magnetic-north prongs. This value is expressed to the nearest 1/2 degree, with mil equivalents shown to the nearest 10 mils. The G-M angle is important to the map reader/land navigator because azimuths translated between the map and ground are in error by the size of the declination angle, if not adjusted for it.
- **Grid convergence**. An arc indicated by a dashed line connects the prongs for true north and grid north. The value of the angle for the center of the sheet is given to the nearest full minute, with its equivalent to the nearest mil. These data are shown in the form of a grid-convergence note.
- **Conversion.** There is an angular difference between the grid north and the magnetic north. Since the location of magnetic north does not correspond exactly with the grid-north lines on the maps, a conversion from magnetic to grid or vice versa is needed.

CAUTION

Declination diagrams older than 20 years may provide magnetic readings which are unreliable when converting True or Grid North with a Magnetic North, or the opposite.

NOTES

6-12. When notes are furnished, simply refer to the conversion notes that appear in conjunction with the diagram explaining the use of the G-M angle. One note provides instructions for converting magnetic azimuth to grid azimuth; the other, for converting grid azimuth to magnetic azimuth. The conversion (add or subtract) is governed by the direction of the magnetic-north prong relative to that of the grid-north prong.

CONVERSION OF GRID AND MAGNETIC AZIMUTHS

6-13. A magnetic compass gives a magnetic azimuth, but in order to plot this line on a gridded map, the magnetic azimuth value is changed to grid azimuth. The opposite process is done for converting a grid azimuth to a magnetic azimuth. The declination diagram is used for these conversions.

6-14. Conversion of grid azimuths to magnetic azimuths and vice versa, depend on whether one is converting easterly or westerly G-M angles, the degree of declination change, and whether one is going from a magnetic azimuth to grid azimuth, or the opposite. (See Figure 6-8 and Table 6-1.) To do this—

- From an easterly magnetic azimuth to grid azimuth, one would add. To go from a grid azimuth to magnetic azimuth, one would subtract. (See Table 6-1.)
- From a westerly magnetic azimuth to a grid azimuth, one would subtract. To go from a grid azimuth to a magnetic azimuth, one would add. (See Table 6-1.)

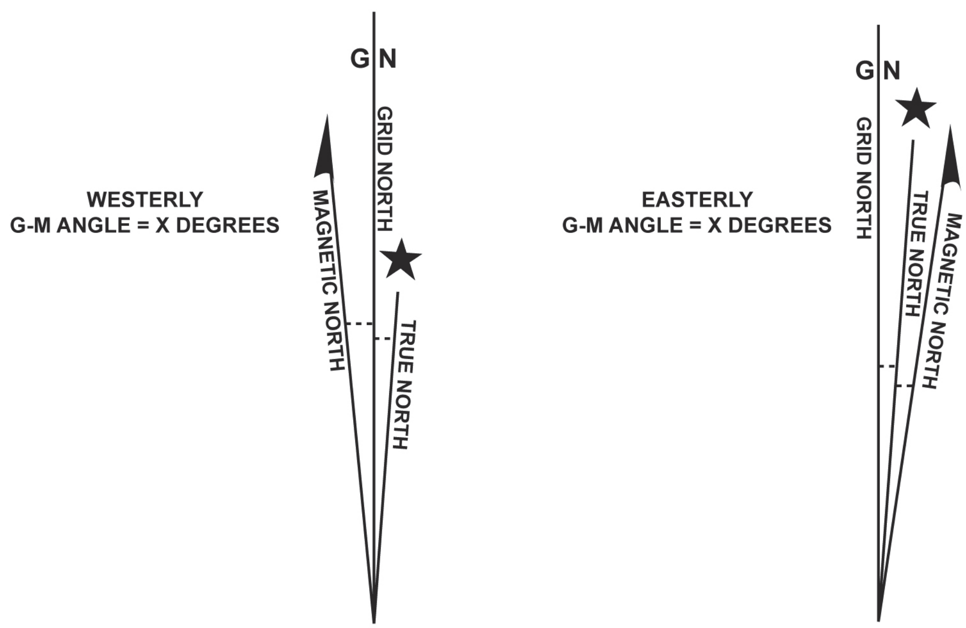

Figure 6-8. Declination diagrams

6-15. There are no negative azimuths on the azimuth circle. Since 0 degree is the same as 360 degrees, then 2 degrees is the same as 362 degrees. This is because 2 degrees and 362 degrees are located at the same point on the azimuth circle. The grid azimuth can now be converted into a magnetic azimuth because the grid azimuth is now larger than the G-M angle. (See Table 6-1.)

Table 6-1 Declination Conversion

	Westerly G-M Angle		Easterly G-M Angle	
Grid azimuth to magnetic azimuth	**ADD**		**SUBTRACT**	
Example	14° G-M Angle West		17° G-M Angle East	
	Grid azimuth	93°	Grid azimuth	303°
	G-M angle (add)	+14°	G-M angle (subtract)	-17°
	Magnetic azimuth	=107°	Magnetic azimuth	=286°
Magnetic azimuth to grid azimuth	**SUBTRACT**		**ADD**	
Example	5° G-M Angle West		12° G-M Angle East	
	Magnetic azimuth	65°	Magnetic azimuth	210°
	G-M angle (subtract)	-5°	G-M angle (subtract)	+12°
	Grid azimuth	=60°	Grid azimuth	=222°
Convert azimuths with angles greater than 360°	Given azimuth		357°	
	Angle of change		+18°	
	Converted azimuth		375°	
	360° subtraction		-360°	
	Desired azimuth		=15°	
Convert azimuths with angles less than 0°	Given azimuth		5°	
	Angle of change		-12°	
	Converted azimuth		-7°	
	360° subtraction		+360°	
	Desired azimuth		=353°	

6-16. The G-M angle diagram should be used each time the conversion of azimuth is required. This procedure is important when working with a map for the first time

Note. When converting azimuths, exercise extreme care when adding and subtracting the G-M angle. A simple mistake of 1 degree could be significant in the field.

INTERSECTION

6-17. Intersection is the location of an unknown point by successively occupying at least two (preferably three) known positions on the ground, and then map sighting on the unknown location. It is used to locate distant or inaccessible points or objects such as enemy targets and danger areas. There are two methods of intersection—the map and compass method and the straightedge method (see Figures 6-9 and 6-10):

- When using the map and compass method—
  1. Orient the map using the compass.
  2. Locate and mark the position on the map,
  3. Determine the magnetic azimuth to the unknown position using the compass.
  4. Convert the magnetic azimuth to grid azimuth.
  5. Draw a line on the map from the position on this grid azimuth.
  6. Move to a second known point and repeat the steps 1 through 5 above.
  7. The location of the unknown position is where the lines cross on the map. Determine the grid coordinates to the desired accuracy.
- The straightedge method is used when a compass is not available. When using it—
  1. Orient the map on a flat surface by the terrain association method.
  2. From a known position (A). Locate and mark the position on the map.
  3. Lay a straightedge on the map with one end at the user's position (A) as a pivot point; then, rotate the straightedge until the unknown point is sighted along the edge.
  4. Draw a line along the straightedge
  5. Repeat the steps at a second known position (B) and check for accuracy.

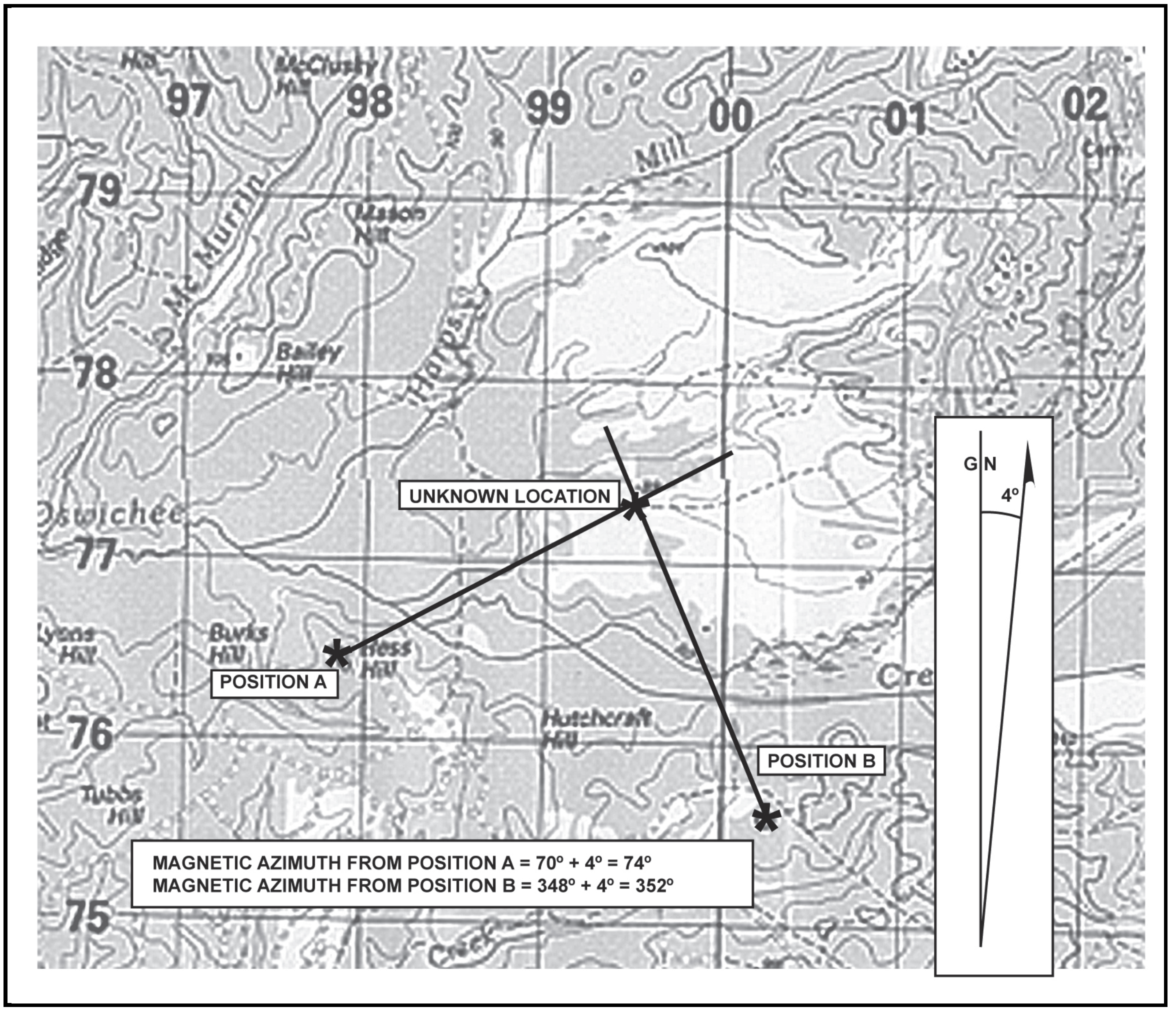

Figure 6-9. Intersection, using map and compass

- The intersection of the lines on the map is the location of the unknown point (C). Determine the grid coordinates to the desired accuracy. (See Figure 6-10.)

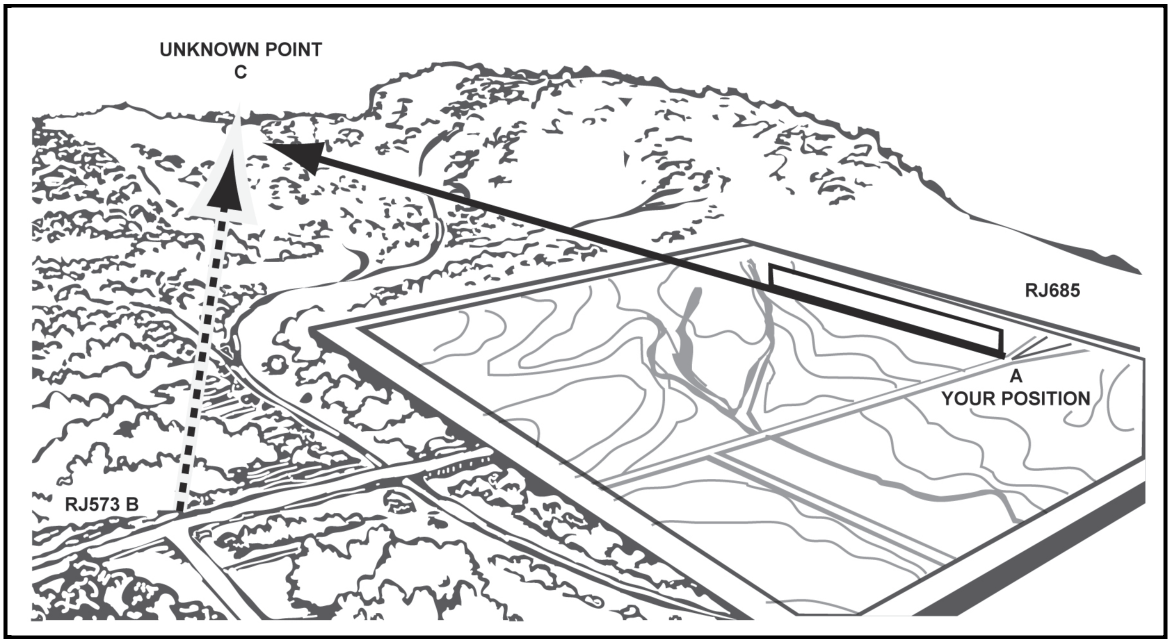

Figure 6-10. Intersection, using a straightedge

RESECTION

6-18. Resection is the method of locating one's position on a map by determining the grid azimuth to at least two well-defined locations that can be pinpointed on the map. For greater accuracy, the desired method of resection is to use three or more well-defined locations.

6-19. When using the map and compass method (see Figure 6-11)—

- Orient the map using the compass.
- Identify two or three known distant locations on the ground and mark them on the map.
- Measure the magnetic azimuth to one of the known positions from the location using a compass.
- Convert the magnetic azimuth to a grid azimuth.
- Convert the grid azimuth to a back azimuth. Using a protractor, draw a line for the back azimuth on the map from the known position back toward the unknown position.
- Measure and convert the magnetic azimuth to a grid azimuth, and convert the grid azimuth to a back azimuth for a second position (and a third position, if desired).
- The intersection of the lines is the location. Determine the grid coordinates to the desired accuracy.

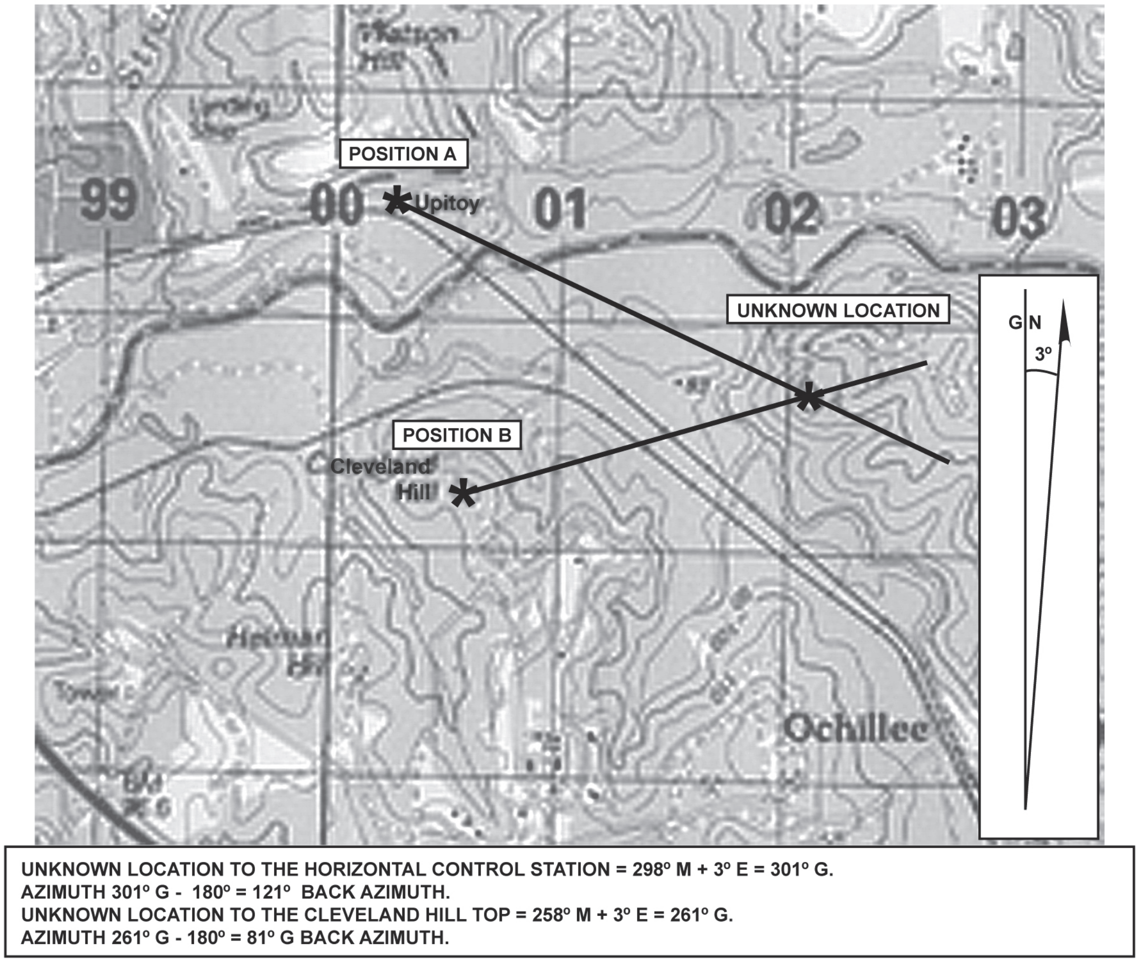

Figure 6-11. Resection with map and compass

6-20. When using the straightedge method (see Figure 6-12)—

- Orient the map on a flat surface by the terrain association method.
- Locate at least two known distant locations or prominent features on the ground and mark them on the map.
- Lay a straightedge on the map using a known position as a pivot point. Rotate the straightedge until the known position on the map is aligned with the known position on the ground.
- Draw a line along the straightedge away from the known position on the ground toward the position.
- Lay a straightedge on the map and draw a line using a second known position.
- The intersection of the lines on the map is the location. Determine the grid coordinates to the desired accuracy.

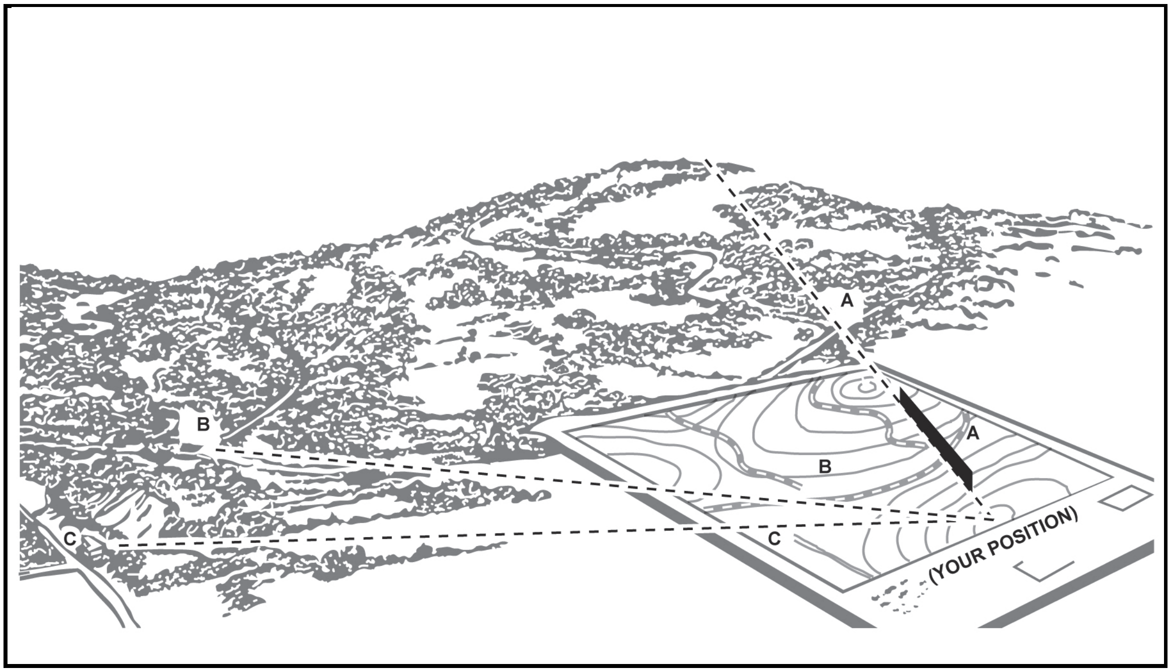

Figure 6-12. Resection with straightedge

MODIFIED RESECTION

6-21. Modified resection is the method of locating one's position on the map when the person is located on a linear feature on the ground, such as a road, canal, or stream. (See Figure 6-13.) Proceed as follows:

- Orient the map using a compass or by terrain association.
- Find a distant point that can be identified on the ground and on the map.
- Determine the magnetic azimuth from the location to the distant known point.
- Convert the magnetic azimuth to a grid azimuth.
- Convert the grid azimuth to a back azimuth. Using a protractor, draw a line for the back azimuth on the map from the known position back toward the unknown position.
- The location of the user is where the line crosses the linear feature. Determine the grid coordinates to the desired accuracy.

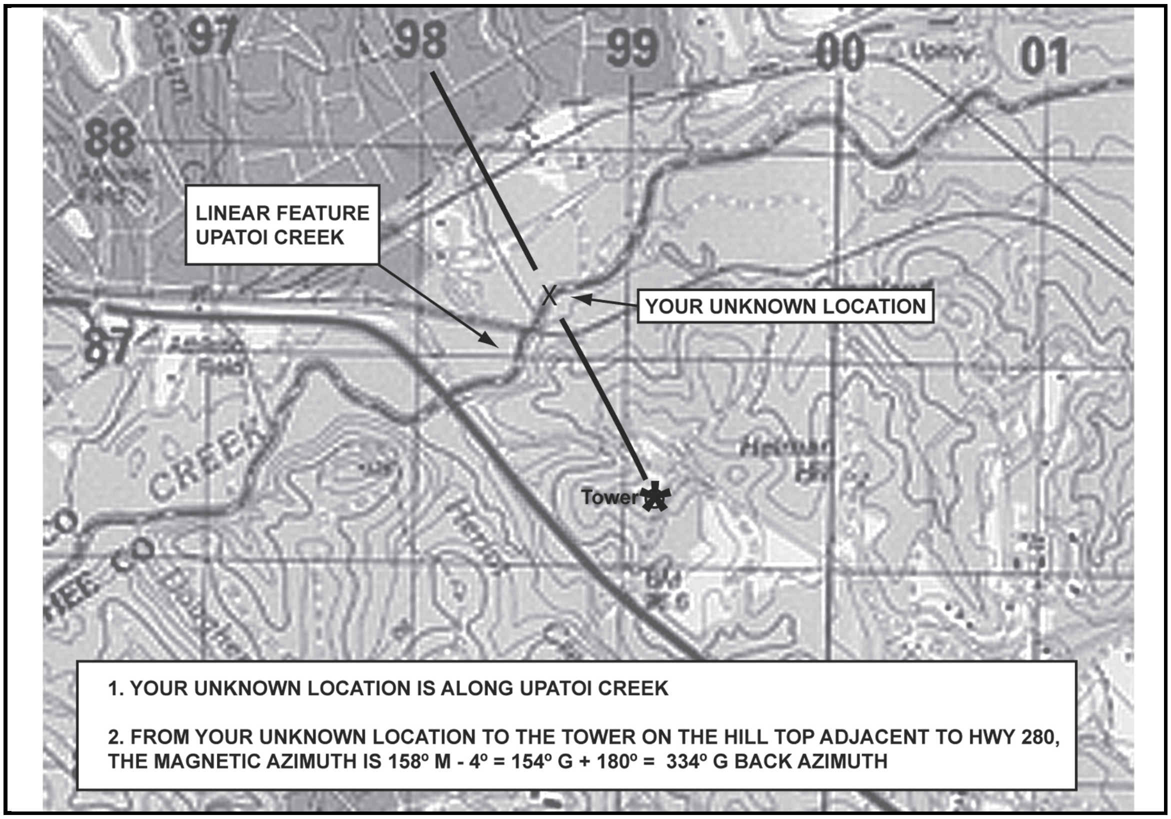

Figure 6-13. Modified resection

POLAR PLOT

6-22. A method of locating or plotting an unknown position from a known point by giving a direction and a distance along that direction line is called polar plot. The following elements are present when using polar plot (see Figure 6-14):

- Present known location on the map.
- Azimuth (grid or magnetic).
- Distance (in meters).

6-23. Using the laser range finder to determine the range enhances accuracy in determining the unknown position's location.

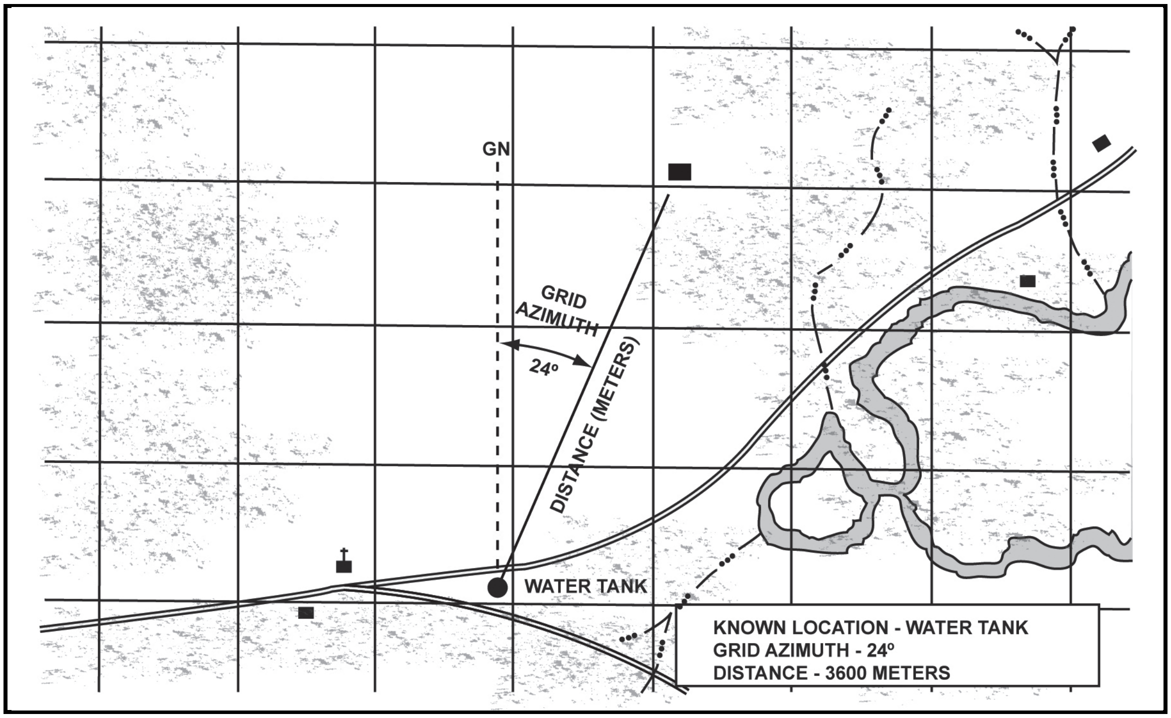

Figure 6-14. Polar plot

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Chapter 7

Overlays

An overlay is a clear sheet of plastic or semitransparent paper. It is used to display supplemental map and tactical information related to military operations. It is often used as a supplement to orders given in the field. Information is plotted on the overlay at the same scale as on the map, or any other graphic being used. When the overlay is placed over the graphic, the details plotted on the overlay are shown in their true position.

PURPOSE

7-1. Overlays are used to display military operations with enemy and friendly troop dispositions, and as supplements to orders sent to the field. They show detail that aid in understanding the orders, displays of communication networks, and other important information. Because overlays can clarify matters that are difficult to explain clearly in writing, they are also used as annexes to reports made in the field.

MAP OVERLAY

7-2. The three steps in making a map overlay are: orienting the overlay material, plotting and symbolizing the detail, and adding the required marginal information. (See Figure 7-1.)

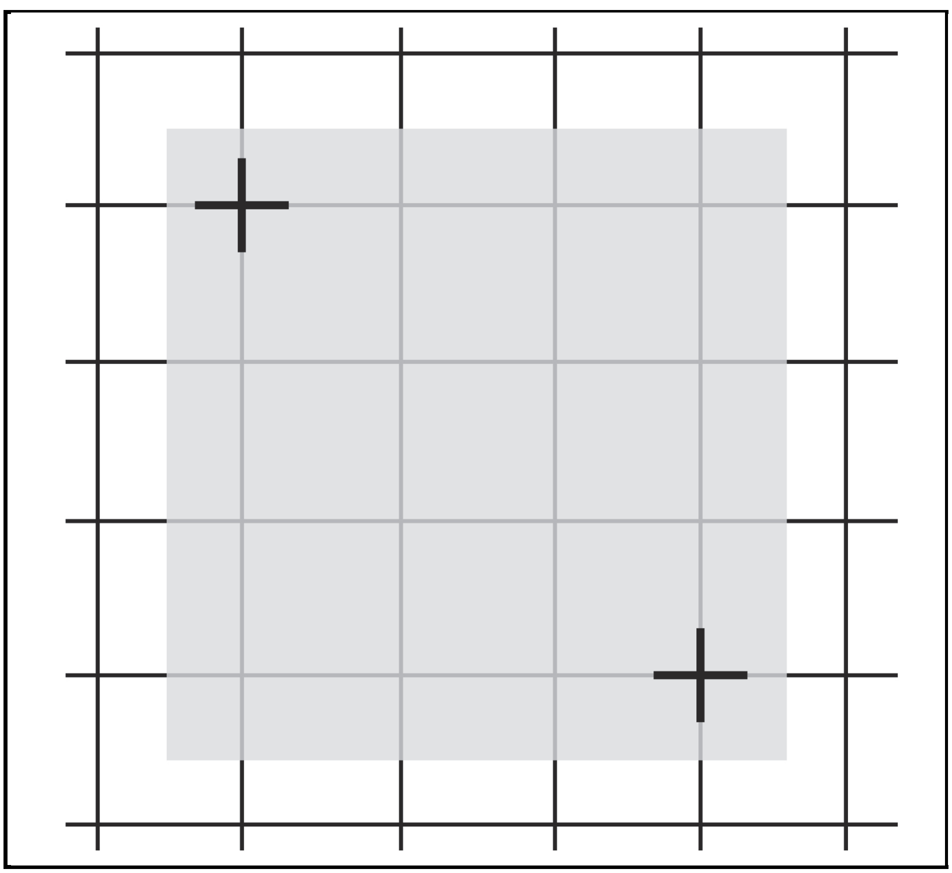

Figure 7-1. Orienting the overlay

7-3. Orient the overlay over the place on the map to be annotated. Then, if possible, attach it to the edges of the map with tape. Trace the grid intersections nearest the two opposite corners of the overlay using a straightedge, and label each with the proper grid coordinates. These register marks show exactly where the overlay fits on the map. Without them, the overlay is difficult to orient.

7-4. It is imperative that absolute accuracy be maintained in plotting the register marks, as the smallest mistake throws off the overlay. When creating an overlay, keep the following considerations in mind:

- To plot detail, use pencils or markers in standard colors that make a lasting mark without cutting the overlay. (Refer to FM 1-02 for more information.)
- Use standard topographic or military symbols where possible. Nonstandard symbols invented by the author are identified in a legend on the overlay. Depending on the conditions under which the overlay is made, it may be advisable to plot the positions first on the map, and then trace them onto the overlay. Since the overlay is to be used as a supplement to orders or reports and the recipient has an identical map, show only the detail that directly concerns the report.
- If observed topographic or cultural features are not shown on the map, such as a new road or a destroyed bridge, plot their positions as accurately as possible on the overlay and mark with the standard topographic symbol.
- If difficulty in seeing through the overlay material is encountered while plotting or tracing detail, lift the overlay from time to time to check the orientation of information being added in reference to the base.

7-5. When all required detail has been plotted or traced on the overlay, print information as close to the lower right-hand corner as detail permits. (See Figure 7-2.) This information includes the following data:

- **Title and objective.** This tells the reader why the overlay was made and may also give the actual location. For example, “Road reconnaissance” is not as specific as “Route 146 road reconnaissance.”
- **Time and date**. Any overlay should contain the latest possible information. An overlay received in time is valuable to the planning staff and may affect the entire situation; an overlay that has been delayed may be of little use. Therefore, the exact time the information was obtained aids the recipients in determining its reliability and usefulness.
- **Map reference**. The sheet name, sheet number, map series number, and scale are included. If the reader does not have the same map that was used to construct the overlay, this information provides the information necessary to obtain the appropriate map.
- **Author**. The name, rank, and organization of the author, supplemented with a date and time of preparation of the overlay, lets the reader know if there is a time difference between when the information was obtained and when it was reported.
- **Legend**. If it is necessary to invent nonstandard symbols to show the required information, the legend shows what these symbols mean.
- **Security classification**. This corresponds to the highest classification of the map or the information placed on the overlay. This is also stated if the information and map are unclassified. The locations of the classification notes are shown in Figure 7-2, and the notes appear in both locations as shown.
- **Additional information**. Any other information that amplifies the overlay is also included. Make it as brief as possible.

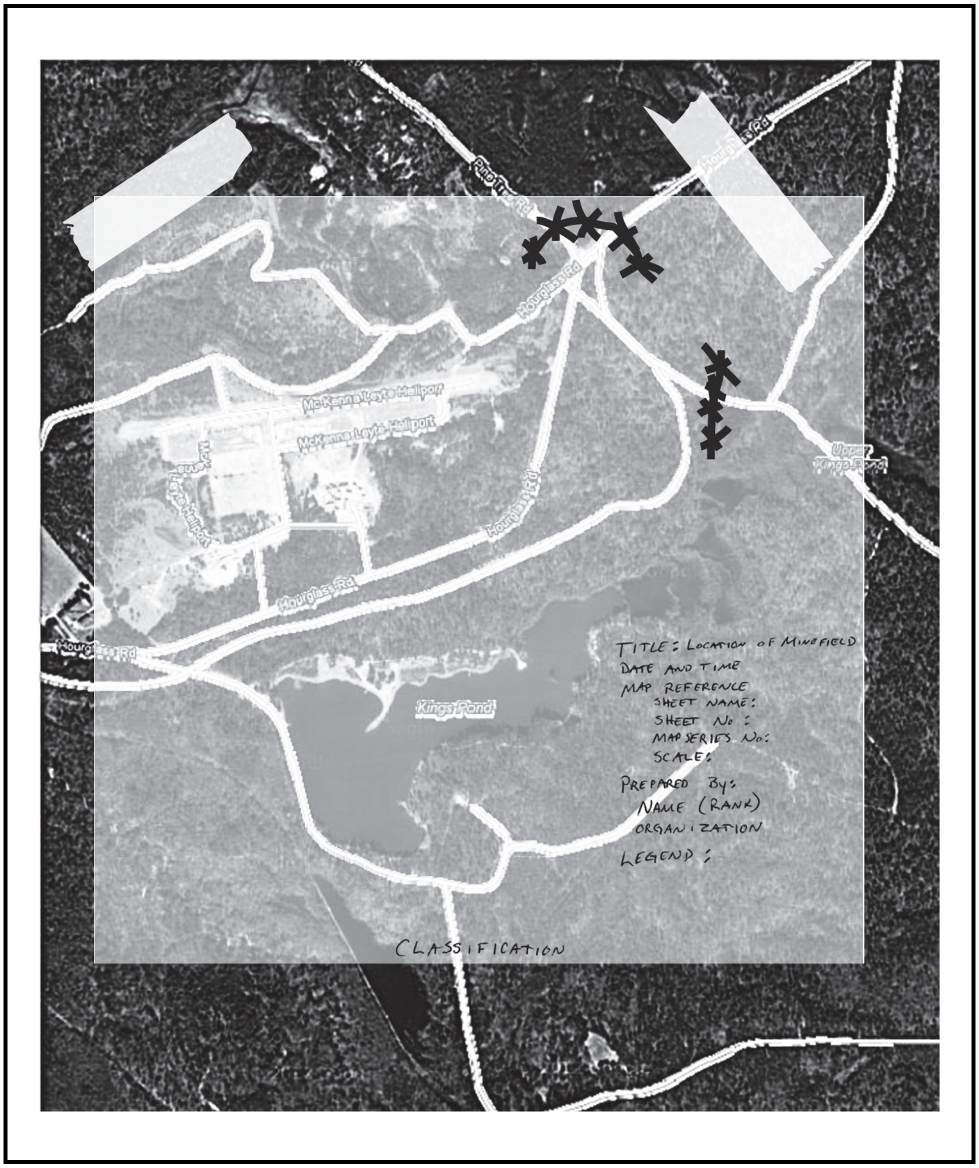

Figure 7-2. Map overlay with marginal information

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PART TWO

Land Navigation

Chapter 8

Navigation Equipment and Methods

Compasses and GPS devices are the primary navigational tools used when moving in an outdoor world. Soldiers should be thoroughly familiar with compasses, GPS devices, and their uses. Part One of this manual discussed the techniques of map reading. To complement these techniques, a mastery of field movement techniques is essential. This chapter describes the lensatic compass and its uses, and some of the field-expedient methods used to find directions.

TYPES OF COMPASSES

8-1. The lensatic compass is the most common and simplest instrument for measuring direction. The artillery M2 compass is a special-purpose instrument designed for accuracy and is discussed in Appendix F. The wrist/pocket compass is a small magnetic compass that can be attached to a wristwatch band. It contains a north-seeking arrow and a dial in degrees. A protractor can determine azimuths when a compass is not available. However, only grid azimuths can be obtained when using the protractor on a map.

LENSATIC COMPASS

8-2. The lensatic compass (see Figure 8-1) consists of three major parts: the cover, base, and lens. The compass cover protects the floating dial. The cover also contains the sighting wire (front sight) and two luminous sighting slots or dots, used for night navigation. The base of the compass contains the following movable parts:

- The floating dial is mounted on a pivot so it can rotate freely when the compass is held level. Printed on the dial in luminous figures are an arrow and the letters E and W. The arrow always points to magnetic north, and the letters fall at E 90 degrees and W 270 degrees on the dial. There are two scales; the outer scale denotes mils and the inner scale (normally in red) denotes degrees.
- Encasing the floating dial is a glass containing a fixed black index line.
- The bezel ring is a ratchet device that clicks when turned. It contains 120 clicks when rotated fully; each click is equal to 3 degrees. A short luminous line that is used in conjunction with the north-seeking arrow during navigation is contained in the glass face of the bezel ring.
- The thumb loop is attached to the base of the compass.
- The lens is used to read the dial and contains the rear-sight slot used in conjunction with the front for sighting on objects. The rear sight also serves as a lock and clamps the dial when closed for its protection. The rear sight is opened more than 45 degrees to allow the dial to float freely.

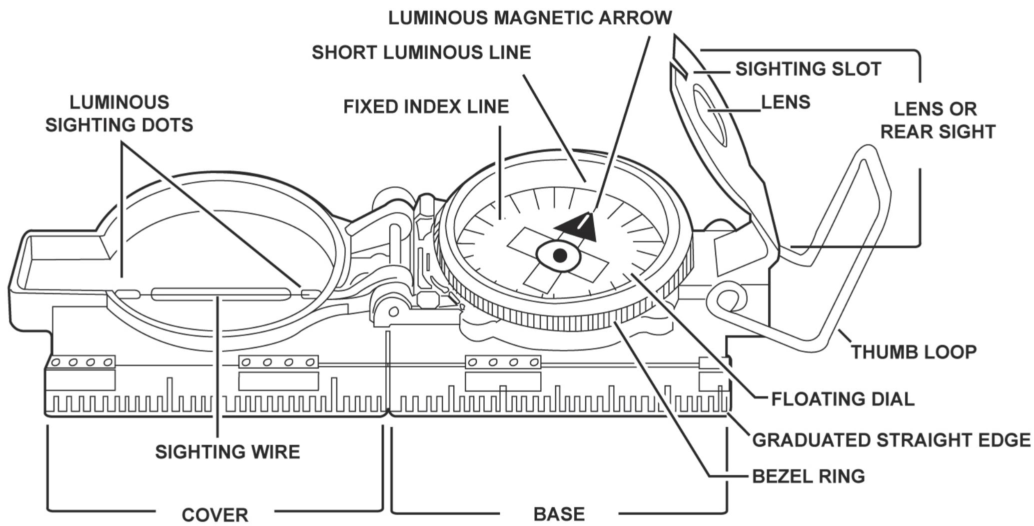

Figure 8-1. Lensatic compass

Note. When opened, the straight edge on the left side of the compass has a 1:50,000 coordinate scale.

WARNING

Some older compasses (pre-1990) have a 1:25,000-scale. This scale can be used with a 1:50,000-scale map, but the values read are divided in half. Check the scale.

COMPASS HANDLING

8-3. Compasses are delicate instruments and should be cared for accordingly. A detailed inspection is required when first obtaining and using a compass. One of the most important parts to check is the floating dial, which contains the magnetic needle. The user also makes sure the sighting wire is straight, the glass and crystal parts are not broken, the numbers on the dial are readable, and that the dial does not stick.

8-4. Metal objects and electrical sources can affect the performance of a compass. However, nonmagnetic metals and alloys do not affect compass readings. The following separation distances are suggested to ensure proper functioning of a compass:

- High-tension power lines...55 m.
- Field gun, truck, or tank...18 m.
- Telegraph or telephone wires and barbed wire........10 m.

8-5. A compass in good working condition is very accurate. However, a compass has to be checked periodically on a known line of direction, such as a surveyed azimuth, using a declination station. Compasses with more than 3 degrees variation should not be used.

8-6. If traveling with the compass unfolded, make sure the rear sight is fully folded down onto the bezel ring. This locks the floating dial, prevents vibration, and protects the crystal and rear sight from damage.

USING A COMPASS

8-7. Magnetic azimuths are determined using magnetic instruments such as lensatic and M2 compasses. Employ the following techniques when using the lensatic compass: centerhold technique and compass-to-cheek technique.

CENTERHOLD TECHNIQUE

8-8. First, open the compass to its fullest so that the cover forms a straightedge with the base. Move the lens (rear sight) to the rearmost position, allowing the dial to float freely. Next, place your thumb through the thumb loop, form a steady base with your third and fourth fingers, and extend your index finger along the side of the compass. Place the thumb of the other hand between the lens (rear sight) and the bezel ring; extend the index finger along the remaining side of the compass, and the remaining fingers around the fingers of the other hand. Pull your elbows firmly into your sides; this places the compass between your chin and your belt.

8-9. To measure an azimuth, simply turn your entire body toward the object, pointing the compass cover directly at the object. Once you are pointing at the object, look down and read the azimuth from beneath the fixed black index line. (See Figure 8-2.) This preferred method offers the following advantages over the sighting technique:

- It is faster and easier to use.
- It can be used under all conditions of visibility.
- It can be used when navigating over all types of terrain.
- It can be used without putting down the rifle. However, the rifle is slung well back over either shoulder.
- It can be used without removing eyeglasses.

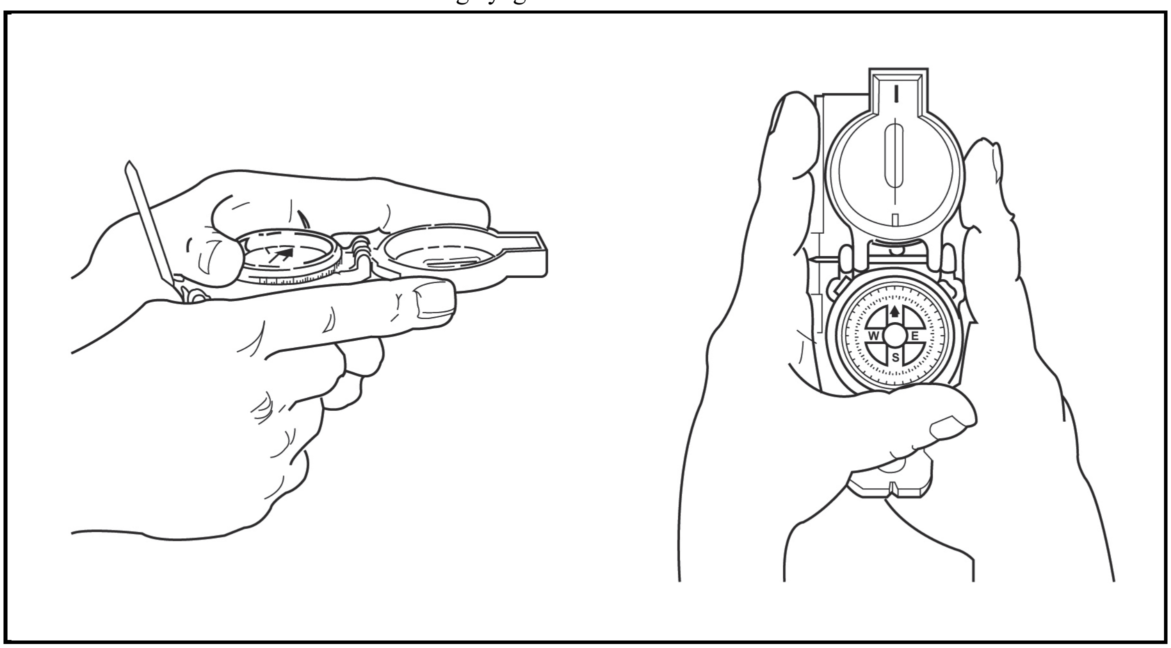

Figure 8-2. Centerhold technique

COMPASS-TO-CHEEK TECHNIQUE

8-10. Fold the cover of the compass containing the sighting wire to a vertical position; then fold the rear sight slightly forward. Look through the rear-sight slot and align the front-sight hairline with the desired object in the distance. Glance down at the dial through the eye lens to read the azimuth. (See Figure 8-3.)

Note. The compass-to-cheek technique is used almost exclusively for sighting. It is the best technique for this purpose.

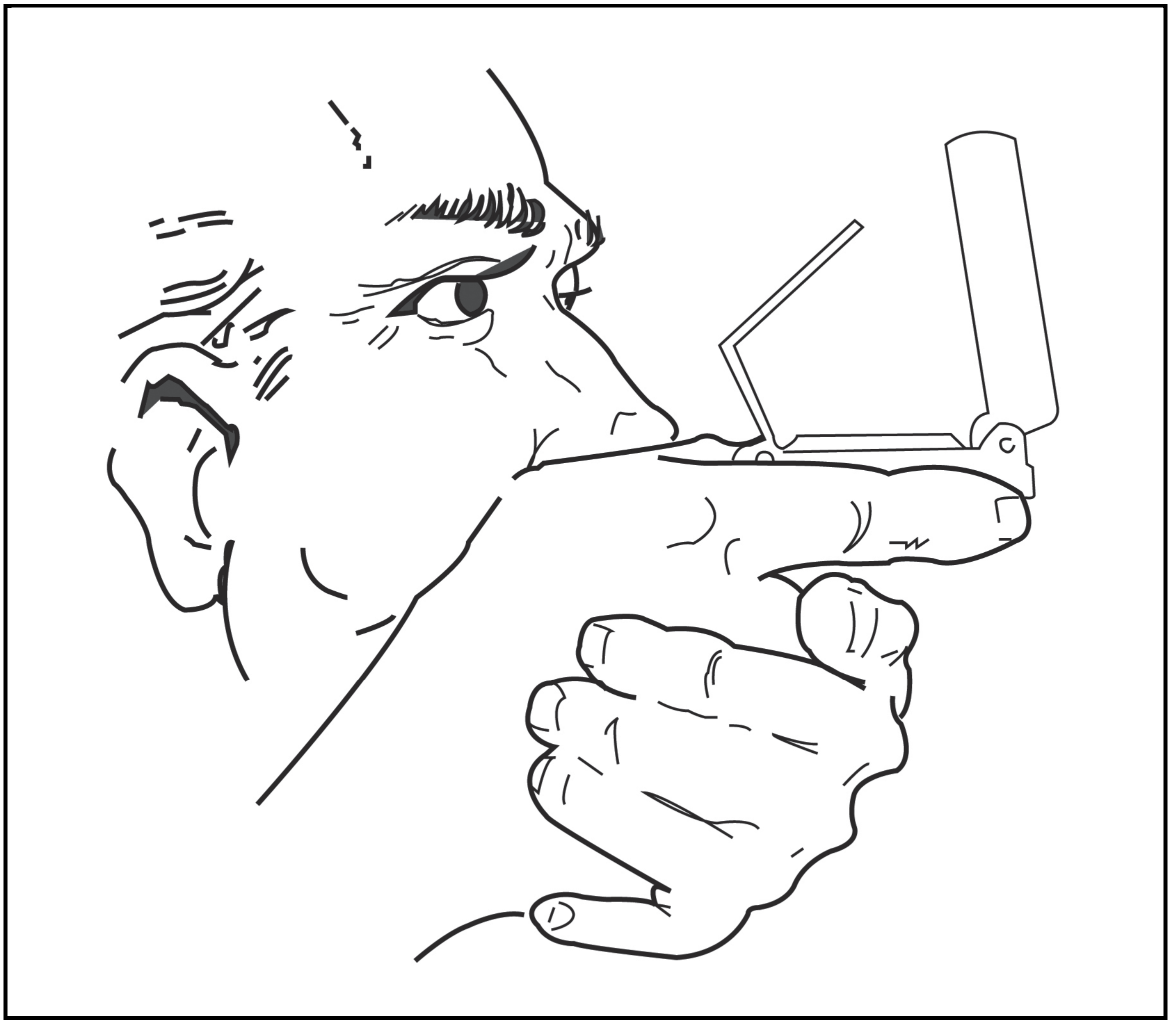

Figure 8-3. Compass-to-cheek technique

PRESETTING A COMPASS AND FOLLOWING AN AZIMUTH

8-11. Although different models of the lensatic compass vary somewhat in the details of their use, the principles are the same. During daylight hours or with a light source—

- Hold the compass level in the palm of the hand.
- Rotate it until the desired azimuth falls under the fixed black index line (for example, 320 degrees), maintaining the azimuth as prescribed. (See Figure 8-4.)
- Turn the bezel ring until the luminous line is aligned with the north-seeking arrow. Once the alignment is obtained, the compass is preset.
- To follow an azimuth, assume the centerhold technique, and turn your body until the north-seeking arrow is aligned with the luminous line. Proceed forward in the direction of the front cover's sighting wire, which is aligned with the fixed black index line that contains the desired azimuth.

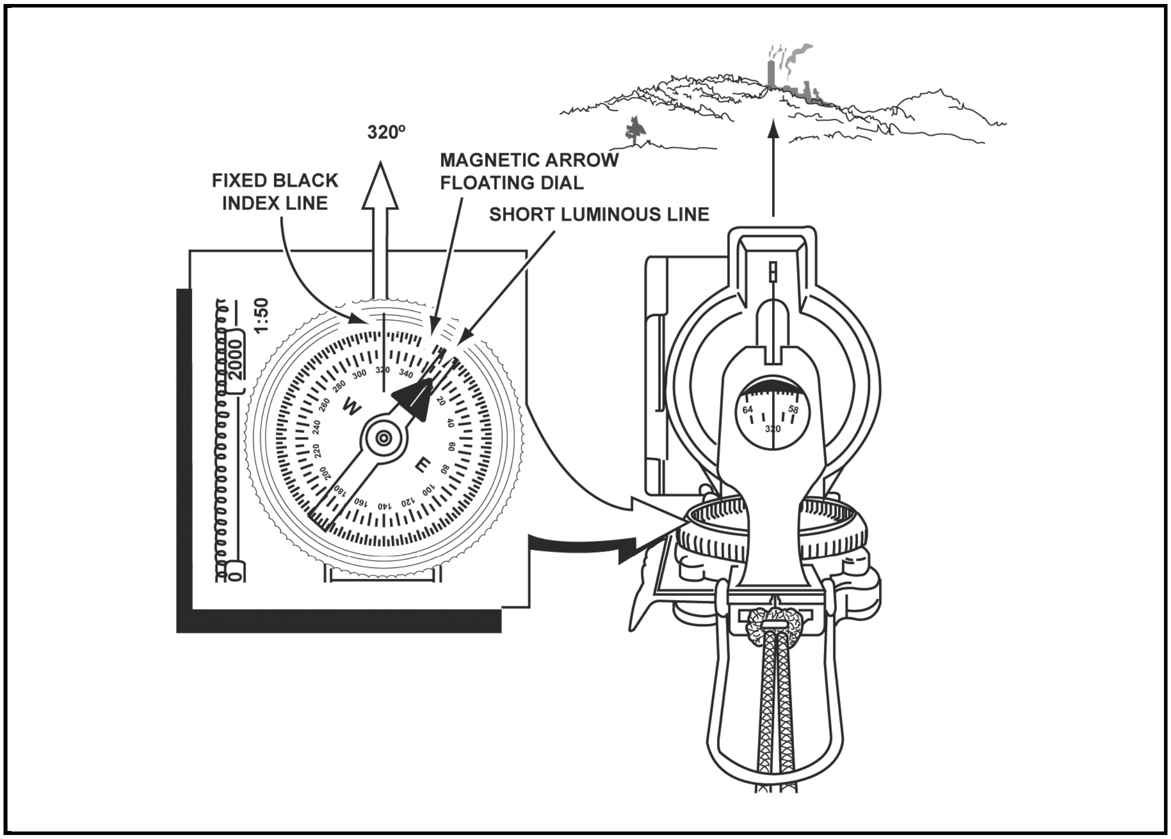

Figure 8-4. Compass preset at 320 degrees

8-12. During limited visibility, an azimuth may be set on the compass by the click method. Remember that the bezel ring contains 3-degree intervals (clicks). To employ the click method—

- Rotate the bezel ring until the luminous line is over the fixed black index line.
- Find the desired azimuth and divide it by three. The result is the number of clicks needed to rotate the bezel ring.
- Count the desired number of clicks. If the desired azimuth is smaller than 180 degrees, the number of clicks on the bezel ring should be counted in a counterclockwise direction. For example, the desired azimuth is 51 degrees; 51 degrees ÷ 3 = 17 clicks counterclockwise. If the desired azimuth is larger than 180 degrees, subtract the number of degrees from 360 degrees and divide by 3 to obtain the number of clicks. Count them in a clockwise direction. For example, the desired azimuth is 330 degrees; 360 degrees − 330 degrees = 30 ÷ 3 = 10 clicks clockwise.
- With the compass preset as described above, assume a centerhold technique and rotate your body until the north-seeking arrow is aligned with the luminous line on the bezel. Proceed forward in the direction of the front cover's luminous dots, which are aligned with the fixed black index line containing the azimuth.
- When the compass is to be used in darkness, an initial azimuth should be set while light is still available, if possible. With the initial azimuth as a base, another azimuth that is a multiple of three can be established using the clicking feature of the bezel ring.

Note. Sometimes the desired azimuth is not exactly divisible by three, causing an option of rounding up or rounding down. Rounding up causes an increase in the value of the azimuth, and the object is to be found on the left. Rounding down causes a decrease in the value of the azimuth, and the object is to be found on the right.

BYPASSING AN OBSTACLE

8-13. To bypass enemy positions or obstacles and still stay oriented, detour around the obstacle by moving at right angles for specified distances. For example, while moving on an azimuth of 90 degrees change the azimuth to 180 degrees and travel for 100 m. Change the azimuth to 90 degrees and travel for 150 m. Change the azimuth to 360 degrees and travel for 100 m. Then, change the azimuth to 90 degrees and return to the original azimuth line. (See Figure 8-5.)

