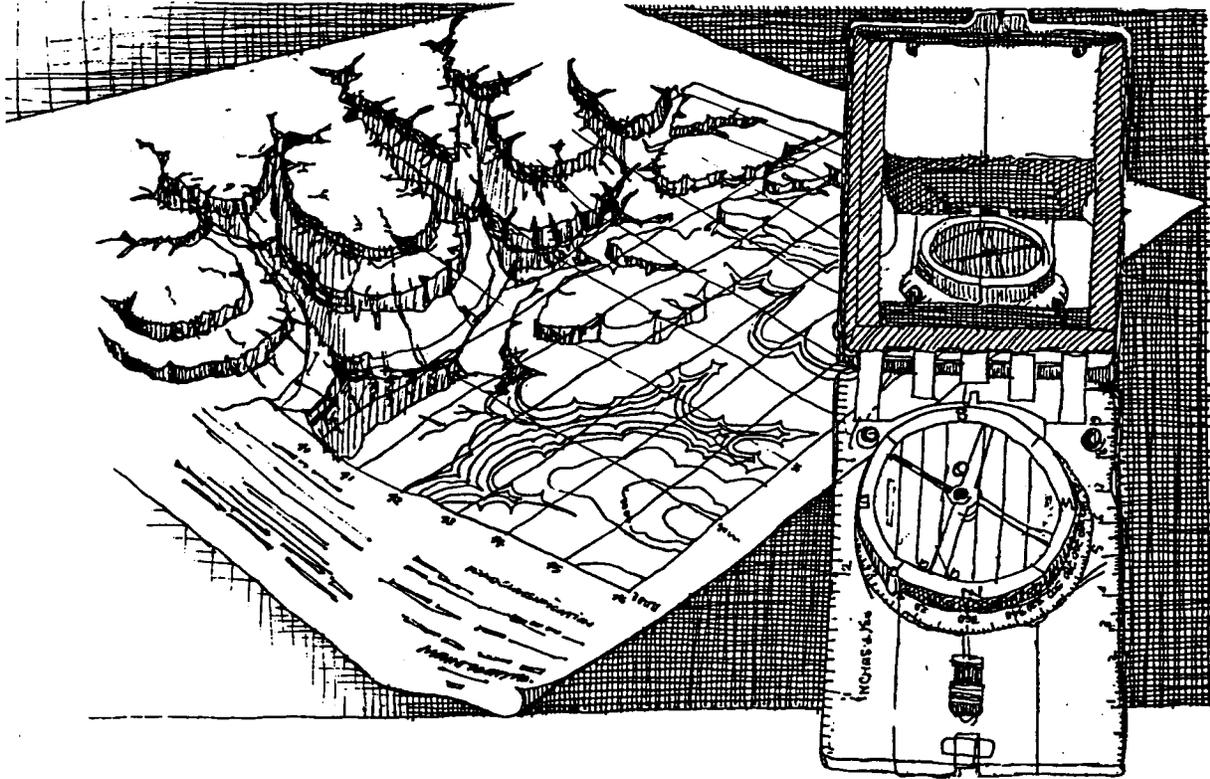


MAP and COMPASS



for
firefighters



NFES 2554

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INTRODUCTION

Maps have long been an integral element in incident support. From urban incidents to wildland operations, maps have provided information necessary to perform required tasks. The importance of maps takes on an even greater significance when considering the growing population and the rapid changes to our environment. In order to plan for and respond to various incidents, an understanding of maps becomes essential for making intelligent decisions.

This self-study course was prepared specifically to introduce you to the basics of map interpretation, compass use, and familiarize you with the United States Geological Survey (USGS) topographic maps, and planimetric maps. Take the time to go through this course at your own pace. It should take between three and eight hours to complete the text, depending on your previous experience and knowledge.

Completely understand each unit before you proceed to the next. The course gives you an opportunity to check your comprehension as you progress through the text. Questions and answers are provided at the end of each unit.

After completing this course, you will have the knowledge to read maps and use the compass effectively. Learning experiences from the course text are limited. It is recommended you practice in the field to enhance the fundamentals you have learned.

MATERIALS NEEDED FOR THE COURSE:

12" or 18" clear plastic rule (1/10 inch graduations)
Clinometer (graduated in degrees and percent)
Silva Ranger compass (360 degree rose), or equivalent
Protractor (360-degree preferred)
Calculator
Dot grids or acreage overlay transparencies (optional)

UNIT 1

PURPOSE OF MAPS

1. PURPOSE OF MAPS

A map is designed for the purpose of permitting you to visualize a portion of the earth's surface with pertinent features properly positioned to facilitate planning and organizing operations. Different types of maps are used for different purposes. One map with all the details of several types of maps would be so cluttered that it would make reading and interpretation difficult.

1.1 Map Definition

A map is a line drawing, to some scale, of an area of the earth's surface. It shows objects and features by conventional signs. A map is a graphic representation of a portion of the earth's surface, drawn to scale on a plane.

1.2 Map accuracy

The accuracy of a map is important. A point or symbol marked on a map must be in proper relation to known landmarks or positions located on the ground in order for the map to be considered reliable. As a result, the "United States National Map Accuracy Standards" were established as the standards of accuracy for published maps. These were issued in 1947 to all Federal agencies producing maps and are currently in effect. The standards require a stringent percent of accuracy within centimeters of both location and elevation points tested.

Cartographers and editors check all maps thoroughly and attempt to keep factual errors to the required standard. However, map accuracy is imperfect for two main reasons:

1. Representational inaccuracy

Maps, although drawn to a scale, are not absolutely accurate because they represent a curved and uneven surface on a flat piece of paper. If you drew a picture on the surface of a sphere, such as an orange, and then peeled the orange and flattened the peel, the picture now would be distorted. Compensating for the roundness of the world on a flat surface is a difficulty encountered by early map makers.

Factual matters are also subject to errors, such as, names, symbols of features, and the classifications of roads or woodlands. Map makers have to rely on local sources for their information. Sometimes the information is wrong. Sometimes names change or new names and features are added in an area.

2. Measurement error

Most of the original surveys undertaken during the first U.S. Public Land Survey were performed under very difficult conditions. The majority of these surveys were well done, but there was a margin of inaccuracy because of human error and inadequate survey procedures and equipment used by the initial surveyors.

UNIT 1
QUESTIONS

1. What is the purpose of a map?

2. List two reasons why maps may be inaccurate in their representation.

A.

B.

3. Why did some measurement error occur in the original surveys?

UNIT 2

CLASSIFICATION OF MAPS

2. CLASSIFICATION

The maps discussed in this text are maps used to depict the features of an area. These maps fall into **three categories**:

2.1 Categories

1. Planimetric Maps

Show the positions of features without showing their relationship to the hills and valleys of the land. They can include rivers, lakes, roads, boundaries, or other human-made, symbolic features. For example:

- a. Common road maps
Road atlas, street maps, and Thomas Guides.
- b. Specific area maps
Preplan maps, floor plan maps, storm drain, sewer and water system maps.
- c. Schematic maps
Agency maps: unit, aviation, resource, district response maps.

2. Topographic Maps

Shows both the horizontal and vertical (relief) positions of features. Topographic maps are often referred to as quadrangles or quads. For example:

- a. Contour maps - are the most common method of representing the shape and elevation of the land. A contour is a line of equal elevation on the ground that delineates the same elevation above or below a specific reference elevation, usually sea level.
- b. Shaded-relief maps - are pictorial. They are shaded to simulate sunlight on the terrain. This shadow effect accentuates the shape of the physical features.

3. Orthophoto Maps

An orthophoto map is a map depicting terrain and other features by color-enhanced photographic images. It is an aerial photograph of the land. Some orthophoto maps are overlain with contour lines and other features commonly associated with

topographic maps. These maps are corrected for scale and are the same size as U.S.G.S. quads.

2.2 The United States Geological Survey

The United States Geological Survey of the Department of the Interior is engaged in topographic and geologic mapping and in collection of information about the public lands. Many of the contour maps we use have been produced by the U.S.G.S.

For incidents on U.S. Forest Service land, consider using topographic maps made by the Forest Service. They are generally more current than U.S.G.S. maps.

UNIT 2
QUESTIONS

1. List the three categories of maps.

2. List three examples of planimetric maps.

3. List the two types of topographic maps.

UNIT 3 MAP LEGEND

3. MAP LEGEND

A legend shows information needed to interpret a map. Each type of map has information represented in a different way relating to its subject matter. The legend can explain map scales, symbols and color.

3.1 Map Scale

The map scale indicates the ratio or proportion of the horizontal distance on the map to the corresponding horizontal distance on the ground.

A representative fraction (R.F.) scale expresses the ratio of the map distance to the ground distance in like units of measurements. It is usually written as a fraction or ratio.

A *representative fraction* is always written with the map distance as 1 (one). A representative fraction of 1/24,000 (1:24,000) means that one UNIT of measurement (inches, millimeters, feet, etc.) on the map is equal to 24,000 of the SAME UNITS on the ground. You CANNOT mix units in a representative fraction. If it is one INCH on the map, it is 24,000 INCHES on the ground.

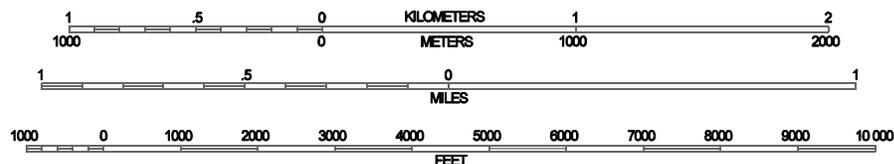
EXAMPLE: R.F. is $\frac{\text{map distance}}{\text{ground distance}} = \frac{1"}{24,000"}$ OR 1:24,000

The larger the representative fraction (the fraction 1 divided by 24,000 is obviously larger than 1 divided by 250,000), the larger and clearer the details shown on it. But on the other hand, the larger the fraction, the smaller the area covered by the same size map sheet.

A *graphic scale* (G.S.) or comparison scale is entirely different. It usually COMPARES map distances to the ground distance in DIFFERENT units of measurements. Usually a graphic scale is a line marked off on a map indicating so many inches or millimeters equal so many feet, kilometers, chains, or miles on the ground. A comparison scale of 1" to 2000 feet means that 1 (one) inch on the map is proportioned to 2000 feet on the ground. We are comparing inches and feet which are DIFFERENT UNITS of measurement.

EXAMPLE: G.S. is map distance to ground distance.

1" to 2000 feet



If the map scale is not given, you can determine it as follows:

1. Locate two points on the map that you can also see on the ground.
2. Measure the distance between the points on the map.
3. Measure the distance between the points on the ground.
4. Divide the ground distance by the map distance, *in the same units*, and record the answer as “1 : (answer)”; This is the map scale.

Example:

Map distance = 2 inches; Ground distance = 4,000 feet (48,000 inches)

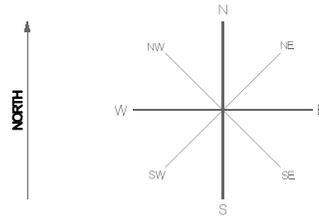
$$48,000 \div 2 = 24,000.$$

Record as 1 : 24,000.

The map scale is 1 : 24,000.