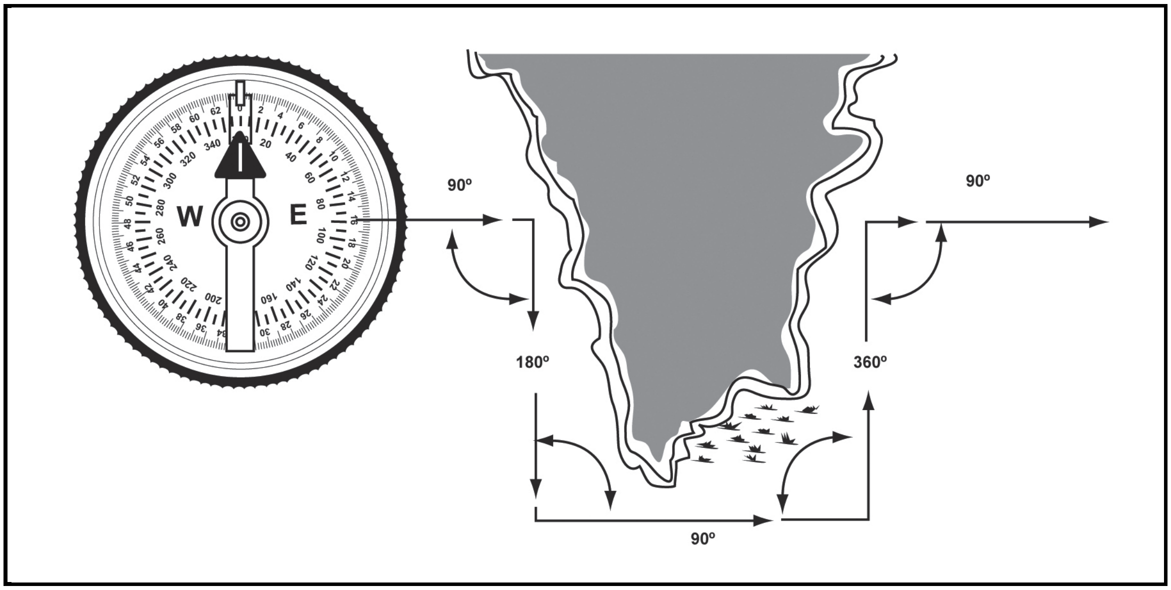

Figure 8-5. Bypassing an obstacle

8-14. Bypassing an unexpected obstacle at night is a fairly simple matter. To make a 90-degree turn to the right, hold the compass in the centerhold technique; turn until the center of the luminous letter E is under the luminous line (*do not* move the bezel ring). To make a 90-degree turn to the left, turn until the center of the luminous letter W is under the luminous line. This does not require changing the compass setting (bezel ring), and it ensures accurate 90-degree turns.

OFFSET

8-15. A deliberate offset is a planned magnetic deviation to the right or left of an azimuth to an objective. Use it when the objective is located along or in the vicinity of a linear feature such as a road or stream. Due to errors in compass or map reading, the linear feature may be reached without knowing whether the objective lies to the right or left. A deliberate offset by a known number of degrees in a known direction compensates for possible errors and ensures that upon reaching the linear feature, the user knows whether to go right or left to reach the objective. Ten degrees is an adequate offset for most tactical uses. Each degree offset moves the course about 18 m to the right or left for each 1000 m traveled. For example, in Figure 8-6, the number of degrees offset is 10 degrees. If the distance traveled to "X" is 1000 m, then "X" is located about 180 m to the right of the objective.

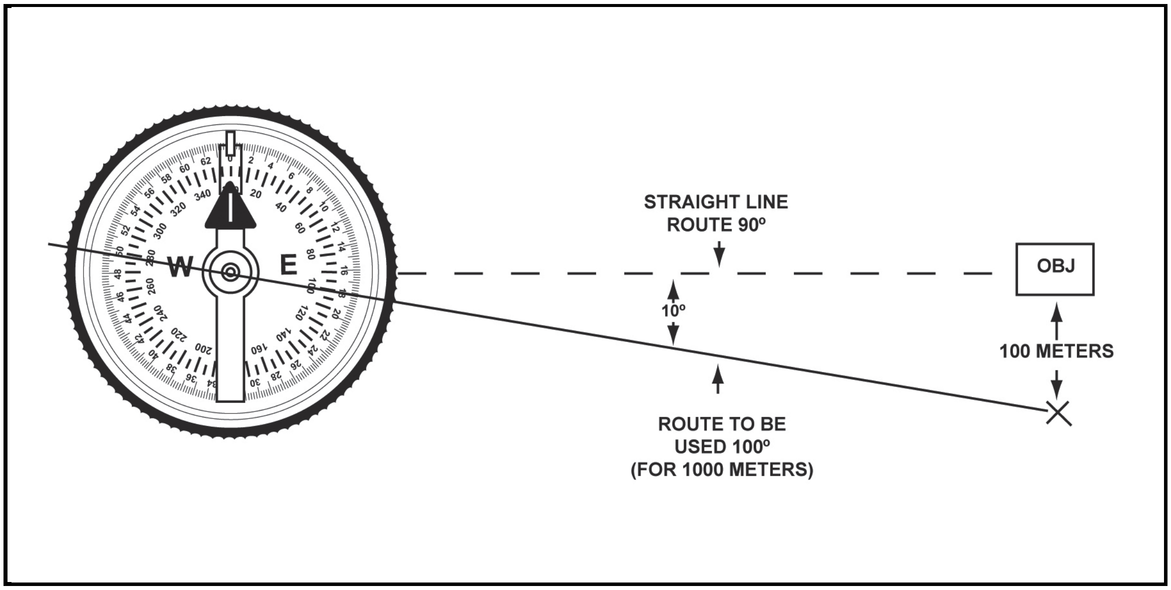

Figure 8-6. Deliberate offset to the objective

FIELD-EXPEDIENT METHODS

8-16. When a compass is not available, different techniques may be used to determine the four cardinal directions. The shadow-tip, watch, and star methods are outlined below.

SHADOW-TIP METHOD

8-17. The shadow-tip method (see Figure 8-7) is a simple and accurate technique to find direction by the sun. It consists of four basic steps:

- **Step 1.** Place a stick or branch into the ground at a level spot where a distinctive shadow is cast. Mark the shadow tip with a stone, twig, or other means. This first shadow mark is always the west direction.
- **Step 2.** Wait 10 to 15 minutes until the shadow tip moves a few inches. Mark the new position of the shadow tip in the same way as the first.
- **Step 3.** Draw a straight line through the two marks to obtain an approximate east-west line.
- **Step 4**. Standing with the first mark (west) to your left, the other directions are simple; north is to the front, east is to the right, and south is to the rear.

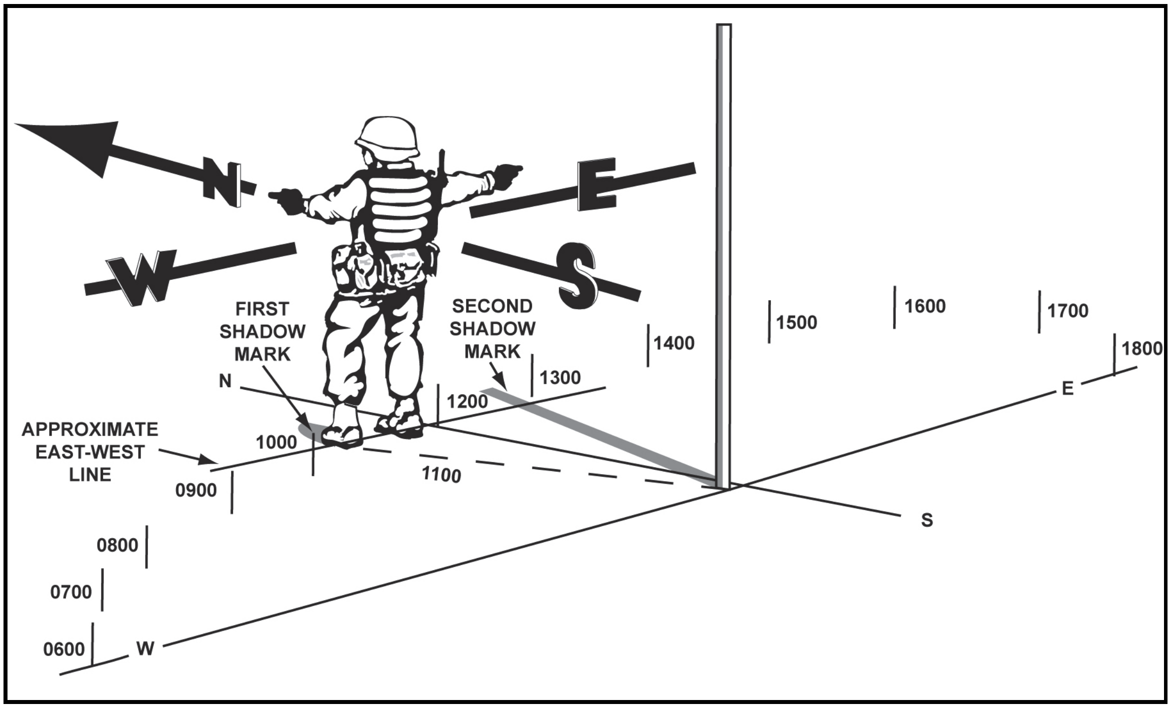

Figure 8-7. Determining directions shadow

8-18. A line drawn perpendicular to the east-west line at any point is the approximate north-south line. If you are uncertain which direction is east and which is west, observe this simple rule—the first shadow-tip mark is always in the west direction, everywhere on earth.

WATCH METHOD

8-19. A watch can be used to determine the approximate true north and true south. In the north temperate zone only, the hour hand is pointed toward the sun. A south line can be found midway between the hour hand and 1200 hours, standard time. If on daylight savings time, the north-south line is found between the hour hand and 1300 hours. If there is doubt as to which end of the line is north, remember that the sun is in the east before noon and in the west after noon.

8-20. The watch may also be used to determine direction in the south temperate zone; however, the method is different. The 1200-hour dial is pointed toward the sun, and halfway between 1200 hours and the hour hand is a north line. If on daylight savings time, the north line lies midway between the hour hand and 1300 hours. (See Figure 8-8.)

8-21. The watch method can be in error, especially in the lower latitudes, and may cause *circling*. To avoid this, make a shadow clock and set your watch to the time indicated. After traveling for an hour, take another shadow-clock reading. Reset your watch, if necessary.

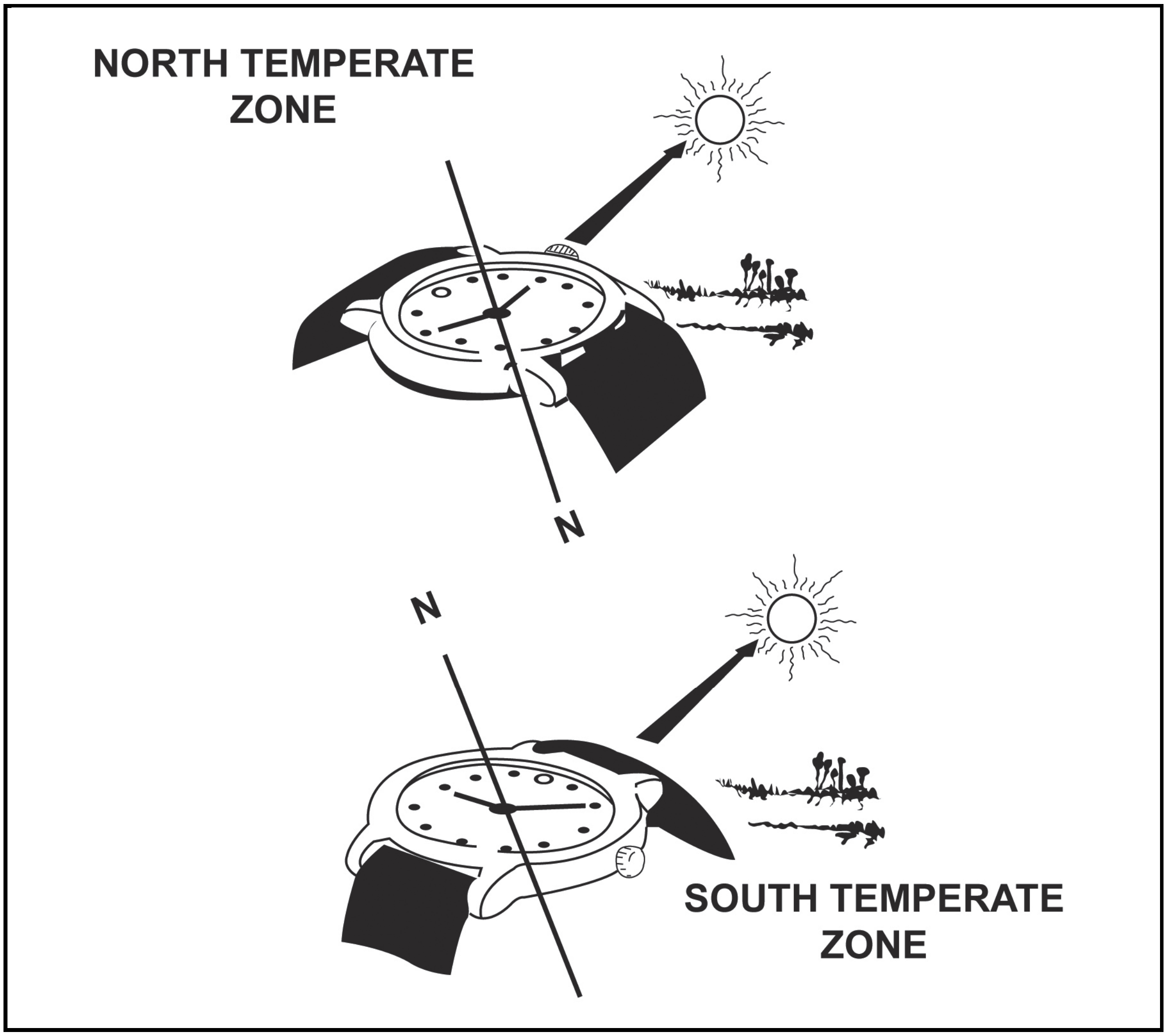

Figure 8-8. Determining direction using a watch

STAR METHOD

8-22. Less than 60 of about 5,000 stars visible to the eye are used by navigators. The stars seen as we look up at the sky at night are not evenly scattered across the whole sky. Instead they are in groups called constellations.

8-23. The constellations that are seen depend partly on where one is located on earth, the time of year, and time of night. The night changes with the seasons due to the journey of the earth around the sun. It also changes from hour to hour because the turning earth makes some constellations seem to travel in a circle, but there is one star that is in almost exactly the same place in the sky all night long every night. It is the North Star, also known as the Polar Star or Polaris.

8-24. The North Star is less than 1 degree off the true north and does not move from its place because the axis of the earth is pointed toward it. The North Star is in the group of stars called the Little Dipper. It is the last star in the handle of the dipper. The two stars in the Big Dipper help when trying to find the North Star. They are called the Pointers, and an imaginary line drawn through them multiplied five times their distance, points directly to the North Star.

8-25. Many stars are brighter than the North Star, but none is more important because of its location. However, the North Star can only be seen in the northern hemisphere so it does not serve as a guide south of the equator. The farther one goes north, the higher the North Star is in the sky, and above latitude 70 degrees it is too high in the sky to be useful. (See Figure 8-9.)

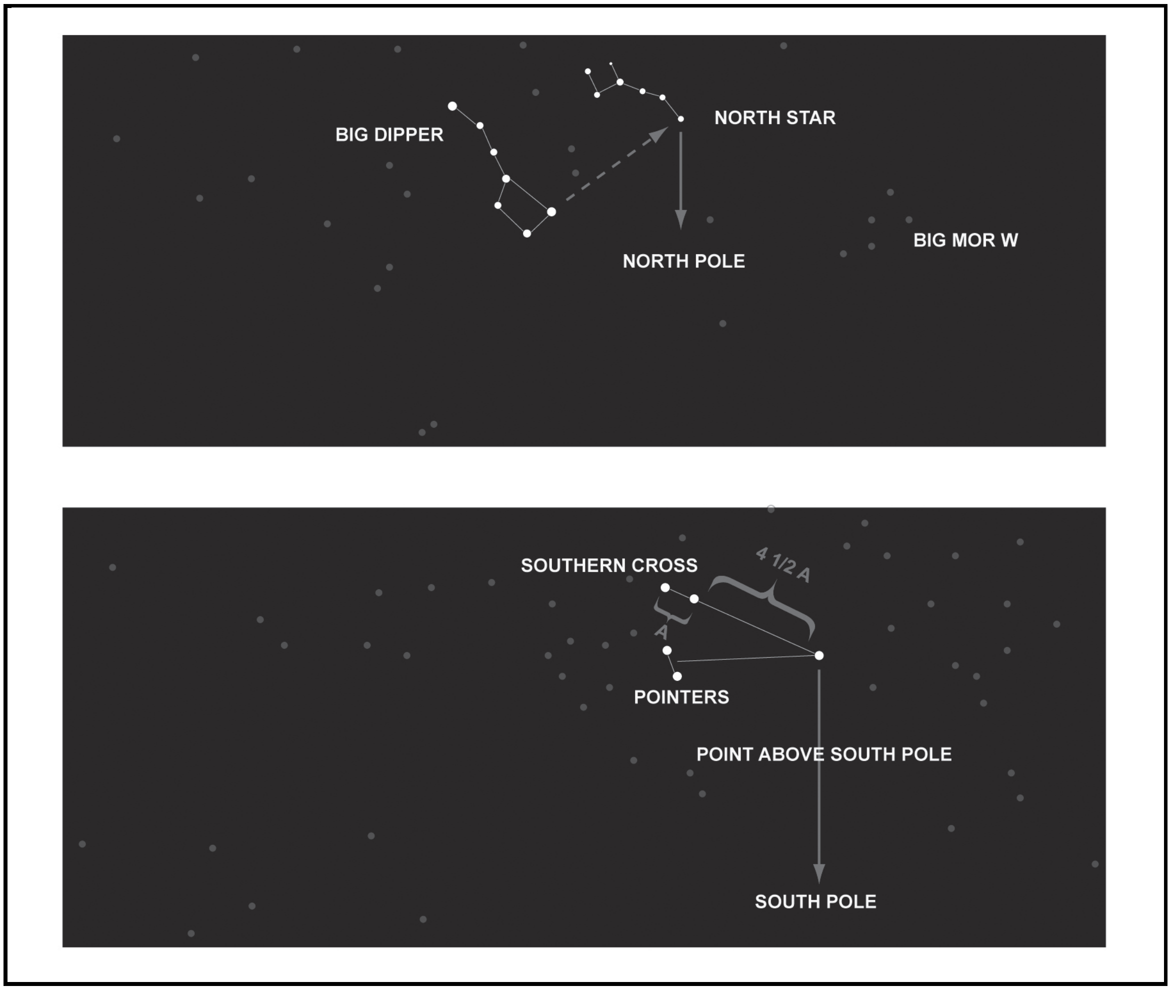

Figure 8-9. Determining direction by the North Star and Southern Cross

8-26. Depending on the star selected for navigation, azimuth checks are necessary. A star near the north horizon serves for about half an hour. When moving south, azimuth checks should be made every 15 minutes. When traveling east or west, the difficulty of staying on azimuth is caused more by the likelihood of the star climbing too high in the sky or losing itself behind the western horizon than it is by the star changing direction angle. When this happens, it is necessary to change to another guide star.

8-27. The Southern Cross is the main constellation used as a guide south of the equator, and the general directions for using north and south stars are reversed. When navigating using the stars as guides, the user knows the different constellation shapes and their locations throughout the world. (See Figures 8-10 and 8-11.)

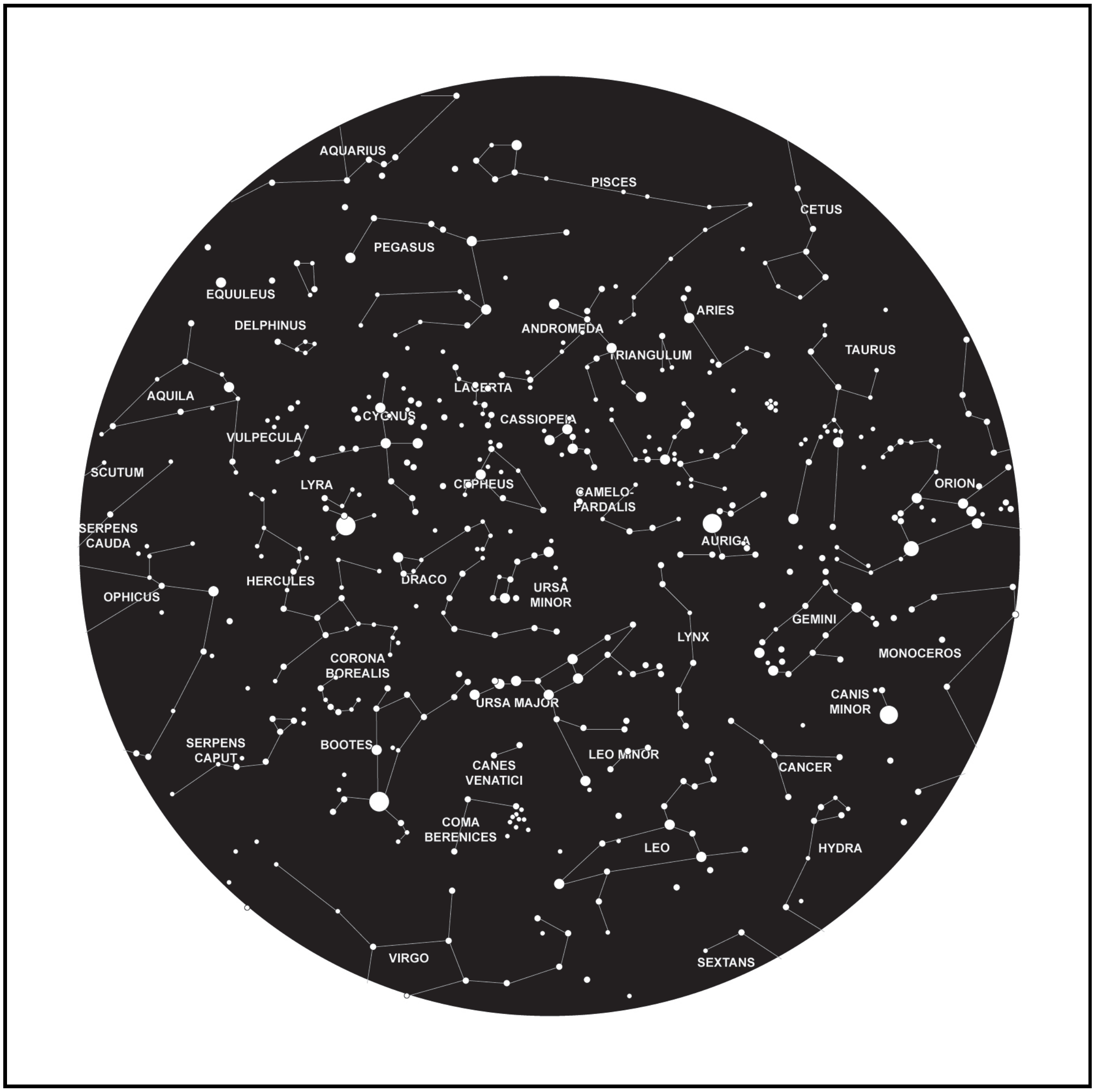

Figure 8-10. Constellations, northern hemisphere

Figure 8-11. Constellations, southern hemisphere

GLOBAL POSITIONG SYSTEM

8-28. The GPS is a space-based, global, all-weather, continuously available, radio positioning navigation system. It is highly accurate in determining position location derived from signal triangulation from a satellite constellation system. It is capable of determining latitude, longitude, and altitude of the individual user. It is fielded in handheld, man pack, vehicular, aircraft, and watercraft configurations. The GPS receives and processes data from satellites on a simultaneous or sequential basis. It measures the velocity and range with respect to each satellite, processes the data in terms of an earth-centered, earth-fixed coordinate system, and displays the information to the user in geographic or military grid coordinates. (See Appendix G, H, and I for more information on the GPS and GPS devices.)

8-29. The GPS can provide precise steering information and position location. The receiver can accept many checkpoints entered in the coordinate system by the user and convert them to the desired coordinate system. The user then calls up the desired checkpoint and the receiver displays direction and distance to the checkpoint. The GPS does not have inherent drift and the receiver automatically updates its position. The receiver can also compute time to the next checkpoint.

8-30. Specific uses for the GPS are position location; navigation; weapon location; target and sensor location; coordination of firepower; scout and screening operations; combat resupply; location of obstacles, barriers, and gaps; and communication support. The GPS also has the potential to allow units to train Soldiers and provide—

- Performance feedback.
- Knowledge of routes taken by the Soldier.
- Knowledge of errors committed by the Soldier.
- Comparison of planned versus executed routes.
- Safety and control of lost and injured Soldiers.

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Chapter 9

Elevation and Relief

The elevation of points on the ground and the relief of an area affect movement, positioning, and sometimes the effectiveness of military units. Soldiers know how to determine locations of points, measure distances and azimuths, and identify symbols on a map. They also determine the elevation and relief of areas on standard military maps. To do this, Soldier's first understand how the mapmaker indicated the elevation and relief on the map.

DEFINITIONS

9-1. The reference or start point for vertical measurement of elevation on a standard military map is the datum plane or mean sea level, the point halfway between high tide and low tide. Elevation of a point on the earth's surface is the vertical distance it is above or below mean sea level. Relief is the representation (as depicted by the mapmaker) of the shapes of hills, valleys, streams, or terrain features on the earth's surface.

9-2. Digital terrain is only accurate to the level of data input and display capabilities of the device, software, and the user display being accessed by the Soldier. These digital devices, systems, simulators, and simulations use digital terrain models and digital elevation models to express map data. Generally digital terrain models represent the sloped contour surface of the earth, without representation of man-made objects and vegetation. The digital elevation model represents the sloped contour surface of the earth, along with surface features such as man-made objects and vegetation. The depiction or exclusion of the map data including elevation, relief, terrain shapes, and terrain features is based on the system and software accessed.

METHODS OF DEPICTING RELIEF

9-3. Mapmakers use several methods to depict relief of the terrain: layer tinting, form lines, shaded relief, hachures, and contour lines.

9-4. Layer tinting is a method of showing relief by color. A different color is used for each band of elevation. Each shade of color, or band, represents a definite elevation range. A legend is printed on the map margin to indicate the elevation range represented by each color. However, this method does not allow the map user to determine the exact elevation of a specific point—only the range.

9-5. Form lines are not measured from a datum plane. Form lines have no standard elevation and give only a general idea of relief. Form lines are represented on a map as dashed lines and are never labeled with representative elevations.

9-6. Relief shading indicates relief by a shadow effect achieved with tone and color that result in the darkening of one side of terrain features such as hills and ridges. The darker the shading, the steeper the slope. Shaded relief is sometimes used in conjunction with contour lines to emphasize these features.

9-7. Hachures are short, broken lines used to show relief and are sometimes used with contour lines. They do not represent exact elevations, but are mainly used to show large, rocky outcrop areas. Hachures are used extensively on small-scale maps to show mountain ranges, plateaus, and mountain peaks.

9-8. Contour lines are the most common method of showing relief and elevation on a standard topographic map. A contour line represents an imaginary line on the ground, above or below sea level. All points on the contour line are at the same elevation. The elevation represented by contour lines is the vertical distance above or below sea level. The three types of contour lines (see Figure 9-1) include—

- **Index.** Starting at zero elevation or mean sea level, every fifth contour line is a heavier line. These are known as index contour lines. Normally, each index contour line is numbered at some point. This number is the elevation of that line.

- **Intermediate.** The contour lines falling between the index contour lines are called intermediate contour lines. These lines are finer and do not have their elevations given. There are normally four intermediate contour lines between index contour lines.
- **Supplementary**. These contour lines resemble dashes. They show changes in elevation of at least one-half the contour interval. Supplementary lines are normally found where there is very little change in elevation, such as on fairly level terrain.

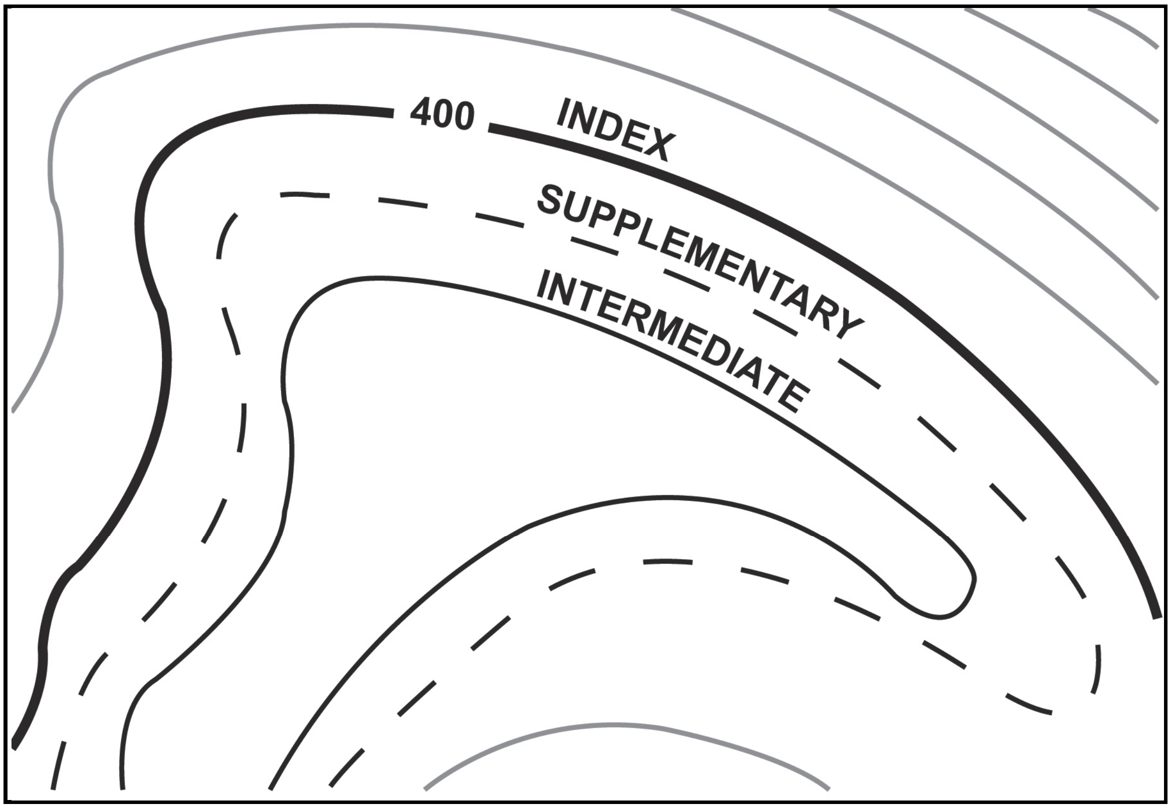


Figure 9-1. Contour lines

CONTOUR INTERVALS

9-9. Before the elevation of a point on the map can be determined, the user knows the contour interval for the map being used. The contour interval measurement given in the marginal information is the vertical distance between adjacent contour lines. Use the following procedures to determine the elevation of a point on the map:

- Determine the contour interval and the unit of measure used; for example, feet, meters, or yards. (See Figure 9-2.) Find the numbered index contour line nearest the point being determined for elevation.
- Determine if the elevation is going higher or lower. In Figure 9-2, point (a) is between the index contour lines. The lower index contour line is numbered 500, which means a point on that line is at an elevation of 500 m above mean sea level. The upper index contour line is numbered 600, or 600 m. Going from the lower to the upper index contour line shows an increase in elevation.
- To determine the exact elevation of point (a), start at the index contour line numbered 500 and count the number of intermediate contour lines to point (a). Point (a) is located on the second intermediate contour line above the 500-m index contour line. The contour interval is 20 m (see Figure 9-2), and each intermediate contour line crossed to get to point (a) adds 20 m to the 500-m index contour line. The elevation of point (a) is 540 m; the elevation has increased.
- To determine the elevation of point (b), go to the nearest index contour line. In this case, it is the upper index contour line numbered 600. Point (b) is located on the intermediate contour line immediately below the 600-m index contour line. Below means downhill or a lower elevation. Therefore, point (b) is located at an elevation of 580 m. If the elevation increases; add the contour

interval to the nearest index contour line. If it is decreasing, subtract the contour interval from the nearest index contour line.

- To determine the approximate elevation to a hilltop without a survey marker, add one-half the contour interval to the elevation of the last contour line. (See Figure 9-2, point c.) In this example, the last contour line before the hilltop is an index contour line numbered 600. Add one-half the contour interval, 10 m, to the index contour line. The elevation of the hilltop would be 610 m.

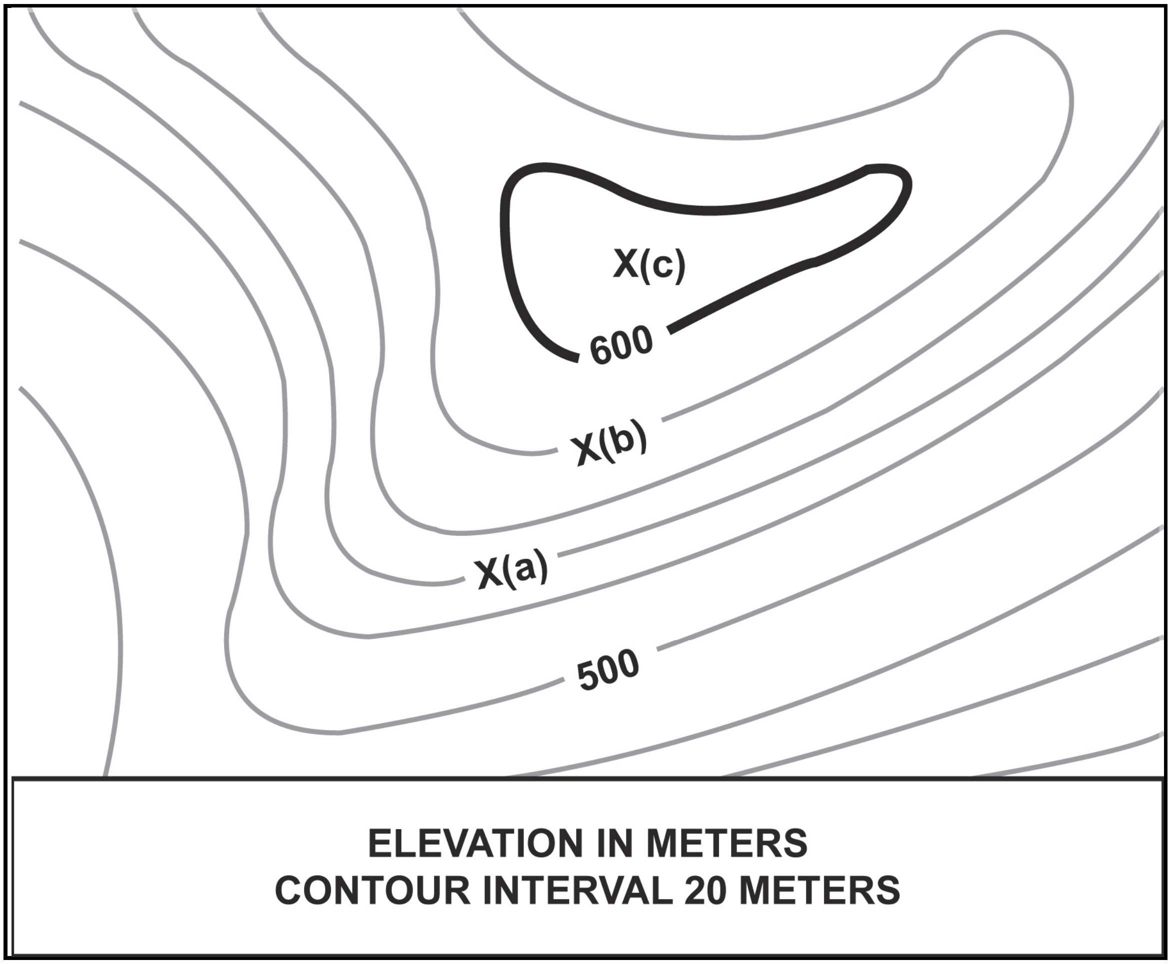


Figure 9-2. Points on contour lines and contour interval note

9-10. There may be times when elevation points need to be determined to a greater accuracy. To do this, determine how far between the two contour lines the point lays. However, most military needs are satisfied by estimating the elevation of points between contour lines. (See Figure 9-3.)

- If the point is less than one-fourth the distance between contour lines, the elevation is the same as the last contour line. In Figure 9-3, the elevation of point A is 100 m. To estimate the elevation of a point between one-fourth and three-fourths of the distance between contour lines, add one-half the contour interval to the last contour line.
- Point B is one-half the distance between contour lines. The contour line immediately below point b is at an elevation of 160 m. The contour interval is 20 m; one-half the contour interval is 10 m. In this case, add 10 m to the last contour line of 160 m. The elevation of point b is about 170 m.

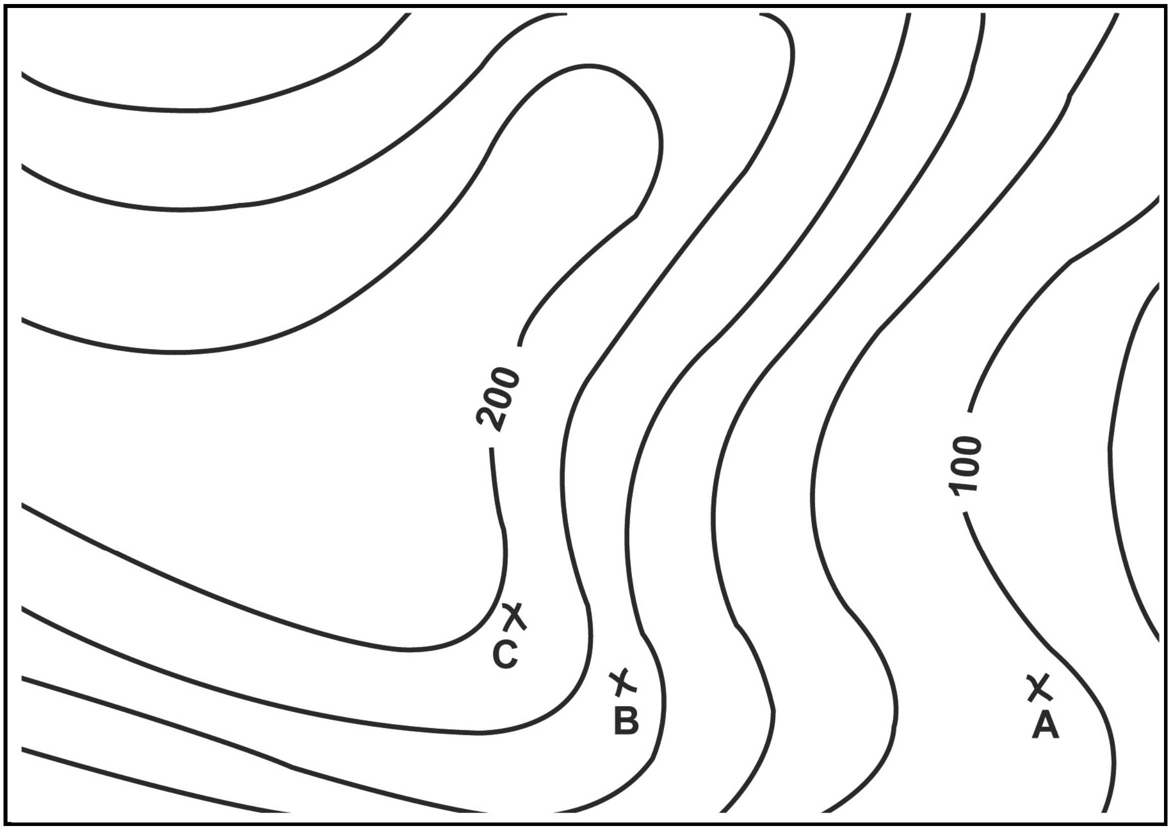


Figure 9-3. Points between contour lines

9-11. A point located more than three-fourths of the distance between contour lines is considered to be at the same elevation as the next contour line. Point C is located three-fourths of the distance between contour lines. In Figure 9-3, point c is considered to be at an elevation of 200 m.

9-12. To estimate the elevation to the bottom of a depression, subtract one-half the contour interval from the value of the lowest contour line before the depression. In Figure 9-4, the lowest contour line before the depression is 240 m in elevation, making the elevation at the edge of the depression 240 m. To determine the elevation at the bottom of the depression, subtract one-half the contour interval. The contour interval for this example is 20 m. Subtract 10 m from the lowest contour line immediately before the depression. The result is that the elevation at the bottom of the depression is 230 m. The tick marks on the contour line forming a depression always point to lower elevations.

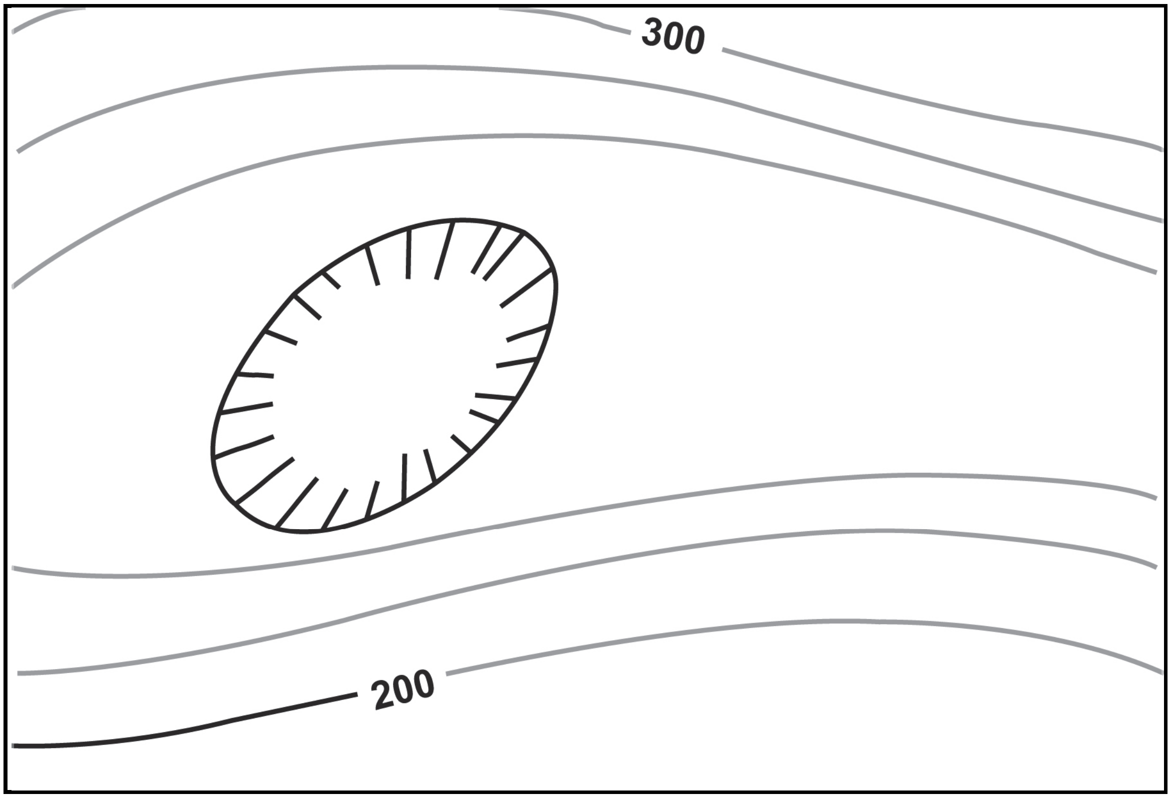


Figure 9-4. Depression

9-13. In addition to the contour lines, bench marks (BMs) and spot elevations are used to indicate points of known elevations on the map. Bench marks, the more accurate of the two, are symbolized by a black X; for example X BM 214. The 214 indicates that the center of the X is at an elevation of 214 units of measure (feet, meters, or yards) above mean sea level. To determine the units of measure, refer to the contour interval in the marginal information.

9-14. Spot elevations are shown by a brown X and are usually located at road junctions, hilltops, and other prominent terrain features. If the elevation is shown in black numerals, it has been checked for accuracy; if it is in brown, it has not been checked.

Note. New maps are printed using a dot instead of a brown X. Maps with a brown X and meter elevation marks continue to be issued.

TYPES OF SLOPES

9-15. The rate of rise or fall of a terrain feature is known as its slope. Depending upon the military mission, Soldiers may need to determine not only the height of a hill, but also the degree of the hill's slope. The speed at which equipment or personnel can move is affected by the slope of the ground or terrain feature. This slope can be determined from the map by studying the contour lines—the closer the contour lines, the steeper the slope; the farther apart the contour lines, the gentler the slope. Four types of slopes that concern the military are gentle, steep, concave, and convex.

9-16. Contour lines showing a uniform, gentle slope are evenly spaced and wide apart. (See Figure 9-5.) Considering relief only, a uniform, gentle slope allows the defender to use grazing fire. The attacking force has to climb a slight incline.

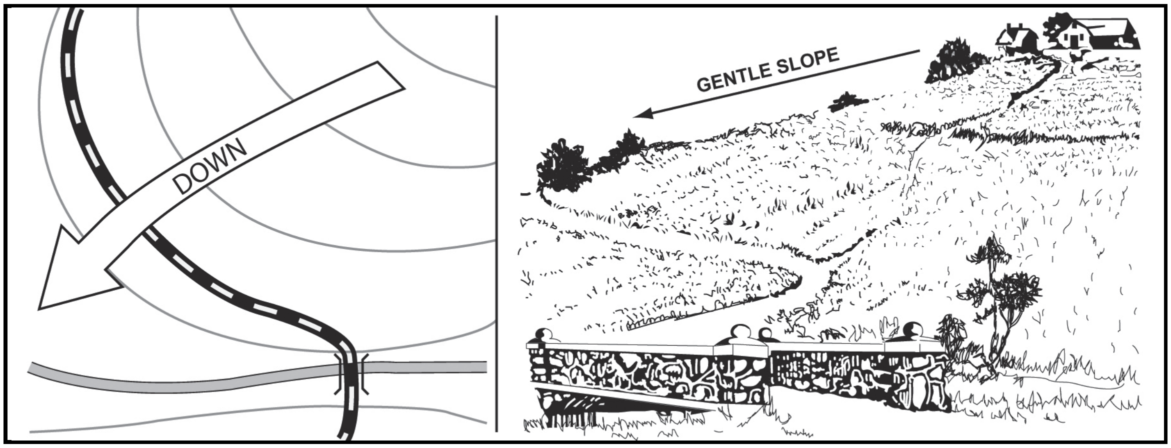


Figure 9-5. Uniform, gentle slope

9-17. Contour lines showing a uniform, steep slope on a map are evenly spaced but close together. The closer the contour lines, the steeper the slope. (See Figure 9-6.) Considering relief only, a uniform, steep slope allows the defender to use grazing fire, and the attacking force has to negotiate a steep incline.

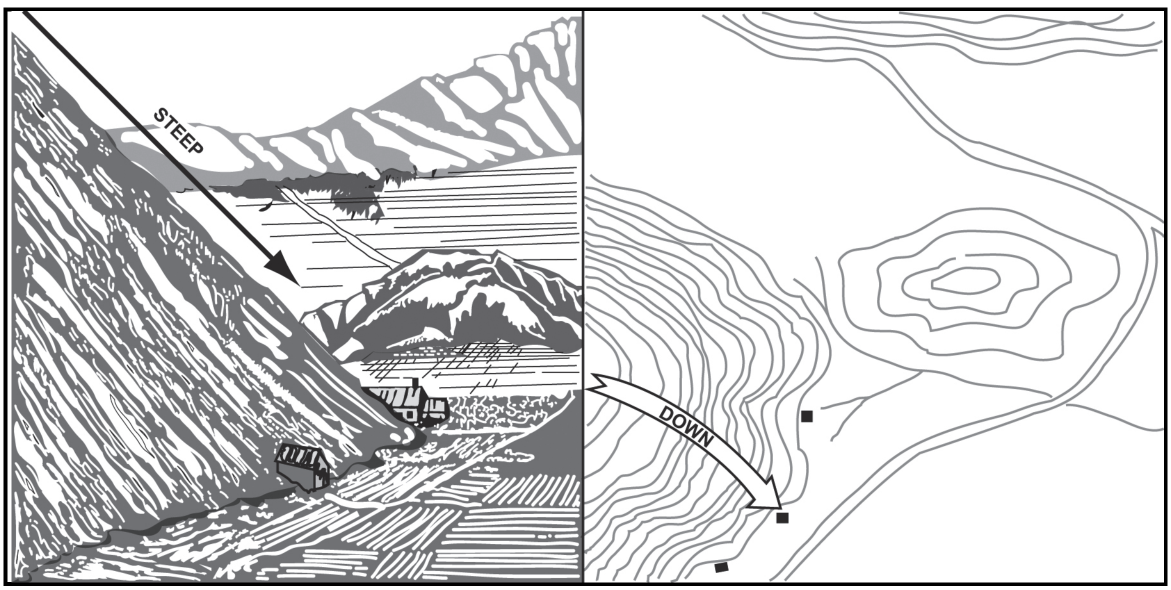


Figure 9-6. Uniform, steep slope

9-18. Contour lines showing a concave slope on a map are closely spaced at the top of the terrain feature and widely spaced at the bottom. (See Figure 9-7.) Considering relief only, the defender at the top of the slope can observe the entire slope and the terrain at the bottom, but cannot use grazing fire. The attacker would have no cover from the defender's observation of fire, and the climb would become more difficult going farther up the slope.

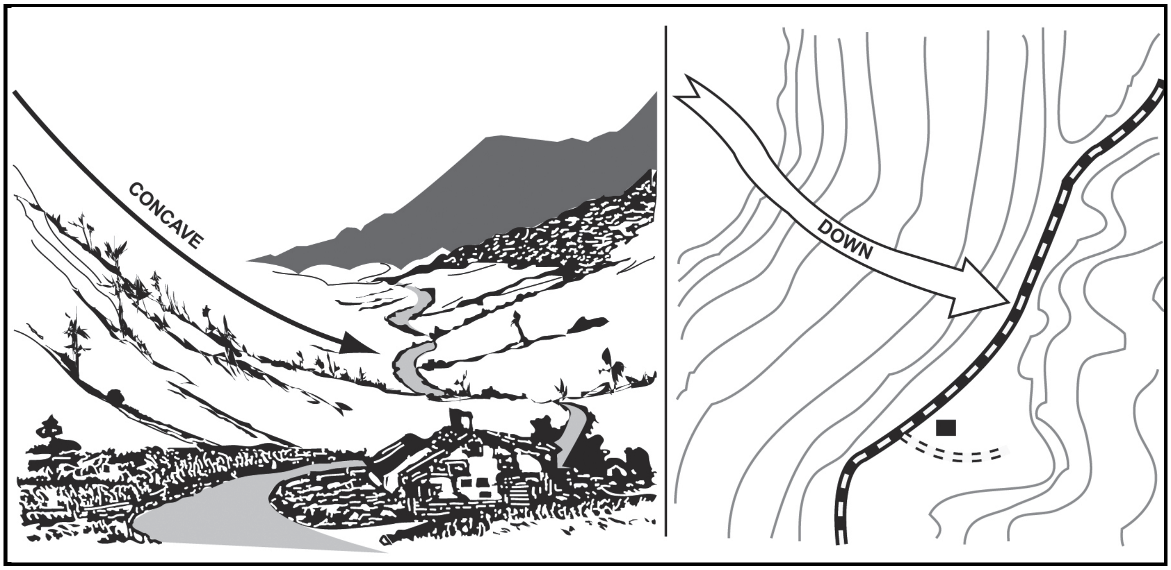


Figure 9-7. Concave slope

9-19. Contour lines showing a convex slope on a map are widely spaced at the top and closely spaced at the bottom. (See Figure 9-8.) Considering relief only, the defender at the top of the convex slope can obtain a small distance of grazing fire, but cannot observe most of the slope or the terrain at the bottom. The attacker has concealment on most of the slope and an easier climb nearing the top.

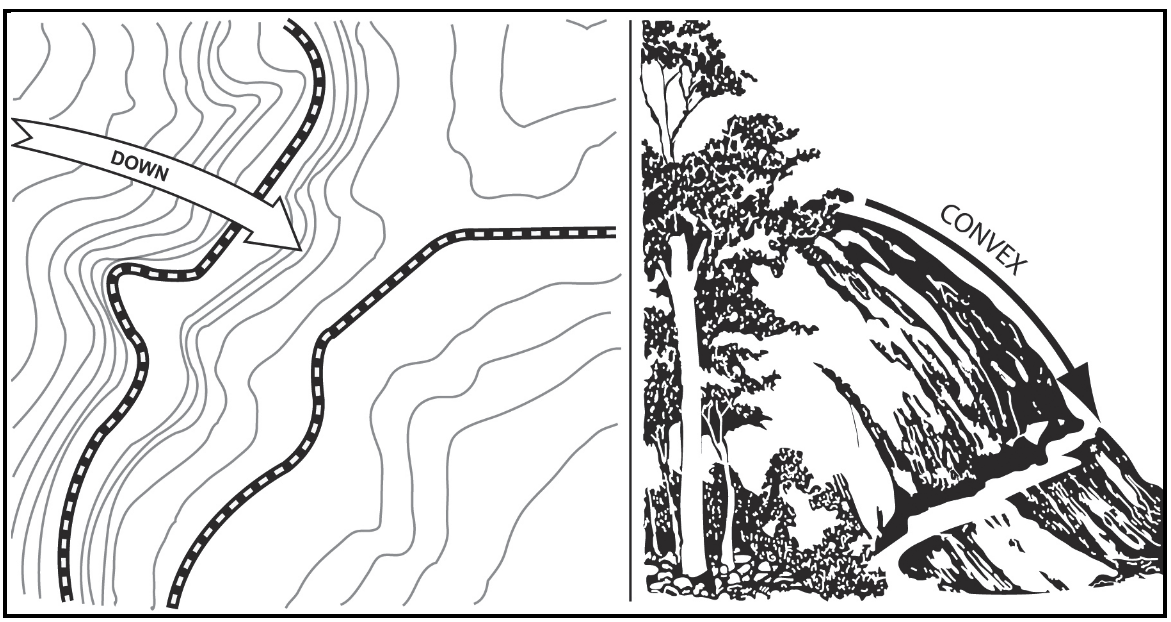


Figure 9-8. Convex slope

PERCENTAGE OF SLOPE

9-20. The speed at which personnel and equipment can move up or down a hill is affected by the slope of the ground and the limitations of the equipment. Because of this, a more exact way of describing a slope is necessary.

9-21. Slope may be expressed in several ways, but all depend upon the comparison of vertical distance (VD) to horizontal distance (HD). (See Figure 9-9.) Before determining the percentage of a slope, the VD of the slope is known. This is determined by subtracting the lowest point of the slope from the highest point. Use the contour lines to determine the highest and lowest point of the slope. (See Figure 9-10.)