3.2 Cardinal Directions

It is common practice for maps to be oriented with north at the top. Most maps have a symbol of an arrow pointing to the north. It is then understood east is right, west is left and south is bottom of the map.



3.3 Map Legend

Most maps have a legend to help interpret the map. Legends describe map symbols, such as what color line delineates a road or land ownership boundary, or what figure represents a building, stream, spring, or heliport.

Primary Highways	
Secondary Highways	
Light Duty Improved Roads	
Street or Other Roads	
Trails	
Interstate Routes	
U.S. Routes	
State Routes	
U.S.F.S. Roads	
U.S.F.S. Trails	
Dams	
Landing Fields	
Airports	
Powerlines	
Railroads	
Gravel Pits	
Mine Sites	
Spot Elevations (meters)	
Wilderness Boundary	
U.S.F.S. Boundary	
County Boundary	
State Boundary	
Hunting Unit Boundary	
Contour Lines	

Map symbols are not the same for every map. They change from map type to map type. However, you can find some symbols the same on various maps.

3.4 Revision Date

Some maps have a revision date, which is when the map was last updated to reflect changes. If the map is very old, it may not be very accurate.

3.5 Represented Colors

In order to make the identification of features on a map easier to interpret and to provide more natural appearance and contrast, map symbols are usually printed in colors with each color representing a class of features. The colors are as follows:

1. BLACK - Most cultural or human-made features, boundaries.
2. BLUE - Water features such as lakes, rivers, or swamps.
3. GREEN - Vegetation such as woods, orchards, or vineyards.
4. BROWN - All relief features, contours, cuts and fills (Topographic maps).
5. RED - Main roads, built-up areas, boundaries, special features.
6. Other colors may be used for special purposes. Their key will be found in the margin/legend of the map.

3.6 Adjoining Maps

Some areas are too large to be shown on a single map. Adjoining maps are frequently indicated in the margins of USGS topographical maps, or by an adjoining quadrangle legend on the map.

1	2	3	1. NORTHEAST EMMETT 2. MONTOUR 3. HORSESHOE BEND 4. SOUTHEAST EMMETT 5. CARTWRIGHT CANYON 6. STAR 7. EAGLE 8. BOISE NORTH
4	PEARL	5	
6	7	8	

ADJOINING 7.5' QUADRANGLE NAMES

A Topographical Map Index circular contains a map of the state divided into quadrangles. If you are working on a large incident, you can use the Index circular to help you identify and order topographical maps that you might need.

3.7 ICS Display Symbols

The Incident Command System uses a standardized, color-coded symbol set. ICS map symbols are not commonly used by the public. The interpretation and drafting of maps with the ICS map symbology will be required for those trainees working on most emergency incidents and prescribed fires.

SUGGESTED FOR PLACEMENT ON BASE MAP		SUGGESTED FOR PLACEMENT ON OVERLAYS	
MINIMUM RECOMMENDED			
BLACK		HIGHLIGHTED GEOGRAPHIC OR MANMADE FEATURES	
BLACK		COMPLETED DOZER LINE	
BLACK		COMPLETED LINE*	
BLACK		LINE BREAK COMPLETED	
RED		FIRE ORIGIN HAZARD (IDENTIFY TYPE OF HAZARD, E.G., POWER LINES)*	
BLUE		INCIDENT COMMAND POST*	
BLUE		INCIDENT BASE*	
BLUE		CAMP (IDENTIFY BY NAME)*	
BLUE		HELISPOT (LOCATION AND NUMBER)*	
BLUE		HELIBASE*	
BLUE		REPEATER/MOBILE RELAY*	
OPTIONAL		TELEPHONE	
OPTIONAL		FIRE STATION	
OPTIONAL		WATER SOURCE (IDENTIFY I.E., POND, CISTERN, HYDRANT)	
BLUE		MOBILE WEATHER UNIT	
BLUE		IR DOWN LINK	
BLUE		FIRST AID STATION*	
RED		UNCONTROLLED FIRE EDGE*	
RED		SPOT FIRE*	
RED		HOT SPOT*	
ORANGE		FIRE SPREAD PREDICTION*	
BLACK		PLANNED FIRE LINE*	
BLACK		PLANNED SECONDARY LINE*	
BLACK		INITIALLY NUMBERED CLOCKWISE FROM FIRE ORIGIN*	
BLACK		INITIALLY LETTERED CLOCKWISE FROM FIRE ORIGIN*	
BLACK		COMBINE DIVISION LETTER WITH CLOCKWISE NUMBERING WITHIN THE DIVISION*	
BLACK		WIND SPEED DIRECTION*	
BLACK		PROPOSED DOZER LINE*	
BLACK		FIRE BREAK (PLANNING OR INCOMPLETE)*	
BLUE		STAGING AREA (IDENTIFY BY NAME)*	
ALL OVERLAYS MUST CONTAIN REGISTRATION MARKS. THESE MAY CONSIST OF IDENTIFIED ROAD INTERSECTIONS, TOWNSHIP RANGE COORDINATES, MAP CORNERS, ETC.			

* = To be used on incident briefing and action plan maps (no color)

ICS SYMBOLS EXERCISE

IDENTIFY THE ICS SYMBOLS BELOW

1.  _____

2.  _____

3.  _____

4.  _____

5.  _____

6. **(A)** _____

7. **[IV]** _____

8.  _____

9.  _____

UNIT 3
QUESTIONS

1. In general, what does a legend show ?

2. Referring to a map scale, describe a representative fraction and give an example:

3. What is a graphic scale on a map ? Give an example:

4. What are the five most common colors found on a U.S.G.S topographic map and what features do those colors represent ?

A. _____
B. _____
C. _____
D. _____
E. _____

5. If you had three different types of maps, could you use the same symbol key for all of them ? Why or why not ?

6. What cardinal direction is usually indicated at the top of map? _____

Bottom of a map? _____

Right of map? _____

Left of map? _____

UNIT 4 GRID LOCATION SYSTEM

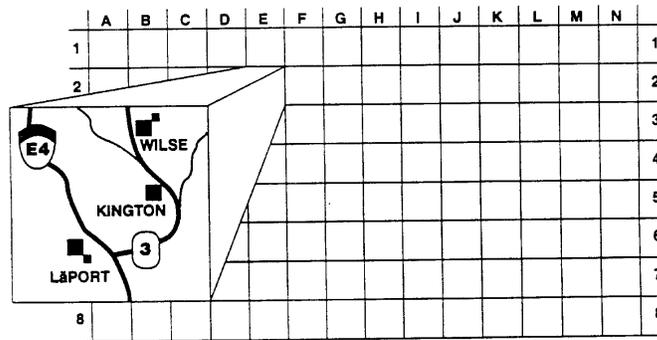
4. GRID SYSTEM

A grid is a network of evenly spaced horizontal and vertical bars or lines intended for defining areas. When placed over a map, a system is created which helps you find a specific location. Some planimetric maps use this system to locate streets or other features.

Grids are usually identified alpha-numerically. However some maps may use only letters or only numbers. These identifiers are placed horizontally and vertically along the edge of the grid, when matched together they identify all the blocks created in the grid.

An index listing names, subjects, etc., together with page numbers and/or alpha-numerical identifiers is usually available with the map grid. It is either at the bottom of the map or at the back of the map book. Given the name of what you want to locate, the index will direct you to the location on the map.

TYPICAL GRID



Example: Kington is located in 2E or E2. Many road maps are gridded like this.

4.1 Road Atlas

A road atlas is one of the most commonly used general purpose maps. "The Thomas Brothers Maps" road atlas is a popular street atlas. An atlas contains much information such as: key map and general charts, cities and communities index, highway and detail street maps, driving tours and index listings of streets, highway, interstates and points of interest. In order to use your road atlas to its potential you must be completely familiar with its contents and how to use it. Read through your atlas and learn all of its components.

The "Key Map" located at the front of the road atlas is the primary guide, and gives an overall picture of the area. It is an artery map of the entire area, designating the most direct route from one community or state to another. The Key Map also shows the designated page number of each map in the atlas. The individual map pages are then defined with the grid locating system, providing an easy-to-use order.

UNIT 4
QUESTIONS

1. What is a Grid Locating System?

2. How are blocks within a grid identified?

3. What is the purpose of a map index?

4. Explain the "Key Map" located at the front of a road atlas.

UNIT 5
RECTANGULAR LAND DESCRIPTION SYSTEM

5.1 RECTANGULAR LAND DESCRIPTION SYSTEM

The United States System of Surveying the Public Lands, frequently referred to as the rectangular system, was planned in 1784 by the Continental Congress and has survived until today with only minor modifications.

The law requires: "Public lands shall be divided by North and South lines and by other lines running East and West so as to form Townships 6 miles square (not 6 square miles, but a square of 6 miles on each side, with an area of 36 square miles). Also the Townships will be divided into 36 sections, and each will contain 640 acres (AS NEARLY AS POSSIBLE)" .

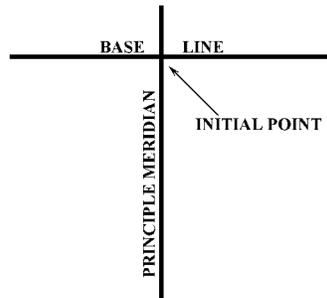
Similar systems are in use in much of Canada, parts of Australia, and a few other areas of the world.

5.1A Initial Or Reference Point

Rectangular land division is based on an Initial Point (also called Reference Point). There are 31 of these Initial Points in the conterminous U.S.

All standard lines representing land divisions are based on two Reference Lines:

1. The imaginary line on the ground running east-west through the initial point is called the "Base Line" .
2. The imaginary line on the ground running north-south through the initial point is called the "Principal Meridian" .