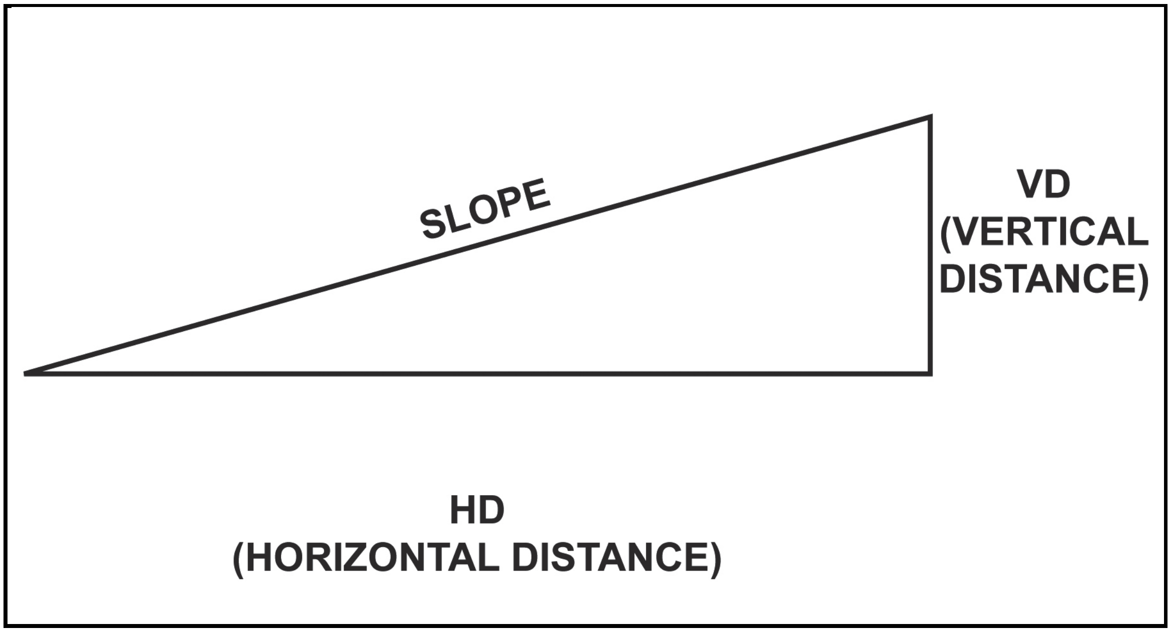


Figure 9-9. Slope diagram

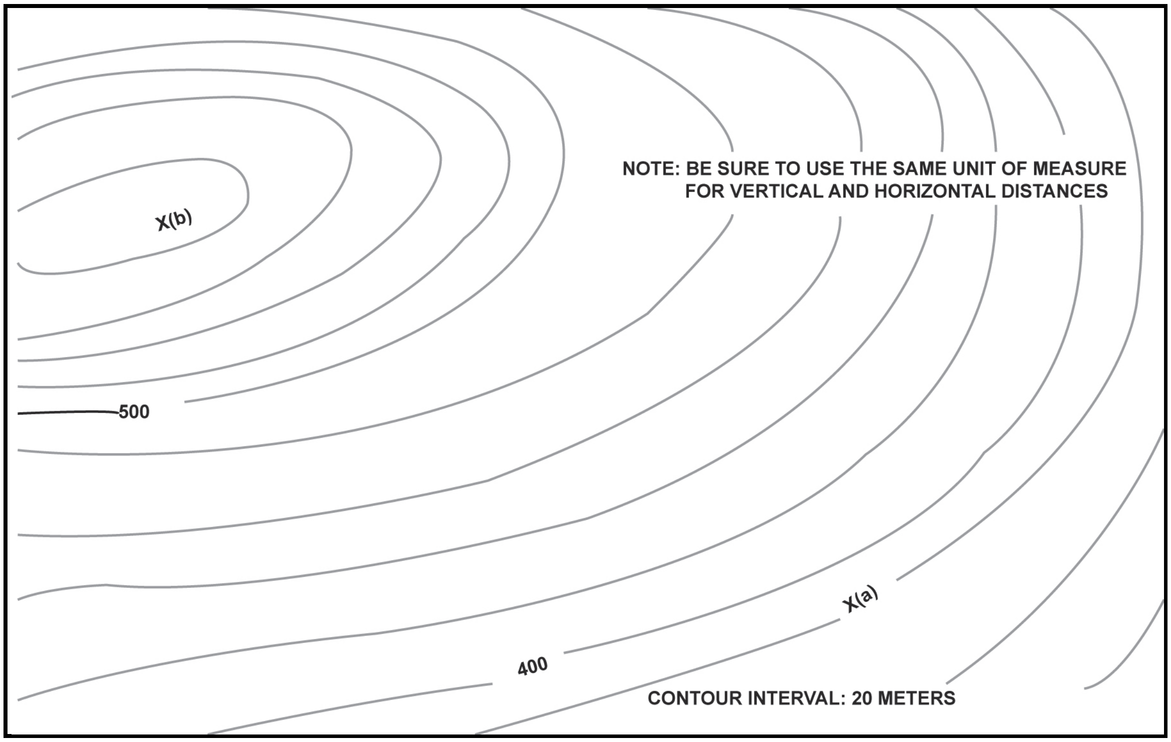


Figure 9-10. Contour lines around a slope

9-22. To determine the percentage of the slope between points (a) and (b) in Figure 9-10, determine the elevation of point (b) (590 m). Then determine the elevation of point (a) (380 m). Determine the vertical distance between the two points by subtracting the elevation of point (a) from the elevation of point (b).The difference (210 m) is the VD between points (a) and (b). Then measure the HD between the two points on the map. (See Figure 9-11.) After the horizontal distance has been determined, compute the percentage of the slope by using the formula shown in Figure 9-12.

Note. The references depicted in Figures 9-10 through 9-14 represent a uniform slope.

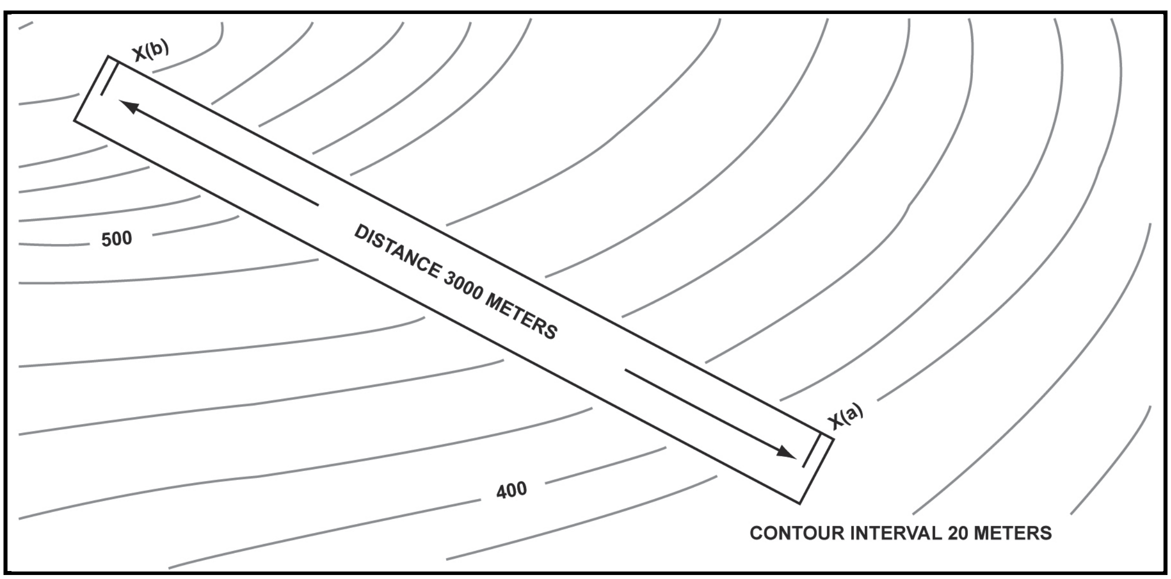


Figure 9-11. Measuring horizontal distance

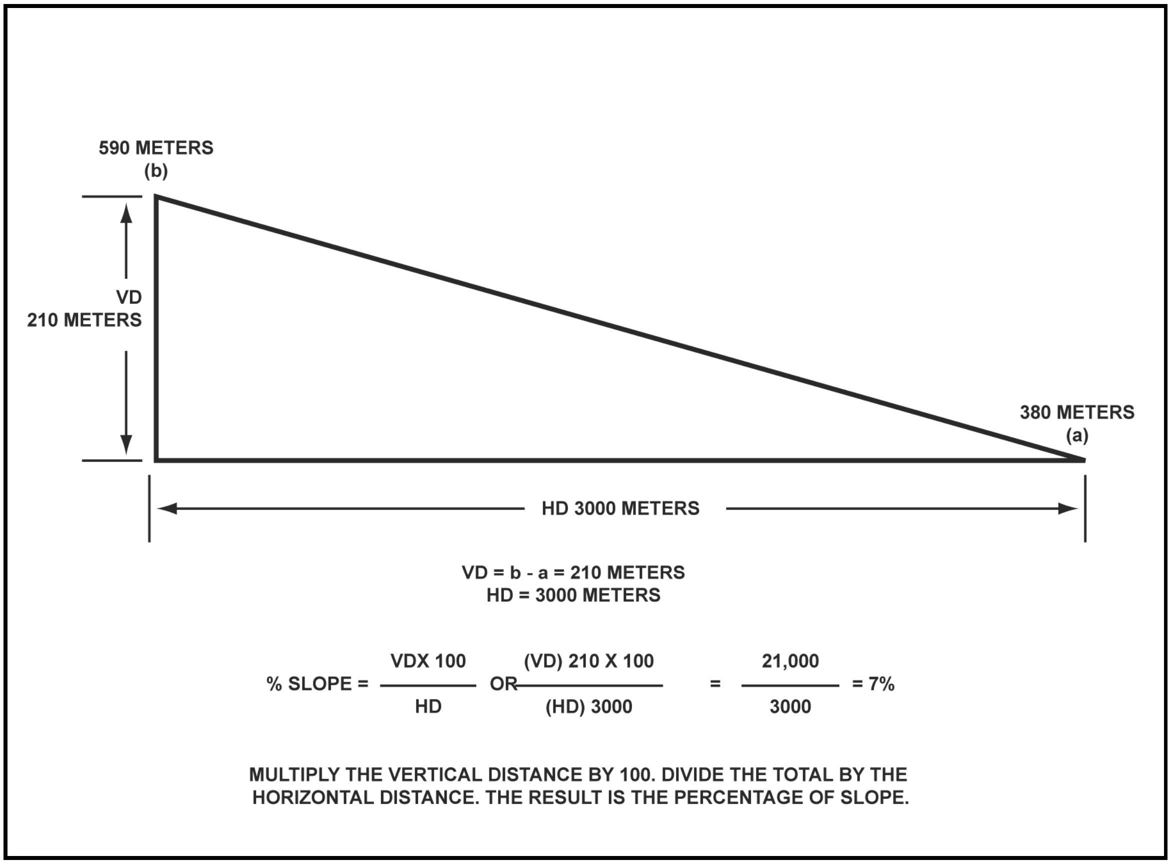
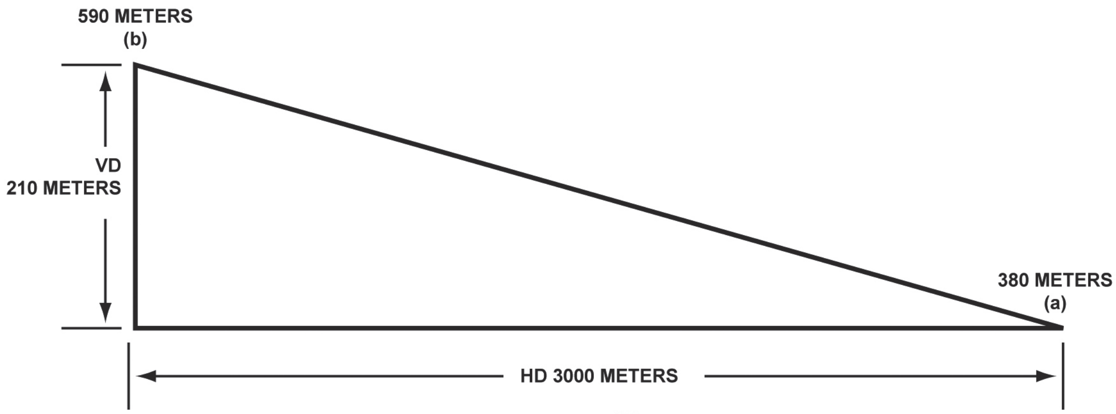


Figure 9-12. Percentage of slope in meters

9-23. The slope angle can also be expressed in degrees. To do this, determine the VD and HD of the slope. Multiply the VD by 57.3 and then divide the total by the HD. (See Figure 9-13.) This method determines the approximate degree of slope and is reasonably accurate for slope angles less than 20 degrees.



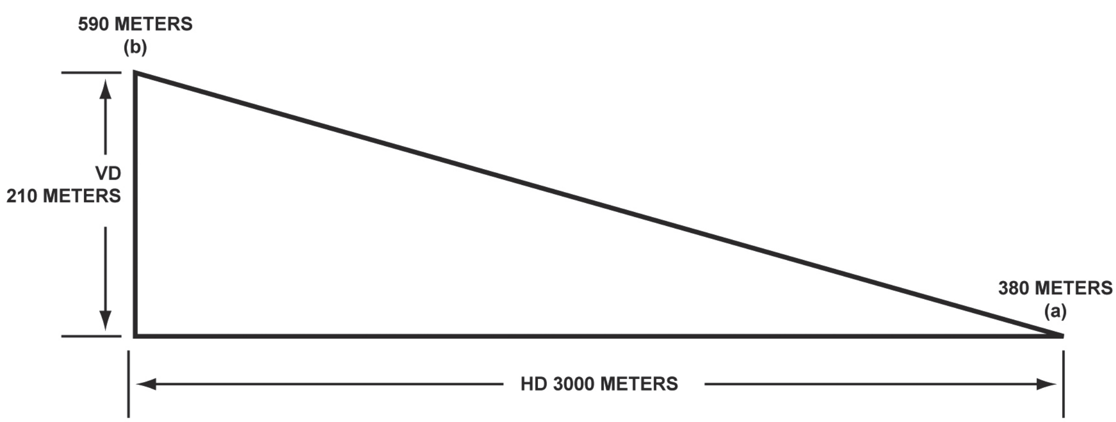
$$\text{GRADIENT} = \frac{\text{VD}}{\text{HD}}$$

VD = b - a = 210 METERS
HD = 3000 METERS

$$\frac{150 \times 57.3}{3000} = \frac{8575}{3000} = 2.9 \text{ OR } 3^{\circ} \text{ OF SLOPE}$$

Figure 9-13. Degree of slope

9-24. The slope angle can also be expressed as a gradient. The relationship of horizontal and vertical distance is expressed as a fraction with a numerator of one. (See Figure 9-14.)



$$\text{GRADIENT} = \frac{\text{VD}}{\text{HD}}$$

VD = b - a = 210 METERS
HD = 3000 METERS

$$\frac{150}{3000} = \frac{1}{20} = \text{1 METER RISE FOR EVERY 20 METERS OF DISTANCE}$$

Figure 9-14. Gradient

TERRAIN FEATURES

9-25. All terrain features are derived from a complex landmass known as a mountain or ridgeline. (See Figure 9-15.) The term ridgeline is not interchangeable with the term ridge. A ridgeline is a line of high ground, usually with changes in elevation along its top and low ground on all sides, from which a total of 10 natural or man-made terrain features are classified.

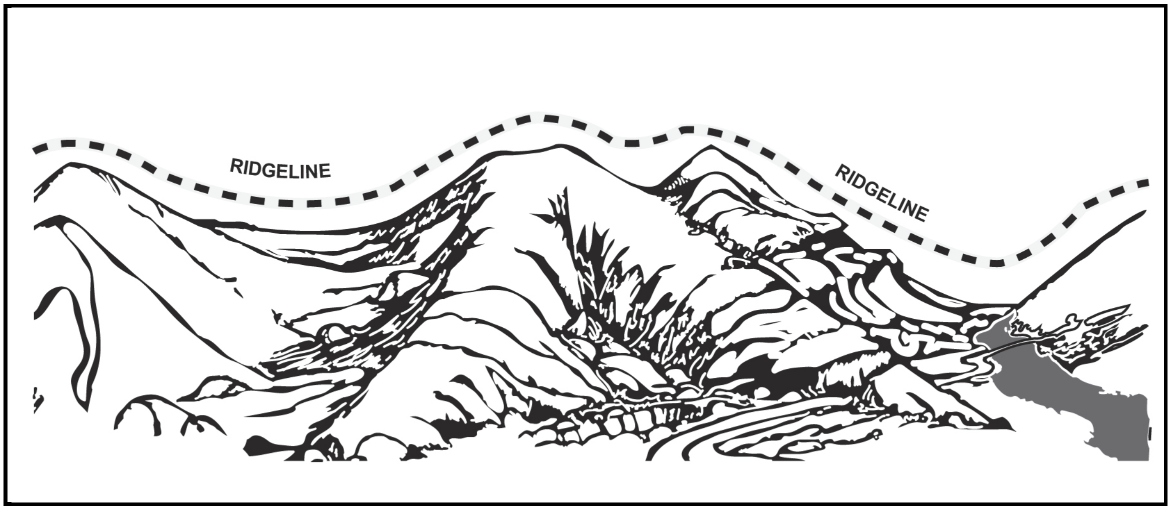


Figure 9-15. Ridgeline

MAJOR TERRAIN FEATURES

9-26. Major terrain features are hills, saddles, valleys, ridges, and depressions. They are uniquely represented on maps.

9-27. A hill is an area of high ground. From a hilltop, the ground slopes down in all directions. A hill is shown on a map by contour lines forming concentric circles. The inside of the smallest closed circle is the hilltop. (See Figure 9-16.)

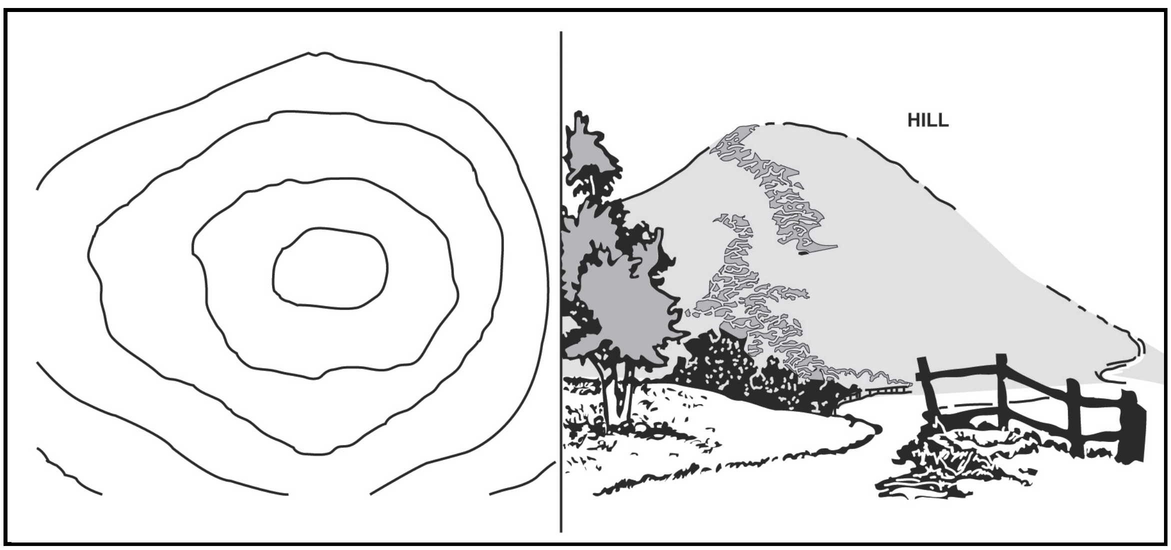


Figure 9-16. Hill

9-28. A saddle is a dip or low point between two areas of higher ground. A saddle is not necessarily the lower ground between two hilltops; it may be simply a dip or break along a level ridge crest. If you are in a saddle, there is high ground in two opposite directions and lower ground in the other two directions. A saddle is normally represented as an hourglass. (See Figure 9-17.)

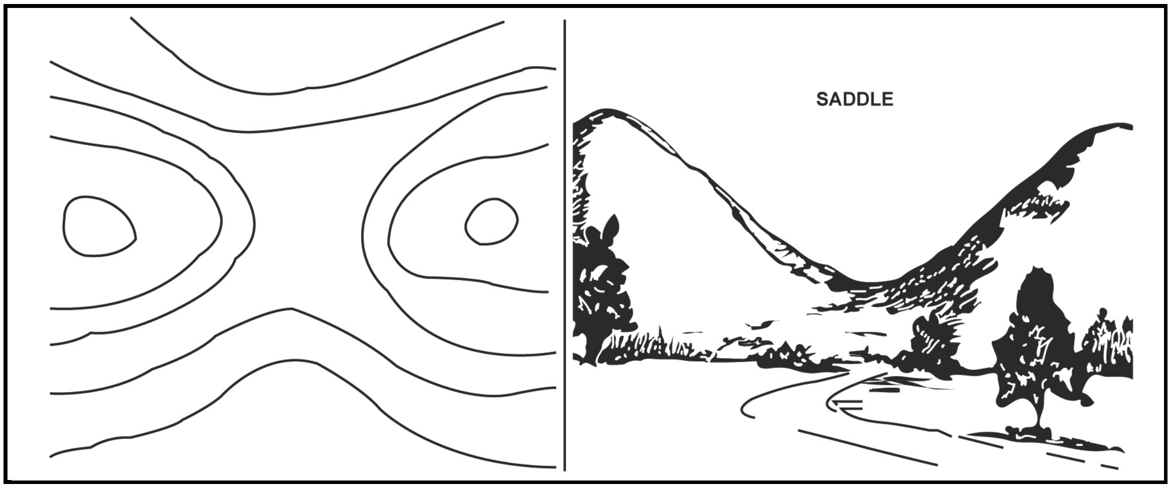


Figure 9-17. Saddle

9-29. A valley is a stretched-out groove in the land, usually formed by streams or rivers. It begins with high ground on three sides and usually has a course of running water through it. If standing in a valley, three directions offer high ground, while the fourth direction offers low ground. Depending upon its size and where a person is standing, it may not be obvious that there is high ground in the third direction, but water flows from higher to lower ground. Contour lines forming a valley are either U-shaped or V-shaped. To determine the direction water is flowing, look at the contour lines. The closed end of the contour line (U or V) always points upstream or toward high ground. (See Figure 9-18.)

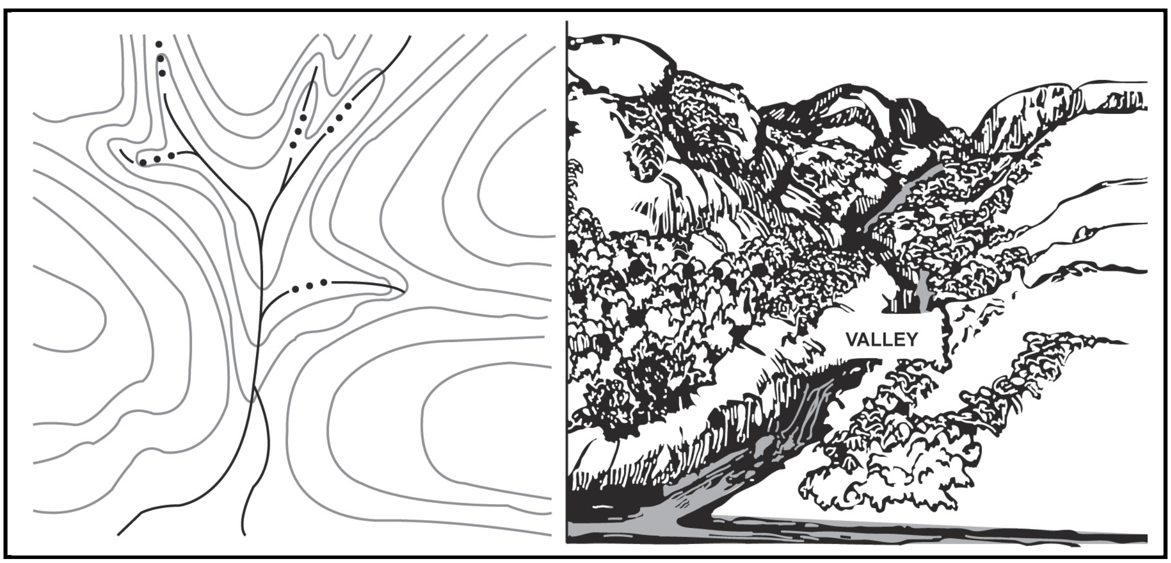


Figure 9-18. Valley

9-30. A ridge is a sloping line of high ground. The centerline of a ridge normally has low ground in three directions and high ground in one direction, with varying degrees of slope. If a ridge is crossed at right angles, a Soldier climbs steeply to the crest and then descends steeply to the base. When moving along the path of the ridge, depending on the geographic location, there may be either an almost unnoticeable slope or a very obvious incline. Contour lines forming a ridge tend to be U-shaped or V-shaped. The closed end of the contour line points away from high ground. (See Figure 9-19.)

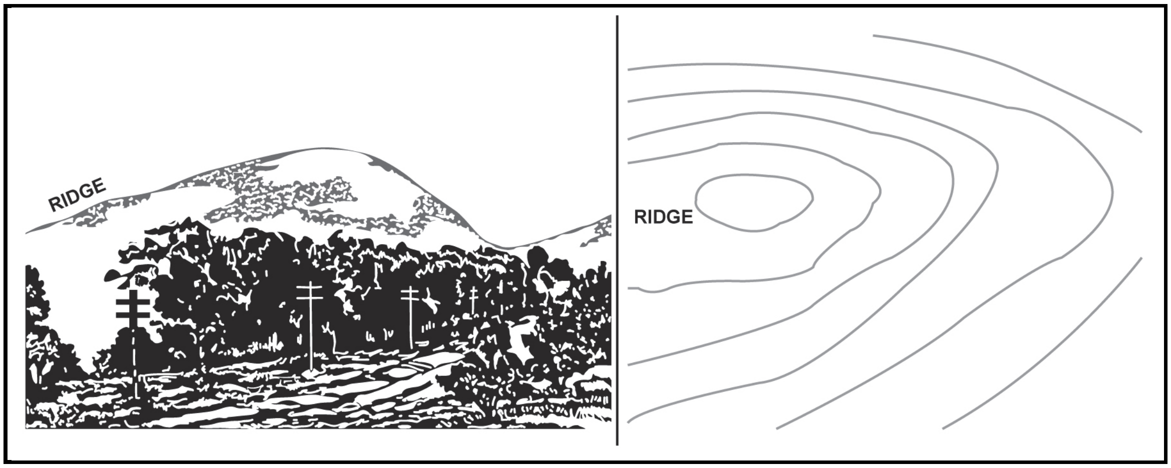


Figure 9-19. Ridge

9-31. A depression is a low point in the ground or a sinkhole. It could be described as an area of low ground surrounded by higher ground in all directions, or simply a hole in the ground. Usually, only depressions that are equal to or greater than the contour interval is shown. On maps, depressions are represented by closed contour lines that have tick marks pointing toward low ground. (See Figure 9-20.)

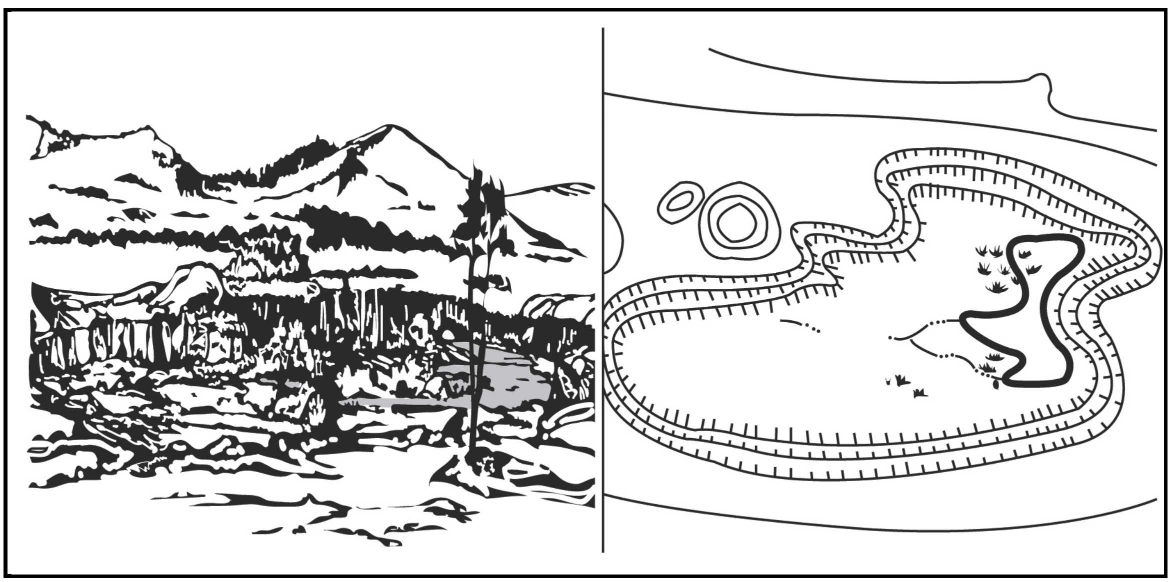


Figure 9-20. Depression

MINOR TERRAIN FEATURES

9-32. Minor terrain features include draws, spurs, and cliffs. They are represented on maps in unique ways.

9-33. A draw is a stream course that is less developed than a valley. In a draw, there is essentially no level ground and little or no maneuver room within its confines. In a draw, the ground slopes upward in three directions and downward in the other direction. A draw could be considered as the initial formation of a valley. The contour lines depicting a draw are U-shaped or V-shaped, pointing toward high ground. (See Figure 9-21.)

Figure 9-21. Draw

9-34. A spur is a short, continuous sloping line of higher ground normally jutting out from the side of a ridge. A spur is often formed by two roughly parallel streams cutting draws down the side of a ridge. The ground slopes down in three directions and up in one. Contour lines on a map depict a spur with the U or V pointing away from high ground. (See Figure 9-22.)

Figure 9-22. Spur

9-35. A cliff is a vertical or near-vertical feature that is an abrupt change of the land. When a slope is so steep that the contour lines converge into one "carrying" contour of contours, this last contour line has tick marks pointing toward low ground. (See Figure 9-23, A.) Cliffs are also shown by contour lines very close together and, in some instances, touching each other. (See Figure 9-23, B.)

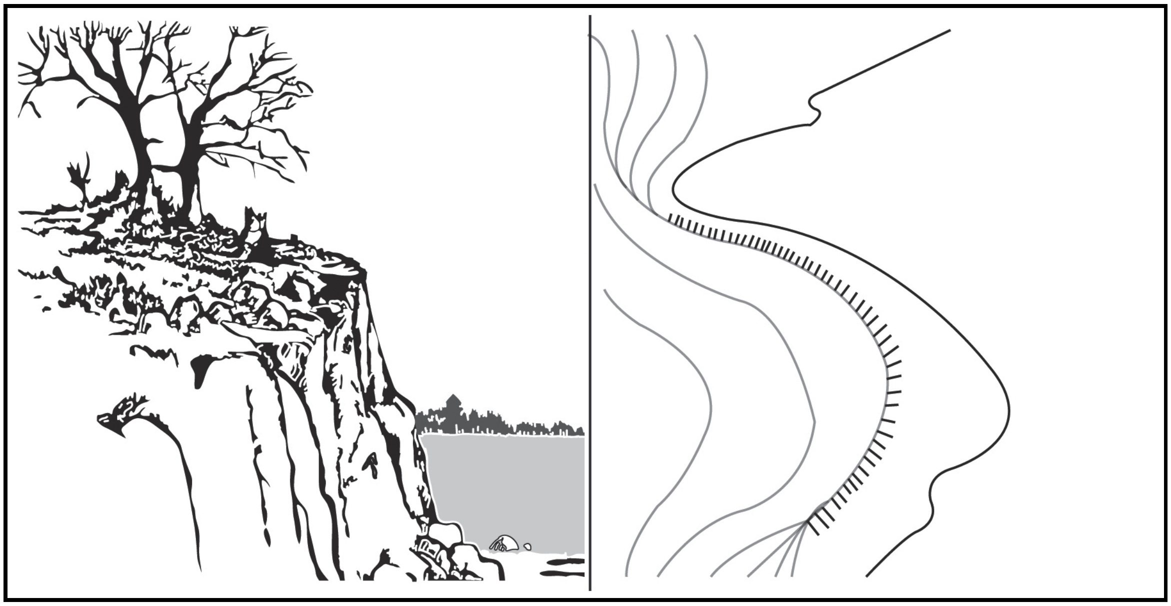


Figure 9-23, A. Cliff (with tick marks)

Figure 9-23, B. Cliff (without tick marks)

SUPPLEMENTARY TERRAIN FEATURES

9-36. Supplementary terrain features include cuts and fills. A cut is a man-made feature resulting from cutting through raised ground, usually to form a level bed for a road or railroad track. Cuts are shown on a map when they are at least 10 feet high, and they are drawn with a contour line along the cut line. This contour line extends the length of the cut and has tick marks that extend from the cut line to the roadbed, if the map scale permits this level of detail. (See Figure 9-24.)

9-37. A fill is a man-made feature resulting from filling a low area, usually to form a level bed for a road or railroad track. Fills are shown on a map when they are at least 10 feet high, and they are drawn with a contour line along the fill line. This contour line extends the length of the filled area and has tick marks that point toward lower ground. If the map scale permits, the length of the fill tick marks are drawn to scale and extend from the base line of the fill symbol. (See Figure 9-24.)

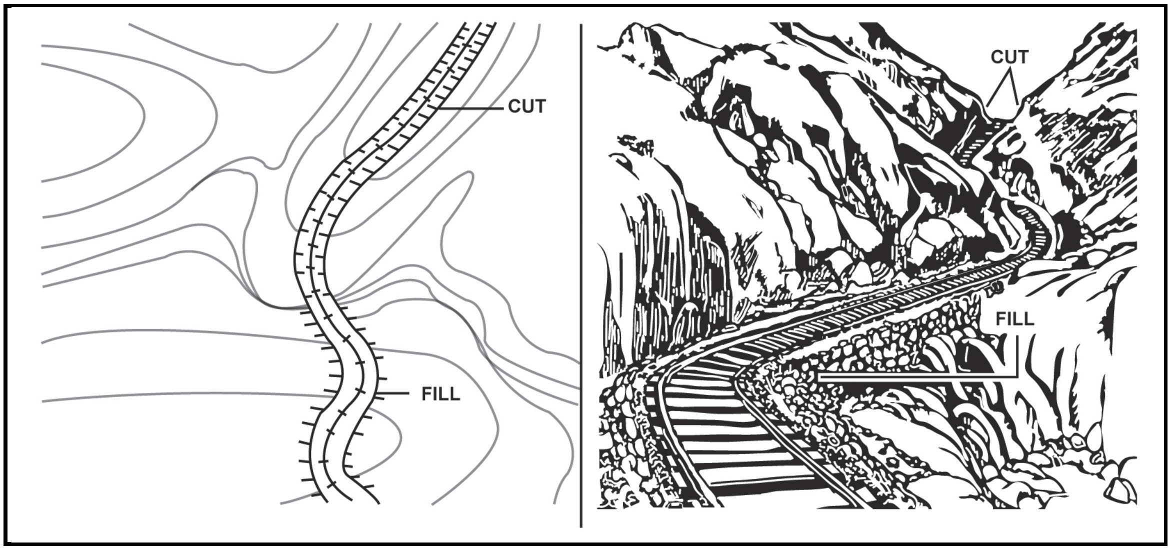


Figure 9-24. Cut and fill

INTERPRETATION OF TERRAIN FEATURES

9-38. Terrain features do not normally stand alone. To better understand these when they are depicted on a map, they need to be interpreted correctly. These terrain features (see Figure 9-25) are interpreted by using contour lines; the shape, orientation, size, elevation, and slope approach; ridgelining; or streamlining.

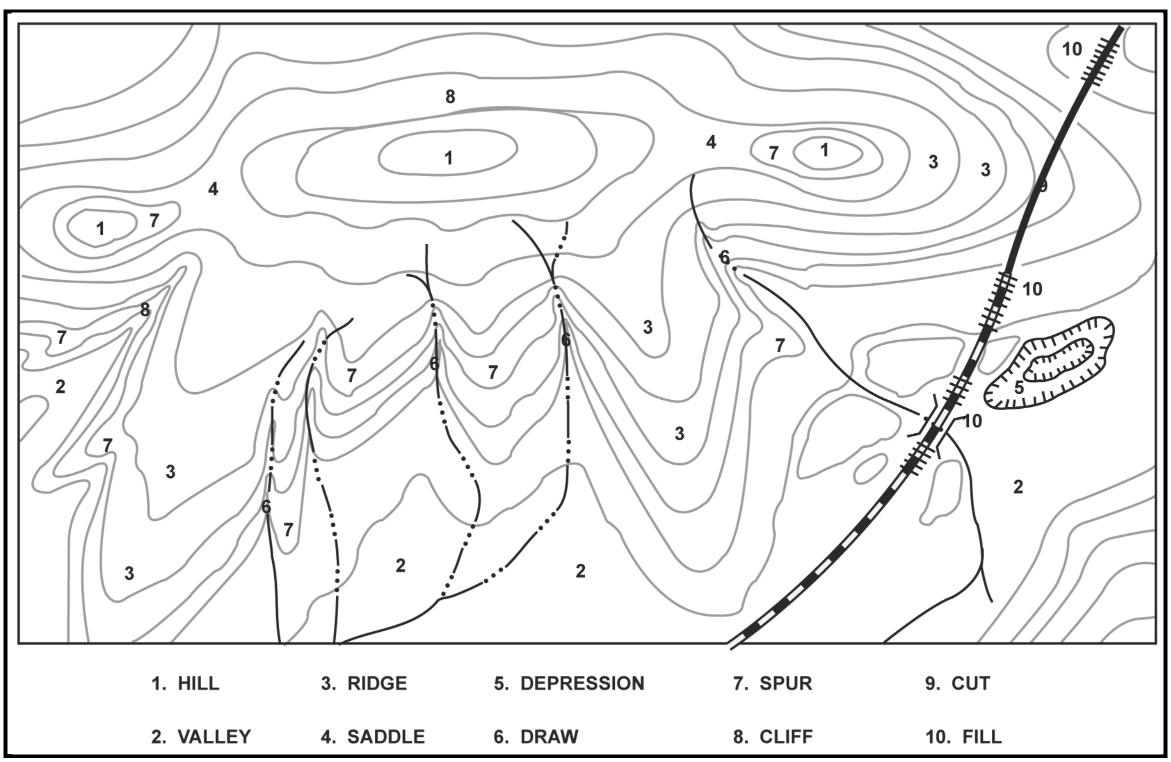


Figure 9-25. Terrain features

9-39. Emphasizing the main contour lines is a technique used to interpret the terrain of an area. By studying these contour lines, one can better understand the layout of the terrain and decide on the best route. The following description pertains to Figure 9-26:

- Running east to west across the complex landmass is a ridgeline. (See paragraph 9-25.) The changes in elevation are the three hilltops and two saddles along the ridgeline. From the top of each hill, there is lower ground in all directions. Because of the difference in size of the higher ground on the two opposite sides of a saddle, a full hourglass shape of a saddle may not be apparent. (See paragraph 9-28.)
- There are four prominent ridges. A ridge is on each end of the ridgeline and two ridges extend south from the ridgeline. The closed ends of the U's formed by the contour lines point away from higher ground. (See paragraph 9-30.)
- To the south lies a valley; the valley slopes downward from east to west. Note that the U of the contour line points to the east, indicating higher ground in that direction and lower ground to the west. Another look at the valley shows high ground to the north and south of the valley.
- Just east of the valley is a depression. Looking from the bottom of the depression, there is higher ground in all directions.
- There are several spurs extending generally south from the ridgeline. (See paragraph 9-34.) Their contour line U's point away from higher ground.
- Between the ridges and spurs are draws. They, like valleys, have higher ground in three directions and lower ground in one direction. Their contour line U's and V's point toward higher ground.
- Two contour lines on the north side of the center hill are touching or almost touching. They have ticks indicating a vertical or nearly vertical slope or a cliff.
- The road cutting through the eastern ridge depicts cuts and fills. The breaks in the contour lines indicate cuts, and the ticks pointing away from the road bed on each side of the road indicate fills.

9-40. Learning to identify several individual terrain features in the field and see how they vary in appearance takes practice. A recommended technique for identifying specific terrain features and then locating them on the map is to use five characteristics: shape, orientation, size, elevation, and slope. Terrain features can be examined, described, and compared with each other and with corresponding map contour patterns in terms of:

- **Shape** is the general form or outline of the feature at its base.
- **Orientation** is the general trend or direction of a feature from the current viewpoint. A feature can be in line, across, or at an angle to the viewpoint.
- **Size** is the length or width of a feature horizontally across its base. For example, one terrain feature might be larger or smaller than another.
- **Elevation** is the height of a terrain feature. This can be described in absolute or relative terms as compared to the other features in the area. One landform may be higher, lower, deeper, or shallower than another.
- **Slope** is the type (uniform, convex, or concave) and angle (steep or gentle) of the sides of a terrain feature.

9-41. The ridgelining technique helps with visualizing the overall lay of the ground within the area of interest on the map. (See Figure 9-26.) Use the following steps to implement this technique:

- Identify on the map the crests of the ridgelines in the area of operation by identifying the close-out contours that lie along the hilltop.
- Trace over the crests so each ridgeline stands out clearly as one identifiable line using solid or colored lines. The usual colors used for this tracing are red or brown; however, other colors may be used. Figure 9-26 depicts the ridgelining tracing using solid lines.
- Go back over each of the major ridgelines and trace over the prominent ridges and spurs that come out of the ridgelines.
- After completing the ridgelining process, the high ground on the map stands out and the relationship between the various ridgelines can be seen.

9-42. The streamlining procedure is similar to that of ridgelining. (See Figure 9-26.) Follow these steps:

- Identify all the mapped streams in the area of operations.

- Trace over them to make them stand out more prominently using dashed or colored lines. The color used for this is usually blue; but again, if blue is not available; another color may be used so long as the distinction between the ridgelines and the streamlines is clear. Figure 9-26 depicts the streamlining tracing as dashed lines.
- Identify other low ground, such as smaller valleys or draws that feed into the major streams, and trace over them. This brings out the drainage pattern and low ground in the area of operation on the map.

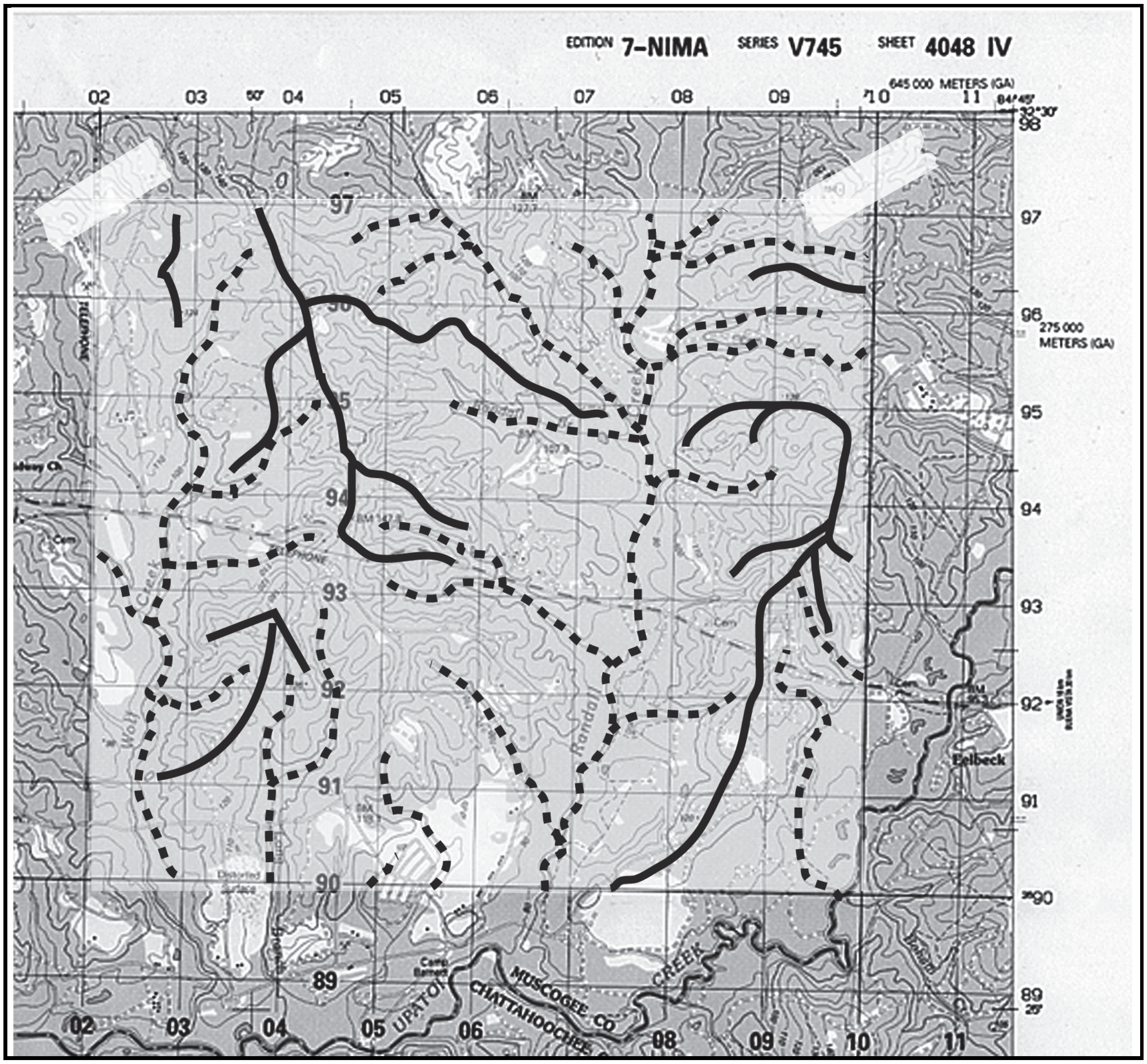


Figure 9-26. Ridgelining and streamlining

PROFILES

9-43. The study of contour lines to determine high and low points of elevation is usually adequate for military operations. However, there may be times when a quick and precise reference to determine exact elevations of specific points is needed. When exactness is demanded, a profile is required. A profile, within the scope and purpose of this manual, is an exaggerated side view of a portion of the earth's surface along a line between two or more points.

9-44. A profile can be used for many purposes. The primary purpose is to determine if line of sight is available. Line of sight is used to—

- Determine defilade positions.

- Plot hidden areas or dead space.
- Determine potential direct fire weapon positions.
- Determine potential locations for defensive positions.
- Conduct preliminary planning in locating roads, pipelines, railroads, or other construction projects.

9-45. A profile can be constructed from a contoured map using the following steps:

- Draw a line on the map from where the profile is to begin to where it is to end. (See Figure 9-27.)
- Find the value of the highest and lowest contour lines that cross or touch the profile line. Add one contour value above the highest and one below the lowest to take care of hills and valleys.
- Select a piece of lined notebook paper with as many lines as was determined above. The standard Army green pocket notebook or other paper with 1/4-inch lines is ideal. Wider lines, up to 5/8-inch, may be used. If lined paper is not available, draw equally spaced horizontal lines on a blank sheet of paper.
- Number the top line with the highest value and the bottom line with the lowest value as determined above.

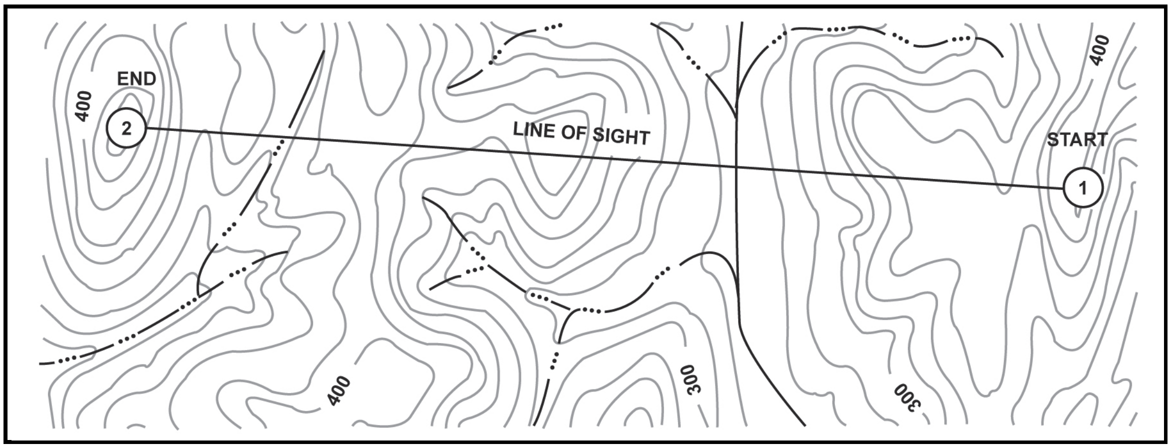


Figure 9-27. Connecting points

- Number the rest of the lines in sequence, starting with the second line from the top. The lines are numbered according to the contour interval. (See Figure 9-28.)
- Place the paper on the map with the lines next to and parallel to the profile line.
- From every point on the profile line where a contour line, stream, intermittent stream, or other body of water crosses or touches, drop a perpendicular line to the line having the same value. Place a tick mark where the perpendicular line crosses the number line. Where trees are present, add the height of the trees to the contour line, and place a tick mark there. Assume the height of the trees to be 50 feet or 15 m where dark green tint is shown on the map. Vegetation height may be adjusted up or down when operations in the area provide known tree heights.
- After all perpendicular lines have been drawn and tick marks placed where the lines cross, connect all tick marks with a smooth, natural curve to form a horizontal view of the terrain along the profile line. (See Figure 9-28.)
- The profile drawn may be exaggerated. The spacing between the lines drawn on the sheet of paper determines the amount of exaggeration and may be varied to suit the purpose.

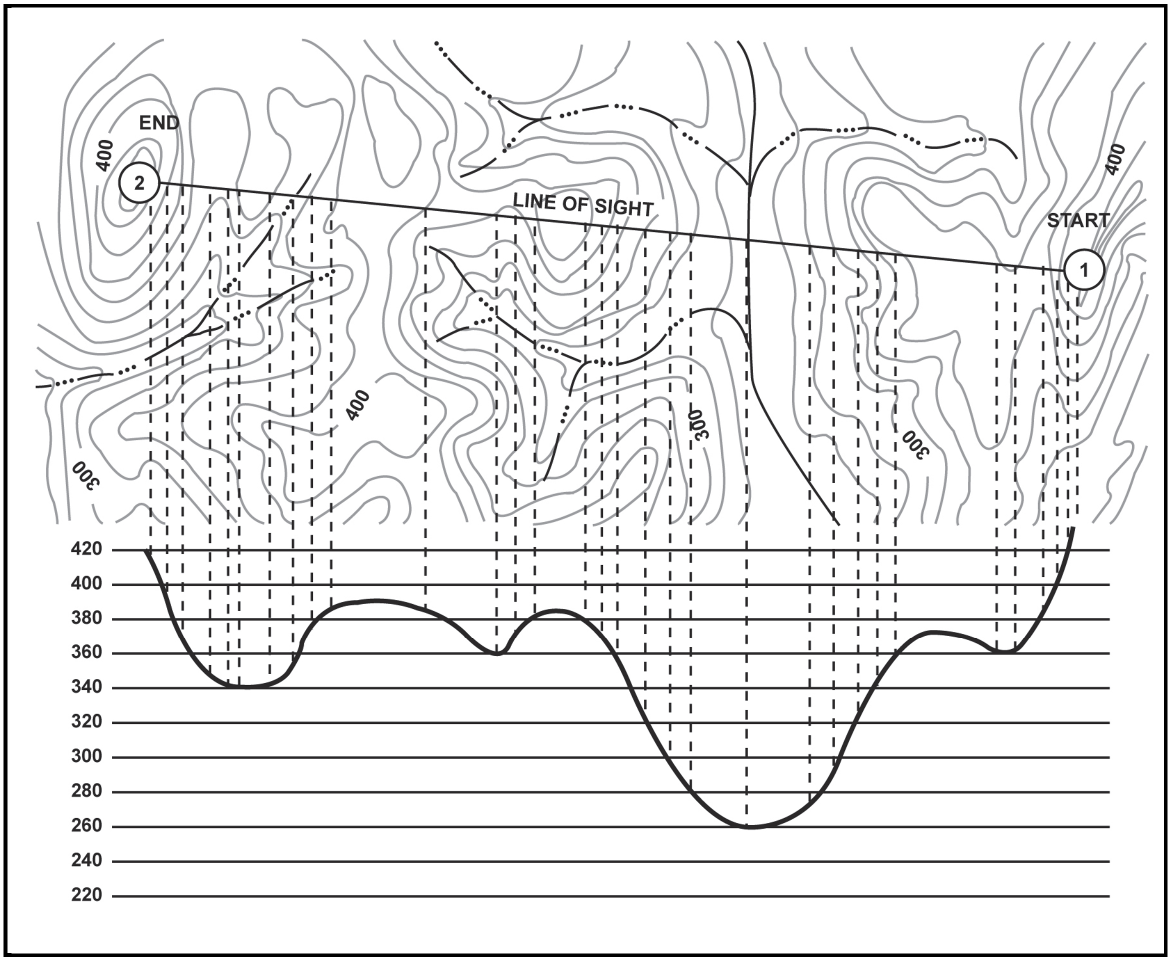


Figure 9-28. Dropping perpendiculars

- Draw a straight line from the start point to the end point on the profile. If the straight line intersects the curved profile, line of sight to the end point is not available. (See Figure 9-29.)

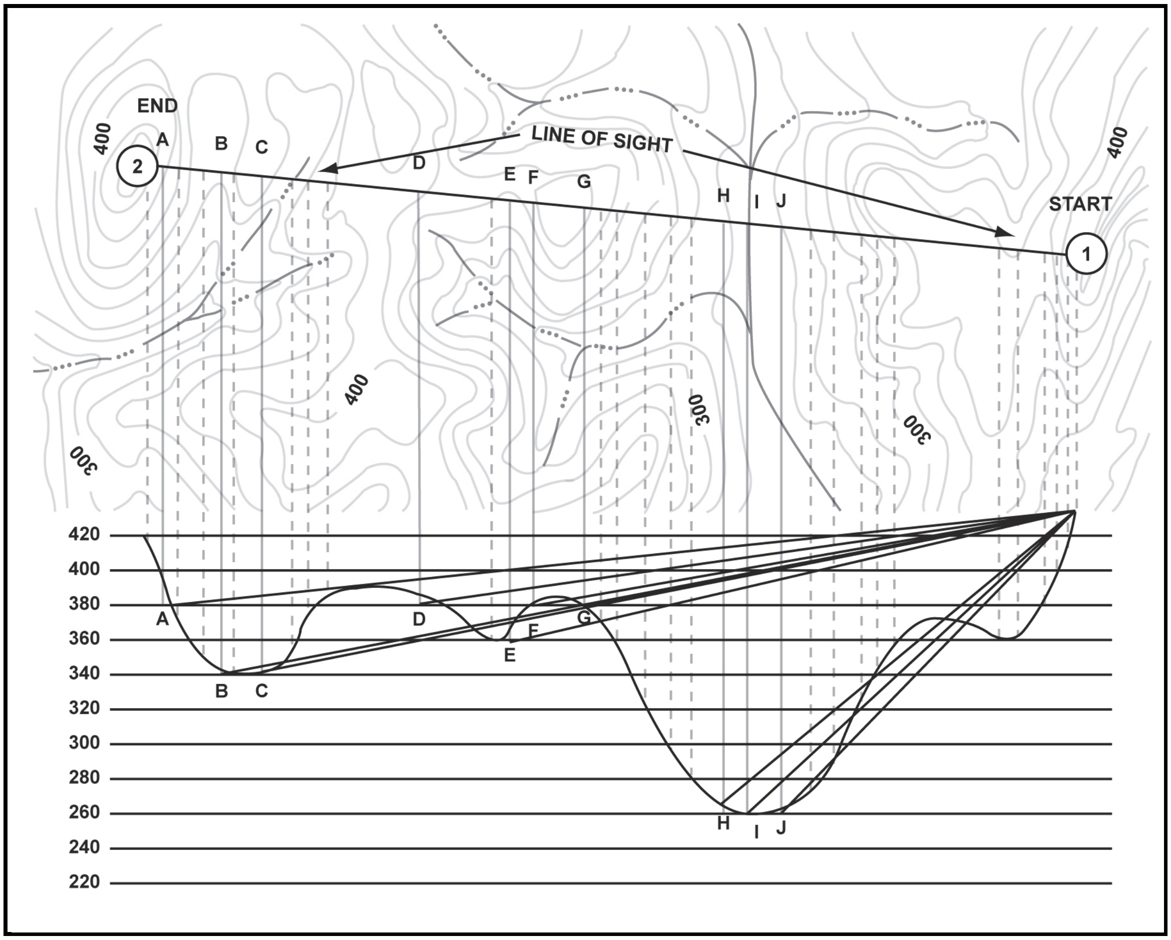


Figure 9-29. Drawing lines to additional points

- Line of sight to other points along the profile line can be determined by drawing a line from the start point to additional points. In Figure 9-30, line of sight is available to:

A – YES	**C – NO**	**E – NO**	**G – YES**	**I - NO**
B – NO	**D – YES**	**F – NO**	**H – NO**	**J - NO**

- The vertical distance between navigable ground up to the line of sight line is the depth of defilade.