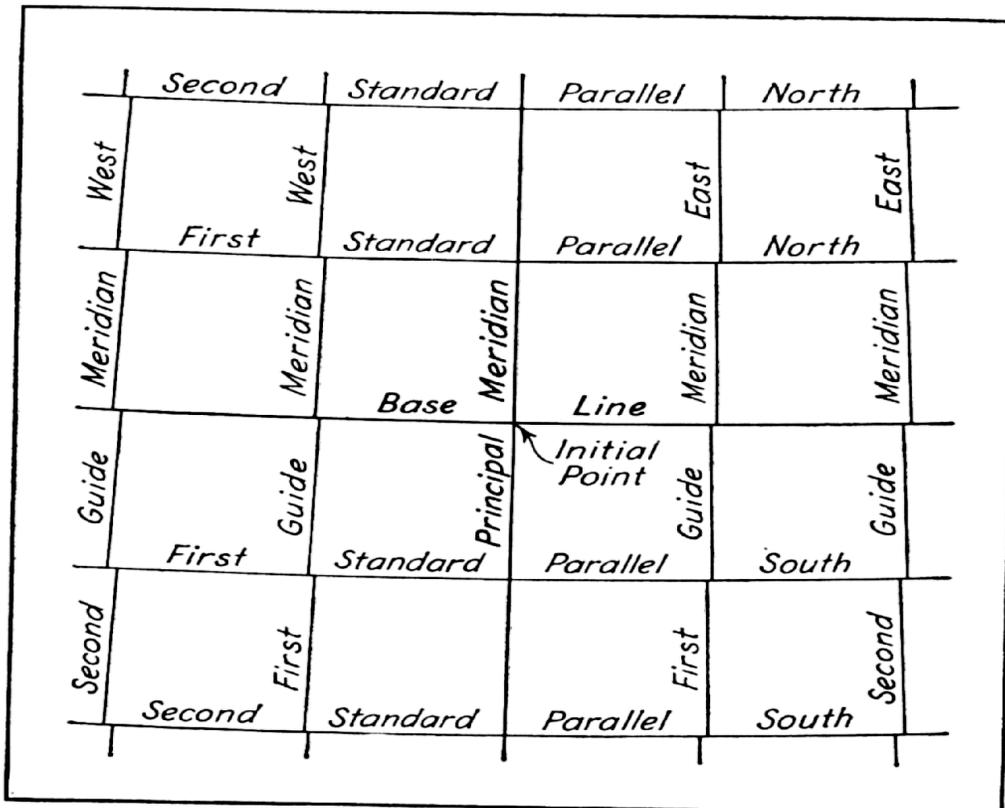


5.1B Correction Lines

Because of the curvature of the earth, additional lines called "Guide Meridians" and "Standard Parallels" are established from each Initial Point:

1. Standard Parallels are established in the same manner as the base line and are located at intervals of 24 miles north and south of the base line. The Parallels north of the Base Line are designated First Standard Parallel North, Second Standard Parallel North, etc., and those south as First Standard Parallel South, etc.
2. Guide Meridians are established in a similar manner as the Principal Meridian. The Meridians east of the Principal Meridian are designated First Guide Meridian East, Second Guide Meridian East, etc., and those west as First Guide Meridian West, etc. Guide Meridians converge because of the curvature of the earth, so the distance between these lines will be 24 miles only at the starting point.

STANDARD PARALLELS AND GUIDE MERIDIANS



Subdivision into 24-mile tracts.

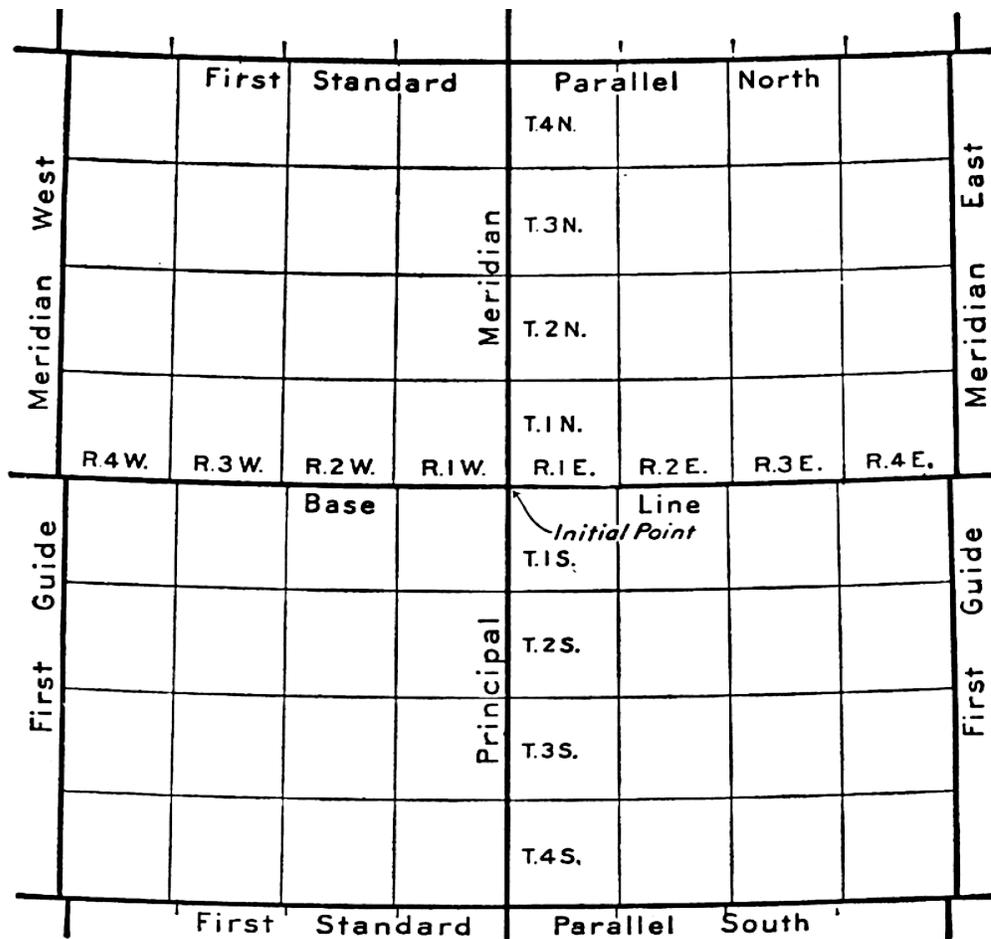
5.1C Townships And Ranges

Township Lines are the series of lines, 6 miles apart, which run east and west parallel to the Base Line. The area between the Base Line and the first Township Line on the south side is called Township 1 South. The area between the first and second Township lines on the south is Township 2 South, and so on. The numbering on the north side of the Base Line is the same.

Range Lines are the series of lines, 6 miles apart, which run north and south parallel to the Principal Meridian. The areas between these lines are numbered much the same as the Township areas. The area between the Principal Meridian and the First line on the east side is Range 1 East. The area between the first and second lines on the east side is Range 2 East. The numbering on the west side of the Principal Meridian is the same.

Proper descriptions of locations have the Township written first followed by the Range and Reference Point (T1N, R3E, SBBM).

Township and Range descriptions are located in the margins and within the map.



5.1D Sections

Townships are subdivided into 36 parts, each one mile square (as near as may be), called Sections. The typical numbering system of the Township is started in the upper right-hand corner, moving across to the left, down and to the right, etc. If you remember that the upper right hand corner is always Number 1 and that the numbers move back and fourth to the bottom you will be able to locate section numbers as necessary.

Each number identifies a section (square area) which is usually one square mile and contains 640 acres. Sections do not always contain 640 acres, nor are they always one square mile.

A properly written section location description would read:

Section (Sec.) 22, T.5N., R.7W.

SECTIONS

6	5	4	3	2	1
7	8	9	10	11	12
18	17	16	15	14	13
19	20	21	22	23	24
30	29	28	27	26	25
31	32	33	34	35	36

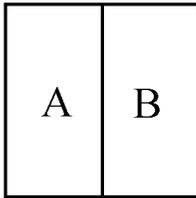
T5N

R7W

5.1D Cont.

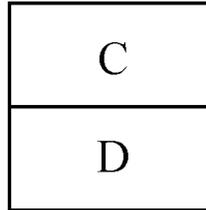
Division of sections - A typical section of 640 acres may be broken down into smaller areas, each successive smaller piece having a unique location description of its own.

Example 1:



Section 22

Example 2:



Section 22

The areas broken down to 1/2 sections of 320 acres would be described as:

Example 1;

Area "A" - W1/2, Sec.22, T.5N., R.7W., M.D.B.&M.

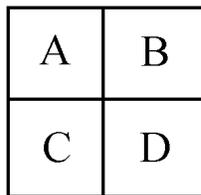
Area "B" - E1/2, Sec.22, T.5N., R.7W., M.D.B.&M.

Example 2;

Area "C" - N1/2, Sec.22, T.5N., R.7W., M.D.B.&M.

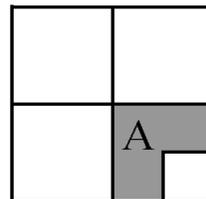
Area "D" - S1/2, Sec.22, T.5N., R.7W., M.D..B.&M.

Example 3:



Section 22

Example 4:



Section 22

The areas broken down into 1/4 sections of 160 acres would be described as:

Example 3;

Area "A" NW1/4, Sec.22, T.5N., R.7W., M.D.B.&M.

Area "B" NE1/4, Sec.22, T.5N., R.7W., M.D.B.&M.

Area "C" SW1/4, Sec.22, T.5N., R.7W., M.D.B.&M.

Area "D" SE1/4, Sec.22, T.5N., R.7W., M.D.B.&M.

If you have two separate portions of a section to describe, use "and" as a connector in the description, as in Example 4:

Area "A" N1/2 and SW1/4 SE1/4, Sec.22, T.5N., R.7W., M.D.B&M.

The quarter sections can further be divided into half (80 acres) or quarter of the quarter (40 acres).

This division of quarters or halves of a divided area, can be continued until broken down to a reasonable size of 10 acre parcels (on one-half inch equals one mile maps) and 2-1/2 acre parcels (on one inch equals one mile or larger scale).

The illustration below shows an area of the section broken down into 2-1/2 acre parcels. Notice the parcels at the bottom labeled "A" and "B"

NW 1/4 160 Acres		W 1/2 NE 1/4 80 Acres		E 1/2 NE 1/4 80 Acres	
TYPICAL SUBDIVISION OF A REGULAR SECTION					
NW1/4 SW1/4 40 Acres		NE1/4 SW1/4 40 Acres		N1/2 NE1/4 SE1/4 20 Acres	
SW1/4 SW1/4 40 Acres		SE1/4 SW1/4 40 Acres		S1/2 NE1/4 SE1/4 20 Acres	
		N1/2NW1/4 SW1/4SE1/4		W1/2 NE1/4	
		S1/2NW1/4 SW1/4SE1/4 5 Acres		E1/2 NE1/4 SW1/4 SE1/4 5 Acres	
		2-1/2 ACRES		2-1/2 ACRES	
		A		B	
		SE1/4 SW1/4 SE1/4 10 Acres		NW1/4 SE1/4 SE1/4 10 Acres	
		SE1/4 SE1/4 SE1/4 10 Acres		NE1/4 SE1/4 SE1/4 10 Acres	

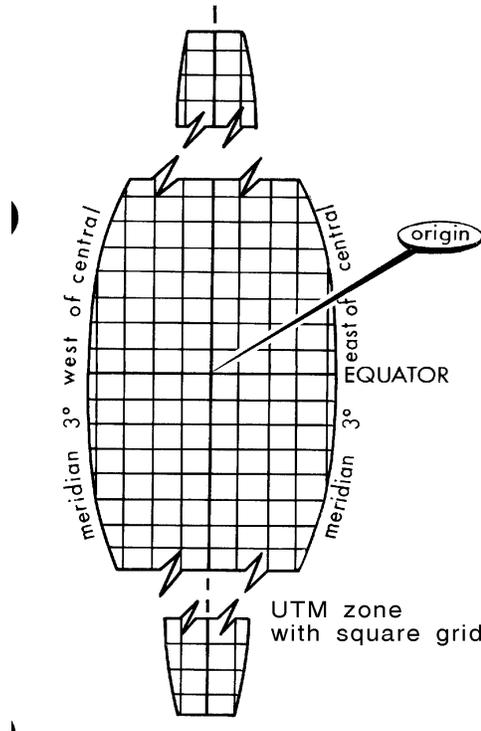
Section 22, T5N, R7W

The areas broken down into parcels of 2-1/2 acres would be described as:

Area "A" - SW1/4 SW1/4 SW1/4 SE1/4, Sec-22, T.5N., R7W.,M.D.B.&M

Area "B" - SE1/4 SW1/4 SW1/4 SE1/4, Sec-22, T.5N., R7W.,M.D.B.&M.

determine location. Within each zone is superimposed a square grid, and although the zone lines converge toward the poles, the grid lines do not. Therefore, as one travels north from the equator, the grid becomes smaller, although the grid squares remain the same.