9-46. When time is short, or when a complete profile is not needed, one may be constructed showing only the hilltops, ridges, and valleys. This is called a hasty profile. It is constructed in the same manner as a full profile. (See Figure 9-30.)

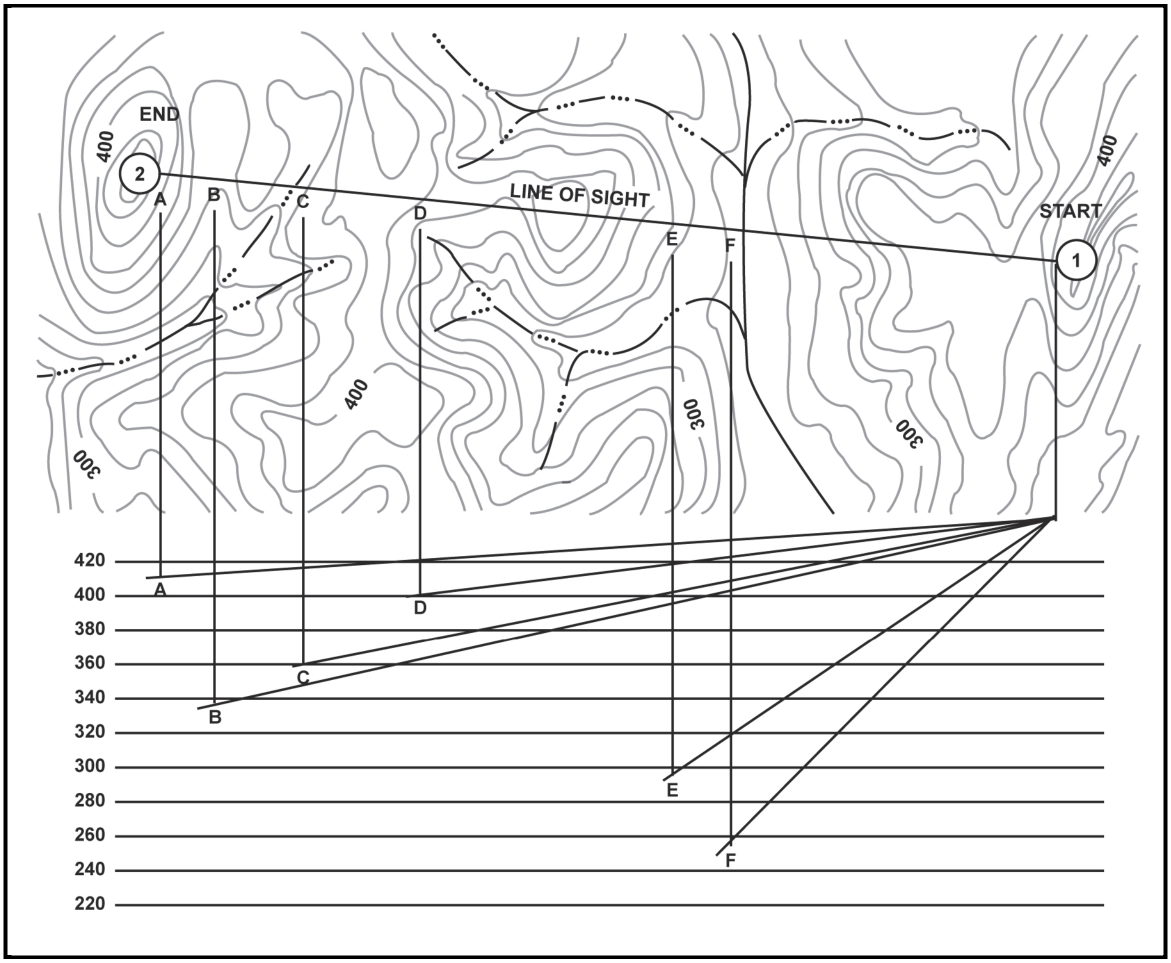


Figure 9-30. Drawing a hasty profile

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Chapter 10

Terrain Association

Failing to use the vast amounts of information available to the eye on the ground and by map reduces the chances for success in land navigation. The Soldier who has repeatedly practiced the skills of identifying and discriminating among the many types of terrain and other features knows how these features are mapped. By studying the map, a Soldier can begin to visualize the shape of the land, estimate distances, and perform quick resection from the many landmarks seen. This Soldier is the one who is at the right place to help defeat the enemy on the battlefield.

This chapter tells how to orient a map with and without a compass, how to find locations on a map, on the ground, how to study the terrain, and how to move on the ground using terrain association and dead reckoning.

ORIENTATION OF THE MAP

10-1. The first step for a navigator in the field is orienting the map. A map is oriented when it is in a horizontal position with its north and south corresponding to the north and south on the ground.

USING A COMPASS

10-2. When orienting a map with a compass, remember that the compass measures magnetic azimuths. Since the magnetic arrow points to magnetic north, pay special attention to the declination diagram. Two techniques are used.

First Technique

10-3. Determine the direction of the declination and its value from the declination diagram. With the map in a horizontal position, take the straightedge on the left side of the compass and place it alongside the north-south grid line with the cover of the compass pointing toward the top of the map. This procedure places the fixed black index line of the compass parallel to north-south grid lines of the map.

10-4. Keeping the compass aligned as directed above, rotate the map and compass together until the magnetic arrow is below the fixed black index line on the compass. At this time, the map is close to being oriented. Rotate the map and compass in the direction of the declination diagram.

10-5. If the magnetic north arrow on the map is to the left of the grid north, check the compass reading to see if it equals the G-M angle given in the declination diagram. The map and compass are then oriented to grid north. (See Figure 10-1.)

10-6. If the magnetic north is to the right of grid north, check the compass reading to see if it equals 360 degrees minus the G-M angle. (See Figure 10-2.)

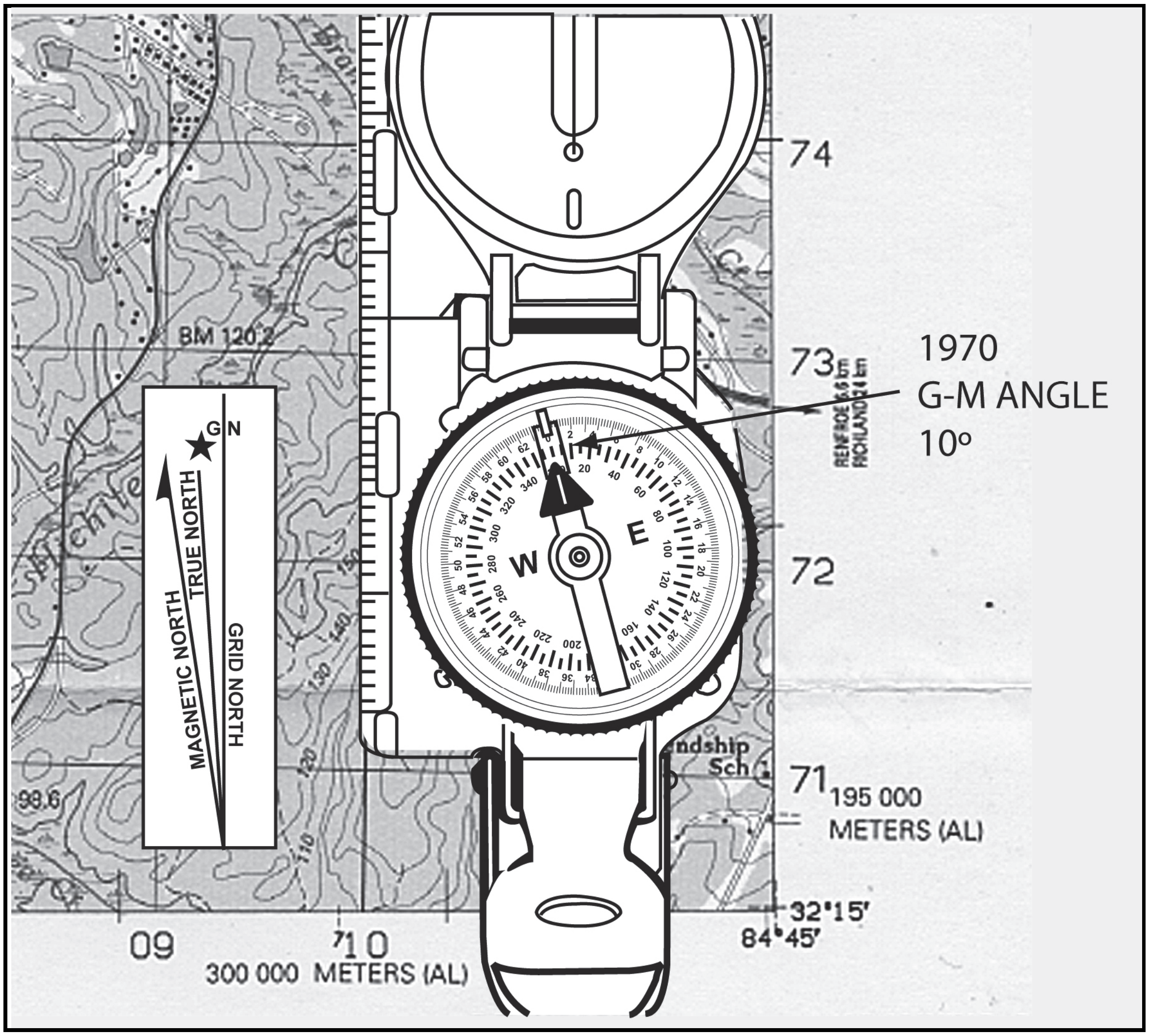

Figure 10-1. Map and compass oriented to grid north with 10 degrees west declination

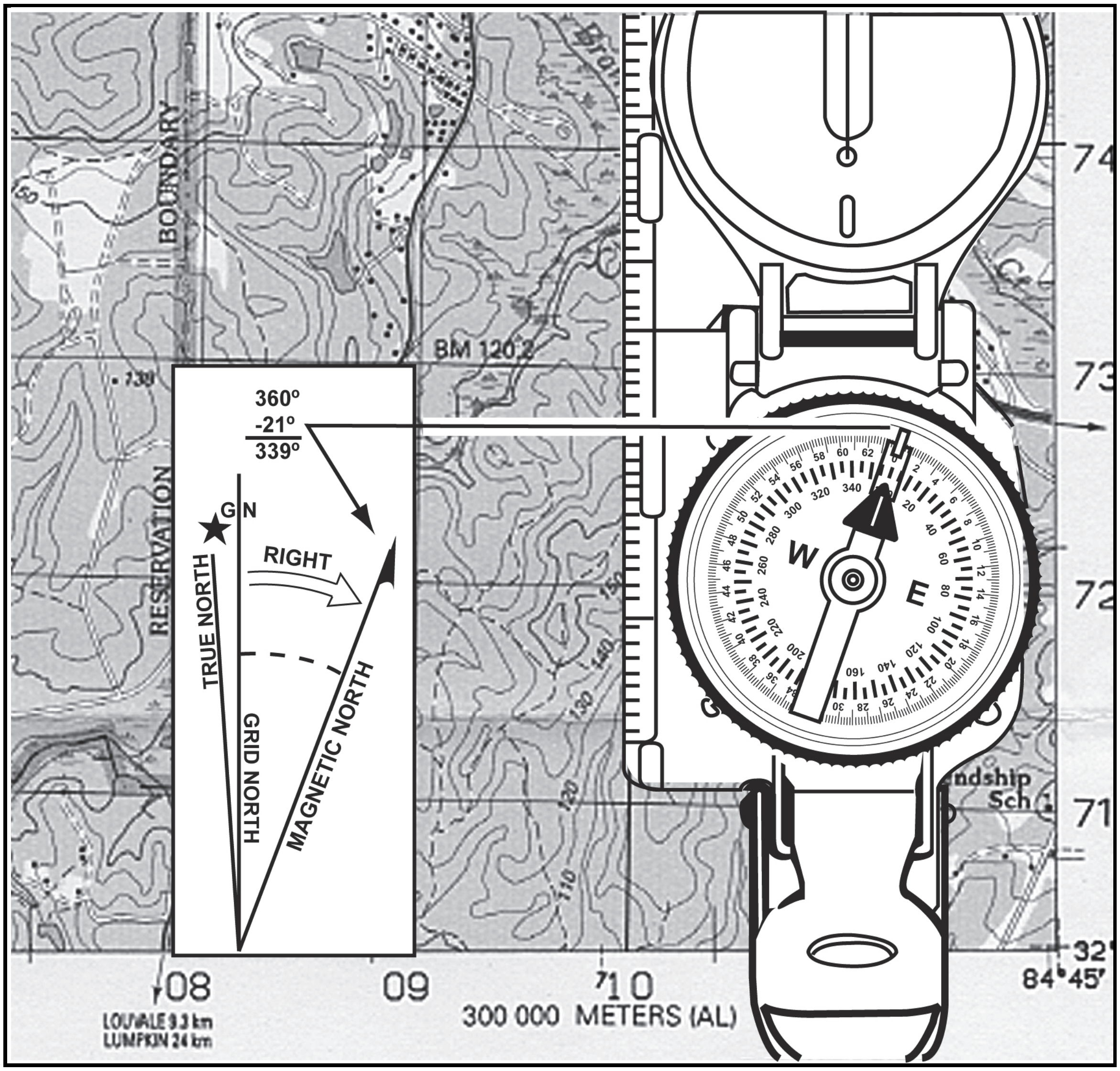

Figure 10-2. Map oriented with 21 degrees east declination

Second Technique

10-7. Determine the direction of the declination and its value from the declination diagram. Using a north-south grid line on the map as a base, draw a magnetic azimuth equal to the G-M angle given in the declination diagram with the protractor.

10-8. If the declination is easterly (right), the drawn line is equal to the value of the G-M angle. Then align the straightedge on the left side of the compass alongside the drawn line on the map. Rotate the map and compass until the magnetic arrow of the compass is below the fixed black index line. The map is now oriented to grid north with the compass oriented to portray an eastern declination. (See Figure 10-3.)

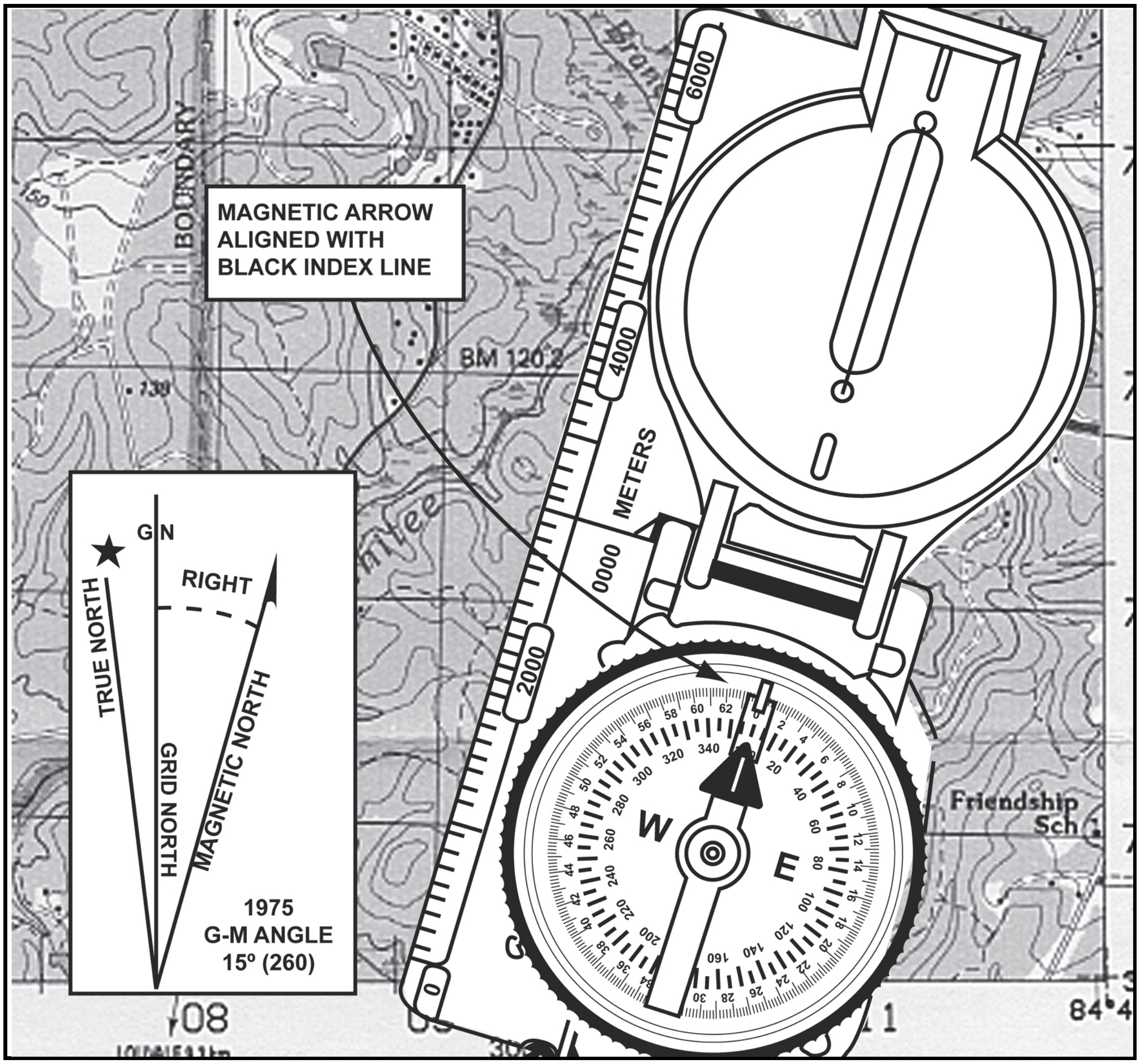

Figure 10-3. Map oriented to grid north with compass portraying a 15 degrees east declination

10-9. If the declination is westerly (left), the drawn line equals 360 degrees minus the value of the G-M angle. Then align the straightedge on the left side of the compass alongside the drawn line on the map. Rotate the map and compass until the magnetic arrow of the compass is below the fixed black index line. The map is now oriented to grid north with the compass oriented to portray a westerly declination. (See Figure 10-4.)

Notes. 1. Once the map is oriented, magnetic azimuths are determined using the compass. Do not move the map from its oriented position since a change in its position moves it out of line with the magnetic north.

2. Special care should be taken when orienting the map with a compass. A small mistake can cause navigation in the wrong direction.

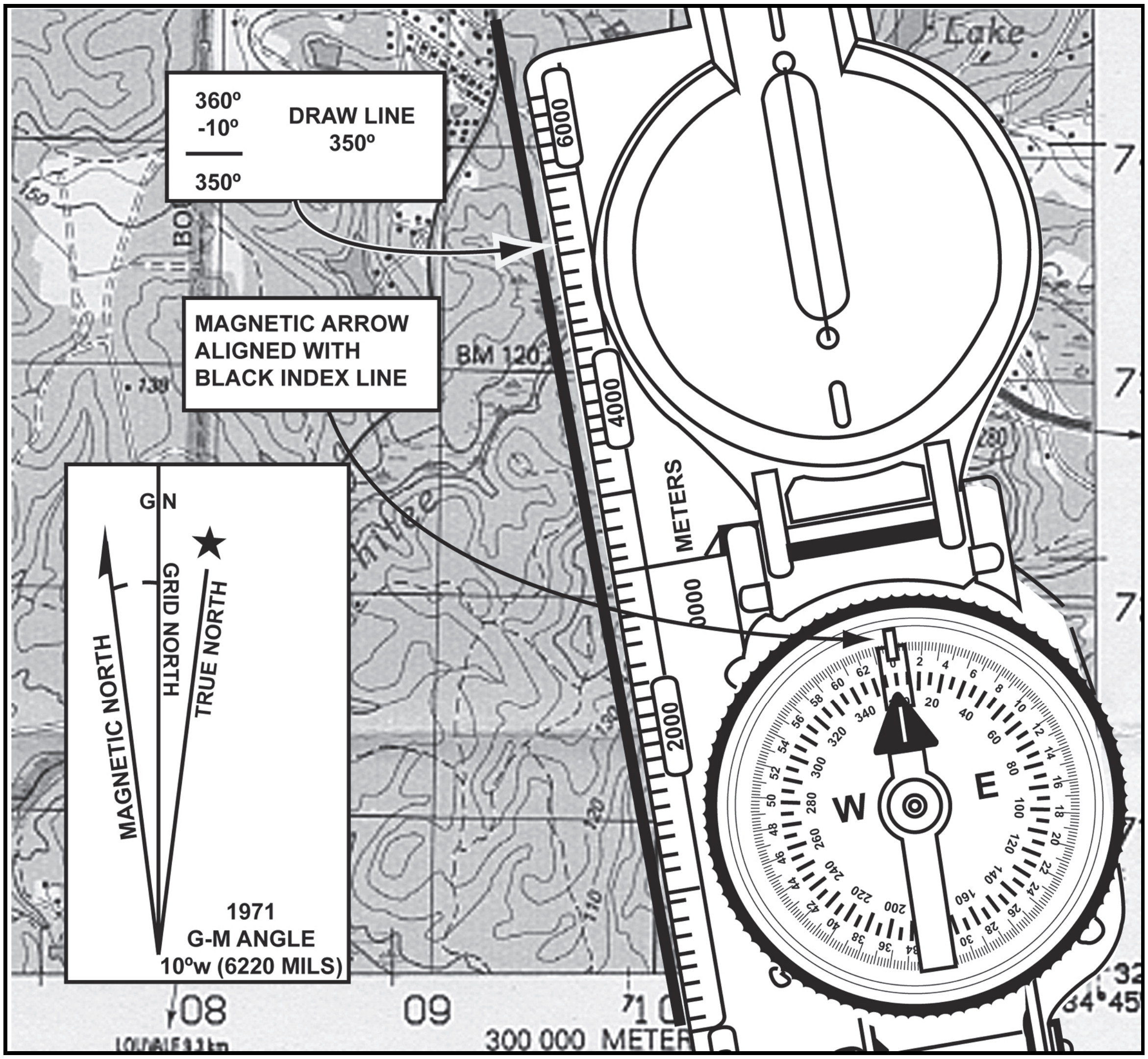

Figure 10-4. Map oriented to grid north with the compass oriented to portray 10 degrees west declination

USING TERRAIN ASSOCIATION

10-10. A map can be oriented by terrain association when a compass is not available or when the user has to make many quick references while moving across country. Using this method requires careful examination of the map and the ground, and knowing the approximate location. (See Figure10-5.)

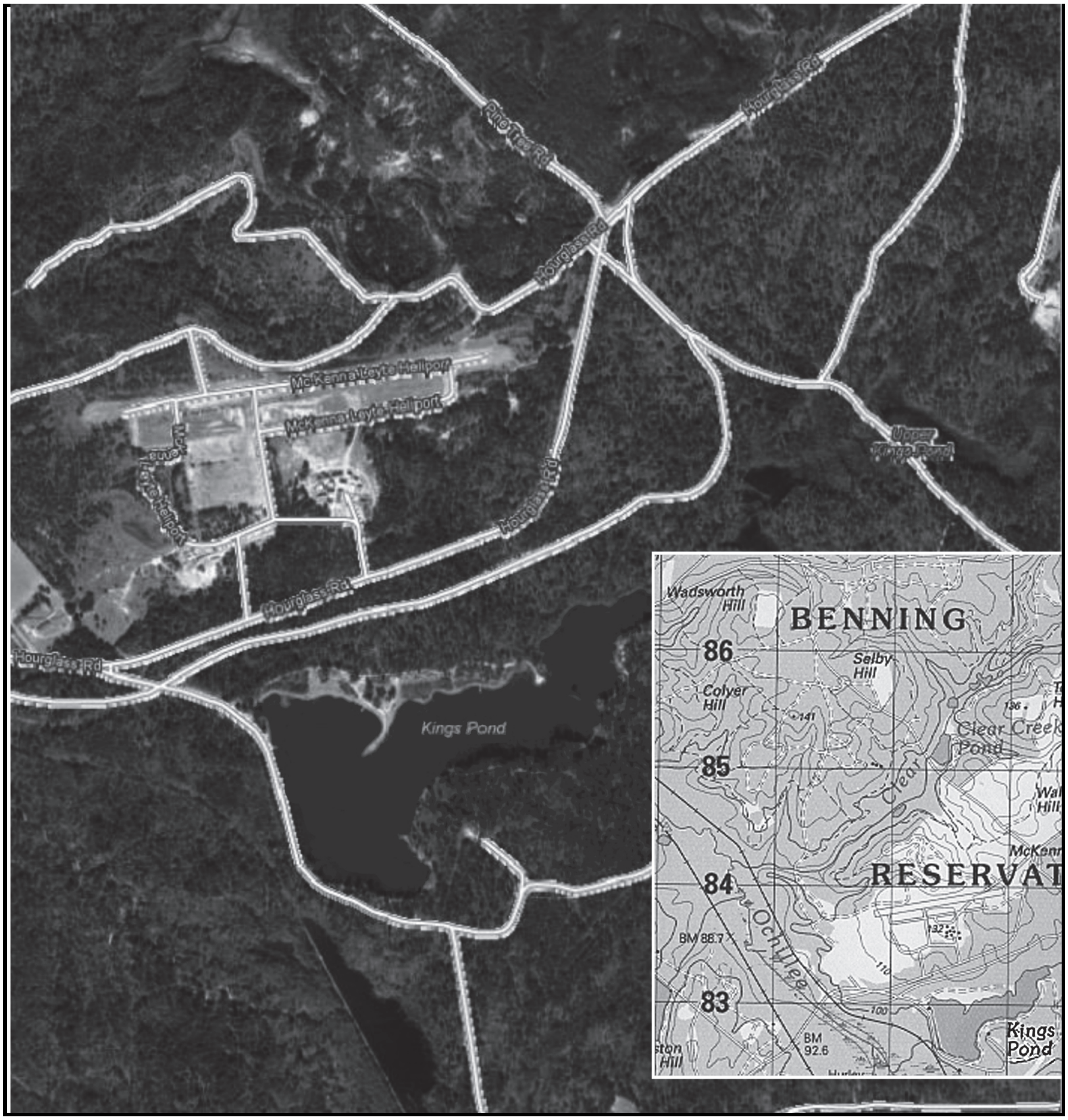

Figure 10-5. Terrain association

USING FIELD-EXPEDIENT METHODS

10-11. When a compass is not available and there are no recognizable terrain features, a map may be oriented by the field-expedient methods described in Chapter 8. (See Figure 10-6.)

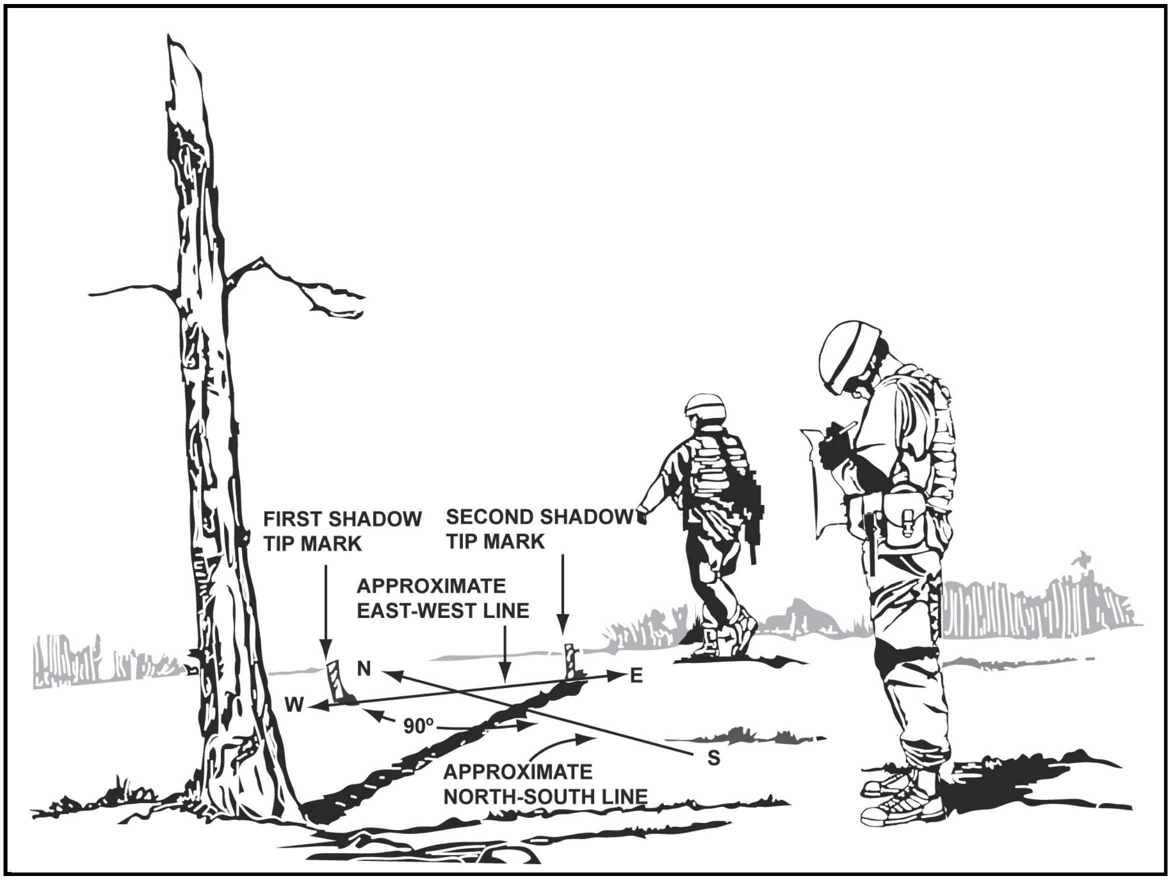

Figure 10-6. Field-expedient method

LOCATIONS

10-12. The key to success in land navigation is to know one's location at all times. With this basic knowledge, direction and how far to travel is determined.

10-13. Most important is the initial location of the user before starting a movement in the field. If movement takes place without establishing the initial location, everything that is done in the field from there on is a gamble. Determine the initial location by referring to the last known position, by grid coordinates and terrain association, or by locating and orienting the start position on the map and ground.

10-14. The known point/known distance (polar plot) location can be determined by knowing the starting point, the azimuth to the desired objective, and the distance to it.

10-15. Finding a location by indirect fire is done with smoke. Use the point of impact of the round as a reference point from which distances and azimuth can be obtained.

TERRAIN ASSOCIATION USAGE

10-16. The technique of moving by terrain association is more forgiving of mistakes and far less time-consuming than dead reckoning. It best suits those situations that call for movement from one area to another. Errors made using terrain association are easily corrected by comparing what is expected from the map to what is seen on the ground. Errors are anticipated and do not go unchecked. Adjustments are easily made based upon what is encountered. Periodic position-fixing through plotted or estimated resection also makes it possible to correct movements, call for fire, or call in the locations of enemy targets (or other information of tactical or logistical importance).

MATCHING THE TERRAIN TO THE MAP BY EXAMINING TERRAIN FEATURES

10-17. By observing the contour lines in detail, the five major terrain features (hilltop, valley, ridge, depression, and saddle) should be determined. This is a simple task in an area where the observer has ample view of the terrain in all directions. One-by-one, match the terrain features depicted on the map with the same features on the ground. In restricted terrain, this procedure becomes harder. However, constantly check the map when moving since it is the determining factor. (See Figure 10-5.)

10-18. When comparing the vegetation, a topographic map should be used to make a comparison of the clearings that appear on the map with the ones on the ground. The user references the legend and becomes familiar with the different symbols such as vineyards, plantations, and orchards that appear on the map. (See paragraph 3-3.) The age of the map is an important factor when comparing vegetation. Some important vegetation features were likely to be different when the map was made. Another important factor about vegetation is that it can change overnight by natural accidents or by man (forest fires, clearing of land for new developments, farming, and other means).

10-19. Quick identification of known terrain features aid navigators when using terrain association. (See paragraph 10-16.) However, terrain association requires periodic position-fixing. The camouflage of important landforms (vegetation camouflaging a radio tower) makes it harder for the navigator to use terrain association.

10-20. Inland bodies of water can help during terrain association. The shape and size of lakes in conjunction with the size and direction of flow of the rivers and streams are valuable help.

10-21. Man-made features are an important factor during terrain association. The user is familiar with the symbols shown in the legend representing those features. The direction of buildings, roads, bridges, high-tension lines, and other features make the terrain inspection a lot easier. However, the age of the map is considered because man-made features appear and disappear constantly.

Examining Terrain During Different Seasons of the Year

10-22. In those areas of the world where the seasons are distinctive, a detailed examination of the terrain should be made during each season. The same piece of land does not present the same characteristics during spring and winter. For example—

- During winter, the snow packs the vegetation, delineating the land and making the terrain features appear as clear as they are shown by the contour lines on the map. Ridges, valleys, and saddles are very distinctive.
- During spring, the vegetation begins to reappear and grow. New vegetation causes a gradual change of the land to the point that the foliage conceals the terrain features and makes the terrain hard to recognize.
- During summer months, the effects are similar to those in the spring.
- Fall makes the land appear different with its change of color and gradual loss of vegetation.
- During the rainy season, the vegetation is green and thick, and the streams and ponds look like small rivers and lakes. In sparsely vegetated areas, the erosion changes the shape of the land.
- During a period of drought, the vegetation dries out and becomes vulnerable to forest fires that change the terrain whenever they occur. Also during this season, the water levels of streams and lakes drop, adding new dimensions and shape to the existing mapped areas.

10-23. As an example of terrain association, see Figure 10-7. The start location is hilltop 514 in the left center of the map:

- **To the north.** The contour lines indicate that the hill slopes down for about 190 m, and that it leads into a small valley containing an intermittent stream. Continuing on a northerly inspection, on the other side of the stream the terrain starts a gradual ascent, indicating a hilltop partially covered with vegetation, until an unimproved road is reached. This road runs along a gradual ridgeline with a northwest direction. Then the contour line spacing becomes narrow, indicating a steeper grade that leads to a narrow valley containing a small intermittent stream. Continuing up, there is a small but prominent ridge with a clearing. The contour lines once again show a steeper grade leading to a moderate valley containing an intermittent stream running in a southeast direction.

- **To the east.** There is a clearing of the terrain as it slopes down to Schley Pond. An ample valley is clearly seen on the right side of the pond, as indicated by the "U" and "V" shape of the contour lines. This valley contains some swamp areas and there is a long ridgeline on the north portion of the valley.
- **To the south.** The terrain gently slopes downward until a clear area is reached. It continues in a downward direction to an intermittent stream running southeast in a small valley. There is also an improved road running in the same direction as the valley. Facing south at the intersection of the roads, there is a clearing of about 120 m on the ridge. At the bottom of it, a stream runs from Schley Pond in a southwest direction through an ample valley fed by two intermittent streams. Continuing on, a steep, vegetated hill is found with a clearing on its top, followed by a small saddle and another hilltop.
- **To the west.** There is a small, clear valley followed by a general ridgeline running northwest in which an unimproved road is located just before a hilltop. Continuing on a westerly direction, there are a series of alternate valleys and ridges.

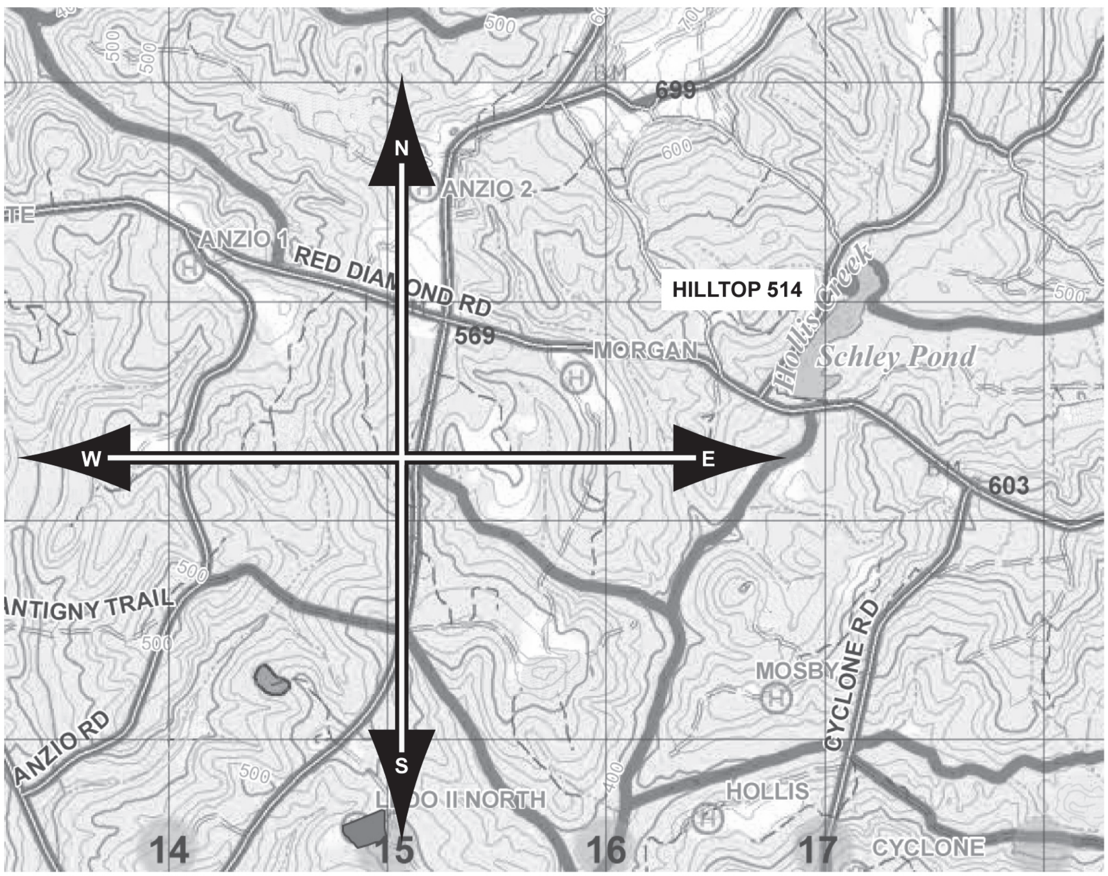

Figure 10-7. Example of terrain association

TACTICAL CONSIDERATIONS

10-24. Military cross-country navigation is intellectually demanding because it is imperative that the unit, crew, or vehicle survive and successfully complete the move in order to accomplish its mission. However, the unnecessary use of a difficult route makes navigation too complicated, creates more noise when proceeding over it, causes wear and tear on equipment and personnel, increases the need for and needlessly complicates recovery operations, and wastes time. On receipt of a tactical mission, the leader begins troop-leading procedures and makes a tentative plan based upon a good terrain analysis.

10-25. One key to success in tactical missions is the ability to move undetected to the objective. There are four steps to land navigation: know where you are, plan the route, stay on the route, and recognize the objective.

KNOW WHERE YOU ARE (STEP 1)

10-26. You need to know where you are on the map and on the ground at all times and in every possible way. This includes knowing where you are relative to—

- Your directional orientation.
- The direction and distances to your objective.
- Other landmarks and features.
- Any impassable terrain, the enemy, and danger areas.
- The advantages and disadvantages presented by the terrain between you and your objective. This step is accomplished by knowing how to read a map; recognize and identify specific terrain and other features; determine and estimate direction; pace, measure, and estimate distances; and plot and estimate a position by resection.

PLAN THE ROUTE (STEP 2)

10-27. Depending upon the size of the unit and the length and type of movement to be conducted, several factors should be considered in selecting a good route or routes to be followed. These include—

- Travel time.
- Travel distance.
- Maneuver room needed.
- Traffic ability.
- Load-bearing capacities of the soil.
- Energy expenditure by troops.
- The factors of mission, enemy, terrain and weather, troops and support available, time available, civil considerations (METT-TC).
- Tactical aspects of terrain.
- Ease of logistical support.
- Potential for surprising the enemy.
- Availability of control and coordination features.
- Availability of good checkpoints and steering marks. In other words, the route is the result of careful map study and should address the requirements of the mission, tactical situation, and time available. It also provides for ease of movement and navigation. Keep in mind that—
  - The three route-selection criteria important for small-unit movements are cover, concealment, and the availability of reliable checkpoint features. The latter is weighted even more heavily when selecting the route for a night operation. The degree of visibility and ease of recognition (visual effect) is the key to proper selection of these features.
  - The best checkpoints are linear features that cross the route. Examples include perennial streams, hard-top roads, ridges, valleys, railroads, and power transmission lines. Next, it is best to select features that represent elevation changes of at least two contour intervals such as hills, depressions, spurs, and draws. Primary reliance upon cultural features and vegetation is cautioned against because they are most likely to change between map revisions.
  - Checkpoints located at places where changes in direction are made mark your decision points. Be especially alert to see and recognize these features during movement. During preparation and planning, it is especially important to review the route and anticipate where mistakes are most likely to be made so they can be avoided.
  - Following a valley floor or proceeding near (not on) the crest of a ridgeline generally offers easy movement, good navigation checkpoints, and sufficient cover and concealment. It is best to follow terrain features whenever possible—not to fight them.

- A lost or late-arriving unit, or a tired unit that is tasked with an unnecessarily difficult move, does not contribute to the accomplishment of a mission. On the other hand, the unit that moves too quickly and carelessly into a destructive ambush or leaves itself open to air strikes also has little effect. Careful planning and study are required each time a movement route is to be selected.

STAY ON THE ROUTE (STEP 3)

10-28. In order to know that the correct route is being followed, compare the evidence encountered while moving according to the plan developed on the map when the route was selected. This may include watching compass readings (dead reckoning) or recognizing various checkpoints or landmarks from the map in their anticipated positions and sequences as they are passed (terrain association). A better way is to use a combination of both techniques.

RECOGNIZE THE OBJECTIVE (STEP 4)

10-29. The destination is rarely a highly recognizable feature such as a dominant hilltop or road junction. Such locations are seldom missed by the most inexperienced navigators and are often dangerous places for Soldiers to occupy. The relatively small, obscure places are most likely to be the destinations.

10-30. Just how does a Soldier travel over unfamiliar terrain for moderate to great distances and know when he reaches the destination? One minor error, when many are possible, can cause the target to be missed. The answer is simple. Select a checkpoint (reasonably close to the destination) that is not so difficult to find or recognize. Then plan a short, fine-tuned last leg from the new expanded objective to the final destination. For example, if possible, plan and execute the move as a series of sequenced movements from one checkpoint or landmark to another using the terrain and a compass to keep on the correct course. After arriving at the last checkpoint, follow a specific compass azimuth and pace off the relatively short, known distance to the final, pinpoint destination. This procedure is called point navigation. A short movement out from a unit position to an observation post (OP) or to a coordination point may also be accomplished in the same manner.

NAVIGATION METHODS

10-31. Staying on the route is accomplished through the use of one or two navigation techniques—dead reckoning and terrain association. These methods are discussed in detail below.

MOVING BY DEAD RECKONING

10-32. Dead reckoning consists of two fundamental steps. The first is the use of a protractor and graphic scales to determine the direction and distance from one point to another on a map. The second step is the use of a compass and some means of measuring distance to apply this information on the ground. In other words, it begins with the determination of a polar coordinate on a map and ends with the act of finding it on the ground.

10-33. Dead reckoning along a given route is the application of the same process used by a mapmaker establishing a measured line of reference upon which to construct the framework of the map. Therefore, triangulation exercises (either resection or intersection) can be easily undertaken by the navigator at any time to determine or confirm precise locations along or near the route. Between these position-fixes, establish your location by measuring or estimating the distance traveled along the azimuth being followed from the previous known point. Depending upon the situation, pacing, a vehicle odometer, or the application of elapsed time can be used for this purpose.

10-34. Most dead reckoned movements do not consist of single straight-line distances due to the tactical and navigational aspects of the terrain, enemy situation, natural and man-made obstacles, time, and safety factors. Another reason most dead reckoning movements are not single straight-line distances is because compasses and pace counts are imprecise measures. Error from them compounds over distance; causing a Soldier to be far from the intended route even if the procedures are performed correctly. The only way to counteract this phenomenon is to reconfirm location by terrain association or resection. Routes planned for dead reckoning generally consist of a series of straight-line distances between several checkpoints with perhaps some travel running on or parallel to roads or trails.

10-35. There are two advantages to dead reckoning. First, dead reckoning is easy to teach and to learn. Second, it can be a highly accurate way of moving from one point to another if done carefully over short distances, even where few external cues are present to guide the movements.

10-36. During daylight, across open country along a specified magnetic azimuth, never walk with the compass in the open position and in front of you. Because the compass does not stay steady or level, it does not give an accurate reading when held or used this way. Begin at the start point and face with the compass in the proper direction, then sight in on a landmark that is located on the correct azimuth to be followed. Close the compass and proceed to that landmark. Repeat the process as many times as necessary to complete the straight-line segment of the route.

10-37. The landmarks selected for this purpose are called steering marks, and their selection is crucial to success in dead reckoning. Steering marks should never be determined from a map study. They are selected as the march progresses and are commonly on or near the highest points visible along the azimuth line being followed. They may be uniquely shaped trees, rocks, hilltops, posts, towers, and buildings—anything that can be easily identified. If a good steering mark is not located to the front, a back azimuth toward some feature to the rear can be used until a good steering mark appears out in front. Characteristics of a good steering mark are:

- It has some characteristics about it, such as color, shade of color, size, or shape (preferably all four), that are recognized upon approach.
- If several easily distinguished objects appear along your line of march, the best steering mark is the most distant object. This procedure enables further distance travel with fewer references to the compass. If there are many options, select the highest object. A higher mark is not as easily lost to sight as is a lower mark that blends into the background upon approach. A steering mark should be continuously visible while moving toward it.
- Steering marks selected at night have even more unique shapes than those selected during daylight. As darkness approaches, colors disappear and objects appear as black or gray silhouettes. Instead of seeing shapes, only the general outlines are visible (that may appear to change during movement as the objects are seen from slightly different angles).

10-38. Dead reckoning without natural steering marks is used when the travel area is devoid of features, or when visibility is poor. At night, it may be necessary to send a member of the unit out in front of the unit's position to create steering marks in order to proceed. The position should be as far out as possible to reduce the number of chances for error during movement. Arm-and-hand signals or a radio may be used in placing the Soldier on the correct azimuth. After being properly located, move forward to this position and repeat the process until some steering marks can be identified or until the objective is reached. When handling obstacles/detours on the route, follow these guidelines:

- When an obstacle forces the march to leave the original line and take up a parallel one, always return to the original line as soon as the terrain or situation permits.
- To turn clockwise (right) 90 degrees, add 90 degrees to the original azimuth. To turn counterclockwise (left) 90 degrees from the current direction, subtract 90 degrees from the present azimuth.
- When making a detour, be certain that only paces taken toward the final destination are counted as part of the forward progress. They should not be confused with the local pacing that takes place perpendicular to the route in order to avoid the problem area and in returning to the original line of march after the obstacle has been passed.

10-39. Sometimes a steering mark on the azimuth of travel can be seen across a swamp or some other obstacle which can be walked around. Dead reckoning can then begin at that point. If there is no obvious steering mark to be seen across the obstacle, perhaps one can be located to the rear. Compute a back azimuth to this point and later sight back to it once the obstacle has been passed in order to get back on track.

10-40. Highly accurate distance estimates and precision compass work may not be required for a deliberate offset technique if the destination or an intermediate checkpoint is located on or near a large linear feature that runs nearly perpendicular to the direction of travel. Examples include roads or highways, railroads, power transmission lines, ridges, or streams. In these cases, apply a deliberate error (offset) of about 10 degrees to the azimuth planned and then move, using the lensatic compass as a guide, in that direction until encountering the linear feature. Turning left or right to find the destination or checkpoint depends upon which way the deliberate offset was planned.

10-41. Because no one can move along a given azimuth with absolute precision, it is better to plan a few extra steps than to begin an aimless search for the objective once reaching the linear feature. This method also copes with minor compass errors and the slight variations that always occur in the earth's magnetic field.

10-42. There are disadvantages to dead reckoning. The farther dead reckoning is travelled without position confirmation in relation to the terrain and other features, the more errors accumulate in the movement. Therefore, confirm and correct the estimated position whenever encountering a known feature on the ground that is also on the map. Periodically, accomplish a resection triangulation using two or more known points to pinpoint and correct your position on the map. Pace counts or a distance measurement should begin anew each time the position is confirmed on the map.

10-43. It is dangerous to select a single steering mark, such as a distant mountaintop, and then move blindly toward it. This hampers sudden calls for needed fire support or medical evacuation. To pinpoint a current location, use resection and terrain association techniques along the way.

10-44. Steering marks can be farther apart in open country, thereby making navigation more accurate. In areas of dense vegetation where there is little relief, during darkness, or in fog, steering marks are close together. However, this introduces more chance for error.

10-45. Dead reckoning is time-consuming and demands constant attention to the compass. Errors accumulate easily and quickly. Every fold in the ground and detours as small as a single tree or boulder also complicate the measurement of distance.

MOVING BY TERRAIN ASSOCIATION

10-46. The technique of moving by terrain association is more forgiving of mistakes and far less time-consuming than dead reckoning. It best suits those situations that call for movement from one area to another. Once an error has been made in dead reckoning, you are off the track. Errors made using terrain association are easily corrected because comparisons between what is expected from the map can be seen on the ground.

10-47. Errors are anticipated and do not go unchecked. Adjustments are easily made based upon what is encountered. After all, the neighborhood grocery store is not found by dead reckoning, but by adjusting movements according to the familiar landmarks encountered along the way. (See Figure 10-8.) Periodic position-fixing through plotted or estimated resection also makes it possible to correct movements, call for fire, call in the locations of enemy targets, or call in other information of tactical or logistical importance.

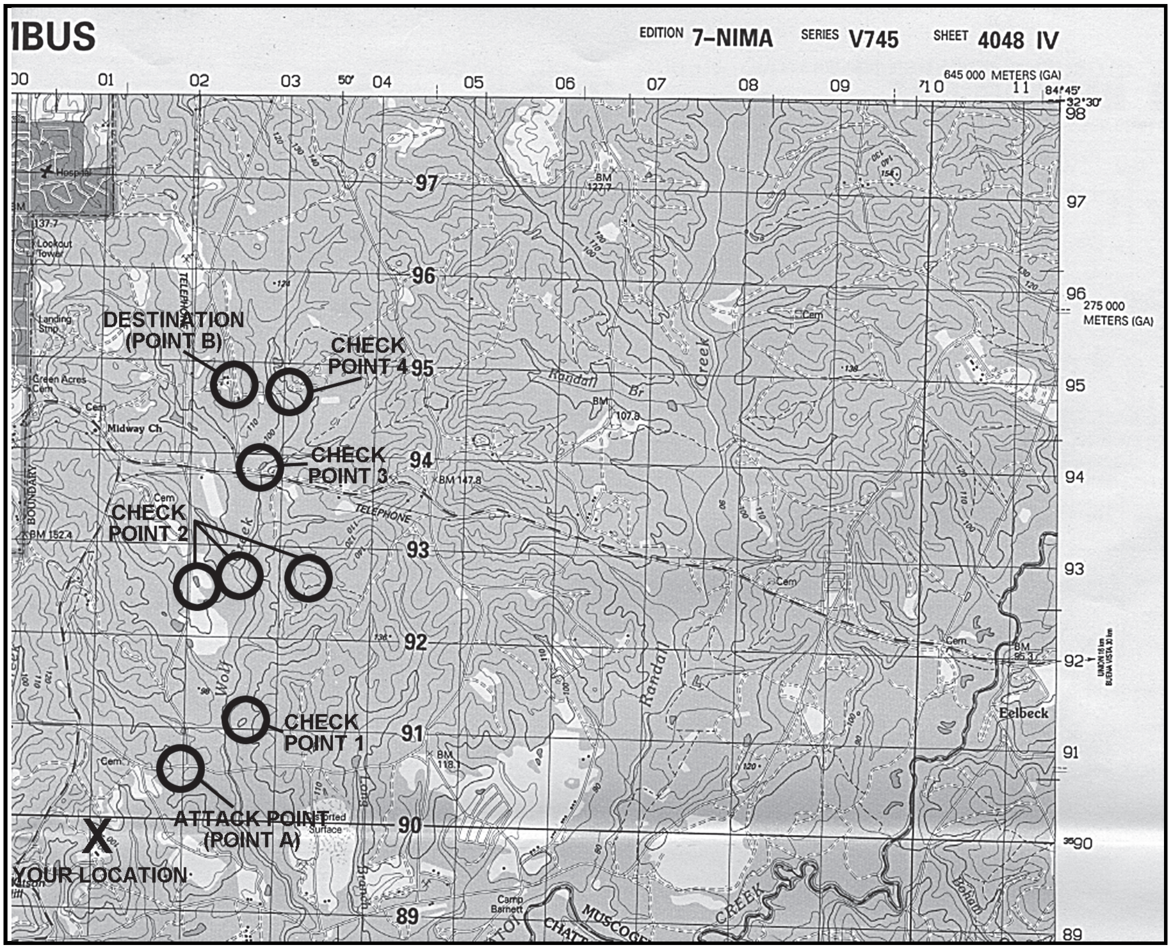

Figure 10-8. Terrain association navigation

Identifying and Locating Selected Features

10-48. Being able to identify and locate the selected features on the map and on the ground are essential for the success in moving by terrain association. The following rules may prove helpful:

- Be certain the map is properly oriented when moving along the route and use the terrain and other features as guides. The orientation of the map needs to match the terrain or it can cause confusion. To locate and identify features being used to guide the movement, look for the steepness and shape of the slopes, the relative elevations of the various features, and the directional orientations in relation to your position and to the position of the other features that can be seen.
- Make use of the additional cues provided by hydrography, culture, and vegetation. All the information that is gathered assists in making the move. The ultimate test and the best practice for this movement technique is to go out in the field and use it. The use of terrain, other natural features, and man-made objects that appear on the map and on the ground are practiced at every opportunity. There is no other way to learn or retain this skill.

Using Handrails, Catching Features, and Navigational Attack Points

10-49. First, because it is difficult to dead reckon without error over long distances with a compass, the alert navigator can often gain assistance from the terrain. Handrails are linear features like roads or highways, railroads, power transmission lines, ridgelines, or streams that run roughly parallel to the direction of travel. Instead of using precision compass work, it is possible to rough compass (using the linear feature to follow the general compass direction) without the use of steering marks for as long as the feature travels on the right or left. It acts as a handrail to guide the way.

10-50. Second, when reaching the point where the route or the handrail changes direction, be aware that it is time to go your separate ways. Some prominent feature located near this point is selected to provide this warning. This is called a catching feature; it can also be used to tell if you have gone too far.

10-51. Third, the catching feature may also be the navigational attack point. This point is the place where area navigation ends and point navigation begins. From this last easily identified checkpoint, the navigator moves cautiously and precisely along a given azimuth for a specified distance to locate the final objective. The selection of this navigational attack point is important. A distance of 500 m or less is most desirable.

Disadvantages of Terrain Association

10-52. The major disadvantage to navigation by terrain association is that the map is interpreted and analyzed to the physical world. Recognition of terrain and other features, the ability to determine and estimate direction and distance, and knowing how to do quick in-the-head position fixing are skills that are more difficult to teach, learn, and retain than those required for dead reckoning.

Combination of Techniques

10-53. The most successful navigation is obtained by combining the techniques described above. Constant orientation of the map and continuous observation of the terrain, in conjunction with compass-read azimuths and distance traveled on the ground, compared with map distance. When used together, they make reaching a destination more certain. One should not depend entirely on compass navigation or map navigation; either or both could be lost or destroyed.

Note. See Appendix J for information on orienteering.

NIGHT NAVIGATION

10-54. Darkness presents its own characteristics for land navigation due to limited or no visibility. However, the techniques and principles are the same as those used for day navigation. Success in nighttime land navigation depends upon rehearsals during the planning phase before the movement, such as detailed analysis of the map to determine the type of terrain in which the navigation is going to take place, and the predetermination of azimuths and distances. Night vision devices (see Appendix K) can greatly enhance night navigation.

10-55. The basic technique used for nighttime land navigation is dead reckoning with several compasses. The point man is in front of the navigator but just a few steps away for easy control of the azimuth. Smaller steps are taken during night navigation, so the pace count is different. It is recommended that a pace count be obtained by using a predetermined 100-m pace course used at night.