For any given position in the northern hemisphere:

NORTHING is the distance in meters of the position north of the equator, measured along a zone line; and

EASTING is the distance in meters of the position east of the zone line.

FOR EXAMPLE:

Let us take a position in Montana described as UTM 5346782 (the northing), 683456 (the easting), zone 12. The physical location of this position is 5 million, 346 thousand, 782 meters north of the equator, along the 12th zone line, and 683 thousand, 456 meters east of the 12th zone line.

UTM is a very precise method of defining geographic locations; even our example, without decimals, defines the position to within one meter in each direction. For the purposes of comparison, one degree of latitude equals about 69 miles or 110,000 meters; one second of latitude equals about 30 meters.

5.4 Other Land Division Systems

Although the Rectangular System of Survey is the official method of land description in the U.S., other systems are also legal land divisions:

1. Spanish Land Grants - In the southwestern United States, a township frequently will be occupied partially by a Spanish Grant. United States Government Surveys do not cover such grants, going only to and including their boundaries. For field references you can just continue known township and range lines into the grant and use the rectangular legal description.
2. Metes and bounds - In the Eastern United States this is a common method of land division. Metes and bounds is a system of establishing boundaries of tracts of land by reference to natural or artificial monuments along it, as distinguished from those established by beginning at a fixed starting point.
3. State Land Coordinate Systems - Established in several western states, these systems were developed to precisely measure and record boundary lines, monuments, and other features.

UNIT 5
QUESTIONS

1. What is the name of the point on which a rectangular land division is based?

2. What is the east-west line through the "point" called?

3. What is the north-south line through the "point" called?

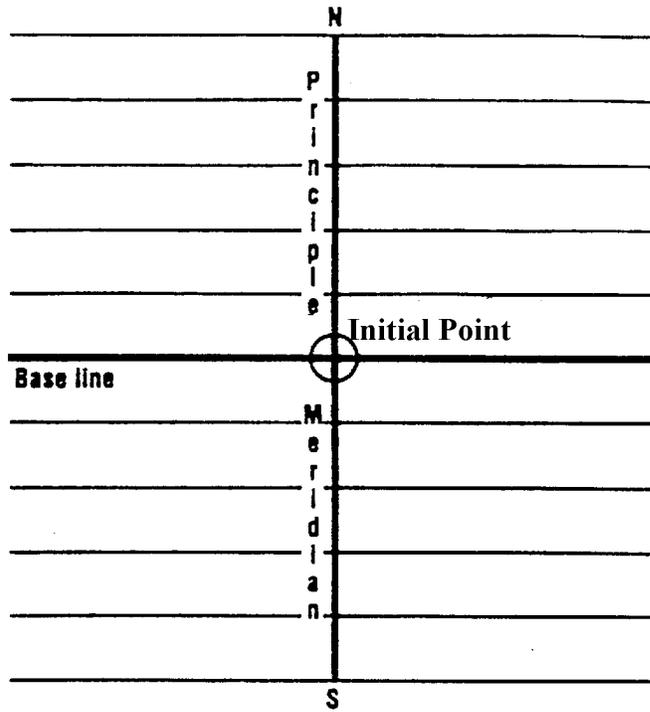
4. How many square miles are within a township?

5. What does each numbered subdivision within a township identify?

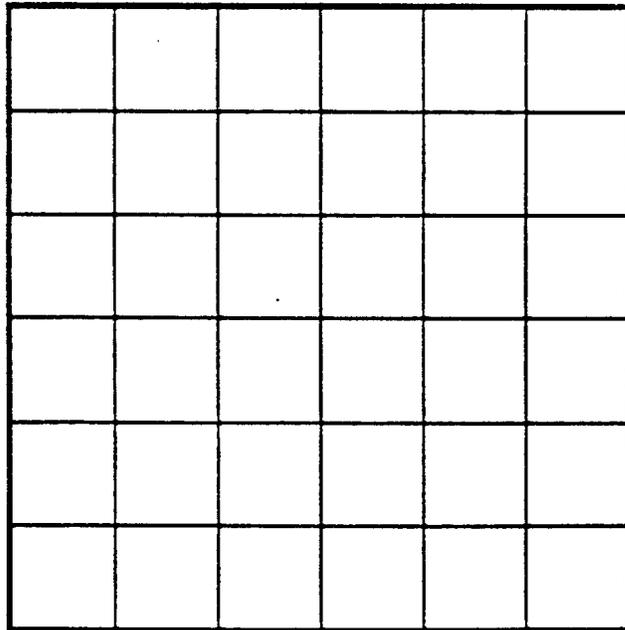
6. Generally, how many acres in a section? _____
7. In which direction do lines of longitude run? _____
8. In which direction do lines of latitude run? _____
9. The lines that parallel the Baseline at 6 mile intervals are called _____ lines.
10. The lines that extend the same direction as the Principal Meridian at 6 mile intervals are called _____ lines.