10-56. Navigation using the stars is recommended in some areas; however, a thorough knowledge of constellations and location of stars is needed. (See Chapter 9.) The four cardinal directions can also be obtained at night using the shadow-tip method with the moon instead of the sun. In this case, the moon needs to be bright enough to cast a shadow.

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Chapter 11

Mounted Land Navigation

A vehicle commander should be able to navigate from one point on the ground to another with or without a compass. This chapter outlines the principles of mounted navigation.

PRINCIPLES

11-1. The principles of land navigation while mounted are basically the same as while dismounted. The major difference is the speed of travel. Walking between two points may take one hour, but riding the same distance may only take 15 minutes. To be effective at mounted land navigation, travel speed is considered.

NAVIGATOR'S DUTIES

11-2. The duties of a navigator are so important and exacting; the navigator should not be given other duties. The leader should never try to be the navigator since normal responsibilities are heavy and one or the other job would suffer.

- **Assembling equipment.** Before the mission starts, the navigator gathers all the equipment that helps with the job performance (maps, pencils, and other items).
- **Servicing equipment.** The navigator is responsible for making sure that all the equipment used or required is working.
- **Recording data for precise locations.** During movement, the navigator makes sure that the correct direction and distance are recorded and followed. Grid coordinates of locations are recorded and plotted.
- **Supplying data to subordinate leaders**. During movement, a change in direction or distance is given to the subordinate leaders in sufficient time to allow them to react.
- **Maintaining liaison with the commander.** The commander normally selects the route to use. The navigator is responsible for following that route; however, there may be times when the route is changed during a tactical operation. For this reason, the navigator maintains constant communication with the commander. The navigator informs the commander when checkpoints are reached, when a change in direction of movement is required, and how much distance is traveled.

MOVEMENT

11-3. When preparing to move, the effects of terrain on navigating mounted vehicles are determined. Great distances are covered very quickly and it is important to develop the ability to estimate the distance traveled. Remember that 0.1 mile is roughly 160 m, and 1 mile is about 1600 m or 1.6 km. Having a mobility advantage helps while navigating, especially when disoriented, as mobility makes it much easier to move to a point where reorientation can take place.

CONSIDER VEHICLE CAPABILITIES

11-4. When determining a route to travel when mounted, consider the capabilities of the vehicles being used. Most military vehicles are limited in the degree of slope they can climb and the type of terrain they can negotiate. Swamps, thickly wooded areas, or deep streams may present no problems to dismounted Soldiers, but the same terrain may completely stop mounted Soldiers. Consider this when selecting a route.

11-5. Most vehicles can knock down a tree. The bigger the vehicle, the bigger the tree it can knock down. Vehicles cannot knock down several trees at once. It is best to find paths between trees that are wide enough for the vehicle. Military vehicles are designed to climb 60-percent slopes on a dry, firm surface. (See Figure 11-1.)

11-6. Approximate slope is determined by looking at the route selected on a map. A contour line in 100 m of map distance on that route indicates a 10-percent slope; two contour lines indicate 20-percent slope, and so forth. If there are four contour lines within 100 m, look for another route.

11-7. Side slope is even more important than the climbing slope. Normally, a 30-percent slope is the maximum in good weather. When traversing a side slope, progress slowly and without turns. Rocks, stumps, or sharp turns can cause the downhill track to be thrown under the vehicle, which would mean a big recovery task.

11-8. For tactical reasons, move in draws or valleys because they provide cover. However, side slopes force slow movement.

Note. The above figures are true for a 10-m or a 20-foot contour interval. If the map has a different contour interval, just adjust the arithmetic. For instance, with one contour line in 100 m, a 20-m interval would give a 20-percent slope.

11-9. Weather can halt mounted movement. Snow and ice are obvious dangers, but more significant is the effect of rain and snow on the load-bearing ability of soil. Cross-country vehicles may be restricted to road movement in heavy rain. If it has rained recently, adjust the route to avoid flooded or muddy areas. A mired vehicle only hinders combat capability.

Prepare Before Movement

11-10. Locate the start point and finish point on the map. Determine the map's grid azimuth from start point to finish point and convert it to a magnetic azimuth. Determine the distance between the start point and finish point, or intermediate points on the map, and make a thorough map reconnaissance of that area.

Figure 11-1. Tracked vehicle capabilities

TERRAIN ASSOCIATION NAVIGATION

11-11. Terrain association is currently the most widely used method of navigation. The navigator plans the route from terrain feature to terrain feature. An automobile driver in a city uses this technique while moving along a street or series of streets, guiding on intersections or features such as stores and parks. Like the driver, the navigator selects routes or *streets* between key points or intersections.

11-12. These routes need to sustain the travel of the vehicle or vehicles, should be relatively direct, and should be easy to follow. In a typical move, the navigator determines the vehicle location and the location of the objective, notes the position of both on the map, and then selects a route between the two. After examining the terrain, the navigator adjusts the route to avoid skylining, and selects key terrain for overwatch positions and concealed routes.

TACTICAL ASPECTS AND EASE OF MOVEMENT

11-13. Use the easiest possible route and bypass difficult terrain. Remember that a difficult route is harder to follow, is noisier, causes more wear and tear (and possible recovery problems), and takes more time. Tactical surprise is achieved by doing the unexpected. Try to select an axis or corridor instead of a specific route. Make sure there is enough maneuver room for the vehicles. (See Figure 11-2.)

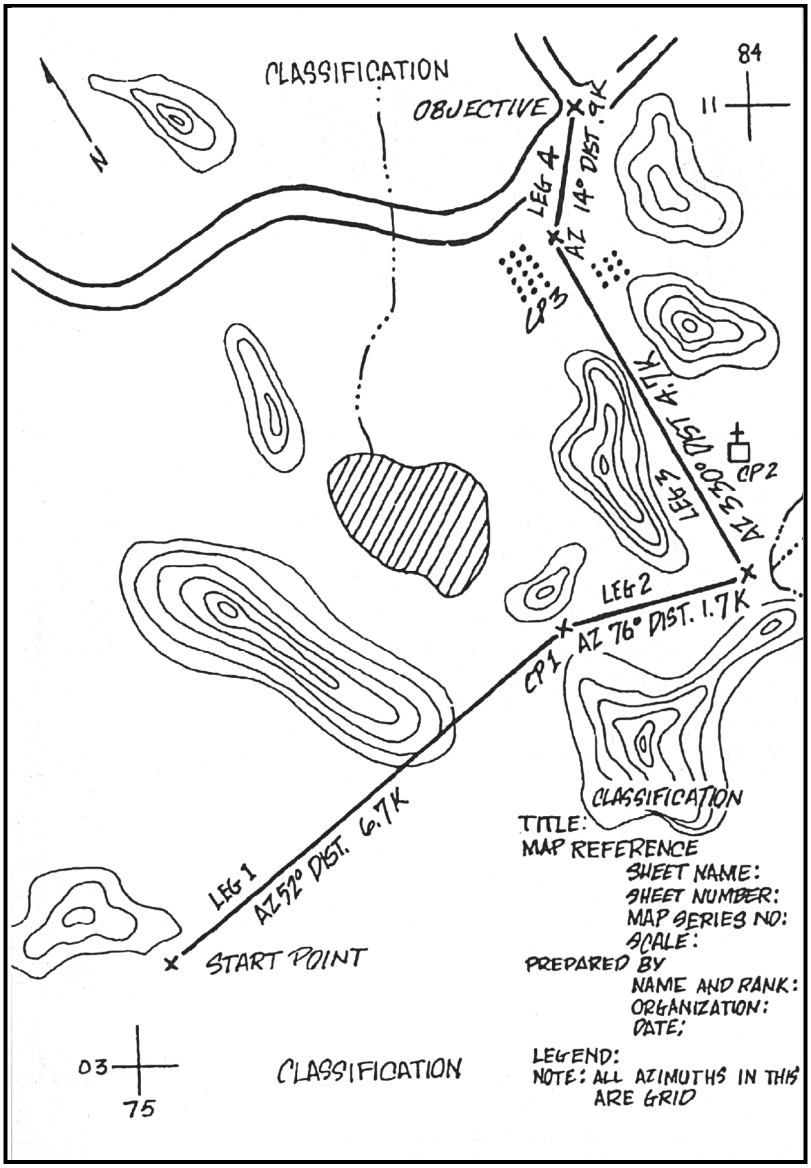

Figure 11-2. Primary route

TERRAIN FEATURES AS CHECKPOINTS

11-14. Terrain checkpoints are easily recognizable in the light, all weather conditions, and at the speed of movement. Find a terrain feature from the location that can be recognized from almost anywhere to use as a guide. (For example, checkpoint 2 is the church and checkpoint 3 is the orchard in Figure 11-2.)

11-15. The best checkpoints are linear features that cross the route. Use streams, rivers, hard-top roads, ridges, valleys, and railroads. The next best checkpoints are elevation changes such as hills, depressions, spurs, and draws. Look for two contour lines of change. It is not possible to spot less than two lines of change while mounted. In wooded terrain, try to locate checkpoints at no more than 1000-m intervals. In open terrain, up to 5000 m is acceptable.

Note. Follow terrain features. Movement and navigation along a valley floor or near (not necessarily on) the crest of a ridgeline is easiest.

DETERMINE DIRECTIONS AND DISTANCE

11-16. Break the route down into smaller segments and determine the rough directions to be followed. It is not necessary to use the compass; just use the main points of direction (north, northeast, east, and so forth). Before moving, note the location of the sun and locate north. Locate changes of direction at the checkpoints picked.

11-17. Determine the total distance to be traveled and the approximate distance between checkpoints. Plan to use the vehicle odometer to keep track of distance traveled. Use the pace-count method and keep a record of the distance traveled. When using a pace count, convert from map distance to ground distance by adding the conversion factors of 20 percent for cross-country movement.

- **Make notes.** Mental notes are usually adequate. Try to imagine what the route is like and remember it.
- **Plan to avoid errors.** Restudy the route selected. Try to determine where errors are most apt to occur and how to avoid trouble.
- **Use a logbook.** When the routes have been selected and the navigator has divided the distance to be traveled into legs, prepare a logbook. This is an informal record of the distance and azimuth of each leg, with notes to aid the navigator in following the correct route. The notes section contains easily identifiable terrain features at or near the point where the direction of movement changes. (See Figure 11-3.)

SAMPLE

ODOMETER READING AT START	ODOMETER READING AT FINISH	DISTANCE IN MILES	AZIMUTH	DEVIATION CORRECTION	NOTES

Figure 11-3. Sample of a logbook format

DEAD RECKONING NAVIGATION

11-18. Dead reckoning is moving a set distance along a set line. Generally, it involves moving so many meters along a set line, usually an azimuth in degrees. When moving in a vehicle, a compass direction may be unreliable in determining the direction of travel. A vehicle-mounted GPS is the preferred method for monitoring direction of travel while mounted.

11-19. Dead reckoning with steering marks is the same for vehicle travel as on foot. The navigator dismounts from the vehicle and moves away at least 18 m. After setting the azimuth on the compass and picking a steering mark (rock, tree, hilltop) in the direction on that azimuth (see Figure 11-4), the navigator remounts. The driver identifies the steering mark and proceeds to it in as straight a line as possible. On arrival at the steering mark or on changes in direction, the navigator repeats the first three steps for the next leg of travel.

11-20. Dead reckoning without steering marks is used only on flat, featureless terrain. The navigator dismounts from the vehicle, which is oriented in the direction of travel, and moves at least 18 m to the front of the vehicle. Facing the vehicle, the navigator reads the azimuth to the vehicle. By adding or subtracting 180 degrees, the forward azimuth (direction of travel) is determined. On order from the navigator, the driver drives on a straight line to the navigator. The navigator remounts the vehicle, holds the compass as it is held while the vehicle is moving, and reads the azimuth in the direction of travel.

11-21. The compass swings off the azimuth determined and picks up a constant deviation. For example, the azimuth was 75 degrees when read away from the vehicle but after remounting and driving straight forward, the compass showed 67 degrees. There is a deviation of -8 degrees. All that is needed is to maintain that 67-degree compass heading to travel on a 75-degree magnetic heading.

11-22. At night, the same technique can be used. From the map, determine the azimuth to travel. Convert the grid azimuth to a magnetic azimuth. Line the vehicle up on that azimuth, and then move well in front of it. Be sure it is aligned correctly. Then mount, have the driver move slowly forward, and note the deviation. If the vehicle has a turret, the above procedure works unless the turret is traversed; this changes the deviation.

11-23. The distance factor in dead reckoning is easy. Just determine the map distance to travel and add 20 percent to convert to ground distance. Use the vehicle odometer to be sure the proper distance is traveled.

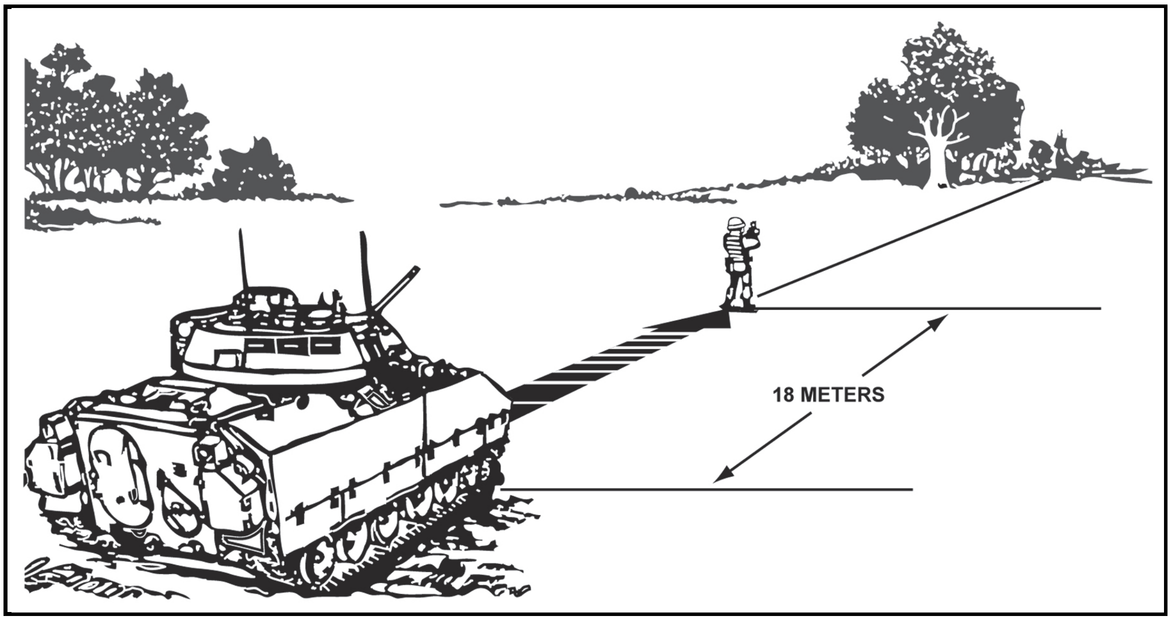

Figure 11-4. Determining an azimuth, dismounted

STABILIZED TURRET ALIGNMENT NAVIGATION

11-24. Another method for vehicles with a stabilized turret is to align the turret on the azimuth of travel, then switch the turret stabilization system on and engage the gun stabilization function. The stabilizer is activated according to the vehicle operating procedures. With the stabilization function engaged the gun tube remains pointed toward the destination no matter which way the vehicle turns. This technique is not harmful to the stabilization system. It is subject to stabilization drift, so use it for no more than 5000 m before resetting.

Note. If the turret has to be taken off-line to engage a target, the entire process is done again.

COMBINATION NAVIGATION

11-25. Some mounted situations may call for a combination of both methods. Just remember the characteristics of each—

- Terrain association is fast, error-tolerant, and is best under most circumstances. It can be used day or night for those proficient in it.

- Dead reckoning is accurate if everything is done precisely. It is also slow, but it works on flat terrain.
- Techniques are frequently a combination of both methods. Dead reckoning is used to travel across a large, flat area to a ridge, and terrain association is used for the rest of the move.

11-26. The navigator needs to be able to use both methods. Probable errors, in order of frequency, include:

- Determining distances to be traveled.
- Traveling the proper distance.
- Properly plotting or locating the objective.
- Selecting easily recognized checkpoints or landmarks.
- Considering the ease of movement factor.

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Chapter 12

Navigation in Different Types of Terrain

The information, concepts, and skills already presented helps in navigating anywhere in the world. However, some important considerations and helpful hints may assist in various special environments. The following information is *not* doctrine.

DESERT TERRAIN

12-1. About five percent of the earth's land surface is covered by deserts. (See Figure 12-1.) Deserts are large arid areas with little or no rainfall during the year. The three types of deserts include mountain, rocky plateau, and sandy or dune deserts. All types of forces can be deployed in the desert. Armor and mechanized Infantry forces are especially suitable for desert combat, except in rough mountainous terrain where light Infantry may be required. Airborne, air assault, and motorized forces can also be advantageously employed to exploit the vast distances characteristic of desert warfare.

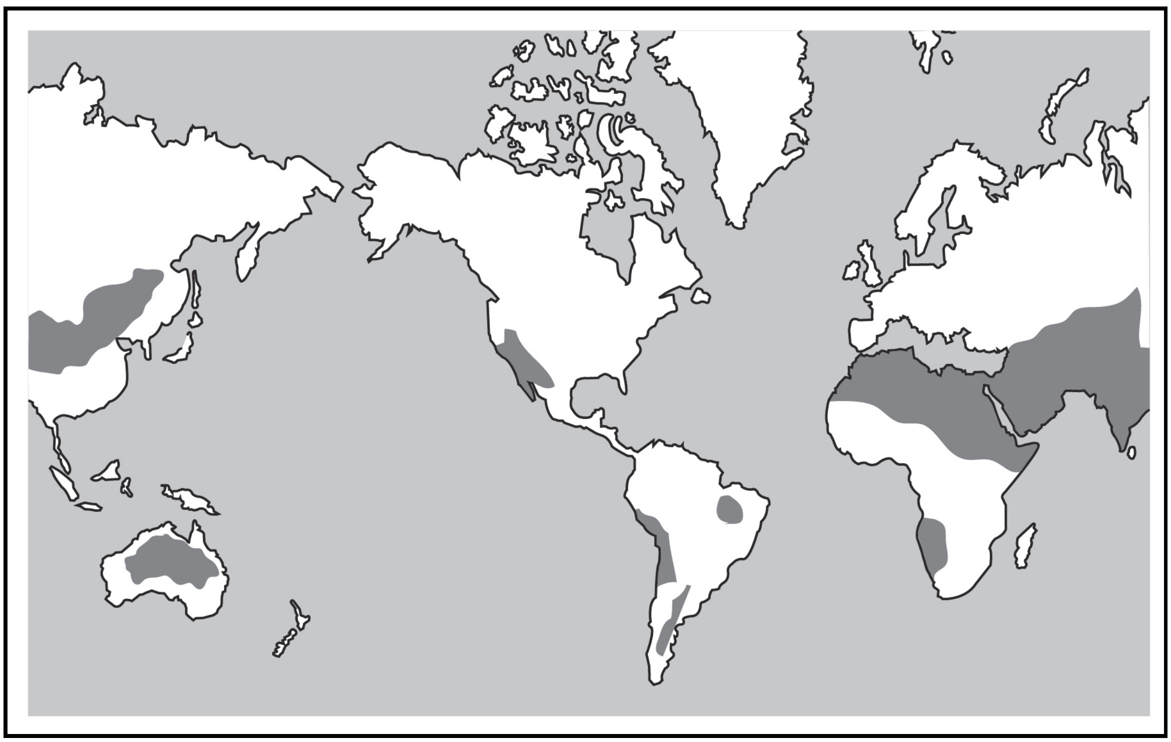

Figure 12-1. Deserts

DESERT REGIONS

In desert regions, terrain varies from nearly flat to lava beds and salt marshes. Mountain deserts contain scattered ranges, or areas of barren hills or mountains. Table 12-1 lists some of the world's major desert regions and their locations.

Table 12-1. Location of major desert regions

Desert Region	*Location*
Sahara	North Africa
Kalahari	Southwest Africa
Arabian	Southwest Asia
Gobi	Mongolia and Northern China
Rub'al Khali	South Arabia
Great Basin, Colorado, Chichuahua, Yuma Sonoran, and Mohave	Northern Mexico and Western United States
Takla Makan	Northern China
Kyzyl Kum	Kazakhstan and Uzbekistan – Central Asia
Kara Kum	Turkmenistan – Central Asia
Syrian	Saudi Arabia, Jordan, Syria, and Iraq
Great Victoria	Western and South Australia
Great Sandy	Northwestern Australia
Patagonia	Southern Argentina and Chile
Atacama	Northern Chile

12-2. Finding the way in a desert presents some degree of difficulty for a person who has never been exposed to this environment. Normally, desert people are nomadic, constantly moving in caravans. Navigating becomes second nature to them. Temperature in the tropical deserts reaches an average of 110 to 115 degrees during the day, so most navigation takes place at night using the stars. Most deserts have some prevailing winds during the seasons. Such winds arrange the sand dunes in a specific pattern that allows the navigator to determine the four cardinal directions. The sun's shadow-tip method may also be used.

12-3. A sense of direction can be obtained by watching desert animals on their way to and from water holes (oases). Water, navigation, and survival are closely related in desert areas. Most deserts have pigeons or doves, and their drinking habits are important to the navigator. As a rule, these birds never drink in the morning or during the day, making their evening flights the most important. When returning from the oases, their bodies are heavier from drinking and their flight is accompanied by a louder flapping of their wings.

12-4. Visibility is also an important factor in the desert, especially in judging distance. The absence of trees or other features prevents comparison between the horizon and the skyline.

INTERPRETATION AND ANALYSIS

12-5. Many desert maps are inaccurate, which makes up-to-date air and ground reconnaissance necessary. In desert mountain areas, contour intervals are generally large, so many of the intermediate relief features are not shown.

12-6. The desert normally permits observation and fire to maximum ranges. The terrain is generally wide open and the exceptionally clear atmosphere offers excellent long-range visibility. Combine this with a powerful sun and low cloud density, and there is nearly unlimited light and visual clarity, which often contribute to gross underestimations of ranges. Errors of up to 200 or 300 percent are not uncommon. However, visibility conditions may be severely affected by sandstorms and mirages (heat shimmer caused by air rising from the extremely hot daytime desert surface), especially if the observer is looking into the sun through magnifying optical instruments.

12-7. Cover can be provided only by terrain feature masking because of the lack of heavy vegetation and man-made objects. It only takes a few meters of relief to provide cover. Concealment in the desert is related to the following factors:

- **Shape.** To prevent observation by the enemy, try to alter the standard shapes of vehicles so they and their shadows are not instantly recognizable.
- **Shine**. Shine or glitter is often the first thing that attracts the observer's eye to movement many kilometers away. It needs to be eliminated.
- **Color and texture.** All equipment should be pattern painted or mudded to blend in with the terrain.
- **Light and noise.** Light and noise discipline are essential because sound and light travel great distances in the desert.
- **Heat.** Modern heat image technology makes shielding heat sources an important consideration when hiding from the enemy. This technology is especially important during night stops.
- **Movement.** Movement itself creates a great deal of noise and dust, but a rapid execution using all the advantages the topography offers helps to conceal it.

NAVIGATION

12-8. When operating in the broad basins between mountain ranges or on rocky plateau deserts, there are frequently many terrain features to guide movement. Observing these known features over great distances may provide a false sense of security in determining precise location, unless the location is frequently confirmed by resection or referencing close-in terrain features. It is not uncommon to develop errors of several kilometers when casually estimating a position in this manner. Obviously, this can create many problems when attempting to locate a small checkpoint or objective, calling for combat support, reporting operational or intelligence information, or meeting combat service support requirements.

12-9. When operating in an area with few visual cues, such as a sandy or sand dune desert, or when visibility is restricted by a sandstorm or darkness, proceed by dead reckoning. The four steps and two techniques for navigation presented earlier remain valid in the desert. However, understanding the desert's special conditions is extremely helpful as the techniques are applied.

12-10. Tactical mobility and speed are key to successful desert operations. Obstacles and areas such as lava beds or salt marshes, which preclude surface movements, do exist. But most deserts permit two-dimensional movement by ground forces similar to that of a naval task force at sea. Speed of execution is essential. Everyone moves farther and faster on the desert. Special navigation aids sometimes used in the desert include:

- **Sun compass.** Used on moving vehicles and sextants, the sun compass requires accurate timekeeping. However, the deviation on a magnetic compass that is caused by the metal and electronics in the vehicle is usually less than +10 degrees.
- **Gyro compass.** The gun azimuth stabilizer is in fact a gyro compass. If used on fairly flat ground, it is useful for maintaining direction over limited distances.
- **Fires.** Planned tracer fire or mortar and artillery concentrations (preferably smoke during the day and illumination at night) provide useful checks on estimated locations.
- **Prepositioned lights.** This method consists of placing two or more searchlights far apart, behind the line of contact, beyond enemy artillery range, and concealed from enemy ground observation. Units in the area can determine their own locations through resection, using the vertical beams of the lights. These lights are moved on a time schedule known to all friendly units.

12-11. The sand, hard-baked ground, rocky surfaces, thorny vegetation, and heat generally found in the desert impose far greater demands for maintenance than planned for in temperate regions. It may also take longer to perform that maintenance.

MOUNTAIN TERRAIN

12-12. Mountains are generally understood to be larger than hills. Rarely do mountains occur individually; in most cases, they are found in elongated ranges or circular groups. When they are linked together they constitute a mountain system. (See Figure 12-2.) Light forces (Infantry, airborne, and air assault forces) operate effectively in mountainous regions because they are not limited by terrain. Heavy forces operate in passes and valleys that are negotiable by vehicle.

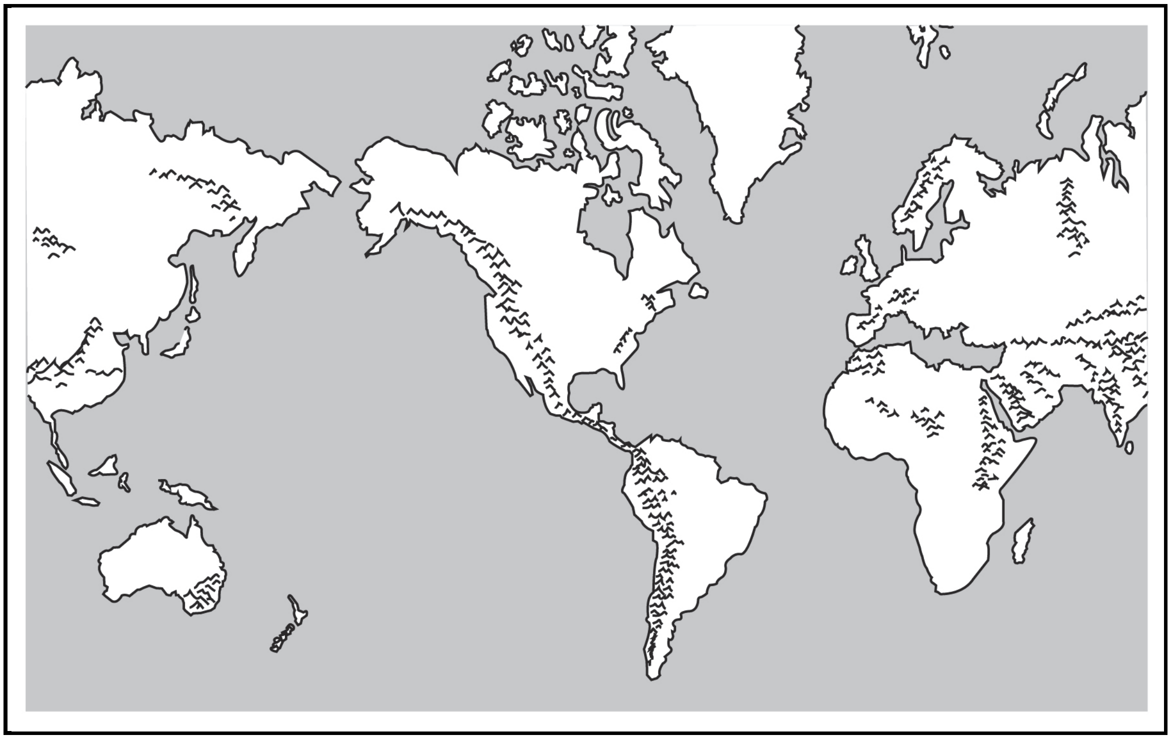

Figure 12-2. Mountain systems

MOUNTAIN SYSTEMS

12-13. Mountain systems are characterized by high, inaccessible peaks and steep slopes. Depending upon the altitude, they may be snow covered. Prominent ridges and large valleys are also found. Navigating in this type of terrain is not difficult providing a careful examination of the map and the terrain is made. Table 12-2 lists the major mountain systems and their locations.

Table 12-2. Location of major mountain systems

Mountain System	*Location*
Andes	Central and South America
Rockies	North America (USA and Canada)
Appalachians	North America (USA and Canada)
Alps	Central Europe
Himalayas	Asia
Caucasus	Western Asia and Europe

12-14. Some minor mountain systems are located in Antarctica, Hawaii, Japan, New Zealand, and Oceania. Because of the elevations, it is always colder (3 to 5 degrees per 300-m gain in altitude) and wetter than usually expected. Wind speeds can increase the effects of the cold even more. Sudden severe storms and fog are encountered regularly. Below the tree line, vegetation is heavy because of the extra rainfall and the land is rarely cleared for farming.

INTERPRETATION AND ANALYSIS

12-15. The heights of mountainous terrain permit excellent long-range observation. However, rapidly fluctuating weather with frequent periods of high winds, rain, snow, or fog may limit visibility. Also, the rugged nature of the terrain frequently produces significant dead space at mid ranges.

12-16. Reduced mobility, compartmented terrain, and the effects of rapidly changing weather increase the importance of air, ground, and map reconnaissance. Since mountain maps often use large contour intervals, microrelief interpretation and detailed terrain analysis require special emphasis.

12-17. At first glance, some mountainous terrain may not appear to offer adequate cover and concealment; however, the situation can be improved. When moving, use rock outcroppings, boulders, and heavy vegetation for cover and concealment; use terrain features to mask maneuvers; and use harsh weather, which often obscures observation, to enhance concealment.

12-18. Since there are only a few routing options, all-around security is of primary concern. Natural obstacles are everywhere, and the enemy can easily construct more.

NAVIGATION

12-19. Existing roads and trails offer the best routes for movement. Off-road movement may enhance security provided there is detailed reconnaissance, photo intelligence, or information from local inhabitants to ensure the route is negotiable. The four steps and two techniques for navigation presented earlier remain valid in the mountains, and understanding special conditions and terrain helps navigation. Other techniques that are sometimes helpful in mountains are aspect of slope and use of an altimeter.

12-20. To determine the aspect of slope, take a compass reading along an imaginary line that runs straight down the slope. It should cut through each of the contour lines at about a 90-degree angle. By checking the map and knowing the direction of slope at the current location, one’s location during movement can be tracked, helping to guide cross-country movement even when visibility is poor.

12-21. Employment of an altimeter with calibrations on the scale down to 10 or 20 m is helpful for land navigators moving in areas where radical changes in elevation exist. An altimeter is a type of barometer that gauges air pressure, except it measures on an adjustable scale marked in feet or meters of elevation rather than in inches or centimeters of mercury. Careful use of the altimeter helps to pinpoint position on a map through a unique type of resection. Instead of finding a position by using two different directional values, just one directional value and one elevation value is used.

JUNGLE TERRAIN

12-22. These large geographic regions are found within the tropics near the equator (Central America, along the Amazon River, Southeast Asia and the adjacent islands, and vast areas in the middle of Africa and India). (See Figure 12-3.) Jungles are characterized as rainy, humid areas with heavy layers of tangled, impenetrable vegetation. Jungles contain many species of wildlife (tigers, monkeys, parrots, snakes, alligators, and much more). The jungle is also a paradise for insects, which are the worst enemy of the navigator because some insects carry diseases (malaria, yellow fever, cholera, and other diseases). While navigating in these areas, very little terrain association can be accomplished because of the heavy foliage. Dead reckoning is one of the methods used in these areas. A lost navigator in the jungle can eventually find a way back to civilization by following a body of water with a downstream flow. However, not every civilization found is of a friendly nature.

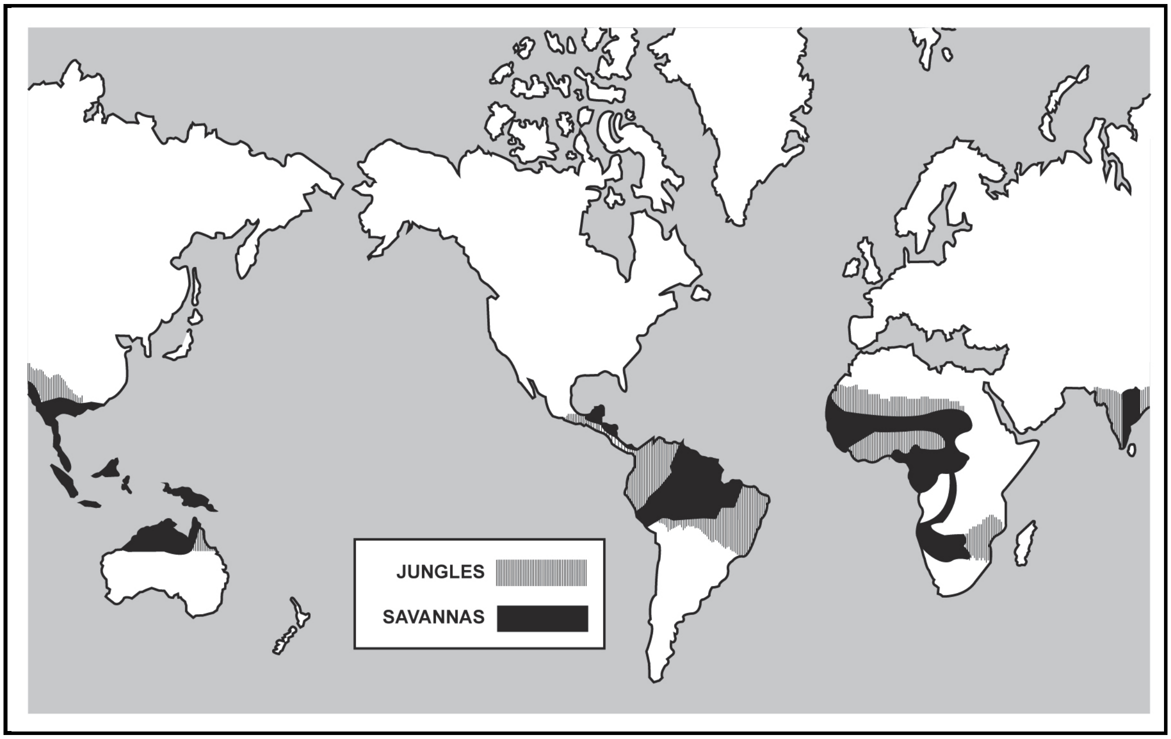

Figure 12-3. Jungles and savannas

OPERATIONS

12-23. Operations in jungles tend to be isolated actions by small forces because of the difficulties encountered in moving and maintaining contact between units. Divisions can move cross-country slowly, but aggressive reconnaissance, meticulous intelligence collection, and detailed coordination are required to concentrate forces this way. More commonly, large forces operate along roads or natural avenues of movement, as is the case in the mountains. Patrolling and other surveillance operations are especially important to ensure security of larger forces in the close terrain of jungles.

12-24. Short fields of observation and fire, and thick vegetation make maintaining contact with the enemy difficult. The same factors reduce the effectiveness of indirect fire and make jungle combat primarily a fight between Infantry forces. Support by air and mechanized forces can be decisive at times, but is not always available or effective.

12-25. Jungles are characterized by high temperatures, heavy rains, high humidity, and an abundance of vegetation. The climate varies with location. Close to the equator, all seasons are nearly alike with heavy rains all year. Farther from the equator (India and Southeast Asia), there are distinct wet (monsoon) and dry seasons. Both zones have high temperatures (averaging 75 to 95+ degrees Fahrenheit), heavy rainfall (as much as 400+ inches annually), and high humidity (90 percent) all year.

12-26. In temperate climates, areas of vegetation are the most likely to be altered and incorrectly portrayed on a map. In jungle areas the vegetation grows so rapidly that it is more likely to be cleared, depicting these areas incorrectly.

INTERPRETATION AND ANALYSIS

12-27. The jungle environment includes dense forests, grasslands, swamps, and cultivated areas. Forests are classified as primary and secondary based upon the terrain and vegetation. Primary forests include tropical rain forests and deciduous forests. Secondary forests are found at the edges of rain and deciduous forests, and in areas where jungles have been cleared and abandoned. These places are typically overgrown with weeds, grasses, thorns, ferns, canes, and shrubs. Movement is especially slow and difficult. The extremely thick vegetation reaches a height of 2 m, severely limiting observation to only a few meters.

12-28. Tropical rain forests consist mostly of large trees with branches spread and locked together to form canopies. These canopies can exist at two and three different levels and may form as low as 10 m from the ground. They prevent direct sunlight from reaching the ground, causing a lack of undergrowth on the jungle floor. Extensive above-ground root systems and hanging vines are common, impeding vehicular travel but improving foot movement. Ground observation is limited to about 50 m, making air observation nearly impossible.

12-29. Deciduous forests are in semitropical zones that have wet and dry seasons. In the wet season, trees are fully leafed; in the dry season, much of the foliage dies. Trees are usually less dense than in rain forests, allowing more sunlight to filter to the ground and produce thick undergrowth. During the wet season, air and ground observation is limited and movement is difficult. During the dry season, both improve.

12-30. Swamps are common to all low, jungle areas where there is poor drainage. When navigating in a swampy area, a careful analysis of map and ground should be taken before movement. Soldiers should travel in small numbers with only the equipment required for their mission, keeping in mind that they are going to be immersed in water part of the time. The usual technique used in swamp navigation is dead reckoning. There are two basic types of swamps: mangrove and palm. Mangrove swamps are found in coastal areas wherever tides influence water flow. Mangrove is a shrub-like tree that grows 1 to 5 m high. These trees have a tangled root system above and below the waterline, which restricts movement by foot or small boat. Observation on the ground and from the air is poor, but concealment is excellent.

12-31. Grassy plains or savannas are generally located away from the equator but within the tropics. These vast land areas are characterized by flatlands with a different type of vegetation than jungles. They consist mainly of grasses (ranging from ground level to 4 m in height), shrubs, and isolated trees. The most difficult areas to navigate are the ones surrounded by tall grass (elephant grass); however, vehicles can negotiate here better than in some areas. There are few or no natural features to navigate by, making dead reckoning or navigation by stars the only techniques for movement. Depending upon the height of the grass, ground observation may vary from poor to good. Concealment from air observation is poor for Soldiers and vehicles.

12-32. Bamboo stands are common throughout the tropics. They should be bypassed whenever possible. They are formidable obstacles for vehicles, and Soldier movement through them is slow, exhausting, and noisy.

12-33. Cultivated areas also exist in jungles. They range from large, well-planned, well-managed farms and plantations to small tracts cultivated by farmers. The three general types of cultivated areas are rice paddies, plantations, and small farms.

NAVIGATION

12-34. Areas such as jungles are generally not accurately mapped because heavy vegetation makes aerial surveys difficult. The ability to observe terrain features, near or far, is extremely limited. The navigator relies heavily upon the compass and dead reckoning techniques when moving in the jungle. Navigation is further complicated by the inability to make straight-line movements. Terrain analysis, constant use of the compass, and an accurate pace count are essential to navigation in this environment.

12-35. Rates of movement and pace counts are particularly important to jungle navigators. The most common error is to overestimate the distance traveled. The distances in Table 12-3 can be used as a rough guide for the maximum distances that might be traveled in various types of terrain during one hour of daylight.

Table 12-3. Guide for maximum travel distance in jungle environments

Type of Terrain	*Maximum Distance (Meters)*
Tropical rain forest	up to 1000
Deciduous forest	500
Secondary jungle	100 to 500
Tall grass	500
Swamps	100 to 500
Rice paddies (wet)	800
Rice paddies (dry)	2000
Plantations	2000
Trails	up to 3000

12-36. Special navigation strategies that are helpful in jungles include:

- **Personal pace table.** The navigator makes a mental or written personal pace table that includes an average pace count per 100 m for all of the types of terrain through which one is likely to navigate.
- **Resection using indirect fire.** Call for mortar or artillery fire (airbursts of white phosphorous or illumination) on two widely separated grids that are not on terrain features similar to the one being occupied and are a safe distance from the estimated location. Directions to the airbursts sometimes are determined by sound.
- **Modified area/point navigation.** Even when making primary use of the compass for dead reckoning, it is frequently possible to area navigate to an expanded objective, which is easily identified by terrain association. Then, simply develop a short, point-navigation leg to the final destination.

ARCTIC TERRAIN

12-37. Arctic terrain includes those areas that experience extended periods of below freezing temperatures. In these areas, the ground is generally covered with ice or snow during the winter season. Although frozen ground and ice can improve trafficability, a deep accumulation of snow can reduce it. Vehicles and personnel require special equipment and care under these adverse conditions.

OPERATIONS

12-38. The terrain, and the type and size of unit operations vary greatly in arctic areas. In open terrain, armored and mechanized forces are effective although they have to plan and train for the special conditions. In broken terrain, forests, and mountains, light forces predominate as usual. However, foot movement may take up to five times longer than in a warmer climate.

INTERPRETATION AND ANALYSIS

12-39. The terrain and cultural features confronted during winter may vary to an extreme, as can the weather. The common factor is an extended period of below freezing temperatures. The terrain may be plains, plateaus, hills, or mountains. The climate is cold, but the weather varies greatly from place to place. Although most arctic terrain experiences snow, some claim impressive accumulations each season such as the lake-effected snow belts off Lake Ontario near Fort Drum, New York. Other areas have many cold days with sunshine and clear nights, and little snow accumulation.

12-40. In areas with distinct local relief and scattered trees or forests, the absence of foliage makes movement by terrain association easier. Observation and fields of fire are greatly enhanced except during snowstorms. In relatively flat, open areas covered with snow (especially in bright sunlight), the resulting lack of contrast may interfere with reading the land. With foliage gone, concealment from the ground and air is greatly reduced. In desert areas, take special care to make best use of the terrain to conceal movements.

12-41. Frozen streams and swamps may no longer be obstacles, making identification of key terrain and avenues of approach difficult in winter.

NAVIGATION

12-42. Special skills may be required in arctic terrain, such as the proper use of winter clothing, skis, and snowshoes. This does not affect navigation strategies and there are no special techniques for navigating in arctic terrain. Be aware of the advantages and disadvantages that may present themselves, and make the most of opportunities while applying the four steps and two techniques for land navigation.

12-43. The highest caliber of leadership ensures that all necessary tasks are performed, security is maintained, and Soldiers and their equipment are protected from the physical effects of cold temperatures. They are tempted to do less than a thorough job during extremely cold temperatures.

12-44. Night navigation may be particularly enhanced when operating in arctic terrain. Moonlight and starlight on a clear night reflect off the snow, enabling daytime terrain association techniques with little difficulty. Even cloudy winter nights are often brighter than clear moonlit summer nights when the ground is dark and covered with foliage. Movements with complete light discipline (no blackout drive lights) can often be executed. On the other hand, areas with severe winter climates experience lengthy periods of darkness each day, which may be accompanied by snow and limited visibility.

URBAN AREAS

12-45. The world continues to become more urbanized each year, making it unlikely that all fighting is done in rural settings. Major urban areas represent the power and wealth of a particular country in the form of industrial bases, transportation complexes, economic institutions, and political and cultural centers. It may be necessary to secure and neutralize them. When navigating in urban places, man-made features such as roads, railroads, bridges, and buildings, become important while terrain and vegetation become less useful.

INTERPRETATION AND ANALYSIS

12-46. Urban operations require detailed planning that provides for decentralized execution. As a result of the rapid growth and changes occurring in many urban areas, the military topographic map is likely to be outdated. Supplemental use of commercially-produced city maps may be helpful, or an up-to-date sketch can be made.

12-47. Urbanized terrain normally offers many avenues of approach for mounted maneuver well forward of and leading to urban centers. In the proximity of these built-up areas, such approach routes generally become choked with urban sprawl and the nature of adjacent natural terrain. Dismounted forces make the most of available cover by moving through buildings and underground systems, along edges of streets, and over rooftops. Urban areas tend to separate and isolate units, requiring the small-unit leader to take the initiative and demonstrate skill in order to prevail.

12-48. The urban condition of an area creates many obstacles, and the destruction of many buildings and bridges as combat power is applied during a battle further limits freedom of movement. Cover and concealment are plentiful, but observation and fields of fire are greatly restricted.

NAVIGATION

12-49. Navigation in urban areas can be confusing, but there are often many cues that present themselves while proceeding. They include streets and street signs; building styles and sizes; the urban geography of industrial, warehousing, residential housing, and market districts; man-made transportation features other than streets and roads (rail and trolley lines); and the terrain features and hydrographic features located within the built-up area. Use the following strategies to stay on the route in an urban area:

- **Process route descriptions.** Write down or memorize the route through an urban area as a step-by-step process. For example, "Go three blocks north, turn left (west) on a wide divided boulevard until crossing over a river bridge. Turn right (north) along the west bank of the river, and…"
- **Conceptual understanding of the urban area**. While studying the map and operating in a built-up area, work hard to develop an understanding (mental map) of the entire area. This advantage allows navigation over multiple routes to any location. It also precludes

getting lost whenever a turn is missed, or being forced off the planned route by obstacles or the tactical situation.

- **Resection**. Whenever there is a vantage point to two or more known features portrayed on the map, do not hesitate to use estimated or plotted resection to pinpoint the current position. These opportunities are often plentiful in an urban setting.

Chapter 13

Unit Training Program Development

Land navigation is a skill that is highly perishable. Soldiers need to use these acquired skills continually to remain proficient. The institution instructs the basic techniques of land navigation, and it tests these skills each time a Soldier attends a leadership course.

However, it is the unit's responsibility to develop a program to maintain proficiency in these skills between institution courses. Leader skill training should include following a route selected by the commander, and planning and following a route selected by the leader.

The unit trainer should be able to set up a sustainment program, a train-the-trainer program, and a land navigation course for the unit's use. It is recommended that units develop a program similar to the one outlined in this chapter.

SET UP A SUSTAINMENT PROGRAM

13-1. A sustainment program in the unit provides Soldiers with training that reinforces and builds on the training received in the institution. All Soldiers should receive this training at least twice a year. The program also provides the unit with a means for identifying the areas in which the Soldiers need additional training.

TRAINING GUIDANCE

13-2. The unit commander first determines the levels of proficiency and any problems that the unit has in land navigation. This determination can be done through after-action reports (AARs) from the unit's rotation to the National Training Center/Joint Readiness Training Center, Army training and evaluation program final reports, feedback from subordinates, personal observation, and annual training. Once the unit commander decides where the training time should be, concentrated training guidance can be issued to subordinate leaders. The staff is directed to provide training sites, resources, and time for the units to train land navigation. It is recommended that land navigation be trained separately and not just as a subtask in tactical training.

13-3. The unit commander also provides subordinate commanders with a means of certifying training. The unit staff provides subject matter experts to ensure the training meets the standards decided upon by the unit commander. Instructors should be certified to instruct, and courses should be certified before the unit uses it.

13-4. The sustainment program should meet the requirements of all the unit's Soldiers. It should address skills from basic map reading to leadership planning and executing a route. Dismounted land navigation without the use of a GPS device, under both day and night conditions, is the primary method to conduct and validate an individual's training. In appropriate units, it is necessary to conduct mounted or GPS-equipped land navigation training. The sustainment program should meet training needs identified as weaknesses known to exist in the unit. The program should cover the following:

- Diagnostic examination.
- Map reading instruction/review.
- Land navigation skills training.
- Dead reckoning training/practice.

- Terrain association training/practice.
- Land navigation written/field examination.
- GPS device instruction / review (unit dependant).
- GPS route planning and waypoint development (unit dependant).
- Mounted land navigation training.

13-5. The sustainment program is developed and maintained in the unit's training files. It is developed into training modules so that the program can be used as a whole or as separate individual modules, depending upon the proficiency of the unit and the commander's decision. The unit commander need only use those modules that fit the training plan.

TRAIN-THE-TRAINER PROGRAM

13-6. A train-the-trainer program in the unit develops trainers who can provide Soldiers with the confidence and skills needed to accomplish all assigned land navigation tasks.

13-7. The unit commander appoints a cadre of officers and NCOs to act as primary and alternate instructors for land navigation training. Use the training modules the unit has developed and have Soldiers go through each module of training until they can demonstrate expertise. Determine which instructors conduct each module of training and have them practice until they are fully prepared to give the training. These instructors act as the training cadre for the entire unit. They train their peers to instruct the subordinate units, and they certify each unit's training.

13-8. Conduct training at the lowest level possible. Leaders are included in all training to keep unit integrity intact.

COMPOSITE RISK MANAGEMENT

13-9. Composite risk management (CRM) balances benefits against potential losses. It provides commanders and leaders with the tools to accomplish realistic training while preserving the scarce resources of personnel, time, and equipment. When used properly, CRM is a training enabler. (Refer to FM 5-19 for more information.)

13-10. Apply CRM for the safe and effective development of training. Listed are the five basic steps to CRM for all training. It is not meant to be an all inclusive listing. For specific requirements to training refer to Commanders Guidance, Unit SOP, Local Range Safety Policies, AR 385-10, DA Pam 385-63, DA Pam 385-30, FM 5-19, and GTA 21-08-001.

SAFETY

13-11. Unit leaders brief and enforce all safety regulations established by local range operations. They coordinate the mode of evacuation of casualties through the appropriate channels, and all installation safety regulations. Unit leaders complete a thorough terrain reconnaissance before using an area for land navigation training. They should look for dangerous terrain, heavily trafficked roads, water obstacles, wildlife, and training debris.

CONDUCT A TRAINING RISK ASSESSMENT

13-12. The officer in charge (OIC) or noncommissioned officer in charge conducts a training risk assessment. It is vital to identify unnecessary risks by comparing potential benefit to potential loss. The CRM process allows units to identify and control hazards, conserve combat power and resources, and complete the mission. This process is cyclic, continuous, and integrated into all phases of operations and training. The five steps to the CRM process include:

- Identify hazards.
- Assess hazards to determine risk.
- Develop controls and make risk decisions.
- Implement controls.
- Supervise and evaluate.

Note. Risk decisions are made at the appropriate level.

IDENTIFY HAZARDS

13-13. Use the METT-TC model to identify hazards. Leaders should also consider the overall area in which training is to be conducted, and the adjacent terrain; borders and locations between lanes. Soldiers may become disorientated or purposely plan to maneuver through these areas. Leaders also need to know how the addition of new elements impacts known hazards, and the environmental impact.

ASSESS HAZARDS TO DETERMINE RISKS

13-14. Once identified, hazards are assessed by considering the likelihood of their occurrence and the potential severity of injury without control measures. When assessing hazards, leaders should consider the Soldiers' current state of training:

- **Frequent**—occurs often, continuously experienced.
- **Likely**—occurs several times.
- **Occasional**—occurs sporadically.
- **Seldom**—unlikely, but could occur at some time.
- **Unlikely**—can assume it does not occur.

Note. Risk assessment matrix and instructions are provided in FM 5-19 and GTA-21-08-001.

DEVELOP CONTROLS AND MAKE RISK DECISIONS

13-15. The unit commander's controls should be clear, concise, executable orders. Leaders apply three types of control measures to risk assessments:

- Educational.
- Physical.
- Avoidance/elimination.

Note. Most vital to developing CRM controls is mature, educated leadership.

Educational Controls

13-16. Educational controls occur when adequate training takes place. They require the largest amount of planning and training time. Leaders implement educational controls using two sequential steps:

- Supervisors and instructors are certified.
- Soldier training is executed.

Note. Prior training is not a substitute for following control measures. Individuals with a higher level of familiarity may feel a need to bypass basic steps or take short cuts. This can lead to an increase in risk taking.

Physical Controls

13-17. Physical controls are the measures emplaced to reduce injuries. This includes protective equipment and certified personnel to supervise the training. Unrestrained physical controls are a hazard.

Avoidance/Elimination Controls

13-18. Avoidance control measures prevent contact with identified hazards. Elimination control measures remove the identified hazard totally.

IMPLEMENT CONTROLS

13-19. Implementation takes place during the preparation, execution, and evaluation phase. When leaders implement the controls, they match the controls to the Soldier’s skill level. Soldier Monitoring Systems (when available) should be considered a match for first time trainees (Basic Officer Leader Course, Officer Candidate School, or initial entry training). Other control measures may be used based on availability rather than original function (cell phones or strobes). Validate the adequacy of available monitoring systems by matching them against control measures.

SUPERVISE AND EVALUATE

13-20. Supervision and evaluation are continuous and may take the form of situation reports, closer reports, back briefs, or AARs. A standardized AAR should include assessment of the CRM process and the effectiveness of established controls. This step allows leaders to refine risk probabilities and eliminate ineffective controls by determining if the implemented controls reduced the residual risk without interfering with the training. This also begins the review and identification of hazards in the cyclic process.

> ***Note.*** In the standard training environment, land navigation areas are considered training ranges and are managed as such. Generally, it is required that units ensure the range layout (land navigation course) is consistent with requirements outlined in TC 25-8. The OIC or noncommissioned officer in charge should coordinate at least one day ahead of actual use to rehearse range (course) setup and conduct.

SOLDIER MONITORING SYSTEMS

13-21. Individual land navigation training may require the use of a Soldier monitoring system or a persistent Soldier monitoring device. Trainers and units validate the need to use Soldier monitoring systems with the type of training being conducted, applicable regulations, and installation and range operations policies. Monitoring systems are required for training cadets.

13-22. Soldier monitoring systems continue to be developed. Current systems include the Homestation Instrumented Training System and the Deployable System for Training and Readiness. Both systems consist of a harness similar to the Multiple Integrated Laser Engagement System (MILES) 2000 harness with GPS. Other systems make take the form of personal locator beacons or smart phones with applications added.

13-23. All available monitoring devices need to be evaluated for training applications and inclusion in training event risk assessment development, along with adherence to local policies and applicable regulations. Final determination for requirements and use of the monitoring systems remains with the training commander.

DEVELOPING LAND NAVIGATION COURSES

13-24. When using an "established" or "unestablished" course, remember that the type used weighs heavily on the variety of risks identified during CRM development. The following is not intended to be a complete listing of all possible issues or benefits to address, but it is intended to be thought-provoking information.

ESTABLISHED LAND NAVIGATION COURSE/LAND NAVIGATION RANGE

13-25. An established land navigation course operates using an approved program of instruction (POI) with a dedicated group of certified (course specific) cadre, and committed training land such as the MCoE land navigation courses (Red Diamond/Uniform) and numerous NCO Education System land navigation courses. An established course requires—

- Long range planning and scheduling the training range/area, following scheduling procedures set by the local installation/range management office.
- Request training support of cadre and appropriate training aids/equipment. Generally when requesting a specialized range, a training packet or range support package is available through local range operations. Occasionally, training units are directed to contact a unit assigned responsibility for the course management such as the installation NCO Academy that manages, schedules training, and supports an established course.
- Minimal commitment of resources and equipment from the training unit.

13-26. An established course offers—

- Known control measures, practiced routinely by cadres.
- Current and approved CRM and POI.
- Surveyed declination stations to validate compass azimuth deviations with cadre support.
- Assigned instructor cadre are certified and have primary responsibility for training land navigation subjects/tasks at the specific course or location. Certification is administered by the United States Army Training and Doctrine Command, installation, proponent, or range operations.
- Assigned instructor cadre are—
  - Subject matter experts who are familiar with likely issues that might be encountered during course negotiation.
  - Instructors qualified in training land navigation and experienced in teaching the POI.
  - Knowledgeable of course specifics, resource requirements, and time needed to complete the course.
  - Proficient in the proven methods of recovery.
  - Experts with an in-depth working knowledge of the training land that (during emergencies) give the cadre the ability to move by the most expeditious route day or night to the point of need.
- Cadre who periodically negotiate the course to identify issues, degradation of negotiable terrain, and monitor known areas of concern—particularly during seasonal changes.
- An approved pace course area to establish or confirm pace count for the terrain.
- Clearly defined lanes not necessarily apparent to the trainee.
- Certified navigation points/lanes, standard reference markers, and well marked boundaries. Generally, committed training land limits the use of motorized vehicles and restricts use of the land-to-land navigation training. Limits placed on training land reduce the risk of possible of unintended contact with personnel outside the training unit. It also limits changes made to the terrain which pose an issue with negotiable terrain such as wire obstacles emplaced for force-on-force or standard two-tier vehicle positions.
- A refined and rehearsed standard operating procedure (SOP) for emergencies that allows rapid, effective response to emergencies based on historic events, AARs, and lessons learned from emergency responses conducted on the course.

Note. All other land navigation courses should be considered unestablished or developing land navigation courses. The use of an established land navigation training area, with trainers not holding current certification on the specific course would fall under the unestablished category.

UNESTABLISHED OR DEVELOPING COURSES

13-27. Typically, units prepare unestablished or developing land navigation courses to meet a specific training objective such as expert Infantryman badge, expert field medical badge, Soldier boards, or to sustain basic Soldier skills.

13-28. Safety is paramount in the complex outdoor environment, and every precaution is taken while replicating realistic battlefield conditions. This may vary from wearing full combat gear, using navigational aids like GPS, or practicing fire team movement with each member taking a portion of the training requirement, such as doing the pace count or acting as the compass man.

13-29. If the patrol does not have access to GPS, or if it is operating in a location where there is no satellite reception, it may be necessary to navigate by dead reckoning. This is done with a compass man and a pace man. (See FM 3-21.8 for more information.)

13-30. An unestablished course may require equipment not normally associated with a unit's mission-essential task list (METL). The required equipment varies dependent on location, trainees, and the training objective. Course requirements include (but are not limited to):

- Schedule the training range/area.

- Training area reconnaissance.
- Development of the POI.
- Course/range set up.
- Documented and rehearsed medical and casualty evacuation procedures with diagramed routes to medical facilities.
- Planned and rehearsed recovery procedures, including prepared search grids, and issued signaling devices and material.
- Loud speaker or public address system for specific use in overdue Soldier recovery.
- Water points.
- Medical/first-aid point.
- Mission command point.
- Schedule for cyclic checks to be conducted by leaders/training cadre. Checks include all active training lanes (recommended to be checked out of sequence), boundary areas, identified no-go terrain, known hazard areas, and areas immediately around navigation points.
- Authorized all-terrain or other vehicles for use as roving guides to conduct perimeter checks, medical extraction vehicles, radio retrains site, mobile water point, and equipment exchange station, and to validate points.
- Establishment of a panic azimuth and easy recognized boundary points (a major terrain feature or manmade linear object such as hard ball road or fence line).
- Commitment of organizational resources and the equipment required for land navigation/training range operations.
- Validation of the POI, unit trainers, and the course itself at the unit level.

13-31. An unestablished course offers—

- Internal training by the lowest level of leaders while maintaining unit integrity.
- Flexibility in training focus and maximum time allocation for each sub-element or sub-organization.
- Course POI tailored to specific needs/goals.
- A challenging test of Soldier's skills, because a newly developed course is completely foreign to trainees.
- Opportunities to train from preparation to completion at concurrent levels and from supporting fields. Training organic engineers, field artillery survey teams, tactical operations center/command post personnel, medics, and other Soldiers depending on the type and level of the unit conducting the training.

13-32. All types of courses have concerns and issues such as the following:

- The navigation course requires validation. Validation during daylight does not negate the requirement to validate during hours of limited visibility.
- Training land used for unit level land navigation is generally on the second or third tier of priority for training land available. This constraint may require creative thinking during POI development to meet the training objectives and commander's intent.
- Conduct a separate CRM analysis for land navigation under limited visibility. Low risk issues may become medium or high risk simply by the change of visual identification conditions (a danger such as a steep slope, drop off, or cliff).
- Consideration for alternate means of limited visibility marking. Often navigation points are marked with a low light source, and Soldiers wear a similar light source for ease of identification. This can cause confusion during recovery operations.
- Each installation/unit/facility is different and presents a unique set of issues, requiring the utilization of different land navigation grade sheets to meet and document the training objective/outcomes.
- The instructor briefs the unit/site SOP and CRM worksheet for all potential contingencies encountered during that training period/event, such as severe weather, fire, evacuation, rally points, and other points of consideration.

- Provide clear marginal information required for successful completion of the course with an emphasis on grid conversion information.
- Validate all lensatic compasses, starting with inspection of the compass and including use of a declination station. Compasses with more than a 3degree variation or have a floating dial that sticks should not be used. (See Chapter 9.)
- Provide a pace count validation area and require trainees to validate their pace count. This is paramount for those who believe a pace count from a previous geographic location is valid, as changes to terrain and conditions such as type of equipment worn and weather can change pace counts significantly.
- Develop a most likely completion time for each land navigation lane prior to the execution of training under daylight and limited visibility conditions. To assist the regional security officer/ OIC in making decisions about overdue trainees and when they should consider activation of lost Soldier procedures.
- Develop lost Soldier procedures.
- When using a Soldier monitoring system, develop actions required when a Soldier is identified as not moving or stationary for a prolonged period of time.
- Follow installation guidelines and appropriate manuals referenced previously in this chapter. Include an "L-hour" sequence of events. Examples of possible requirements are:
  - Develop a basic search plan prior to initiating training.
  - Have a sketch handout available of the course, including boundaries of the exercise area.
  - Have a sketch with details of the search plan to be used by search teams.
  - Develop, brief, and implement a signal plan.
  - Establish accountability procedures which include redundant/periodic checks for all trainees, cadre, and support personnel.

13-33. Develop a decision timeline based upon unit SOP/range operations policy and applicable regulations. L-hour definition and refinement should be addressed in the CRM process, with the basic designation of L-hour; the time the lost Solider was scheduled to return from the exercise, the Soldier was determined to be missing by the chain of command, or the Soldier failed to report completion or a loss of the Soldier monitoring tracking signal. An example of an "L-hour" activity timeline is:

- L + 0 = Notify all cadre, conduct 100 percent accountability, organize search teams according to the search plan.
- L + .5 = move search teams to search start positions.
- L + 1 = notify range operations/higher headquarters. Index training, recall all trainees, and move to a holding area to prevent independent searches.
- L + 1 = Initiate search team sweeps of their search grids.

Note. Continue development of the L-hour timeline until the plan has all available resources committed, including involvement of the installation and installation assets. Follow installation and local policies or regulations when and where applicable.

Set Up a Land Navigation Course

13-34. The unit commander provides specific guidance on what is required in the development of a land navigation course. It depends upon the unit's mission, training plan, and tasks to be trained. The basic guidelines to use when setting up a course include:

- **Determine the type of course.** This can be an established or unestablished course.
- **Determine the standards.** The unit commander determines the standards for the course. Recommended standards for an unestablished course are—
  - Distance between points should be no less than 300 m and no more than 1200 m.
  - Total distance of lanes should be no less than 2700 m and no more than 11,000 m.

  - Total number of position stakes should be no less than seven for each lane and no more than nine for each lane.
  - Time allowed should be no less than three hours and no more than four hours.
- **Decide on the terrain.** The unit should use terrain that is similar to the terrain they will be using in tactical exercises, but the terrain should be different each time training is conducted. The training area for a dismounted course needs to be at least 25 square kilometers. Mounted courses require twice as much terrain so that vehicles are not too close to each other.
- **Perform a map and ground reconnaissance.** Check the terrain to determine position stake locations, look for hazards, and develop training briefings. The difference in each course depends upon the commander's guidance. The following sequence can be used to develop a land navigation course:
  - Plot the locations of the position stakes on a 1:50,000-scale map.
  - Fabricate or order position stakes.
  - Request support from the local engineer or field artillery unit to survey the locations of the position stakes.
  - Emplace the position stakes in the surveyed locations.
  - Certify the course by having the subject matter experts negotiate each lane of the course.
  - Prepare course requirement sheets and print them.
  - Complete a risk assessment of the training area.
  - Begin teaching.

Appendix A
Map Folding Techniques

FOLDING METHODS

A-1. Figure A-1 shows two ways of folding maps to make them small enough to be carried easily and still be available for use without having to unfold them entirely.

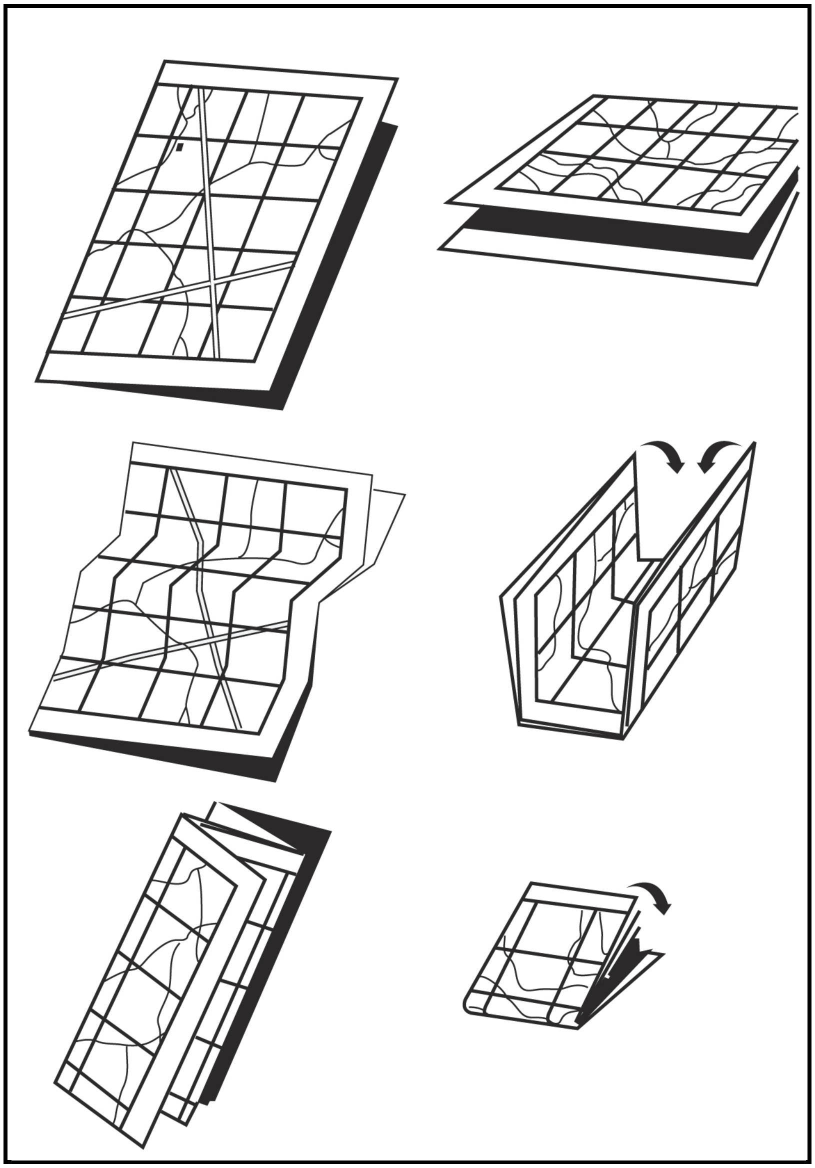

Figure A-1. Two methods of folding a map

MAP PROTECTION

A-2. After a map has been folded, it should be placed in a folder for protection. Apply adhesive to the back of the segments corresponding to A, F, L, and Q. (See Figure A-2.)

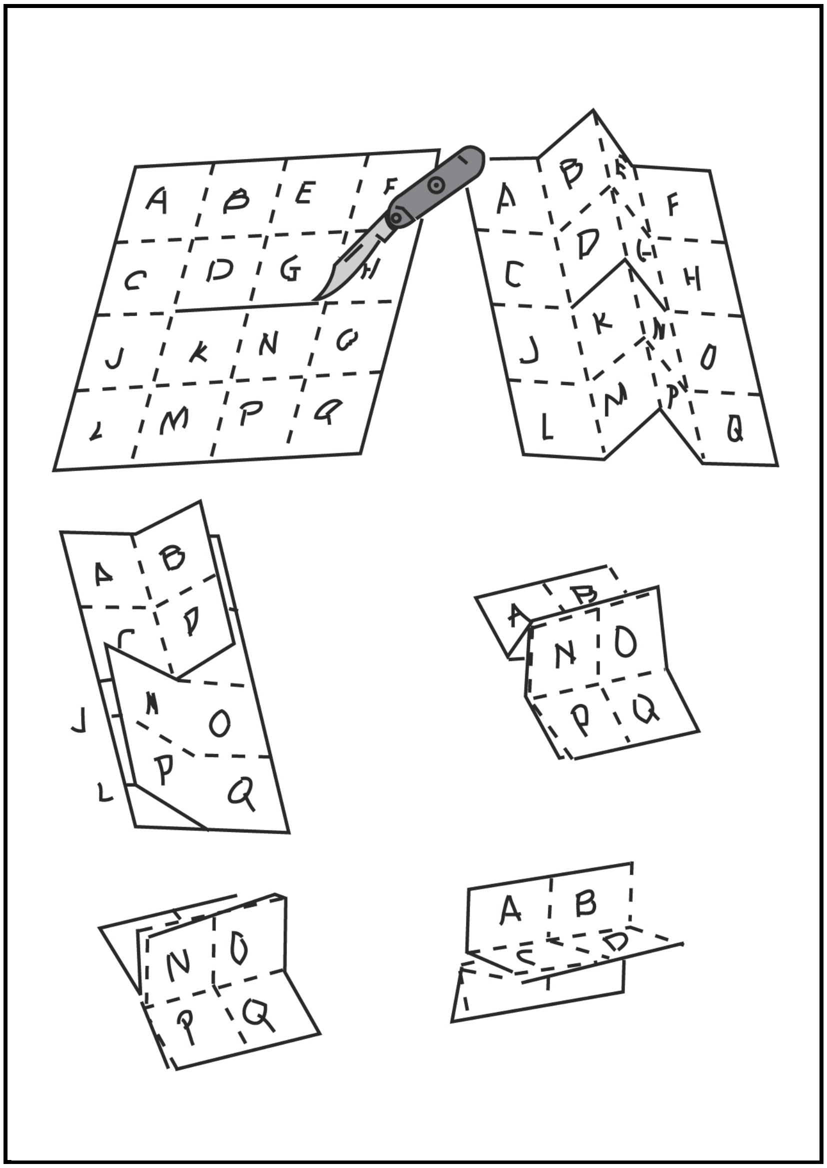

Figure A-2. How to slit and fold a map for special use

Note. Before attempting to cut and fold a map as illustrated in Figure A-2, make a practice cut and fold with a piece of paper.

Appendix B
Joint Operations Graphics

Joint operations graphics (JOGs) are based on the format of the standard 1:250,000-scale military topographic maps. They contain additional information needed in present-day joint air-ground operations.

TYPES OF GRAPHICS

B-1. Each JOG is prepared in two ways; one is designed for air operations and the other for ground operations. Each version is identified in the lower margin as JOINT OPERATIONS GRAPHIC (AIR) or JOINT OPERATIONS GRAPHIC (GROUND).

BASIC CONTENTS

B-2. The basic topographic information is the same on both JOG versions.

- Power transmission lines are symbolized as a series of purple pylons connected by a solid purple line.
- Airports, landing facilities, and related air information are shown in purple. The purple symbols that may be unfamiliar to the user are shown in the legend in the margin.
- The top of each obstruction to air navigation is identified by its elevation above sea level and its elevation above ground level.
- Along the north and east edges of the graphic, detail is extended beyond the standard sheet lines to create an overlap with the graphics to the north and to the east.
- Layer tinting and relief shading are added as an aid to interpreting the relief.
- The incidence of the graphic in the world geographic reference system is shown by a diagram in the margin.

JOINT OPERATIONS GRAPHICS (AIR)

B-3. The JOG (AIR) series, prepared for air use, contains detailed information on air facilities such as radio ranges, runway lengths, and landing surfaces. The highest terrain elevation in each 15-minute quadrangle is identified by the large open-faced figures shown in the legend. Elevations and contours on JOG (AIR) sheets are given in feet.

JOINT OPERATIONS GRAPHICS (GROUND)

B-4. The JOG (GROUND) series is prepared for use by ground units, and only stable or permanent air facilities are identified. Elevations and contours are located in the same positions as on the air version, but are given in meters.

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Appendix C
Foreign Maps

The use of foreign maps poses several problems to the land navigator. These products are often inferior in content reliability and topographic accuracy to those produced by the National Geospatial-Intelligence Agency. Clues to these weaknesses are the apparent crudeness of the maps, unusually old compilation dates, or differences in mapped and actual terrain. The following characteristics should be examined closely.

MAP CHARACTERISTICS

C-1. Of all the symbols on foreign maps, those for hydrography conform most closely to NGA usage. The use of blue lines and areas to depict streams, rivers, lakes, and seas seems to be universally accepted. The one caution to be observed is that foreign cartographers use different sets of rules to govern what is and what is not included on the map. Distinction between perennial and intermittent streams is usually not made.

C-2. The classification and symbols for vegetation on most foreign maps are different than those used on NGA maps. The vegetation included on many foreign maps is often extensive, identifying not only vegetated areas but also the specific types of vegetation present. Green is the predominant color used to represent vegetation, although blue and black are sometimes used. The symbols that depict the various types of vegetation differ greatly from one foreign map to another.

C-3. Perhaps the most striking difference between NGA and foreign maps is the set of symbols used to portray cultural features. Some symbols found on foreign maps are very unusual. Symbols for linear features on foreign maps are also likely to confuse the user who is accustomed to NGA symbols. NGA uses ten basic road symbols to portray different classes of roads and trails; foreign cartographers use many more.

C-4. Foreign maps generally use contour lines to portray terrain relief, but substantial variability exists in the contour intervals employed. They may range from 5 to 100 m.

C-5. Scales found on foreign maps include 1:25,000, 1:63,360, 1:63,600, 1:75,000, and 1:100,000. Most foreign large-scale topographic maps have been overprinted with 1000m grid squares, so it is unlikely that the variable scales have much effect on the ability to use them. However, it is important to learn how to estimate grid coordinates because the 1:25,000 and 1:50,000 grid coordinate scales may not work.

INTERPRETING FOREIGN MAPS

C-6. After discussing the many difficulties and limited advantages encountered when using foreign maps, it is only appropriate to offer a strategy to help with the task. In the August 1942 issue of The Military Engineer, a contributor suggested a five-step process for reading and interpreting foreign maps. It is as appropriate today as it was when it was first proposed:

- **Step 1.** Look for the date of the map first. There are generally four dates: survey and compilation, publication, printing and reprinting, and revision. The date of the survey and compilation is most important. A conspicuous date of revision generally means that the entire map was not redrawn—only spot revisions were made.
- **Step 2.** Note whether the publisher is military, government, or civilian. Maps published by the government or the military are generally most accurate.
- **Step 3.** Look at the composition. To a great extent, this reveals the map's accuracy. Was care taken in the cartography? Are symbols and labels properly placed? Is the draftsmanship precise? Is the coastline or river bank detailed?
- **Step 4.** Observe the map's color. Does it enhance your understanding or does it obscure and confuse? The importance of one subject (coloring) must warrant canceling others. If it confuses, the map is probably not very accurate.

- **Step 5.** Begin to decode the various map colors, symbols, and terms. Study these items by examining one feature classification at a time (culture, hydrography, topography, and vegetation). Use a notebook to develop an English version of the legend or create a new one.

C-7. In dealing with the challenge of using a foreign map, be certain to use these five steps. The world portrayed on a map represents a kind of international language of its own, which allows one to determine the map's accuracy easily and to decode its colors, symbols, and labels.

Appendix D
Sketches

A sketch is a free-hand drawing of a map, picture of an area, or route of travel. It shows enough detail and has enough accuracy to satisfy special tactical or administrative requirements.

PURPOSE OF SKETCHES

D-1. Sketches are useful when maps are not available or the existing maps are not adequate, or to illustrate a reconnaissance or patrol report. Sketches may vary from hasty to complete and detailed, depending upon their purpose and the degree of accuracy required. For example, a sketch of a large minefield requires more accuracy than a hasty sketch of a small unit's defensive position.

TYPES OF MILITARY SKETCHES

D-2. The scale of a sketch is determined by the object in view and the amount of detail required to be shown. The sketch of a defensive position for a platoon or company normally calls for a sketch of larger-scale than a sketch for the same purpose for a division. Military sketches also include road and area sketches.

D-3. A field sketch (see Figure D-1) shows the north arrow, scale, legend, and the following features:

- Power lines.
- Rivers.
- Main roads.
- Towns and villages.
- Forests.
- Rail lines.
- Major terrain features.

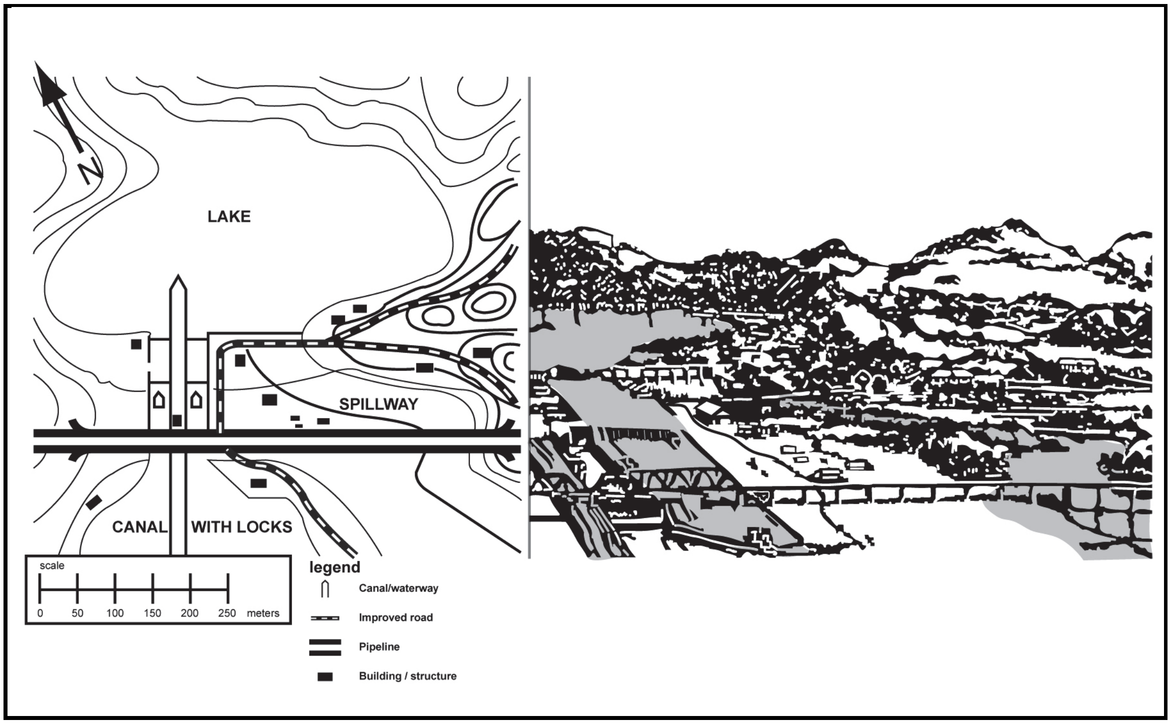

Figure D-1. Sketch map

D-4. Road sketches show the natural and military features on and in the immediate vicinity of the road. In general, the width of terrain sketches does not exceed 365 m on each side of the road. Road sketches may be used to illustrate a road when the existing map does not show sufficient detail.

D-5. Area sketches include sketches of positions, OPs, or particular places.

D-6. A position sketch is one of a military position, campsite, or other area of ground. To complete a position sketch effectively, the sketcher has access to all parts of the area being drawn.

D-7. An OP sketch shows the military features of ground along a friendly OP line as far toward the enemy position as possible.

D-8. A place sketch is one of an area made by a sketcher from a single point of observation. Such a sketch may cover ground in front of an OP line, or it may serve to extend a position or road sketch toward the enemy.

Appendix E

Units of Measure and Conversion Factors

This appendix provides conversion tables for units of measure and conversion factors that are used in military operations. Tables E-1 through E-5 contains information useful to all map readers.

Table E-1. English system of linear measure

12 inches	=	1 foot
36 inches	=	1 yard
3 feet	=	1 yard
1,760 yards	=	1 mile statute
2,026.8 yards	=	1 mile nautical
5,280 feet	=	1 mile statute
6,080.4 feet	=	1 mile nautical
63,360 inches	=	1 mile statute
72,963 inches	=	1 mile nautical

Table E-2. Metric system of linear measure

1 millimeter	=	0.1 centimeter	=	0.0393 inches
10 millimeters	=	1.0 centimeter	=	0.3937 inches
10 centimeters	=	1.0 decimeter	=	3.937 inches
10 decimeters	=	1.0 meter	=	39.37 inches
10 meters	=	1.0 decameter	=	32.81 feet
10 decameters	=	1.0 hectometer	=	328.1 feet
10 hectometers	=	1.0 kilometer	=	0.62 mile
10 kilometers	=	1.0 myriameter	=	6.21 miles

Table E-3. Equivalent units of angular measure

1 mil	=	1/6400 circle	=	0.05625°	=	0.0625 grad
1 grad	=	1/400 circle	=	16.0 mils	=	0°54' = 0.9°
1 degree	=	1/360 circle	=	about 17.8 mils	=	about 1.1 grad

Table E-4. Conversion factors

One	Inches	Feet	Yards	Statute Miles	Nautical Miles	mm
Inch	1	0.0833	0.0277	-	-	25.40
Foot	12	1	0.333	-	-	304.8
Yard	36	3	1	0.00056	-	914.4
Statute Mile	63,360	5,280	1,760	1	0.8684	-
Nautical Mile	72,963	6,080	2,026	1.1516	1	-
Millimeter	0.0394	0.0033	0.0011	-	-	1
Centimeter	0.3937	0.0328	0.0109	-	-	10
Decimeter	3.937	0.328	0.1093	-	-	100
Meter	39.37	3.2808	1.0936	0.0006	0.0005	1000
Decameter	393.7	32.81	10.94	0.0062	0.0054	10,000
Hectometer	3,937	328.1	109.4	0.0621	0.0539	100,000
Kilometer	39,370	3,281	1,094	0.6214	0.5396	1,000,000
Myriameter	393,700	32,808	10,936	6.2137	5.3959	10,000,000

Table E-5. Ground distance at map scale

One	cm	dm	M	dkm	hm	km	mym
Inch	2.540	0.2540	0.0254	0.0025	0.0003	-	-
Foot	30.48	3.048	0.3048	0.0305	0.0030	0.0003	-
Yard	91.44	9.144	0.9144	0.0914	0.0091	0.0009	-
Statute Mile	160,930	16,093	1609	160.9	16.09	1.6093	0.1609
Nautical Mile	185,325	18,532	1853	185.3	18.53	1.8532	0.1853
Millimeter	0.1	0.01	0.001	0.0001	-	-	-
Centimeter	1	0.1	0.01	0.001	0.0001	-	-
Decimeter	10	1	0.1	0.01	0.001	0.0001	-
Meter	100	1	1	0.1	0.01	0.001	0.0001
Decameter	1,000	10	10	1	0.1	0.01	0.001
Hectometer	10,000	100	100	10	1	0.1	0.01
Kilometer	100,000	1,000	1000	100	10	1	0.1
Myriameter	1,000,000	10,000	10,000	1000	100	10	1

Appendix F

M2 Compass

The M2 compass is a rustproof and dustproof magnetic instrument that provides slope, angle of site, and azimuth readings. One of the most important features of the M2 compass is that it is graduated in mils and does not require a conversion from degrees to mils as does the M1 compass. It can be calibrated to provide a grid azimuth or it can be used without calibration to determine a magnetic azimuth.

COMPASS CHARACTERISTICS

F-1. The M2 compass (see Figures F-1, F-2, and F-3) is a multiple-purpose instrument used primarily to obtain azimuths and angles of site. It also measures grid azimuths after the instrument has been set for the local declination. The main characteristics of the M2 compass are—

- Angle-of-site scale: 1200-0-1200 mils.
- Azimuth scale: 0 to 6400 mils.
- Dimensions closed: 2 3/4 inches by 1 1/8 inches.
- Weight: 8 ounces.

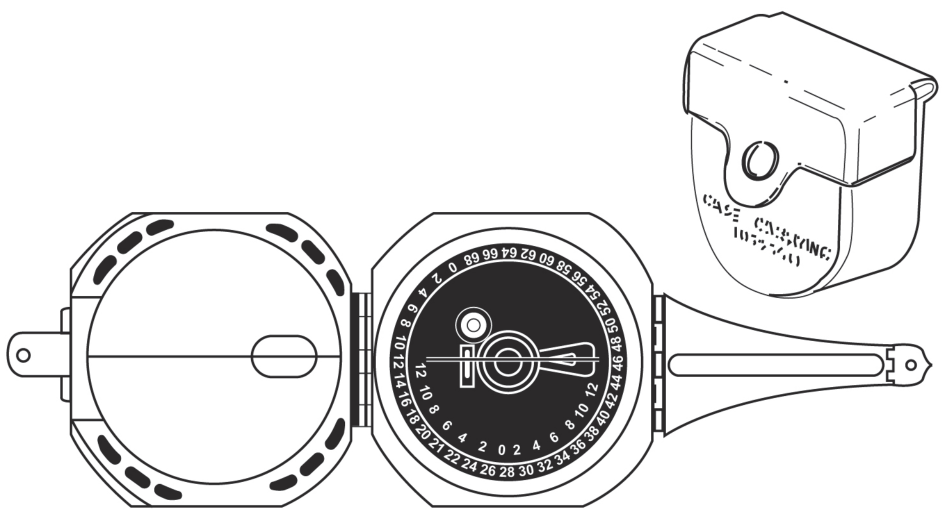

Figure F-1. Compass, M2, (top view)

COMPASS PARTS

F-2. The principal parts of the compass are the compass body assembly, angle-of-site mechanism, magnetic needle and lifting mechanism, azimuth scale and adjuster, and the front and rear sights. The details of each part are described below.

F-3. The compass body assembly consists of a nonmagnetic body and a circular glass window that covers the instrument. This keeps dust and moisture from its interior, protecting the compass needle and angle-of-site mechanism. A hinge assembly holds the compass cover in the position in which it is placed. A hole in the cover coincides with a small oval window in the mirror on the inside of the cover. A sighting line is etched across the face of the mirror.

F-4. The angle-of-site mechanism is attached to the bottom of the compass body. It consists of an actuating (leveling) lever located on the back of the compass, a leveling assembly with a tubular elevation level, and a circular level. The instrument is leveled with the circular level to read azimuths and with the elevation level to read angles of site. The elevation (angle-of-site) scale and the four points of the compass (represented by three letters and a star) are engraved on the inside bottom of the compass body. The elevation scale is graduated in two directions; each direction is graduated from 0 to 1200 mils in 20-mil increments and numbered every 200 mils.

F-5. The magnetic needle assembly consists of a magnetized needle and a jewel housing that serves as a pivot. The north-seeking end of the needle is white. (Newer compasses have the north and south ends of the needle marked "N" and "S" in raised, white lettering.) On some compasses a thin piece of copper wire is wrapped around the needle for counterbalance. A lifting pin projects above the top rim of the compass body. The lower end of the pin engages the needle-lifting lever. When the cover is closed, the magnetic needle is automatically lifted from its pivot and held firmly against the window of the compass.

F-6. The azimuth scale is a circular dial geared to the azimuth scale adjuster. This permits rotation of the azimuth scale about 900 mils in either direction. The azimuth index provides a means of orienting the azimuth scale at 0 or the declination constant of the locality. The azimuth scale is graduated from 0 to 6400 in 20-mil increments and numbered at 200-mil intervals.

F-7. The front sight is hinged to the compass cover. It can be folded across the compass body, and the cover closed. The rear sight is made in two parts—a rear sight and a holder. When the compass is not being used, the rear sight and holder are folded across the compass body and the cover is closed.

USING THE COMPASS

F-8. The compass should be held as steadily as possible to obtain accurate readings. The use of a sitting or prone position, a rest for the hand or elbows, or a solid nonmetallic support helps eliminate unintentional movement of the instrument. When being used to measure azimuths, the compass cannot be near metallic objects.

F-9. To measure a magnetic azimuth—

- Zero the azimuth scale by turning the scale adjuster.
- Place the cover at an angle of about 45degrees to the face of the compass so that the scale reflection is viewed in the mirror.
- Adjust the front and rear sights to the desired position. Sight the compass using these methods:
  - Raise the front sight and the extended rear sight assembly perpendicular to the face of the compass. (See Figures F-2 and F-3.) Sight over the tips of the front and rear sights. If the object is above the line of sighting, fold the rear sight toward the eye as needed. The instrument is correctly aligned when the level is centered, and the operator sees the tips of the sights and the center of the object at the same time.
  - Raise the rear sight approximately perpendicular to the face of the compass. Sight on the object through the opening in the rear sight holder and through the window in the cover. Keep the compass level and raise or lower the eye along the opening in the rear sight holder until the black center line of the window bisects the object and the opening in the rear sight holder.
  - Fold the rear sight holder out parallel with the face of the compass, with the rear sight perpendicular to its holder. Sight through or over the rear sight and view the object through the window in the cover. If the object sighted is at a lower elevation than the compass, raise the rear sight holder as needed. The compass is correctly sighted when the compass is level and the operator sees the black center line of the window bisecting the rear sight and the object sighted.

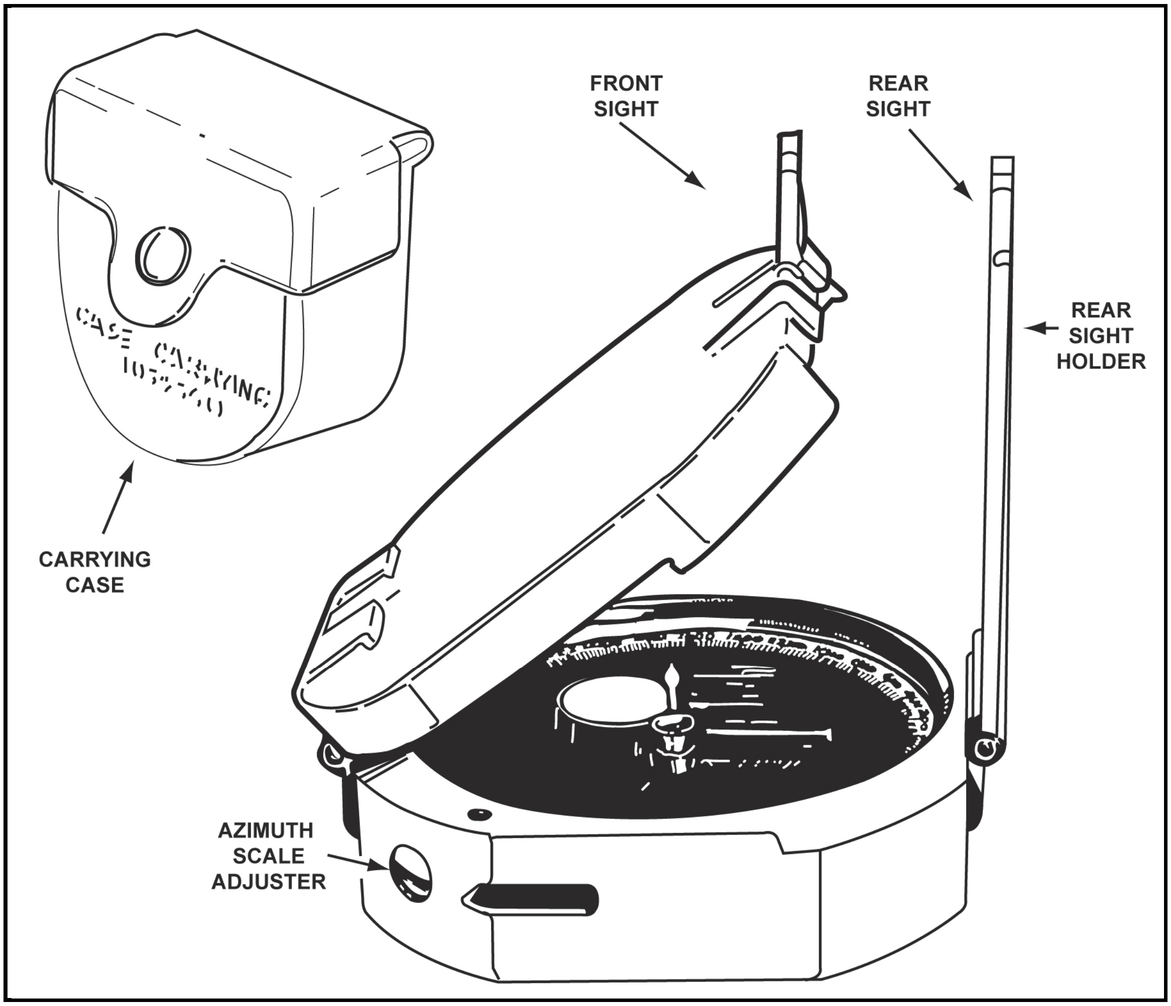

Figure F-2. Compass, M2 (side view)

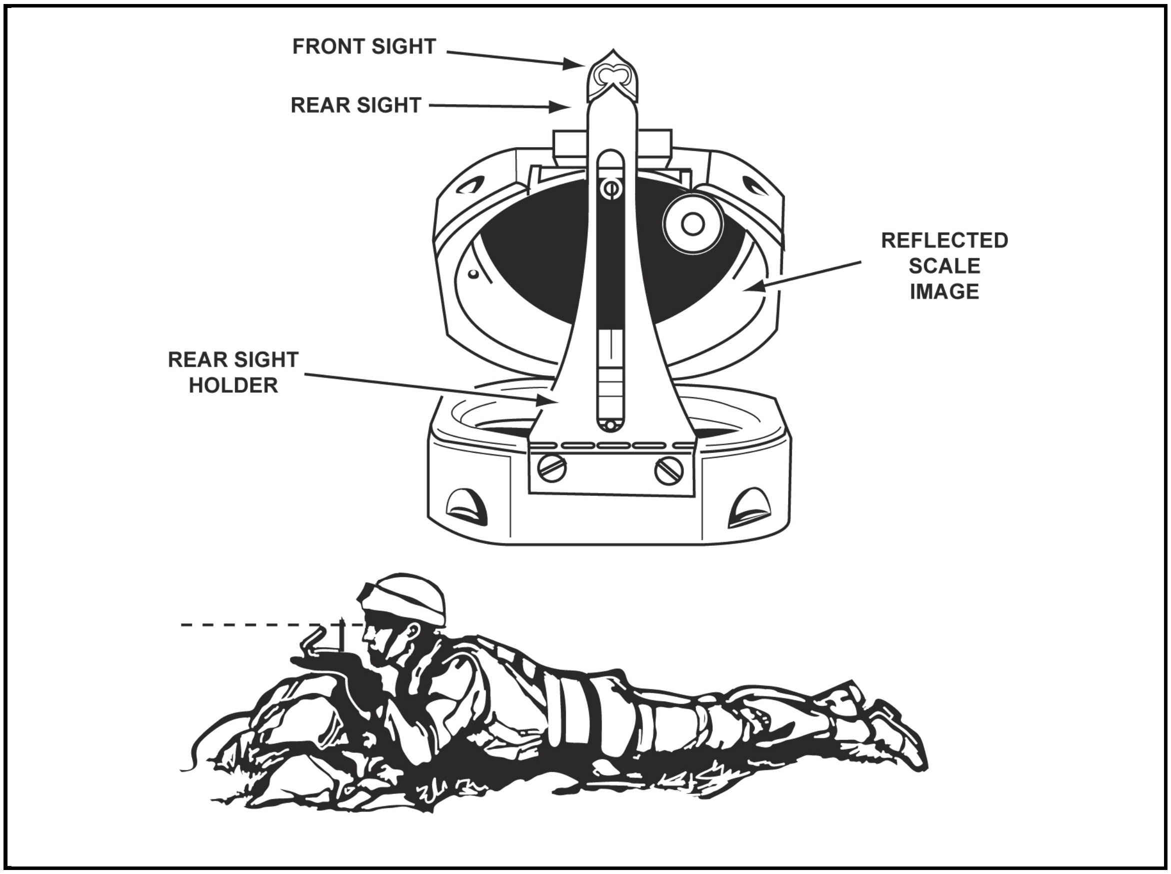

Figure F-3. Compass, M2 (user's view)

- Hold the compass in both hands, at eye level, with the arms braced against the body and the rear sight near the eyes. For precise measurements, rest the compass on a nonmetallic stake or object.
- Level the instrument by viewing the circular level in the mirror and moving the compass until the bubble is centered. Sight on the object, look in the mirror, and read the azimuth indicated by the black (south) end of the magnetic needle.

F-10. To measure a grid azimuth—

- Index the known declination constant on the azimuth scale by turning the azimuth scale adjuster. Be sure to loosen the locking screw on the bottom of the compass. (The lightweight plastic M2 compass has no locking screw.)
- Measure the azimuth as described above. The azimuth measured is a grid azimuth.

F-11. To measure an angle of site or vertical angle from the horizontal—

- Hold the compass with the left side down (cover to the left) and fold the rear sight holder out parallel to the face of the compass, with the rear sight perpendicular to the holder. Position the cover so that, when looking through the rear sight and the aperture in the cover, the elevation vial is reflected in the mirror.
- Sight on the point to be measured.
- Center the bubble in the elevation level vial (reflected in the mirror) with the level lever.
- Read the angle on the elevation scale opposite the index mark. The section of the scale graduated counterclockwise from 0 to 1200 mils measures plus angles of site. The section of the scale graduated clockwise from 0 to 1200 mils measures minus angles of site.

Appendix G
Global Positioning System

The ability to determine position location accurately has always been a major problem for Soldiers. However, the Global Positioning System has solved that problem. Soldiers are now able to determine their position accurately to within 10 m. (Refer to TM 11-5820-1172-13 for more information.)

HOW GPS WORKS

G-1. The GPS is a satellite-based, radio navigational system. It consists of a constellation with 24 active satellites that interface with a ground-, air-, or sea-based receiver. Each satellite transmits data that enables the GPS receiver to provide precise position and time to the user. The GPS receivers come in several configurations; handheld, vehicular-mounted, aircraft-mounted, and watercraft-mounted.

G-2. The GPS locates the user's position on earth by measuring the distance from a group of satellites in space to the user's location. For accurate three-dimensional data, the receiver needs to track four or more satellites. Most GPS receivers provide the user with the number of satellites that it is tracking, and whether or not the signals are good. Some receivers can be manually switched to track only three satellites if the user knows the altitude. This method provides the user with accurate data much faster than that provided by tracking four or more satellites. Each type of receiver has a number of mode keys that have a variety of functions. To better understand how the GPS receiver operates, refer to the operator's manual.

SYSTEM CAPABILITIES

G-3. The GPS provides worldwide, 24-hour, all-weather, day or night coverage when the satellite constellation is complete. The GPS can locate the position of the user accurately to within 21 m—95 percent of the time. However, the GPS has been known to locate the position of the user within 8 to 10 m. It can determine the distance and direction from the user to a programmed location or the distance between two programmed locations called waypoints. It provides exact date and time for the time zone where the user is located. The data supplied by the GPS is helpful in performing several techniques, procedures, and missions that require Soldiers to know their exact location. Some examples are:

- Sighting.
- Surveying.
- Sensor or minefield emplacement.
- Forward observing.
- Close air support.
- Route planning and execution.
- Amphibious operations.
- Artillery and mortar emplacement.
- Fire support planning.

LIMITATIONS

G-4. A constellation of 24 satellites broadcasts precise signals for use by navigational sets. The satellites are arranged in six rings that orbit the earth twice each day. The GPS navigational signals are similar to light rays, so anything that blocks the light reduces or blocks the effectiveness of the signals. The more unobstructed the view of the sky, the better the system performs.

COMPATIBILITY

G-5. All GPS receivers have primarily the same function, but the input and control keys vary between the different receivers. The GPS can reference and format position coordinates in the following systems:

- **Degrees, minutes, seconds:** Latitude/longitude-based system with position expressed in degrees, minutes, and seconds.

- **Degrees, minutes:** Latitude/longitude-based system with position expressed in degrees and minutes.
- **Universal Transverse Mercator:** Grid zone system with the northing and easting position expressed in meters.
- **Military grid reference system:** Grid zone/grid square system with coordinates of position expressed in meters. The following is a list of land navigation subjects from other sections of this manual in which GPS can be used to assist Soldiers in navigating and map reading:
  - **Grid coordinates (see Chapter 4).** GPS makes determining a 4-, 6-, 8-, and 10-digit grid coordinate of a location easy. On most GPS receivers, the position mode gives the user a 10-digit grid coordinate to their present location.
  - **Distance (see Chapter 5) and direction (see Chapter 6).** The mode for determining distance and direction depends on the GPS receiver being used. One thing the different types of receivers have in common is that to determine direction and distance, the user enters at least one waypoint. When the receiver measures direction and distance from the present location or from waypoint to waypoint, the distance is measured in only a straight line. Distance can be measured in miles, yards, feet, kilometers, meters, or nautical knots or feet. For determining direction, the user can select degrees, mils, or rads. Depending on the receiver, the user can select true north, magnetic north, or grid north.
  - **Navigational equipment and methods (see Chapter 9).** Unlike the compass, the GPS receiver when set on navigation mode guides the user to a selected waypoint by actually telling the user how far left or right the user has drifted from the desired azimuth. With this option, the user can take the most expeditious route possible, moving around an obstacle or area without replotting and reorienting.
  - **Mounted land navigation (see Chapter 12).** While in the navigation mode, the user can navigate to a waypoint using steering and distance, and the receiver tells the user how far there is yet to travel, and at the current speed, how long it takes to get to the waypoint.
  - **Navigation in different types of terrain (see Chapter 12).** The GPS is capable of being used in all terrain, especially more open terrain like the desert.
- **Unit sustainment.** The GPS can be used to read coordinates to quickly and accurately establish and verify land navigation courses. (Refer to Chapter 14 for more information.)

Appendix H

Precision Lightweight GPS Receiver

The precision lightweight GPS receiver (PLGR) is a highly accurate satellite signal navigation set (referred to in this appendix as AN/PSN-11).

OPERATIONAL CONCEPT

H-1. The AN/PSN-11 is designed for battlefield use anywhere in the world. It is sealed watertight for all-weather day or night operation. The AN/PSN-11 is held in the left hand and operated with the thumb of the left hand. Capability is included for installation in ground facilities, and air, sea, and land vehicles. The AN/PSN-11 is operated as a stand-alone using prime battery power and an integral antenna. It can be used with an external power source and external antenna.

H-2. The AN/PSN-11 provides the user with position coordinates, time, and navigation information under all conditions, if—

- No obstructions block the line-of-sight satellite signal from reaching the antenna.
- Valid crypto keys are used to protect the AN/PSN-11 from intentionally degraded satellite signals.

H-3. Many data fields such as elevation, display units of information. The format of the units can be changed to the most familiar format.

H-4. Map coordinates are entered as a waypoint. When a waypoint is selected as a destination, the AN/PSN-11 provides steering indications, azimuth, and range information to the destination. A desired course to a waypoint is entered. Offset distance from this course line is shown.

H-5. Up to 999 waypoints can be entered, stored, and selected as a destination. A route is defined for navigation either start-to-end or end-to-start. The route consists of up to nine legs (ten waypoints) linked together.

SYSTEM CAPABILITIES

H-6. Data provided by the AN/PVS-11 helps complete missions such as:

- Siting.
- Surveying.
- Tactical reconnaissance.
- Sensor emplacement.
- Artillery forward observing.
- Close air support.
- General navigation.
- Mechanized maneuvers.
- Engineer surveying.
- Amphibious operations.
- Parachute operations.
- Signal intelligence.
- Electronic warfare.
- Ground-based forward air control. This data is displayed on the AN/PSN-11display. It is also available from a serial data port.

CHARACTERISTICS

H-7. The AN/PSN-11 is less than 9.5 inches long, 4.1 inches wide, and 2.6 inches deep. It weighs 2.75 pounds with all batteries in place. The small size and light weight make the set easy to carry and use. The durable plastic case is sealed for all-weather use. The AN/PSN-11 features make it easy to use. (These features are highlighted in the physical description in Figure H-1).

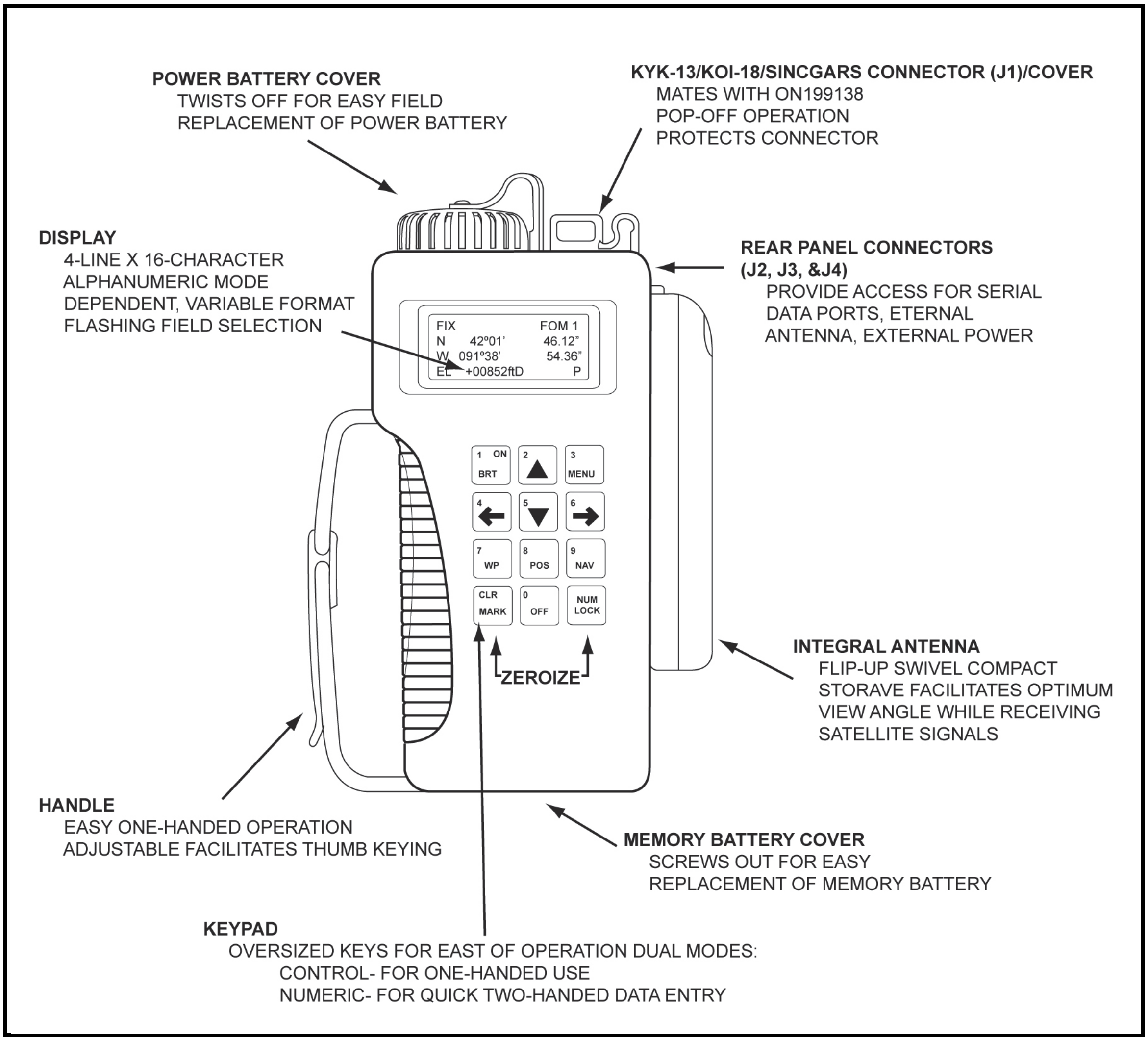

Figure H-1. Physical features of the AN/PSN-11

H-8. The approximate battery life (Table H-1) is based on operating the PLGR in continuous mode, at room temperature, and without keypad/display lighting. Several operator selectable settings are available to extend battery life. No power conservation is required when using external power.

> **WARNING**
>
> **DO NOT USE external power such as vehicle power or the AC to DC power adapter while the BA-5800 power battery is installed. The battery may explode causing personal injury and equipment damage.**

Table H-1. PLGR Batteries

Type	*Size and Voltage*	*Use*	*Life*	*Rechargeable?*
Lithium	AA 1.5 volt	Primary	16.5 hours	No
Alkaline	AA 1.5 volt	Primary	11.5 hours	No
Alkaline	AA 1.5 volt	Primary	7 hours	Yes
Nickel Metal Hydride	AA 1.5 volt	Primary	10 hours	Yes
Lithium	1/2 AA 3.6 volt	Memory	6 months	No

WARNING

If abused, lithium batteries can explode, causing severe injury. Be sure to store batteries in original packaging until ready to use, and observe polarity during installation. Reverse polarity can cause damage to the battery and receiver.

H-9. Do not mix new batteries with old batteries. Do not mix battery types. Do not reverse battery polarity. Use only fresh/new batteries.

SET UP AND CONTROL

H-10. Setting up the operation parameters of the AN/PSN-11 is critical. This section describes the display, and the procedures and principles used in setting the display to suit the needs of the user. This display consists of seven pages that allows the user to control the following parameters:

- Operating mode.
- Type of satellites to use.
- Coordinate system.
- Units.
- Magnetic variation.
- Display customization.
- Navigation display mode.
- Elevation hold mode.
- Time and error formats.
- Datum.
- Automatic off timer.
- Datum port configuration.
- AutoMark mode.

H-11. Perform the following procedures to set up the AN/PSN-11 for continuous operation: Turn the AN/PSN-11 **ON**. Once it has completed its built-in-test (BIT) press the **MENU** key and move the cursor to **SETUP.** (See Figure H-2.) Activate the SETUP function.

<move>	select
STATUS	**SETUP**
INIT	TEST
HELP	<MORE> P

Figure H-2. SETUP function

H-12. The first screen (see Figure H-3) allows the operator to set the operating mode and satellite vehicle (SV) -type. Scroll through the operating modes and select **CONT** and for the SV-type **Mixed**.

SETUP MODE:	**CONT**
Continuous	POS
and VEL	update
SV-TYPE: **mixed**	P

Figure H-3. Operating mode and SV-type

H-13. The second screen (see Figure H-4) allows the operator to set up the units. Scroll through the available coordinates and select **MGRS-New** and **Metric**. For the elevation select **meter** and **MSL** and for the angle select **degrees** and **magnetic**.

SETUP	UNITS
MGRS-New	**Metric**
Elev: **meter**	**MSL**
ANGL: Deg **Mag**	P

Figure H-4. Set up the units

H-14. The third screen (see Figure H-5) should be set for the magnetic variation (MAGVAR) or GM angle for the area. The operator can select "calculate the degree" or manually enter degrees as an easterly or westerly GM angle; for example, **E021.0** for the TENINO map sheet.

SETUP		MAGVAR
Type:	Calc	deg
	WWM	1995
		P

Figure H-5. Magnetic variation or GM angle setup

H-15. The fourth screen (see Figure H-6) of setup allows the operator to set the elevation hold, time, and error. The operator should set the ELHOLD to **automatic**. As for time, the operator needs to know, from their present location, how many hours they are ahead of or behind Greenwich Mean Time. For example, during daylight savings time, Fort Benning, GA. is **Loc=Z-0400**. To set the ERR, the operator selects **-+m** to know in meters how accurate the PLGR is operating.

SETUP	
ELHold:	**automatic**
TIME:	Loc=**Z-0400**
ERR: **+-m**	P

Figure H-6. Set elevation, time, hold, and error

H-16. The fifth screen (see Figure H-7) of setup allows the operator to set the AN/PSN-11 datum to the area of operation and to set the automatic off timer. The AN/PSN-11 has fifty-two map datum sets available. For example, if the map datum is WGS-84, the operator sets the AN/PSN-11 to WGS-84. If the map is 1927 North America datum, the operator sets the datum to NAS-C. The automatic timer off is used to turn the AN/PSN-11 off after a prescribed time once it has acquired a fixed position. The operator should set this mode to **off.**

SETUP		DTM: **NAS-C**
NA27CONUS		/Clk66
AUTOMATIC	OFF	
Timer: **off**		P

Figure H-7. Set the PLGR datum

H-17. The sixth screen (see Figure H-8) in setup is the in/out port screen. This page allows the operator to control serial communications, HAVEQUICK, and 1PPS options. Select **Standard** unless otherwise directed and select **off** for HAVEQUICK and 1PPS.

```
SETUP I/O
SERIAL:        Standard
HAVEQUICK:     Off
1PPS: Off                P
```

Figure H-8. In/out port screen

H-18. The seventh screen (see Figure H-9) is setup AUTOMARK. This feature allows the operator to have the AN/PSN-11 periodically wake up, acquire a position fix, store the position as a waypoint, or return to the mode of operation it was previously in. The operator should set this mode to **off**. The remaining pages for SETUP are for advanced GPS users.

```
SETUP          AUTOMARK
MODE: off         WP002
26-04-01          0935L
REPEAT      00h00m    P
```

Figure H-9. AUTOMARK setup

H-19. Once the AN/PSN-11 is set up, the operator can obtain a position. This procedure is accomplished by activating the position (POS) key. The position displayed is **old** information until the receiver collects and calculates satellite data and displays the current position. The receiver needs to be tracking three satellites to obtain a two-dimensional fix position, and four or more satellites for a three-dimensional fix position. The third dimension is elevation.

WAYPOINT OPERATIONS

H-20. A waypoint is the location of a point on a desired course described by coordinates or a physical location. A normal mission consists of a series of waypoints. The waypoints available on the AN/PSN-11 are 999 (numbered 01 through 999).

H-21. This paragraph describes the AN/PSN-11 waypoint displays and waypoint operations. The waypoint display pages are used to perform the following operations:

- Enter, edit, or review waypoints.
- Copy waypoints.
- Determine the distance between waypoints.
- Calculate a new waypoint.
- Clear waypoints.
- Define a mission route.

H-22. To enter a waypoint, the operator needs to press the waypoint **(WP)** key. (See Figure H-10.) When the waypoint menu appears, the ENTER function flashes. The operator presses the down arrow key to activate this field. Now the operator enters a waypoint name, grid zone designator, 100,000-m grid square identifier, 10-digit grid coordinate, and elevation.

```
WP   <move>        sel
ENTER  EDIT       COPY
SR-CALC RNG       CALC
DIST  CLEAR      ROUTE
```

Figure H-10. Enter a waypoint

H-23. To enter a waypoint name, the operator presses the right arrow key until the first letter of the word UNUSED (WP#) is flashing. (See Figure H-11.) Scroll up or down through the alphabet changing the letter U to whatever is desired. For example, if the operator wanted to name their waypoint NORTH STAR, the operator scrolls down the alphabet until the letter U is changed to the letter N. (See Figure H-12.) The operator repeats this process for the remaining letters.

WP002	UNUSED002
B	MGRS-New
AN	00000e 00000n
No EL	CLR P

Figure H-11. Unused

WP002	**NORTHSTAR**
10T	MGRS-New
EG	**13130e 95750n**
No EL	CLR **N**

Figure H-12. Change a name

- Second line, the operator enters the grid zone designator for the area of operation. For example, the Fort Benning area falls in the 16S zone.
- Third line, the operator enters a 10-digit grid coordinate with its 100,000-m grid square identifier. For example, if the waypoint location is Offutt Lake, Tenino map sheet, the 100,000-m grid square identifier is EG. Then, the operator plots the grid coordinates on the map and enters it into the AN/PSN-11.

Note. The operator plots 8-digit grid coordinates, however a 10-digit coordinate is entered. Therefore, the 5th and 10th digit entered is a zero (0).

- For the fourth line, if the elevation of the waypoint is known, the operator can enter it. If the elevation is not known the operator can just leave the data as zero or No EL. The operator moves the cursor until the up and down arrow symbol appears before the letter P or N in the bottom right corner. When activating the down arrow key the operator stores the waypoint into the AN/PSN-11's memory. The AN/PSN-11 notifies the operator that the waypoint has been stored.

Note. When entering numbers, the NUM LOCK can be activated. The letter N appears in the bottom right corner allowing the operator to use the numbers on the keypad rather than scrolling up or down.

NAVIGATION

H-24. Navigation is using the AN/PSN-11 to find the present position, relative to other points. The AN/PSN-11 provides azimuth, range, and steering information in a variety of formats. There are four navigation display modes that may be accessed and selected. The navigation display mode selected determines the type of information shown on the navigation displays. These navigation displays give the user the most useful information for a certain mission profile: **SLOW, 2D FAST, 3D FAST, OR CUSTOM.**

H-25. In **SLOW** navigation mode, the AN/PSN-11 performs two-dimensional (2D) navigation. SLOW navigation mode is used for land or sea navigation, when the user cannot maintain the minimum speed necessary (about 1.5 kph).

H-26. In **2D FAST** navigation mode, the AN/PSN-11 performs 2D navigation. 2D FAST navigation mode is used for land or sea navigation, when the user can maintain the minimum speed necessary for GPS to compute navigation parameters based on velocity.

H-27. In **3D FAST** navigation mode, the AN/PSN-11 performs three-dimensional (3D) navigation. 3D FAST navigation mode has an APPROACH sub-mode. 3D FAST navigation mode is used for air navigation, when the user can travel in three dimensions and can maintain the minimum speed necessary for GPS to compute navigation parameters based on velocity.

H-28. In **CUSTOM** navigation mode, the AN/PSN-11 performs the user's navigational display pages as so desired. It can be set up to support the individual user's performances or mission requirements. The custom display modes available are direct, course to, course from, route, and approach.

NAVIGATE BY DEAD-RECKONING

H-29. The AN/PSN-11 can navigate on land using a dead-reckoning method. The operator presses the NAV key activating the navigation function. The first screen that appears is the navigation mode. (See Figure H-13.) For example**, SLOW, 2D FAST, 3D FAST, CUSTOM, DIRECT, CRS TO, and CRS FROM.**

```
2D FAST          DIRECT
WP002         NORTHSTAR

                      P
```

Figure H-13. Navigation mode

H-30. The operator selects the **2D FAST** and **DIRECT**. The second line is the waypoint to be navigated. (Scroll through the waypoints that are stored to choose the desired waypoint.)

H-31. To see the azimuth that the navigator should be traveling on, go to the next page by pressing the down arrow key. (See Figure H-14.) This page tells the navigator what azimuth they are heading on (TRK=tracking), and the actual azimuth the navigator should be heading on (AZ). The fourth line tells the navigator steering (STR), a direction (< >), and a number of degrees the navigator needs to move to travel on the actual azimuth.

```
NORTHSTAR002 +-30m
TRK  305.3 M
AZ    311.3 M
STR  >6                P
```

Figure H-14. Azimuth

H-32. The third screen (see Figure H-15) tells the navigator the range or distance to their waypoint and how much time (TTG2) it takes them to get to their waypoint. This page also lets the navigator know what the elevation difference is from their present location to the waypoint and by how much they can miss their waypoint by (MMD).

```
RNG      3598.55km
TTG2     0036:05
ELD      -00050m
MMD2     30m        P
```

Figure H-15. Range or distance

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Appendix I

Defense Advanced GPS Receiver

The defense advanced GPS receiver (DAGR) is a handheld or host platform-mounted device that receives and decodes radio frequency signals from GPS satellite Link One (L1) and Link Two (L2). It provides position, velocity (ground speed), and timing (PVT) reports, and navigation capabilities. Although the DAGR has many features, this appendix only covers the procedures to place the unit into operation, create waypoints, navigate with the DAGR, use the situational awareness function, and troubleshoot.

SYSTEM CAPABILITIES

I-1. The DAGRs primary function is to navigate through terrain using stored waypoint position information. The DAGR is also used in operations such as waypoint calculations, data transfer, targeting, determining jamming sources, gun laying, and man overboard.

I-2. The DAGR is primarily a handheld unit with a built-in integral antenna, but can be installed in a host platform (ground facilities; air, sea, and land vehicles) using an external power source and an external antenna. (See Figure I-1.) The DAGR used as a handheld unit can also operate with an external L1/L2 antenna and a source of external power. Table I-1 describes some of its characteristics and capabilities.

Figure I-1. Defense advanced GPS receiver (DAGR)

Table I-1. DAGR characteristics and capabilities

Selected Characteristics and Capabilities	
Length:	6.35 inches
Width:	3.46 inches
Depth:	1.58 inches
Weight w/batteries:	1 pound
Number of waypoints in memory:	999
Number of routes in memory:	15 with up to 1,000 legs for each
Miscellaneous capabilities:	• Provides signal acquisition using up to 12 channels. • All satellites in view are tracked using 11 channels. • Provides navigation using up to 10 channels. • Produces no signals that can reveal one's position. • Resists jamming. • Determines and stores the azimuth of a jamming signal source. • Uses an internal compass to compute track and ground speed when moving at or below 0.5 m per second. • Compatible with night vision goggles and does not cause blooming. • Maps can be loaded.

I-3. Crypto variable (CV) keys may be loaded into the DAGR for increased PVT accuracy, and protection from intentional false or spoofed satellite signals. Mission data can be selectively cleared or zeroized at any time.

CONTROLS AND INDICATORS

I-4. The DAGR function keys are located beneath the display that contains three display windows. The operator accesses the various DAGR functions by bringing up and selecting items from menus. Data is changed by using the cursor keys.

I-5. The DAGR control keys (see Figure I-2) can be used to perform two actions. The operator can push and hold the key to access one function or push and release the key to access another. Table I-2 describes the keys and their associated functions.

Figure I-2. Function keys

Table I-2. DAGR function keys

Key	*Push and Hold*	*Push and Release*
F1/IN Function Key	F1 functions*	Zooms in on the situational awareness and map pages.
F2/OUT Function Key	F2 functions*	Zooms out on the situational awareness and map pages.
F3/STATUS Function Key	F3 functions*	Displays the current DAGR status.
PWR/QUIT Key	Turns the DAGR off or on.	• Cancels an operation. • Pages backwards when using a page set. • Returns to a previous display in a series of operational displays.
POS/PAGE KEY	Present position page	Scrolls to the next page of data.
BRIGHTNESS/MENU Key	Toggles the keypad and turns display lighting on and off.	Accesses display menus.
WP/ENTER Key	Selects between different waypoint functions.	• Selects items from pop-up menus. • Selects a field (highlight) when no field is currently selected. • Makes choices within lists.
* The functions these keys access are displayed sequentially from left to right on the toolbar at the bottom of the display.		

Editing Data

I-6. After the steps are completed to edit a field, the DAGR uses the same process for all operations to select and edit data in the display window. Use the cursor control keys to make selections or enter data in the display window. The left, right, up, and down cursor control keys function as follows:

- Push and release a cursor control key for one scroll (movement) of the cursor from field to field or option to option in the display.
- Push and hold a cursor control key for an accelerated scroll in the desired direction.
- Up and down cursor control keys are used to scroll through data vertically within a selected field as well as to move from field to field. For example, to enter new waypoint coordinates move to each digit, make the correction, push ENTER to confirm the change, and then move to the next digit.
- The left and right cursor control keys are used to scroll through data horizontally as well as move from field to field.
- The procedure to select and enter data into fields depends on the type of data and how it is presented. This includes—
  - Editing field options from a list. A list editor is a pop-up containing a menu of choices not requiring individual character editing. Scroll to the correct entry and select it by pushing ENTER.
  - Editing fields containing only numbers. A number editor is a pop-up containing numeric characters for editing. Use the left and right cursor keys to select the digit to edit. Use the up and down cursor keys to select the new digit, then push ENTER.

- Editing fields containing alphanumeric Characters. A text editor is a pop-up containing alphanumeric characters for editing. Use the cursor control keys to select the character to edit, and then push ENTER.

Multifunction Keys

I-7. The DAGR also has two sets of multifunction keys:

- **PWR/QUIT** and **POS/PAGE** key. Push and release the PWR/QUIT and POS/PAGE keys simultaneously to activate the emergency zeroize display. Confirmation from the user is required before the action is completed.
- **BRIGHTNESS/MENU** key and up or down cursor control key. When the keypad/display lighting is on, push and hold the BRIGHTNESS/MENU key and push the respective up or down cursor control key simultaneously to adjust lighting brightness level.

Lighting, Battery, and Function Indicators, and Labels

I-8. The DAGR displays the lighting status, battery strength, and the function being used in the display window:

- **Lighting status indicator.** The lighting status indicator is located in the upper right corner of the display next to the battery status indicator. It resembles a light bulb when the keypad/display lighting is on, and it does not appear when the lighting is off.
- **Battery status indicator.** The battery status indicator is located in the upper right corner of the display. It resembles a battery and the darkened portion indicates how much battery life remains.
- **Function key labels.** Each of the three function keys of the keypad has an associated function key label shown in the toolbar window at the bottom of the display. The function key actions are activated by pushing and holding the respective key on the keypad directly below the toolbar window.

Display Windows

I-9. The DAGR display contains page, toolbar, and message windows. (See Figure I-3.) The page and toolbar windows are also divided into two sections that are always visible. The message window appears as needed to display additional messages, including pop-up information.

- Display windows are not individually selected; only fields included in the windows may be selected. The operator can request help text or a menu specific to the currently displayed page when no fields are selected.
- The page window is where the majority of display interaction occurs. A page may contain several individual fields. The fields may contain "read only" data or data that can be modified. A page may contain multiple horizontal or vertical views, as denoted by scrollbars at the right side or bottom of the page window. The scrollbars are controlled by the cursor control keys.
- The toolbar window consists of three display sections and is located at the bottom of the screen. It displays labels for the push and hold keys referred to as function keys (F1, F2, and F3). The function keys are used to change the page being displayed or to perform a single action (for example, go to the NAV display page).

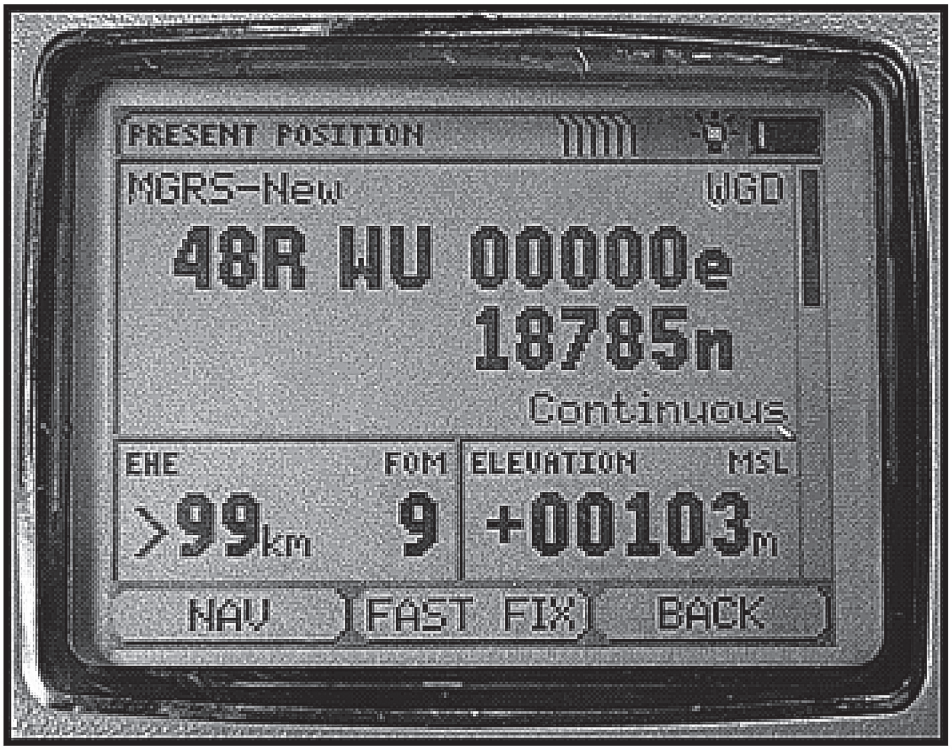


Figure I-3. DAGR display

Display Windows and Pop-Ups

I-10. When conditions warrant operator notification, message windows are used to attract the operator's attention. Messages are categorized as notes, alerts, cautions, and warnings based on the impact of the message to the operator's mission. The message window is displayed over the page window. The message is cleared (through operator acknowledgement or self-removal) before the page window functionality can be resumed.

I-11. Message, menu, help, and editor pop-ups are displayed over the page window. The operator initiates a pop-up by pushing the MENU key, or by pushing the ENTER key when a field is selected. The pop-up is cleared by making a selection from the pop-up display or pushing the QUIT key. Page window functionality is resumed after removing the pop-up. Pop-ups may have menus, allow editing, and have help text pop-ups associated with the displayed information.

Editors

I-12. The DAGR provides a variety of editors for the operator to change or customize page field content. Editors are accessed through the page or field menu. Actual DAGR editor titles correspond with the field being edited (for example, when editing a waypoint name field, the text editor title is Name). The operator primarily uses the number editor when selecting courses and creating waypoints. (See TM 11-5820-1172-13 for more information.)

I-13. The number editor is used when editing numeric field values (for example, grid coordinates). The number editor utilizes key functions as follows:

- Up/down cursor control keys—scroll to desired digit or characters.
- PAGE key—scroll to the first digit or character value.
- Left/right cursor control keys—move the cursor left or right (for example, move to the next digit in a coordinate).
- ENTER key—save changes and exit.
- QUIT key—exit without saving changes.

I-14. The list editor (see Figure I-4) utilizes key functions the same as the number editor, except the PAGE key is used to scroll down larger lists. The list editor is used when editing operator-selectable data (for example, selecting from a pick list). List editors are also used for special lists (for example, including a waypoint number and name) or additional information of the highlighted item in a display footer (for example, datum information).

I-15. The text editor is used when editing text and numeric characters. It allows selection of the characters A through Z, 0 through 9, dash (-), slash (/), period (.), and space ( ) to be entered into the text box. To select/activate a given key, the ENTER key is used. There are four command keys: Clear, Ins Char, Del Char, and Save.

- **Clear.** The clear key clears the selected character and all characters to the right of the selected character and replaces them with the space character.
- **Ins Char.** Insert character shifts the selected character and all characters following the selected character to the right by one character, and inserts a space character at the selected location. The new space character becomes the selected character and the character at the end of the text string is deleted (last character of the last line of editable text).
- **Del Char.** Delete character shifts all characters following the selected character to the left by one character, thereby overwriting the selected character, and a space character is inserted at the end of the text string (last character of the last line of editable text). The character replacing the selected character becomes the new selected character.
- **Save.** Saves the changes made to the text string and exits the text editor. Instead of using the cursor keys to highlight the SAVE command, the MENU key can be pushed to access a list of options (undo changes, save and exit, exit and no save, reset to default and editor help). These options provide shortcuts to close the text editor.

Menus

I-16. The DAGR uses the general menu structure to access and edit information. The four menu types are—

- **Main menu:** provides submenu choices.
- **Submenu:** provides page (function) choices.
- **Page menu:** provides specific functions or editors associated with the page.
- **Field menu:** provides specific functions or editors associated with the field.
  - With a page displayed or a field highlighted, the corresponding menu may be viewed by pushing the MENU key. Pushing the QUIT key allows the user to back out of the menu and return to the previous display. When a highlighted menu selection has an arrow symbol to its right, pushing the right cursor control key or the ENTER key causes the submenu to be displayed.
  - Field and page menu items that are not currently available (for example, Edit Field) appear as light gray text. Although the cursor can be placed on disabled items, the pop-up menu does not allow selection of that item.

Figure I-4. List editors

I-17. DAGR menus are accessed in steps. The operator accesses each level, selects the next menu, and proceeds down the hierarchy until reaching the desired field. The operator uses the cursor keys to highlight and the ENTER key to select.

- Going from the main menu to a field menu, use the steps to access the desired field menu:
  - Access the main menu and select the correct submenu by highlighting it and pushing ENTER.
  - From the submenu, select the correct page menu by highlighting it and pushing ENTER.
  - From the page menu, select the correct field menu by highlighting it and pushing ENTER.
- Following DAGR power-up, and from any display (except a pop-up message), access the main menu by pushing the MENU key twice. With a submenu open, the main menu is accessed by pushing the QUIT key. When a page menu or a field menu is open, the main menu is accessed by pushing the MENU key.
- The operator can immediately access the waypoint functions by pushing and holding the WP/ENTER key.

Note. When a page is displayed, other pages of the submenu page set are accessed by pushing the PAGE or QUIT keys.

I-18. POS/PAGE set speeds access to the most commonly used DAGR functions. It is accessed by pushing and holding the POS/PAGE key. After accessing the POS/PAGE set, the PAGE or QUIT key can be pushed to view all pages of the POS/PAGE set. The POS/PAGE set consists of the following pages:

- The present position page (see Figure I-5) displays the operator's present position and contains ten fields. The operator can scroll the page to view the additional field data. The ten fields include: present position coordinates, coordinate and grid system, datum identifier, current operating mode, estimated horizontal error (EHE), FOM, elevation reference, ground speed, estimate time error, and MAGVAR.
- The situational awareness page provides a graphic display of relationships between present position, track, waypoints, routes, and alerts. The situational awareness page includes a north reference indicator, speed and track, position error data, and a range scale.
- The NAV pointer page (see Figure I-6) displays a pointer directing the operator towards the displayed waypoint. It also displays the current navigation method, destination waypoint number, and name, azimuth, and range fields.
- The map page displays a graphic map of relationships between current position, landmarks, map objects, and selected waypoints. With a map previously loaded, the map page automatically displays a map with present position of the DAGR shown at the center of the display. The operator uses zoom and pan operations, and waypoint selections to obtain a desired view. When navigating, the map page provides the operator with a mapped view of surrounding terrain and potential obstructions (for example, a body of water).
- The SV sky view page (see Figure I-7) displays status information on tracked satellites (for example, acquiring satellites). The current operating status is shown at the top of the display. Numbers inside black circles indicate satellites in use to acquire or maintain the current DAGR position. The corresponding number at the left side of the display provides a bar graph indication of satellite signal strength and code status. The longer the bar, the greater the signal strength. A black bar indicates ephemeris data is collected. If the DAGR cannot display satellite information, no bars appear at the far left side of the display.

Note. The operator can remove the SV sky view and map page from the POS/PAGE set, but not the present position, situational awareness, and NAV pointer pages. The operator can add up to seven additional display pages to the nonremovable pages of the POS/PAGE set for a total of up to 10 display pages.

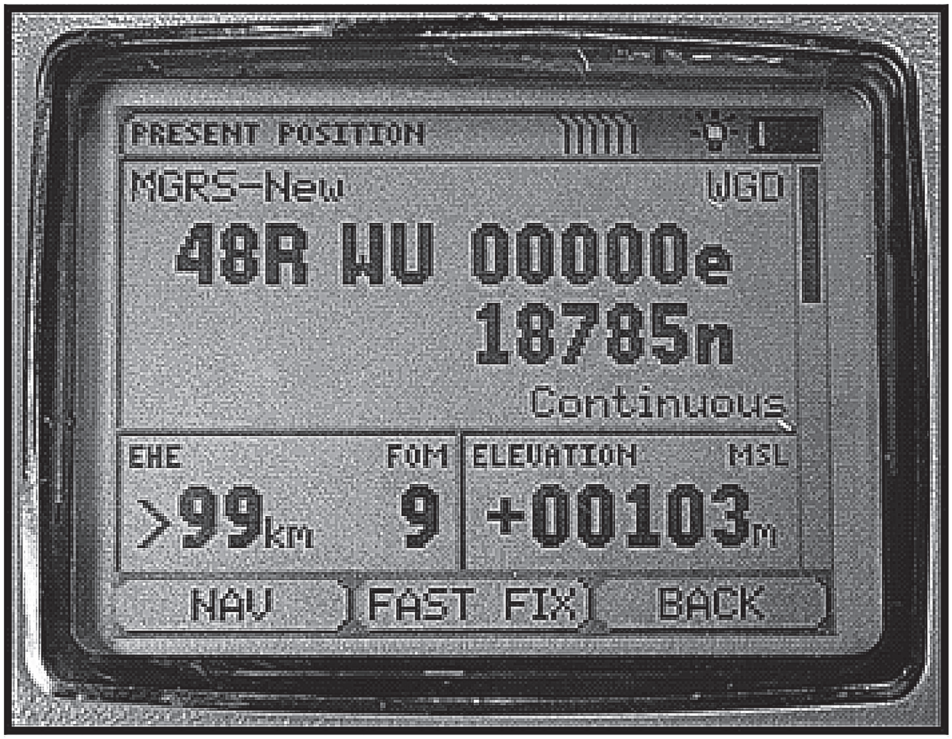


Figure I-5. Present position

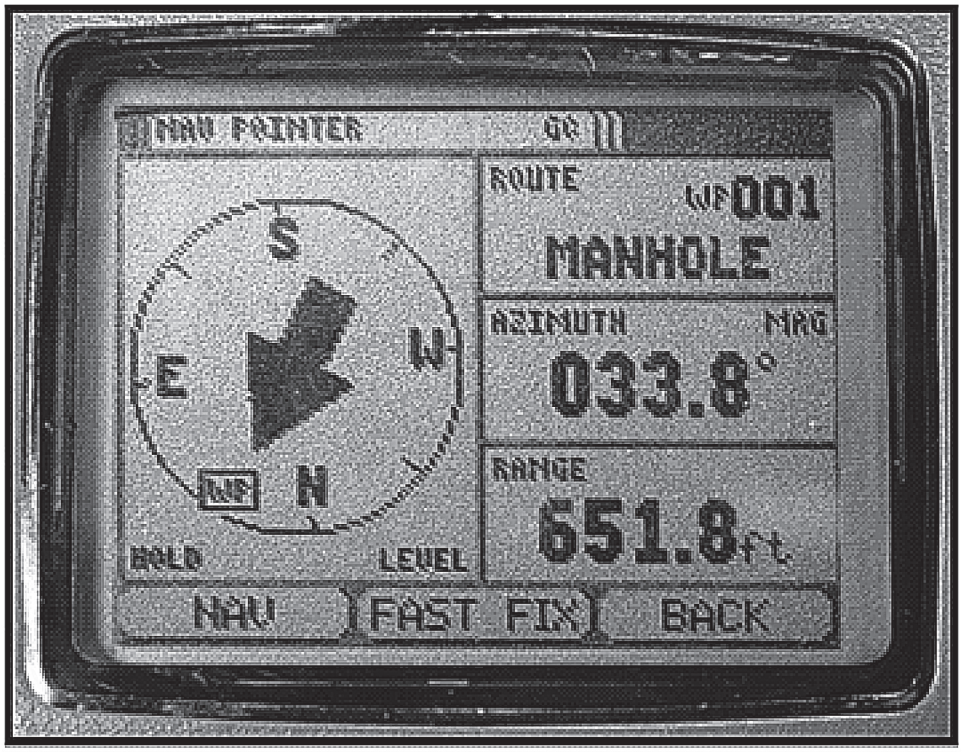


Figure I-6. NAV pointer

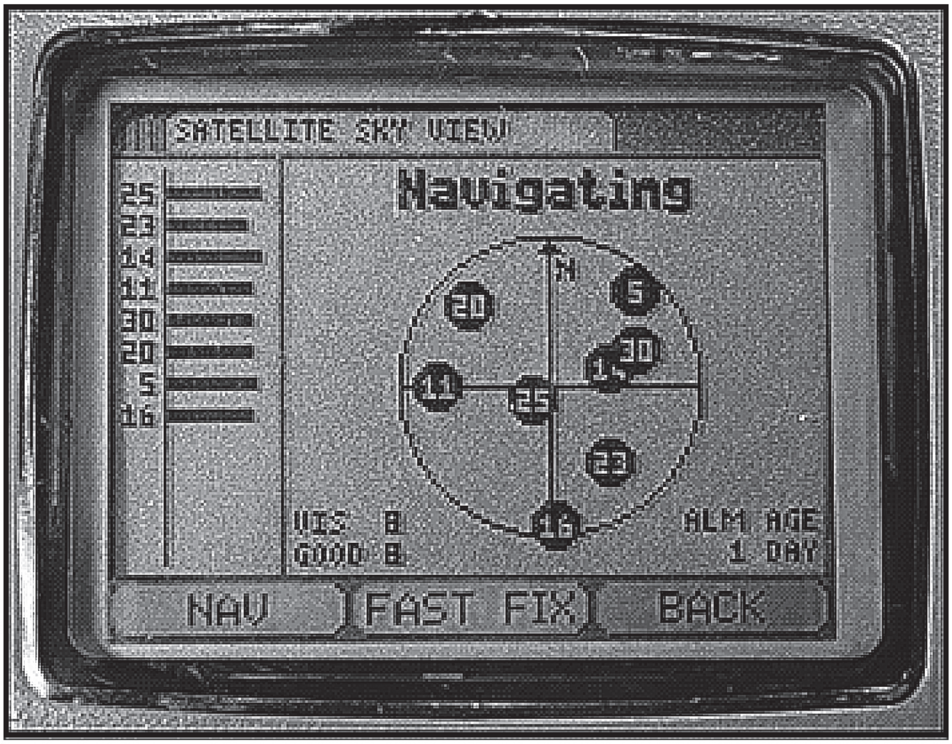


Figure I-7. SV sky view

OPERATIONAL CHECKOUT PROCEDURES

I-19. Performing the operational checkout procedures on the DAGR determines if the unit is operating correctly. These checks aid the user in detecting a DAGR malfunction that may be corrected in the field. If the DAGR passes the operational checkout procedure, the unit is ready to use; if the DAGR does not pass the operational checkout procedure, proceed to the troubleshooting procedures. After operational checkout procedures, but before use, ensure—

- The correct function set is being used (basic or advanced).
- The correct user profile is being used, if using the advanced function set.
- The DAGR is set to the desired operating mode:
  - Inspect the DAGR and external cables and equipment for damaged and or missing parts.
  - Push the POWER key to turn the DAGR on, and make sure the DAGR has a clear view of the sky. During power up, observe the power-on status indicated.

Note. A test summary page can be accessed from the system submenu for a listing of tests that passed or failed. Do not use the DAGR if the status field shows display. Make sure the DAGR passes the self-tests and the battery strength indicator shows sufficient remaining battery power. Do not use the DAGR if a self-test fails.

I-20. After the DAGR successfully completes the power-on self-test and shows the SV sky view page or present position page, perform the following procedure for an operator-induced commanded self-test:

- Activate commanded DAGR self-test.

Note. The self-test does not track SVs, determine position, or provide navigation data. Operator confirmation is required to enter this mode. The self-test lasts approximately four minutes and requires operator intervention to complete.

- If the present position page is not already displayed, push and hold the POS key (except when showing a message pop-up, then push the QUIT key first). The present position page is displayed. Push the MENU key.
- Highlight select op mode, then push the ENTER key.
- Highlight test, then push the ENTER key.
- The DAGR displays an ENTER TEST MODE message prompting the operator to confirm or cancel entering test mode. Push the ENTER key to confirm.
- A test in progress display appears with the specific area of testing listed at the bottom, and a bar graph denoting progress. The DAGR automatically tests multiple areas.

Note. While performing the following keypad test, push and hold the ENTER key to test the ENTER key. Push and release the ENTER key to advance to the next display.

- After the displayed tests are completed, the keypad test is displayed. Push each key on the keypad and verify the corresponding key shown on the display toggles between normal and highlighted appearance. Push the ENTER key to continue to the next display.
- The display light test display appears with the brightness adjustment cycling between 0 percent and 100 percent. The percentage adjustment is reflected in the light bulb of the display. Push the ENTER key to continue.
- The contrast test display appears with the contrast adjustment cycling between 0 and 100 percent. The percentage adjustment is reflected in the bar graph of the display. Push the ENTER key to continue.
- The display test beginning message appears momentarily. After sequencing through white, light gray, dark gray, and black, the display test completed message appears, followed by the power-on status display listing self-test results as pass or fail.

Note. A test summary page can be accessed from the System submenu for a listing of tests that passed or failed. Do not use the DAGR if the status field shows FAILED.

- If the power-on status remains displayed and does not time out, push the ENTER key to acknowledge.
- The SV sky view page is displayed. Push the MENU key.
- Highlight select op mode, then push the ENTER key.
- Highlight continuous, then push the ENTER key. This mode enables the DAGR to acquire a current position fix.
- After satellites are acquired and a current position fix is obtained, the DAGR display stops blinking and tracking SVs is shown on the SV sky view page. The display then automatically switches to the present position page.

> ***Note.*** If the DAGR does not acquire satellites, the display blinks between black and gray text and goes into standby mode (both handheld and host platform operation). If the DAGR display continues to blink, verify a clear view of the sky, then perform the manual initialization procedure.

DAGR BATTERIES

I-21. The DAGR requires two sets of batteries to operate fully, although it can operate on only the primary battery. Table I-3 shows the types of batteries the DAGR can use.

I-22. The approximate battery life is based on operating the DAGR in continuous mode, at room temperature, and without keypad/display lighting. Several operator selectable DAGR settings are available to extend battery life. No power conservation is required when using external power. Internal batteries are not required when using external power, and need not be removed when connected to external power.

Table I-3. Types of batteries

Type	*Size and Voltage*	*Use*	*Life*	*Rechargeable?*
Lithium	AA 1.5 volt	Primary	16.5 hours	No
Alkaline	AA 1.5 volt	Primary	11.5 hours	No
Alkaline	AA 1.5 volt	Primary	7 hours	Yes
Nickel Metal Hydride	AA 1.5 volt	Primary	10 hours	Yes
Lithium	1/2 AA 3.6 volt	Memory	6 months	No

WARNING

If abused, lithium batteries can explode, causing severe injury. Be sure to store batteries in original packaging until ready to use, and observe polarity during installation. Reverse polarity can cause damage to the battery and receiver.

I-23. Do not mix new batteries with old batteries. Do not mix battery types. Do not reverse battery polarity. Use only fresh/new batteries.

I-24. If the DAGR is being used for the first time and there are no memory settings to be saved, the memory battery is not important, but still needs to be installed. To ensure all settings from previous usage are retained, ensure a good memory battery is installed (check memory battery date on battery page) or external power is applied to the unit before installing or replacing the primary batteries.

I-25. If all primary and memory power is lost, memory information is lost, and the DAGR resets to default settings after power-up. Use the following steps to install the primary battery:

- Ensure power to the DAGR is off.
- Hold the unit firmly upside down with the battery pack facing up.
- Push or pull the latch located on the battery pack to release the battery pack. Lift up on the battery pack and remove it from the unit.
- Position the battery removal strap into the channel of the battery pack before installing new batteries.
- Install new batteries and ensure correct polarity installation for each battery (marked on battery pack).
- Before installing the battery pack, inspect the battery pack gasket for damage or dirt. Lubricate or replace gasket, if necessary. Ensure the battery removal strap is not protruding from the battery pack.

I-26. To install a new battery pack, position the tab on the battery pack in the slot on the DAGR. Use the following steps to install the battery pack:

- Close the battery pack against the DAGR until the battery pack is engaged.

- Ensure power to the DAGR is off.
- Place the unit upside down on a nonabrasive surface with the memory battery cover facing up.
- Use a flat-blade screwdriver to loosen the three screws securing the memory battery cover, and remove the cover from the unit.
- Remove the expired memory battery and properly dispose of it.
- Install the new memory battery.
- Before reinstalling the memory battery cover, inspect the gasket for damage or dirt. Lubricate or replace the gasket, if necessary.
- Reinstall the memory battery cover, and tighten the three screws.

OPERATING PROCEDURES

I-27. Operating procedures include turning the power on, conducting a self-test, selecting the mode of operation, and turning the power off at the end of the operation.

I-28. Several steps and checks are conducted before turning the DAGR on. (Refer to TM 11-5820-1172-13 for more information.).

- To ensure proper battery life and proper unit operation, check the batteries to make sure they are of the same type, are not a mix of old and new batteries, and are still good (by checking the battery indicator).
- If using external power, be sure the battery cable is properly connected.
- Be sure the DAGR has an open view of the sky to acquire the present position. When position data fields blink between black and gray text, the DAGR is not tracking satellites or has not yet acquired the present position.
- Manually enable and orient the internal compass.
- To operate in -20 degree Centigrade or below conditions, ensure the heater has been on for at least 20 minutes before powering up.
- If a warning or other message displays while operating the DAGR, follow the display instructions.

I-29. Push the PWR key to turn the DAGR on. A display page briefly appears indicating the DAGR software version. After the power is on, the normal operating mode is continuous when operating on external power and fix when operating on battery power. If a CV key, group-unique variable (GUV) key, or an SV code condition exists, acknowledge the message(s) accordingly.

- The power-on status message (see Figure I-8) appears and provides the following information. (All messages may not be listed as they are dependent on how the DAGR is configured. Use the up/down cursor control keys to scroll and view the entire display message.)
  - The self-test message displays the self-test results as PASS (no self-test failures found) or FAIL (self-test failures detected). This message is always displayed.
  - The battery used message indicates the primary battery capacity used (amount of time in hours and minutes the DAGR has been operated using primary battery). It is displayed when using internal primary battery power only.
  - The battery left message indicates the primary battery capacity remaining (in hours and minutes). It is displayed when using internal primary battery power only.
  - The CV message indicates whether or not CV keys are loaded. If they are loaded, the message indicates whether or not the DAGR has the current CV key.
  - The power message indicates which power is being used—internal or external.
  - The days remaining message indicates the number of days remaining in the mission. It also indicates if enough CV keys are loaded for mission duration.
  - The default message indicates that the DAGRs position, time, and date are default values. It also indicates if initialization is recommended for the DAGR.

I-30. The power-on status message times out in two seconds, and the DAGR is ready for use if the status message indicates that the self-test has passed and the DAGR does not need initialization. If the self-test indicates FAIL, the operator is prompted to push the ENTER key to acknowledge, but the DAGR is not ready to use. If any of the following conditions exist, a message requiring the operator’s acknowledgement appears.

- No CVs or GUV keys are loaded.
- No CV key for today is loaded.
- Not enough CV keys are loaded for duration of mission (if mission duration is entered).
- SV code is set to mixed.

I-31. After the power-on status display times out or is acknowledged, the DAGR displays the SV sky view page with satellite acquisition status appearing at the top. Initially, the status is displayed as ACQUIRING SVS and when successful, the status changes to TRACKING SVS.

I-32. After the DAGR has acquired the current position, the unit automatically switches to the Present Position page and displays the position coordinates, elevation, and the EHE.

I-33. During satellite acquisition, the PAGE or QUIT keys can be used to access the present position page. If the DAGR is not tracking satellites, the display blinks and the present position page displays the last position recorded by the receiver before being turned off.

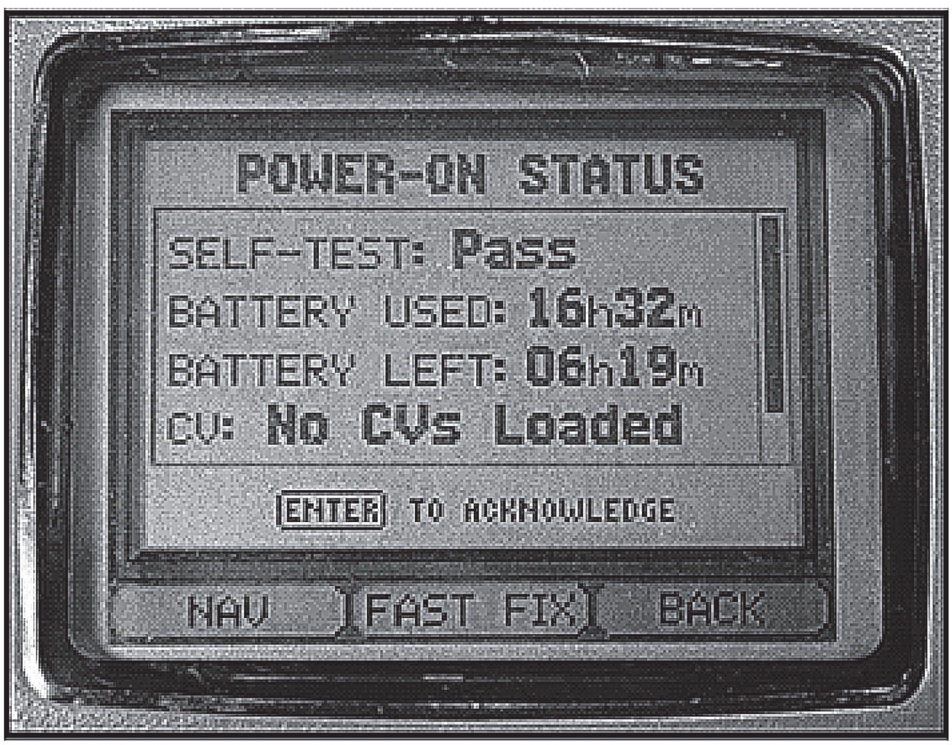


Figure I-8. Power-on status

Note. Adjust the DAGR keypad/display lighting by pushing and holding the BRIGHTNESS key and the respective up or down cursor control key.

I-34. Conduct the self-test using the same procedures described earlier in this appendix.

I-35. The DAGR mode of operation can be selected from any display, except a message pop-up, by pushing the MENU key twice to display the main menu. The normal (default) operating mode is continuous when the DAGR uses external power, and fix when it uses battery power. The DAGR can operate in eight different modes:

- The continuous mode uses the most power, and tracks satellites to produce a continuous PVT solution.
- The fix mode tracks satellites to produce a current PVT solution. After a position fix is obtained, it automatically transitions to the standby mode.
- When the DAGR is in the standby mode, which uses reduced power, it does not acquire and track satellites but performs all functions that do not require satellites.
- The other available modes are: average, time only, rehearsal, test, and off. (Refer to TM 11-5820-1172-13 for more information.)
- To select an operating mode (see Figure I-9)—
  - From any display except a message pop-up, push and hold the POS/PAGE key until the present position page is displayed.
  - Push the MENU key.
  - Highlight the select op mode option and then push the ENTER key.
  - Highlight the desired operating mode and then push the ENTER key.
  - The display returns to the present position page and displays the current operating mode.

I-36. The user performs the following operations to turn the DAGR off after use:

- Push and hold the PWR/QUIT key. The power down warning page is displayed. If some functions are enabled, such as Auto-on, a message appears before the power down warning.
- Wait the allotted time for the DAGR to turn off, or push the WP/ENTER key to turn it off immediately.

Figure I-9. Operating modes

MANUAL INITIALIZATION

I-37. If the DAGR has been moved a long distance and is not operating properly, it may need to be initialized according to its new position. Some indications that it needs to be manually initialized include:

- Difficulty obtaining a position fix.
- Datum is mismatched with navigation waypoints.
- Datum does not match the geographical map being used. (Refer to TM 11-5820-1172-13 for more information.)

CREATION OF WAYPOINTS

I-38. A waypoint is a position reference used to navigate, define routes, or mark points of interest. The waypoints page is accessed using the WP key or from the WP/routes/alerts submenu. The waypoints page provides a table that lists all DAGR waypoints. The waypoints editor page allows the user to create new waypoints, edit existing waypoints, clear waypoints, copy waypoints, or view only desired waypoints (search, sort, and filter). The waypoint editor page is accessed from the waypoints page.

I-39. The menu functions on the waypoints page (see Figure I-10) are:

- **Create/new.** This function provides a list of unused waypoints (numbers). After selecting a new waypoint number, the waypoint editor page is used to set up the waypoint.
- **Edit waypoint.** This function displays the waypoint editor page for editing the selected waypoint.
- **Copy.** The copy function copies a selected waypoint's data. This data can then be pasted into another waypoint, or range of waypoints. Operator confirmation is required before the DAGR overwrites existing waypoints.
- **Clear.** The clear function clears a single waypoint, a range of waypoints, or all waypoints. Operator confirmation is required before the DAGR clears the waypoints.
- **Units.** This function provides an editor to select range, angle, north reference, or elevation (advanced) units.
- **Navigate to waypoint.** This function displays the NAV pointer page.
- **Search.** The search function searches for and displays waypoints by a name or remark (up to ten characters each).
- **Sort.** The sort function sorts and displays the entire list of waypoints in ascending alphanumeric order by name, number, range from present position, range from selected waypoint, or identity.
- **Filter.** The filter function displays a filtered list of waypoints. Filter choices are: all used WPs, all unused WPs, within range (specified by operator), and unfilter (display all waypoints).
- **Waypoint summary.** The waypoint summary displays the number of waypoints used and unused.

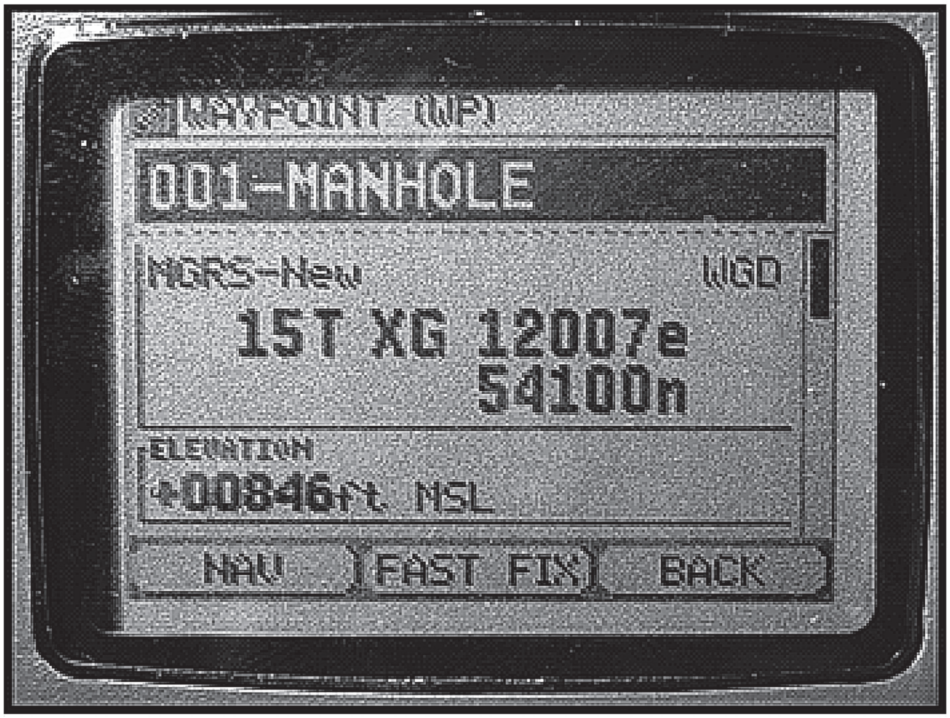


Figure I-10. Creating waypoints

I-40. Perform the following steps to create a waypoint.

- From any display, push and hold the WP key. Waypoint function choices are displayed.
- Highlight create new WP, then push the ENTER key
- The waypoint editor page automatically displays the first unused waypoint with current (if tracking satellites) or last position information. Revise information as necessary.
  - Use the left and right cursor keys to move between the digits.
  - Use the up and down keys to change the digit, and push ENTER to enter the new digit.
- Complete the action by highlighting one of the following and pushing the ENTER key.
  - Save and exit. The display briefly shows the waypoint stored message, then returns to the waypoints page with the new waypoint information saved and highlighted.
  - Exit and no save. When this option is selected, the display returns to the waypoints page without saving the waypoint.
  - Edit field. This selection displays an editor for the highlighted field.
  - Undo changes. Undo changes clears all changes made, and the display returns to the Waypoints Editor page for editing.

- Help. This selection displays help text for the highlighted field.

CREATION OF A NEW ROUTE

I-41. By creating a route, the operator creates or designates existing waypoints to define the course to take. Waypoints define the end of each leg of the route and the sum of these legs becomes the route. The route editor page allows the operator to view, edit, and create routes.

I-42. The routes page is accessed from the WP/routes/alerts submenu. It provides a table that lists all routes stored in DAGR. Vertical scrolling is used to view all routes. If a route is undefined or invalid, double dashes appear in the route name and legs columns of the table. The route list includes the following information for each route:

- **NUM**—displays the route number (01 through 15).
- **Route Name**—displays the route name of up to ten characters.
- **Legs**—displays the number of route legs (1 to 1,000). This quantity matches the number of waypoints in a route.
  - From the routes page, highlight the desired new route number, or if the highlighted route is not changed, the first unused route number is automatically used. Push the MENU key. Highlight create and push the ENTER key.
  - Highlight create/new and push the ENTER key. The route editor page displays the first unused route if no route number was previously selected, or the operator-selected route.
  - Scroll down the page into the route leg table and highlight the first row containing all double dashes (unused leg), then push the ENTER key. Highlight the desired ending waypoint for the leg of the route, then push the ENTER key. The route editor displays the route leg with the selected end waypoint. Repeat this step to create all desired route legs. After creating all route legs, push the MENU key.

Note. The top row of the route leg table always has end waypoint 000–POS representing present position.

  - Complete the action by highlighting one of the following and pushing the ENTER key.
    - Save and exit. The display briefly shows the route stored message, then returns to the routes page with the new route information saved and highlighted.
    - Exit and no save. The display returns to the routes page without saving the route.
    - Maximize/minimize table. The display returns to the routes page with the route table maximized (displaying five routes at once) or minimized (displaying three routes at once).
    - Insert WP after. From the select WP editor, highlight the desired waypoint, then push the ENTER key. The route editor page highlights a new leg (inserted after the original highlighted leg) created from the entered waypoint.
    - Swap with next. The route editor displays the highlighted route leg swapped with the one that was next (disabled if the highlighted route leg is the last leg).
    - Remove WP. The route editor page displays with the highlighted leg removed.
    - Edit field. This selection displays an editor for the highlighted field (leg). (See Figure I-11.)
    - Undo changes. Undo changes clears all changes made, and the display returns to the route editor page for editing.
    - Help. This selection displays help text for the highlighted field.

Figure I-11. Create a route

- To calculate the length of a route, highlight a desired route from the routes page, and push the MENU key.
  - Highlight calculate length, then push the ENTER key.
  - The route length is displayed. Push the ENTER key to acknowledge.
  - The DAGR returns to the routes page.

CREATION OF A NEW ALERT

I-43. Setting the DAGRs alert function indicates when the operator is approaching or has passed a waypoint (see Figure I-12) or a predefined line or area. The alerts page is accessed from the WP/routes/alerts submenu, or by using the status key and receiver status menu. The alerts page provides a table showing all DAGR alerts. The operator can create new alerts, edit existing alerts (using alert editor page), clear alerts, copy alerts, and enable or disable alerts.

I-44. The alert editor page is accessed from the alerts page. Vertical and horizontal scrolling is used to view all alerts and table columns. If alert data are undefined or invalid, double dashes appear in the table columns. Use the status key to view the receiver status display and check the alert status or access the alerts page.

Figure I-12. Alert message

- From the alerts page, highlight the desired new alert number, or if the highlighted alert is not changed, the first unused alert number is automatically used. Push the MENU key.
- Highlight create/new, then push the ENTER key. The alert editor page displays the first unused alert (up to 33 alerts can be created) if no alert was previously selected. Revise the information as necessary using standard editing techniques, and then push the MENU key. Highlight the desired option from the multiple options provided, then push the ENTER key.
- Complete the action by highlighting one of the following and pushing the ENTER key:
  - Save and exit. The display briefly shows the alert stored message, and then returns to the alerts page with the new alert information saved and highlighted.
  - Exit and no save. The display returns to the alerts page without saving the alert.
  - Edit field. This selection displays an editor for the highlighted field.
  - Undo changes. Undo changes clears all changes made, and the display returns to the alerts editor page for editing.
  - Help. This selection displays help text for the highlighted field.

DAGR NAVIGATION

I-45. The operator usually navigates directly to a waypoint or follows a route with legs created by moving to a series of waypoints. The elevation hold and bulls-eye method can also be used.

I-46. The operator pushes the MENU key twice, highlights navigation, and pushes the ENTER key. The operator then scrolls to navigation setup and pushes the ENTER key, scrolls to the navigation method field and pushes ENTER. The operator selects either direct to or route. (Although other methods are available, such as course to approach and so on; direct to and route are the most common and are discussed below. Refer to TM 11-5820-1172-13 for the other methods.)

- **Direct to.** Set the WP field to the waypoint being navigated to.
  - Highlight the WP field, then push the ENTER key.
  - Highlight the desired waypoint and push the ENTER key.
  - Set the WP alert mode field to on or off. When the alert mode field is on, the DAGR visually alerts the operator upon arrival at the waypoint.
  - The calc type field appears on all NAV setup page displays when using advanced function set. There are two methods used for calculating navigation information: Rhumb line (RL) or great circle (GC).
    - Rhumb line—produces constant compass directions and allows lines of latitude to be used as paths.
    - Great circle—produces the shortest path to the navigation waypoint, but the compass direction of travel changes due to the curvature of the earth.
- **Route.** Perform the following steps to navigate using a series of waypoints along a route that has been previously created:
  - Highlight route and push the ENTER key.
  - Set the route field to the desired navigation route number/name.
    - Highlight route field, then push the ENTER key.
    - Highlight the desired route and push the ENTER key.
    - Configure the calc type field and the alert function the same as for the direct to method.

I-47. To navigate with the DAGR, access the NAV pointer page, then travel the azimuth pointed by the pointer field arrow. The compass dial rotates so the top of the dial indicates the current ground track.

- If the DAGR internal compass is active, hold level appears at the bottom of the pointer field. The internal compass activates when moving below a preset speed for a preset amount of time.
- While moving toward the destination waypoint, the range field value steadily decreases and the azimuth field value changes.
- The operator uses the steering 2D field directional arrow and angular value to align the track with the azimuth for navigation to the leg ending waypoint. When off course, the left and right directional arrows and angular value appear. When on course, the on course indicator (.....) appears, and the track field and azimuth field values match.
- During route navigation, the operator can reverse the direction of travel on the route by changing the setting of the direction field of the NAV setup page.
- The DAGR recognizes it has reached the waypoint when it reaches a radius from the waypoint (default is 5 m) set in the alert radius field of the waypoint editor page. The operator confirms waypoint arrival only if the WP alert mode field of the NAV setup page was previously set to on. If the operator is using the route function, the DAGR automatically switches to the next leg.
- The operator sets the direction field to Forward or Reverse for desired direction of navigation through the route legs.

SITUATION AWARENESS

I-48. The situational awareness page provides a graphic display of the DAGRs current position compared to other waypoints, routes, and alerts shown on the display. It is accessed from the NAV submenu. (See Figure I-13.)

I-49. Track, ground speed, north indicator, position error, and range scale data all provide additional DAGR present position information. The operator can select view orientation, view content (waypoints, routes, and alerts), edit displayed waypoints, measure between selected points, and track history.

Figure I-13. Situational awareness

I-50. The present position symbol (waypoint 000 inside a circle) is at the center of the display (unless fields are selected) with a track indicator staff.

- Ground speed and track are displayed in the lower left corner.
- If the DAGR internal compass is being used, displayed track text alternates with the instruction to HOLD LEVEL.
- The range scale is displayed in the lower right corner. The north reference indicator is displayed in the upper left corner and always points to true north.
- Position error (EHE, EPE, EVE, or FOM) is displayed as a ± value in the upper right corner (except FOM is displayed as a value of 1 to 9, with 1 being the best).
- The operator can set the display view orientation as follows:
  - North-up—top of the display is north.
  - Track-up—top of the display is current track.

- Course-up—top of the display is current navigation course (if defined, otherwise defaults to current track).
- Operator-entered—top of display is an operator-entered value.

I-51. The situational awareness page provides a graphic display of waypoints, routes, alerts, and track history. Page characteristics include zoom range scale, panning/scrolling, and measuring range between points.

- Waypoint numbers are provided in the center of a shape and a direction indicator staff is attached, if applicable. Highlighted symbols (shown on the bottom row) denote selected waypoints. The operator can select which waypoints to display.
- Routes are shown as dashed lines with arrows indicating route direction from waypoint to waypoint (legs of the route). The display of waypoints used to define the route is based upon the selected waypoint view option. The operator can select which routes are displayed.
- Waypoints are used to define alerts. Alerts are displayed as selected by the operator (none, enabled, or all) using shapes to denote the alert type. Spikes displayed as part of the alert perimeter represent the dangerous side or area of an alert. Use the status key and the receiver status menu to check alerts and their status.
- The operator can zoom in or out using the IN or OUT keys on a scale of 50 feet to 800 miles, 50 yards to 800 nautical miles, or 50 m to 800 km (English, nautical, or metric units). Range scale is shown in the lower right hand corner of the display.
- Overzoom is displayed in place of the range scale when the DAGR speed is too fast for the selected zoom scale. The operator may zoom out until overzoom is no longer displayed. When zooming in or out with the cursor displayed, the display centers upon the cursor. When a waypoint is selected, the display centers upon the waypoint and the cursor moves to the center of the display.
- The operator uses the cursor control keys to pan (move) the display to a horizontal point. Default panning is the present position (POS) at the center of the display. A cursor appears when scrolling in any direction. Scrolling the cursor to the edge of the view pans the display.
- When the measurement function of the page menu is used, a measurement box appears. The measurement box provides azimuth (AZ), range (RNG), slant range (SR), and elevation angle (ELA) data computed from a starting point position (DAGR position) to the current cursor position. A corresponding line between the points also appears. The operator can set the starting point as a point other than present position and restart the measurement. When the cursor is moved to a waypoint, the waypoint symbol is highlighted to signify the waypoint is selected for generating measurement data.

I-52. The map page is accessed from the navigation submenu. (See Figure I-14.) The map page provides a graphic map display of relationships between current position, landmarks, map objects, and selected waypoints. With a map previously loaded (covering present position), the map page automatically displays a map with the DAGRs present position shown at the center of the display. The operator uses zoom and pan operations, and waypoint selections to obtain a desired view. When navigating, the map page provides the operator with a mapped view of surrounding terrain and potential obstructions (for example, a body of water).

- The map page is always oriented with the top of the map appearing at the top of the display.
- The present position symbol (waypoint 000 inside a circle) is at the center of the display (unless the operator is panning the display).
- A scale value (dependent upon the map in use) is provided in the lower right corner of the map page.
- The map page uses no fields and no cursor.
- The map page provides a graphic display of waypoints and map objects. Page characteristics include zoom range scale, panning, and map selection.

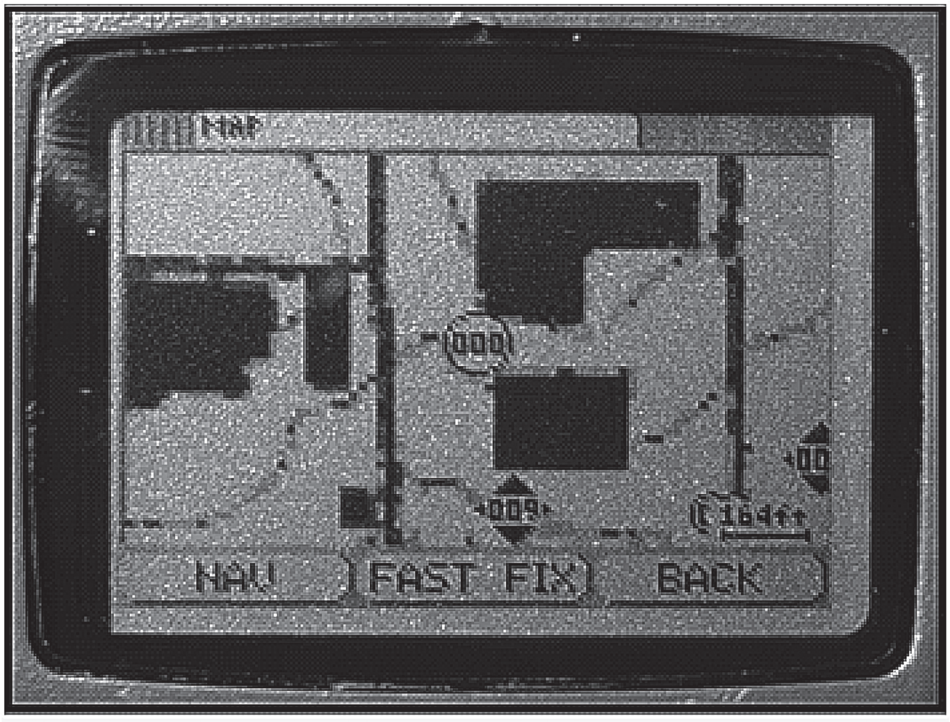


Figure I-14. Map page

- Waypoint numbers are displayed in the center of a shape denoting their identity or type as follows:
  - Friendly—circle.
  - Hostile—diamond.
  - Neutral—square.
  - Unknown—cloud. Present position is always displayed as waypoint 000.
- The operator can select which waypoints to display from the map page menu. Operator selectable waypoint view options are:
  - None—only present position is displayed.
  - Navigation—displays waypoints being used for navigation inside the map coverage area as determined by the NAV setup page from WP, or to WP fields.
  - Operator-selected—displays waypoints inside the map coverage area that have been selected by the operator for viewing.

TROUBLESHOOTING

I-53. Troubleshooting procedures detect and isolate DAGR failures and malfunctions. These procedures are similar to the operational checkout procedures. After a DAGR failure has been found and corrected, perform the operational checkout procedure again to make sure the DAGR is operating properly. If troubleshooting confirms a DAGR failure and repair is beyond what is covered in the DAGR training manual, turn the DAGR unit in.

I-54. Inspect the DAGR and external cables and equipment for damage or missing parts. If the DAGR is damaged or parts are missing, turn the unit in.

I-55. Push the PWR key to turn the DAGR on. If the DAGR display does not come on after power is applied, check the primary battery and primary battery pack, and the external connections to the power source. If the battery connections are good but the display does not come on, turn the unit in.

- If operating in cold conditions, allow additional time (up to 20 minutes) for the display to appear.
- Observe the power-up test results. If a failure occurs, check all external connections and rerun the self-test. Follow instructions on the display or turn the unit in.
- After power-up when using primary power batteries, check the primary battery life indicator to determine if the battery has sufficient life. If battery life is insufficient, replace primary batteries and update battery information on the battery page.
- After power-up, ensure a low memory battery message does not show. Access the battery page and check the date shown in the memory battery installed field. If the DAGR shows a date approximately six months old, then replace the memory battery and update the memory battery information on the battery page.

I-56. After power-up, perform an operator-induced self-test.

- If the DAGR fails the self-test, check all external connections if applicable, and rerun the self-test.
- Follow instructions on the display or turn the unit in.

I-57. After power-up, if the DAGR passes the self-test and the display still blinks between black and grey text, perform the following:

- Move the DAGR (or external antenna) to an open view of the sky.
- Hold the DAGR at a 90-degree angle to the horizon.
- Ensure satellite acquisition time is at least two minutes.
- Ensure the DAGR is in a satellite tracking mode of operation.
- Perform the manual initialization procedure.
  - If the display does not stop blinking, turn the unit in.
  - If the display stops blinking, troubleshooting is complete.

Appendix J
Orienteering

Orienteering is a competitive form of land navigation suitable for all ages, and degrees of fitness and skill. It provides the suspense and excitement of a treasure hunt. The object of orienteering is to locate control points by using a map and compass to navigate through the woods. Courses may be as long as 10 km.

History of Orienteering

J-1. Orienteering began in Scandinavia in the nineteenth century. It was primarily a military event and part of military training. The modern version of orienteering was formed in Sweden as a competitive sport in 1919. Ernst Killander, its creator, can rightfully be called the father of orienteering.

J-2. In the early 1930's, the sport received a technical boost with the invention of a new compass that was more precise and faster to use. The Kjellstrom brothers, Bjorn and Alvan, and their friend Brunnar Tillander, were responsible for this new compass. They were among the best Swedish orienteers at that time, with several individual championships among them. Orienteering was brought to the U.S. in 1946 by Bjorn Kjellstrom.

J-3. Today, each orienteer is given a 1:50,000 topographic map with the various control points circled. Each point has a flag marker and a distinctive punch that is used to mark the scorecard. Competitive orienteering involves running from checkpoint to checkpoint. It is more demanding than road running because of the terrain, and the orienteer constantly concentrates, makes decisions, and keeps track of the distance covered. Orienteering challenges the mind and the body; however, the competitor's ability to think under pressure and make wise decisions is more important than speed or endurance.

Orienteering Course

J-4. The orienteering area should be on terrain that is heavily wooded, preferably uninhabited, and difficult enough to suit different levels of competition. The area needs to be accessible to competitors, and its use coordinated with appropriate terrain and range operations offices.

J-5. The ideal map for an orienteering course is accurate, multicolored, and large-scaled. A topographic map is a graphic representation of selected man-made and natural features of a part of the earth's surface plotted to a definite scale. The distinguishing characteristic of a topographic map is the portrayal of the shape and elevation of the terrain by contour lines.

J-6. For orienteering within the U.S., large-scale topographic maps are available from the National Geospatial-Intelligence Agency, Hydrographic Topographic Center. The scale suitable for orienteering is 1:50,000.

J-7. The challenge for the course setter is to keep the course interesting, but never beyond the ability of the individual or group. General guidance is to select locations that are easily identifiable on the map and terrain, and accessible from several routes.

J-8. Those who set up the initial event should study a map for likely locations of control points and verification of the locations. Better yet, they should coordinate with an experienced competitor in selecting the course.

Types of Courses

J-9. Orienteering includes several forms of events. Some of the most common are route, line, cross-country, and score orienteering.

Route Orienteering

J-10. This form can be used during the training phase and in advanced orienteering. In this type of event, a master or advanced competitor leads the group as they walk a route. Beginners trace the actual route walked on the ground onto their maps. They circle the location of the different control points found along the walked route. When they finish, the maps are analyzed and compared. During training, time is not a factor.

J-11. Another variation is when a course is laid out on the ground with markers for the competitor to follow. There is no master map, as the course is traced for the competitor by flags or markers. The winner of the event is the competitor who has successfully traced the route and accurately plotted the most control points on the map.

Line Orienteering

J-12. At least five control points are used during this form of orienteering training. The competitor traces on the map a preselected route from a master map. The object is to walk the route shown on the map, circling the control points on the map as they are located on the ground. (See Figure J-1.)

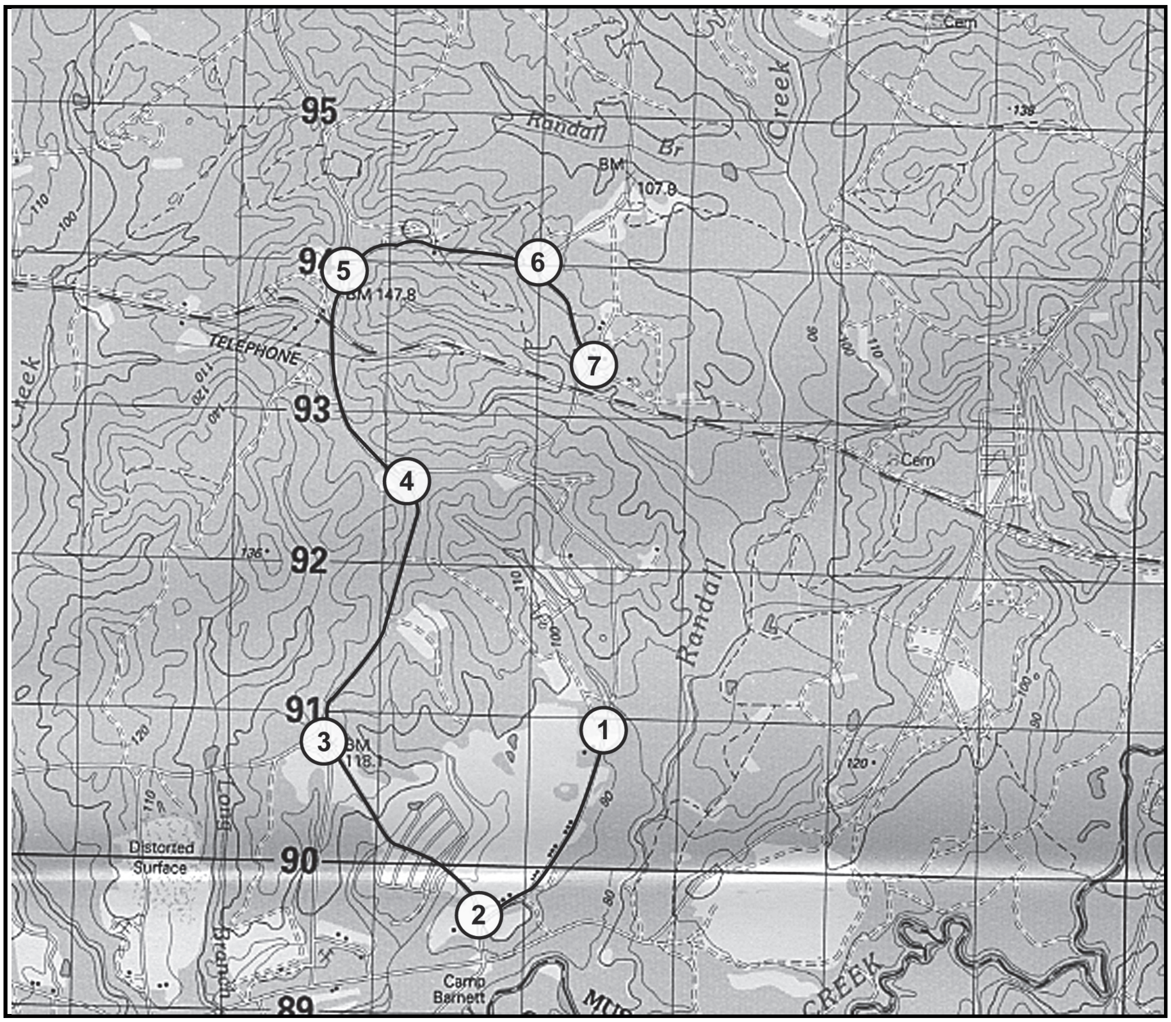


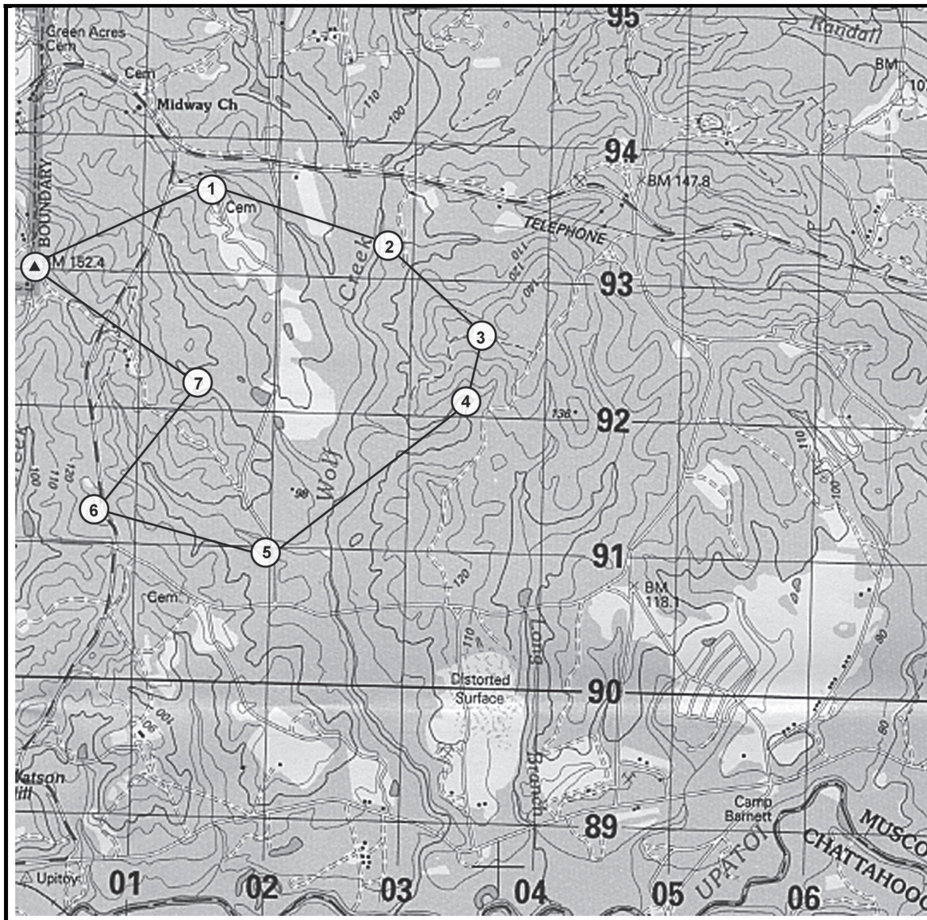
Figure J-1. Line orienteering

Cross-Country Orienteering

J-13. This is the most common type of orienteering competition. It is sometimes called free or point orienteering and is considered to be the most competitive and intriguing of all events. (See Figure J-2.) In this event, all competitors visit the same controls in the same order. With the normal one-minute starting interval, it becomes a contest of route choice and physical skill. The winner is the contestant with the fastest time around the course.

J-14. After selecting the control points for the course, determine the start and finish locations. The last control point should be near the finish. In describing each controlled location, an eight-digit grid coordinate and a combination of two letters identifying the point (control code) should be included in each descriptive clue list that is normally given to each competitor at least two minutes before the start time.

J-15. Usually, 6 to 12 control markers are on the course in varying degrees of difficulty and distances apart, so that there are no easy, direct routes. Instead, each competitor is faced with many choices of direct but difficult, or indirect but easier routes. Each controlled location is circled, and the order in which each is to be visited is clearly marked on the master map. The course may be a closed transverse with start and finish collocated, or the start and finish may be at different locations. The length of the course and difficulty of control placement varies with the competitors' degree of expertise. Regardless of the class of event, all competitors indicate on their event cards proof of visiting the control markers. Inked stamps, coded letters, or punches are usually used to do this procedure.



CONTROL NUMBER	COORDINATES	CONTROL CODE	DESCRIPTION OF CLUES
1	GA01539360	WE	CEMETERY, NORTHERN PART
2	GA02789323	WT	CREEK JUNCTION CENTER
3	GA03529260	DA	DRAW CENTER
4	GA03399209	WK	SOUTH END OF RUNWAY
5	GA01969098	CM	EAST OF POND
6	GA00739122	RD	HILLTOP
7	GA01419218	JD	SPUR

Figure J-2. A cross-country orienteering map

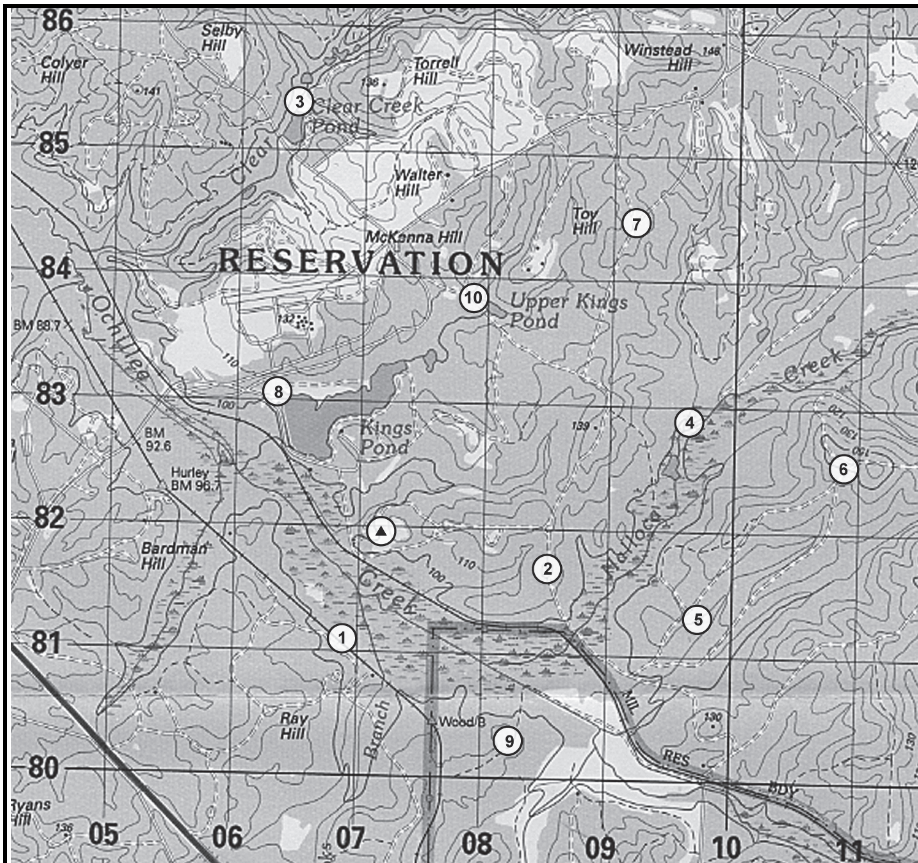
> ***Note.*** The same orienteering range may serve in both cross-country and score events. However, a separate set of competitor maps, master maps, and event cards are necessary.

Score Orienteering

J-16. In this event, the area chosen for the competition is blanketed with many control points. (See Figure J-3.) The controls near the start/finish point (usually identical in this event) have a low point value, while those more distant or more difficult to locate have a high point value. This event requires the competitor to locate as many control markers as possible within the specified time (usually 90 minutes). Points are awarded for each control visited and deducted for exceeding the specified time. The competitor with the highest point score is the winner.

J-17. Conducting a score event is basically the same as the cross-country event at the start. The competitor is given a map and an event card. The event card lists all the controls with their different point values. When released to the master map, the competitor finds the circles and numbers indicating the location of all the controls listed on the event card. All the red circles are copied onto the competitor's map. Then the route is chosen for amassing the highest possible point score in the time available. The course is designed to ensure that there are more control points than can possibly be visited in the allotted time. Again, each control marker visited is indicated on the event card.

J-18. It is important for the competitor to take time initially to plot the most productive route. A good competitor may spend up to 6 minutes in the master map area while plotting the ideal route. There is no reward for returning early with time still available to find more points, so the good competitor is able to coordinate time, distance, and land navigation ability in running the course.



CONTROL NUMBER	COORDINATES	CONTROL CODE	DESCRIPTION OF CLUES
1	GA06898106	TD	RAILROAD BRIDGE - NORTH
2	GA08518169	RZ	TOP OF HILL
3	GA06458541	CD	NORTH OF POND
4	GA09618284	PR	CENTER CREEK JUNCTION
5	GA09758131	AC	BUILDING
6	GA10798253	SM	RUINS
7	GA09178446	WN	ROAD JUNCTION - NORTH
8	GA06358296	YV	BUILDING WEST END OF POND
9	GA08248030	NT	TOP OF HILL
10	GA08948383	YM	EAST END OF POND

Figure J-3. A score orienteering map

OFFICIALS

J-19. The same officials can be used at the start and finish. Although more officials or assistants can be used, the following lists the minimum number of people needed for a competition. These officials or assistants are needed at the start:

- **Course organizer.** Briefs the orienteers in the assembly area, issues event cards and maps, and calls orienteers forward to start individually.
- **Recorder.** Records orienteer's name and start time on recorder's sheet, checks orienteer's name and start number on the event card, and issues last-minute instructions.
- **Timer.** Controls the master clock and releases the orienteers across the start line at their start time (usually at one-minute intervals) to the master map area.

J-20. These officials or assistants are needed at the finish:

- **Timer.** Records the finish time of each orienteer on the orienteer's event card and passes the card to the recorder.

- **Recorder.** Records the finish time of each orienteer on the orienteer's event card and passes the card to the course organizer.
- **Course organizer.** Verifies correctness of names, finish times, and final score; posts orienteers positions on results board; and accounts for all orienteers at the end of event.

START/FINISH AREA

J-21. The layout of the start/finish areas for orienteering events is basically the same for all forms. This area consists of:

- **Assembly area.** This is where orienteers register and receive instructions, maps, event cards, and start numbers. They may also change into their orienteering clothes if facilities are available, study their maps, and fill out their event cards here. Sanitation facilities should be available in this area.
- **Start.** At the start, the orienteer reports to the recorder's and timer's table to be logged in by the recorder and released by the timer.
- **Master map area.** There are three to five master maps 20 to 50 m from the start. When the orienteer arrives at this area, the map the orienteer carries is marked with all the course's control points. Having done this, the route to be followed is then determined. A good orienteer takes the time to orient their map and carefully plot the route before rushing off. It is a good idea to locate the master map area out of sight of the start point to preclude orienteers tracking one another.

EQUIPMENT

J-22. Competitions require several items to be a success. The following is a list of equipment needed by the host of an orienteering event:

- Master maps, three to five, mounted.
- Competitor maps, one each.
- Event cards, one each.
- Recorder's sheets, two.
- Descriptive clue cards, one each.
- Time clocks, two.
- Rope, 100 to 150 feet, with pegs for finish tunnel.
- Card tables, one or two.
- Folding chairs, two or three.
- Results board.
- Control markers, one per point.
- Extra compasses.
- Whistle, for starting.
- First-aid kit.
- Colored tape or ribbon for marking route to master map and from last control point to finish.

CONTROL MARKERS

J-23. Control markers are orange-and-white markers designating each control point. (See Figure J-4.) Ideally, they should have three vertical square faces, forming a triangle with the top and bottom edges. Each face should be 12 inches on a side and divided diagonally into red and white halves or cylinders (of similar size) with a large, white, diagonal stripe dividing the red cylinder. For economy or expediency, 1-gallon milk cartons, 5-gallon ice cream tubs, 1-gallon plastic bleach bottles, or foot-square plaques, painted in the diagonal or divided red and white colors of orienteering may be used.

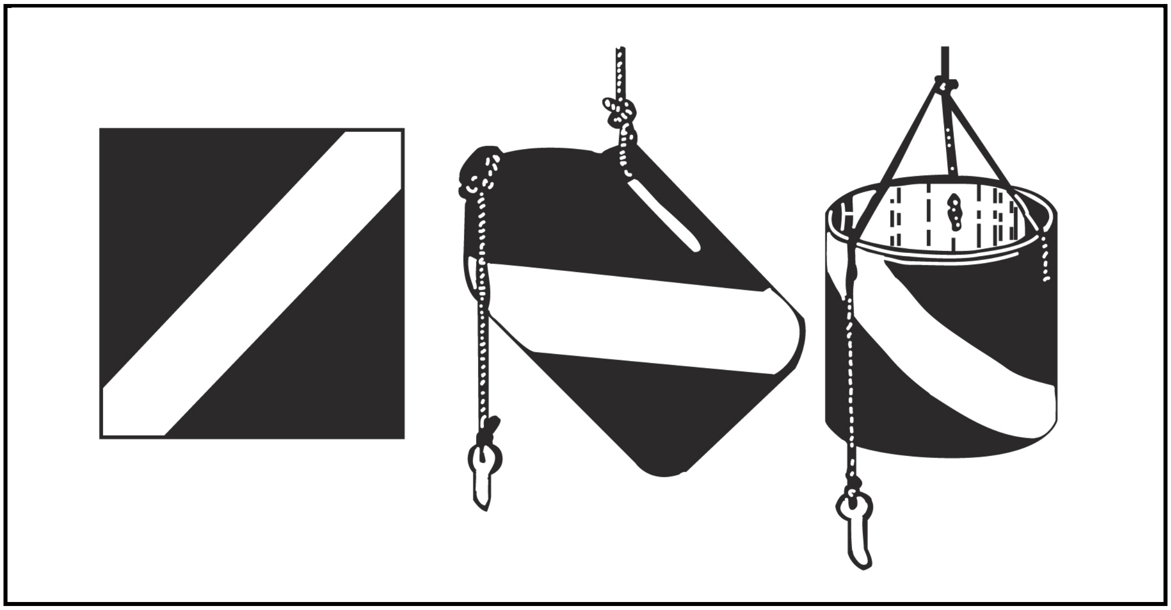


Figure J-4. Control markers

J-24. Each marker should have a marking or identification device for the orienteer to use to indicate the control has been visited. This marker may be the European-style punch pliers, a self-inking marker, different colored crayons at each point, different letter combinations, different number combinations, or different stamps or coupons. The marking device is unique, simple, and can readily transcribe to the event cards. The control marker should normally be visible from at least 10 m. It should not be hidden.

RECORDERS SHEETS

J-25. A suggested format for the recorder's sheet is depicted in Figure J-5.

RECORDER'S SHEET

NAME	NO.	TEAM-CLASS	START TIME	FINISH TIME	TIME TAKEN	CONTROLS MISSED	POSITION

SAMPLE

Figure J-5. Sample recorder's sheet

EVENT CARD

J-26. The event card can be made before the event and should be as small as possible, as it is carried by the competitor. It contains the following items: name, start number, start time, finish time, total time, place, and enough blocks for marking the control points. As indicated earlier, it may also contain a listing of descriptive clues. (See Figure J-6.)

RESULTS BOARD

J-27. This board displays the orienteer's position in the event at the finish. (See Figure J-7.) There are a variety of ways to display the results, from blackboard to ladder-like to a clothesline-type device where each orienteer's name, point score, and time are listed.

CROSS-COUNTRY ORIENTEERING TEAM

NAME ____________ COMPANY ____________ COURSE ____________ TEAM ____________

NAME ____________ COMPANY ____________ START TIME ____________ FINISH TIME ____________

CHECKPOINTS **DESCRIPTION CLUES**

1	2
3	4
5	4

SAMPLE

NOTE: All control signs are located at eye level on trees.

Total Value of Points ____________

Penalty Points ____________

Final Score ____________

1. All work is individual team effort.
2. You must not join with or coordinate with any other team.
3. You must personally visit each point you indicate on your scorecard.

Figure J-6. Sample cross-country orienteering event card

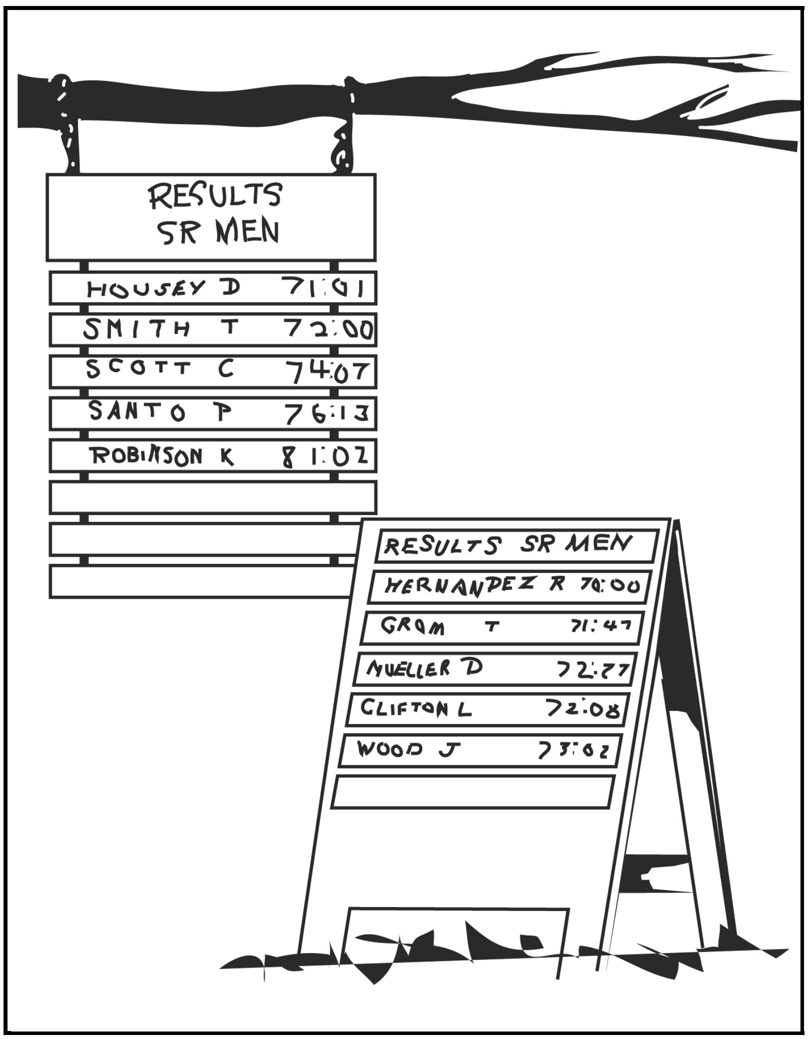


Figure J-7. Sample results board

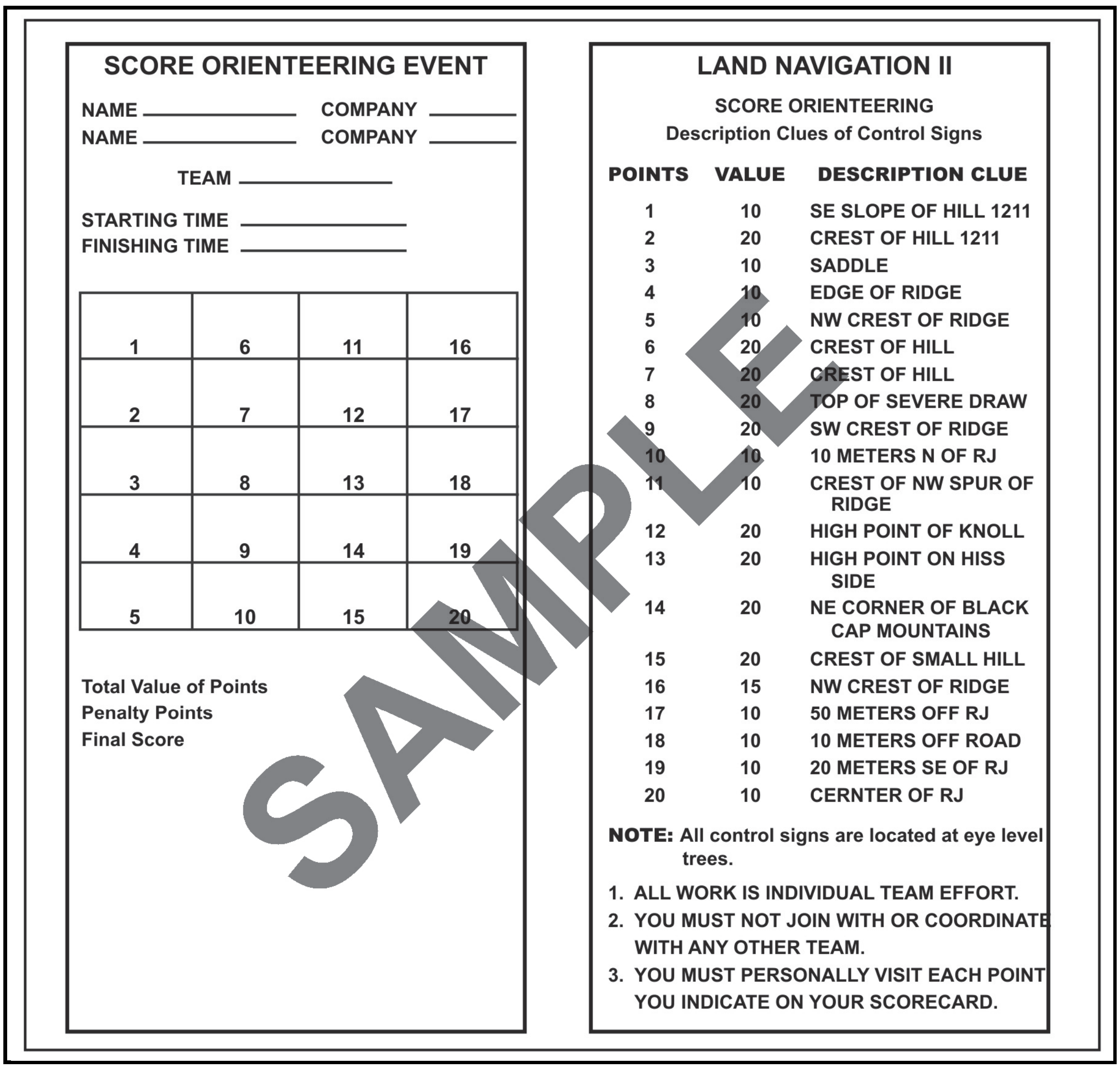
CLUE DESCRIPTION CARD

J-28. These cards are prepared with the master maps after the course is set. They contain the descriptive clues for each control point, control code, grid coordinate references, returning time for competitors, removal times for each location, and panic azimuth. (See Figure J-8.) The terminology on these needs to be identical to that listed in the definition section. These cards and the master maps are kept confidential until the orienteers start the event.

SCORING

J-29. The cross-country or free event is scored by the orienteer's time alone. All control points are visited and failure to visit one results in disqualification. In this event, the fastest time wins. A variation that can be introduced for novices is to have a not-later-than return time at the finish and add minutes to the orienteer's final time for minutes late and control points not located. The score event requires the amassing of as many points as possible within the time limit. Points are deducted for extra time spent on the course, usually one point for each 10 seconds extra.

J-30. A monetary prize is not awarded. A suggested prize for beginners is an orienteering compass or some other practical outdoor-sports item.



SCORE ORIENTEERING EVENT

NAME ____________ COMPANY ________
NAME ____________ COMPANY ________

TEAM ____________

STARTING TIME ____________
FINISHING TIME ____________

1	6	11	16
2	7	12	17
3	8	13	18
4	9	14	19
5	10	15	20

Total Value of Points
Penalty Points
Final Score

LAND NAVIGATION II

SCORE ORIENTEERING
Description Clues of Control Signs

POINTS	VALUE	DESCRIPTION CLUE
1	10	SE SLOPE OF HILL 1211
2	20	CREST OF HILL 1211
3	10	SADDLE
4	10	EDGE OF RIDGE
5	10	NW CREST OF RIDGE
6	20	CREST OF HILL
7	20	CREST OF HILL
8	20	TOP OF SEVERE DRAW
9	20	SW CREST OF RIDGE
10	10	10 METERS N OF RJ
11	10	CREST OF NW SPUR OF RIDGE
12	20	HIGH POINT OF KNOLL
13	20	HIGH POINT ON HISS SIDE
14	20	NE CORNER OF BLACK CAP MOUNTAINS
15	20	CREST OF SMALL HILL
16	15	NW CREST OF RIDGE
17	10	50 METERS OFF RJ
18	10	10 METERS OFF ROAD
19	10	20 METERS SE OF RJ
20	10	CERNTER OF RJ

NOTE: All control signs are located at eye level trees.

1. ALL WORK IS INDIVIDUAL TEAM EFFORT.
2. YOU MUST NOT JOIN WITH OR COORDINATE WITH ANY OTHER TEAM.
3. YOU MUST PERSONALLY VISIT EACH POINT YOU INDICATE ON YOUR SCORECARD.

SAMPLE

Figure J-8. Sample clue description card

SAFETY ON THE COURSE

J-31. A first-aid kit is available at the start and finish, and one of the officials should be trained in first-aid or have a medic at the event. Other safety measures include:

- **Control points.** Locate the controls where the safety of the competitor is not jeopardized by hazardous terrain or other circumstances.
- **Safety lane.** Have a location, usually linear, on the course where the competitor may go if injured, fatigued, or lost. A good course usually has its boundary as a safety lane. Then a competitor can set a panic azimuth on the compass and follow it until reaching the boundary.
- **Finish time.** All orienteering events have a final return time. At this time, all competitors report to the finish line even if they have not completed the course.
- **Search-and-rescue procedures.** If all competitors have not returned by the end of the competition, the officials should drive along the boundaries of the course to pick up the missing orienteers.

CONTROL POINT GUIDELINES

J-32. When the control point is marked on the map as well as on the ground, the description of that point is prefaced by the definite article *the*; for example, *the pond*. When the control point is marked on the ground but is not shown on the map, then the description of the point is prefaced by the indefinite article *a*; for example, *a trail junction*. In this case, care is taken to ensure that no similar control exists within at least 25 m. If it does, then the control is not used, or it is specified by a directional note in parentheses; for example, a depression (northern). Other guidelines include:

- Points of the compass are denoted by capital letters; for example, S, E, SE.
- Control points within 100 m of each other or different courses are not to be on the same feature, or on features of the same description or similar character.
- For large (up to 75 m across) features or features that are not possible to see across, the position of the control marker on the control point should be given in the instructions. For example, the east side of the pond; the north side of the building.
- If a very large (100 to 200 m) feature is used, the control marker should be visible from most directions from at least 25 m.
- If a control point is near but not on a conspicuous feature, this fact and the location of the marker should be clearly given; for example, 10 m E of the junction. Avoid this kind of control point.
- Use trees in control descriptions only if they are prominent and a totally different species from those surrounding it. Never use bushes and trees as control points.
- Number control points in red on the master map.
- For cross-country events, join all control points by a red line indicating the course’s shape.

MAP SYMBOLS

J-33. The map symbols in Figure J-9 are typical topographic and cultural symbols that can be selected for orienteering control points.

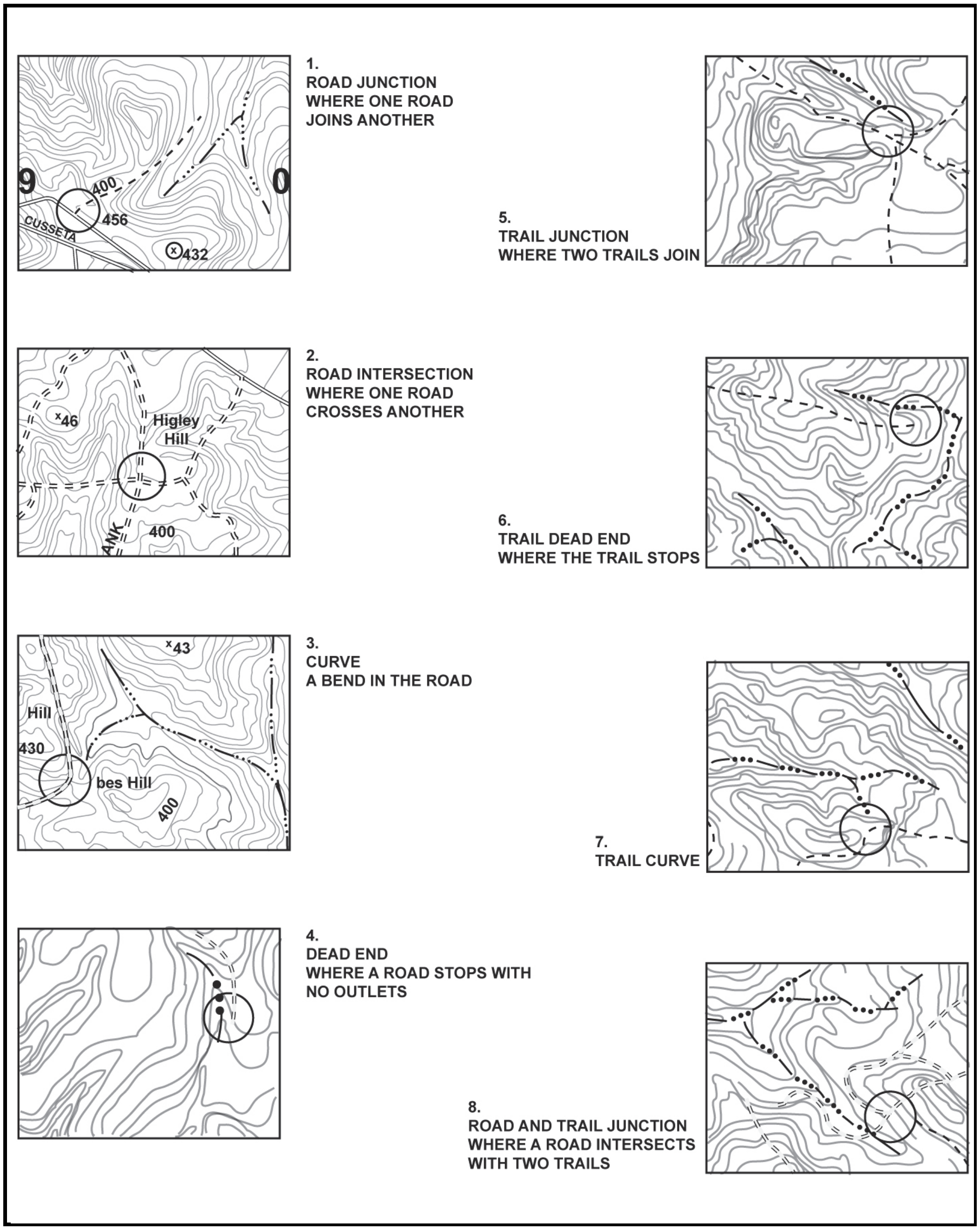


Figure J-9. Map symbols

ORIENTEERING TECHNIQUES

J-34. The orienteer should try not to use the compass to orient the map. The terrain association technique is recommended instead. The orienteer should learn the following techniques:

- **Pacing.** One of the basic skills that the orienteer should develop early is how to keep track of distance traveled while walking and running. This is done on a 100-m pace course.
- **Thumbing.** This technique is very simple, but the map has to be folded small to use it. The orienteer finds the current location on the map and places a thumb directly next to it. The orienteer moves from point to point on the ground without moving their thumb from the initial location. To find the new location, look at the map and use the thumb as a point of reference for the last location. This technique prevents the orienteer from looking all over the map for their location.
- **Handrails.** This technique enables the orienteer to move rapidly on the ground by using existing linear features such as trails, fences, roads, and streams that are plotted along the route. They can also be used as limits or boundaries between control points. (See Figure J-10.)
- **Attack points.** These are permanent known landmarks that are easily identified on the ground. They can be used as points of reference to find control points located in the woods. Some examples of attack points are stream junctions, bridges, and road intersections.

Figure J-10. Handrails

Civilian Orienteering

J-35. Civilian orienteering is conducted under the guidelines of the United States Orienteering Federation with more than 70 clubs currently affiliated with the organization. Although civilian orienteering is a form of land navigation, the terms, symbols, and techniques are different from the military.

J-36. An expert military map reader/land navigator is by no means ready to compete in a civilian orienteering event. However, military experience in navigating on the ground and reading maps helps individuals to become good orienteers. Several orienteering practices and complete familiarization with the map symbols and terms before participating in a real orienteering event is recommended.

Map

J-37. The standard orienteering map is a very detailed, 1:15,000-scale, colored topographical map. All orienteering maps contain only north-south lines that are magnetically drawn; this eliminates declination conversions. Because of the absence of horizontal lines, grid coordinates cannot be plotted and therefore are not needed.

J-38. Despite standard orienteering symbols, the legend in orienteering maps has a tendency to change from map to map. A simple way to overcome this problem is to become familiar with the legend every time a different map is used.

J-39. The scale of orienteering maps is 1:15,000. This requires an immediate adjustment for the military land navigator, especially while moving from point to point. It takes a while for a person that commonly uses a 1:50, 000-scale to get used to the orienteering map.

J-40. The normal contour interval in an orienteering map is 5 m. This interval, combined with the scale, makes the orienteering maps so meticulously detailed that a 1-m boulder, a 3-m shallow ditch, or a 1-m depression shows on the map. This may initially shock a new orienteer.

J-41. The names of landforms are different from those commonly known to the military. For example, a valley or a draw is known as a reentrant; an intermittent stream is known as a dry ditch. These terms, with a description of clues indicating the position and location of the control points, are used instead of grid coordinates.

J-42. The characteristics of the map, the absence of grid coordinates, the description of clues, and the methods used in finding the control points are what make civilian orienteering different from military land navigation.

Appendix K
Additional Aids

This appendix provides information on the operation and function of already fielded, and soon to be fielded, devices that can be used as aids to navigation.

NIGHT VISION DEVICES

K-1. Night vision devices (NVDs) are self-contained passive devices in a monocular or binocular form that enable improved night vision using ambient light from the night sky (such as the moon, stars, and sky glow). Current NVDs can provide an infrared light source and positive focus control to permit close-in viewing under limited illumination.

K-2. These devices are designed to assist the following tasks:

- Mission command.
- Fire control
- Terrain navigation.
- Operation and maintenance of vehicles.
- Traffic control.
- Patrolling.
- Radar team employment.
- Flight-line functions.
- Reconnaissance.
- Close-in surveillance.
- First-aid.
- Selection of positions.
- Rear and critical area security.
- Combat engineer tasks.
- Resupply activities.

K-3. NVDs can assist the land navigator under limited visibility conditions. Infrared markers, luminescent tape, and chemical lights may be placed at selected intervals along the unit's route of movement to be observed through the NVD. Another navigation technique is having one person read the map while another person reads the terrain, both using NVDs. This allows the map reader and the terrain interpreter to exchange information on what terrain is observed on the map and on the ground. It allows each user to concentrate the NVD on one task. Land navigation, especially mounted, is a task better performed by more than one person. The above technique allows one Soldier to perform map interpretation in the cargo portion of the vehicle while another Soldier, possibly the driver, transmits information pertaining to the terrain observed on the ground.

ENHANCED POSITION LOCATION REPORTING SYSTEM USER UNIT

K-4. The Enhanced Position Location Reporting System (EPLRS)/Joint Tactical Information Distribution System (JTIDS) are computer-based systems that provide near real-time, secure data communications, identification, navigation, position location, and automatic reporting. This supports the information needed by commanders for the location, identification, and movement of friendly forces.

K-5. The EPLRS is based upon synchronized radio transmissions in a network of users controlled by a master station. The major elements of an EPLRS community include the airborne, surface vehicular, and man-pack users; the EPLRS master station; and an alternate master station. The system can handle 370 user units in a division-size deployment per master station with a typical location accuracy of 15 m. The man-pack unit weighs 23 pounds and includes the basic user unit, user readout, antenna, backpack, and two batteries.

K-6. The EPLRS is deployed at the battalion and company level. Its use allows—

- Infantry or tank platoons to locate their positions, know the location of their friendly units, navigate to predetermined locations, and be informed when near or crossing boundaries.
- Artillery batteries to locate forward observers and friendly units, and position firing batteries.
- Aircraft to locate their exact positions; know the location of other friendly units; navigate to friendly units, or a location entered by the pilot; navigate in selected flight corridors; and be alerted when entering or leaving corridors or boundaries.
- Mission command elements at all echelons to locate and control friendly units/aircraft.

K-7. The network control station is located at the brigade level to provide position location/navigation and identification services. It also provides interface between the battalion and company systems, and the JTIDS terminals.

K-8. The EPLRS is fielded to Infantry, Armor, field artillery, military police, engineer, intelligence, aviation, signal, and air defense artillery units. It is a system that allows units to navigate from one point to another with the capability of locating itself and other friendly units equipped with the same system.

Position and Azimuth Determining System

K-9. The Position and Azimuth Determining System (PADS) is a highly mobile, self-contained, passive, all-weather, survey-accurate position/navigation instrument used by field artillery and air defense artillery units for fire support missions. Its basis of issue is two sets per artillery battalion. The device is about the size of a 3-kilowatt generator and weighs 322.8 pounds in operational configuration.

K-10. The two-man PADS survey party uses the high mobility multipurpose wheeled vehicle, commercial utility cargo vehicle, small-unit support vehicle, or the M151 1/4-ton utility truck. The system can be transferred while operating into the light observation helicopter (OH-58A) or driven into the CH-47 medium cargo helicopter.

K-11. The system provides real-time, three-dimensional coordinates in meters, and a grid azimuth in mils. It also gives direction and altitude. The PADS can be used by the land navigator to assist in giving accurate azimuth and distance between locations. A unit requiring accurate information for its present location can also use PADS. If used properly, it can assist many units in the performance of their mission.

Ground Vehicular Laser Locator Designator

K-12. The ground/vehicle laser locator designator (G/VLLD) is the Army's long-range designator for precision-guided semi-active laser weapons. It is two-man portable for short distances and can be mounted on the M113A1 interim fire support team vehicle when it has the vehicle adapter assembly. The G/VLLD provides accurate observer-to-target distance, vertical angle, and azimuth data to the operator. All three items of information are visible in the operator's eyepiece display.

K-13. The G/VLLD is equipped with an AN/TAS-4 night sight. This night sight increases the operator's ability to detect and engage targets during reduced visibility caused by darkness or battlefield obscuration. The G/VLLD can give the navigator accurate line-of-sight distance to an object. The system can be used to determine its present location using resection, and can assist the navigator in determining azimuth and distance to his objective.

WARNING

Laser devices are potentially dangerous. Their rays can burn someone's eyes if they look directly at them. Users should not direct the beams at friendly positions or where they could reflect off shiny surfaces into friendly positions.

Other Soldiers must know where lasers are being used, and take care not to look directly at the laser beam.

Glossary

Acronym/Term	Definition
2D	two-dimensional
3D	three-dimensional
A	
AAR	after-action report
app	application
AR	Army regulation
ARNG	U.S. Army National Guard
ARNGUS	Army National Guard of the United States
B	
BM	bench mark
C	
cm	centimeter
CM	central meridian
CONUS	continental United States
CRM	composite risk management
CV	crypto variable
D	
DA	Department of the Army
DAGR	defense advanced GPS receiver
DD	Department of Defense (form)
DOTD	Directorate of Training and Doctrine
DTED	digital terrain elevation data
E	
E	east
EHE	estimated horizontal error
EPLRS	Enhanced Position Location Reporting System
G	
G-2	Assistant Chief of Staff, Intelligence
G-6	Assistant Chief of Staff, Command, Control, Communications, and Computer Operations
GD	ground distance
GEOREF	World Geographic Reference System
G-M	grid-magnetic

Acronym/Term	Definition
GPS	Global Positioning System
GTA	graphic training aid
G/VLLD	ground/vehicular laser locator designator
H	
HD	horizontal distance
J	
JOG	joint operations graphic
JTIDS	Joint Tactical Information Distribution System
K	
km	kilometer
kph	kilometer per hour
L	
L1	satellite Link One
L2	satellite Link Two
LAT	latitude
M	
m	meter
m/	mil (graphic)
MAGVAR	magnetic variance
MCoE	Maneuver Center of Excellence
MD	map distance
METT-TC	mission, enemy, terrain and weather, troops and support available, time available, civil considerations
MGRS	military grid reference system
mph	miles per hour
N	
N	north
NCO	noncommissioned officer
NGA	National Geospatial-Intelligence Agency
NOAA	National Oceanic and Atmospheric Administration
NVD	night vision device
O	
OBJ	object (graphic)
OIC	officer in charge
OP	observation post

Acronym/Term	Definition
	P
PADS	Position and Azimuth Determining System
PLGR	precision lightweight GPS receiver
PME	professional military education
POI	program of instruction
POS	position
PVT	position, velocity, and timing
	R
RF	representative fraction
	S
S	south
SOP	standard operating procedure
SV	satellite vehicle
	T
TRADOC	United States Army Training and Doctrine Command
	U
UPS	universal polar stereographic
U.S.	United States
USAR	United States Army Reserve
UTM	universal transverse Mercator
	V
VD	vertical distance
VMap	vector map
	W
W	west

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DA Pam 385-63, *Range Safety*, 30 January 2012.
GTA 5-2-12, *Coordinate Scale and Protractor*, June 2008.
GTA 21-08-001, *Composite Risk Management Quick Reference Booklet,* 10 July 2007.

DOCUMENTS NEEDED

These documents must be available to the intended user of this publication.

AR 115-11, *Geospatial Information and Services,* 10 December 2001.
AR 380-5, *Department of the Army Information Security Program,* 29 September 2000.
AR 380-40, *Safeguarding and Controlling Communications Security Material,* 9 July 2012.
AR 385-10, *The Army Safety Program,* 23 August 2007.

FORMS

DA Form 2028, *Recommended Changes to Publications and Blank Forms*.
DD Form 1348, *DOD Single Line Item Requisition System Document (Manual)*.
DD Form 1348M, *DOD Single Line Item Requisition System Document (Mechanical)*.

READINGS RECOMMENDED

No additional readings are recommended.

WEBSITES

Most Army doctrinal publications and regulations are available online at: http://www.apd.army.mil and http://www.atn.army.mil.

The Defense Logistics Agency - Mapping Customer Operations: http://www.aviation.dla.mil/rmf/
Mapping Agency Technical Manual 8358.1, 20 September 1990: http://earth-info.nga.mil/GandG/publications/tm8358.1/toc.html
National Geospatial-Intelligence Agency: https://www1.nga.mil/Pages/default.aspx
NOAA magnetic field calculator: http://www.ngdc.noaa.gov/geomag-web/?id=declinationFormId#declination

Other electronic technical manuals and official sources are available online at:
Logistical Support Activity – LOGSA: https://www.logsa.army.mil/etms/online.cfm
Orienteering USA: http://orienteeringusa.org/.
The Military Engineer: http://themilitaryengineer.com/.

Most joint publications are available online at: http://www.dtic.mil/doctrine/doctrine/doctrine.htm.

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By order of the Secretary of the Army:

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Chief of Staff

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