UNIT 5
EXERCISE 1

1. Identify the Township areas and write their correct description:



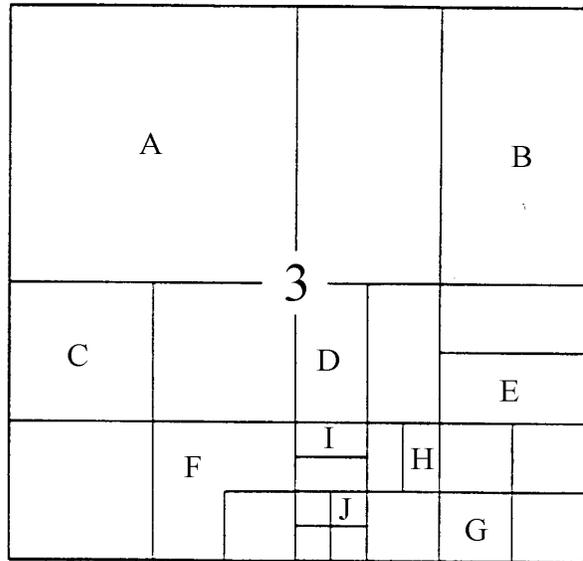
2. Number the Sections in this typical Township:



UNIT 5
EXERCISE 3

4. Using the exercise sketch representing a section comprising 640 acres, solve the following problems by indicating the acreage and giving the legal description to each of the lettered areas:

- A. Acres: _____ Describe: _____
- B. Acres: _____ Describe: _____
- C. Acres: _____ Describe: _____
- D. Acres: _____ Describe: _____
- E. Acres: _____ Describe: _____
- F. Acres: _____ Describe: _____
- G. Acres: _____ Describe: _____
- H. Acres: _____ Describe: _____
- I. Acres: _____ Describe: _____
- J. Acres: _____ Describe: _____



Section 3, Township 2 South, Range 4 E

UNIT 6
DETERMING SIZE OF AREA

6. DETERMINING THE SIZE OF AN AREA

There are a number of methods to determine the size of an area. Area can be expressed in square miles, acres, blocks, square feet, or any other square unit of linear measurement. Also an area can be estimated by comparing it to areas of known size.

6.1. Basic mathematical calculations

The most common method for calculating area will be measuring length and width and then multiplying the two. (LENGTH X WIDTH = AREA)

Some units of measure you can use are:

LINEAR

12 inches	=	1	foot
3 feet	=	1	yard
5280 feet	=	1	mile
66 feet	=	1	chain
80 chain	=	1	mile

AREA

1 acre	=	208 feet x 208 feet
1 acre	=	43,560 square feet
1 acre	=	10 square chains
640 acres	=	1 square mile
1 section	=	1 square mile*
1/2 section	=	320 acres*
1/4 section	=	160 acres*

*Generally the size, but may vary.

When you first arrive at an incident and are asked for an estimated acreage, you do not have the time to follow the exact steps for perfection. You can, however, use this information as the basis for making a good guess. The more you know about calculating acreage, the easier it is to become an accurate estimator.

Acreage is always calculated in square measure, and the answer will be in square units: square feet, square yards, square chains. Both the length and the width must be figured.

Computing Acreage by Chain:

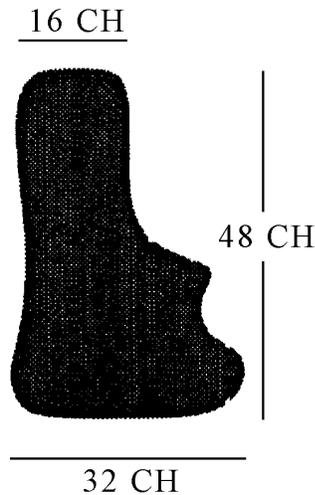
10 square chains equals one acre. 10 is the conversion factor.

$$\begin{aligned} \text{A RECTANGULAR AREA} &= (\text{CHAINS} \times \text{CHAINS}) \\ \text{ACRES} &= (5 \text{ CHAINS} \times 10 \text{ CHAINS}) \text{ DIVIDED BY } 10 \\ \text{ACRES} &= 50 \text{ DIVIDED BY } 10 = 5 \text{ ACRES} \end{aligned}$$

To compute an odd shaped area, it is often necessary to take two or more measurements across the area and obtain an average length and width. So if you had an area that is 32 chains wide at one end and 16 chains wide at the other end, you add 32 and 16 which equal 48. Divide 48 by 2 which equals 24. The average width is 24 chains.

The area of this example is: 24 ch (width) X 48 ch (length) = 1152 ch²

$$1152 \text{ ch}^2 \div 10 \text{ ch}^2 / \text{acre} = 115.2 \text{ acres}$$



Computing Acreage by Feet:

43,560 square ft. equals one acre.

LENGTH (in feet) x WIDTH (in feet)	DIVIDED BY 43,560	= ACREAGE
(2,640' x 1,320')	DIVIDED BY 43,560	= ACREAGE
3,484,800'	DIVIDED BY 43,560	= 80 ACRES

6.2 Estimation By Comparison

When estimating the size of an area, it is best to compare areas of known size such as:

- a. A football field - 1 acre
- b. The lot that your house is on - 1/4 acre to 1/2 acre

Use common sense when estimating area on a map:

- a. If the area is entirely within a single section, it usually isn't more than 640 acres.
- b. Compare acreage estimates to section divisions; half-sections, quarter-sections, etc.

UNIT 6
QUESTIONS

1. What is the most common calculation to figure the size of an area?

Determine the equivalent unit of measurement for the following:

2. 2.5 mile = _____ chains
3. 1.5 chains = _____ yards
4. 29,040 feet = _____ miles
5. 3 chains x 20 chains = _____ acres
6. 250 feet x 262 feet = _____ acres
7. 1 section = _____ square mile/miles

Determine the estimated area in acreage:

8. 4.5 football fields _____ acres
9. Parcel of land approximately 40 chains x 20 chains
_____ acres
10. A ranch that covers approximately 1/8 area of a section on a map
_____ acres

UNIT 6
EXERCISE

Estimate the area (in acres) within 10% accuracy (+ or -) of the fires on map found on the next page.

The fires are numbered areas indicated by arrows.

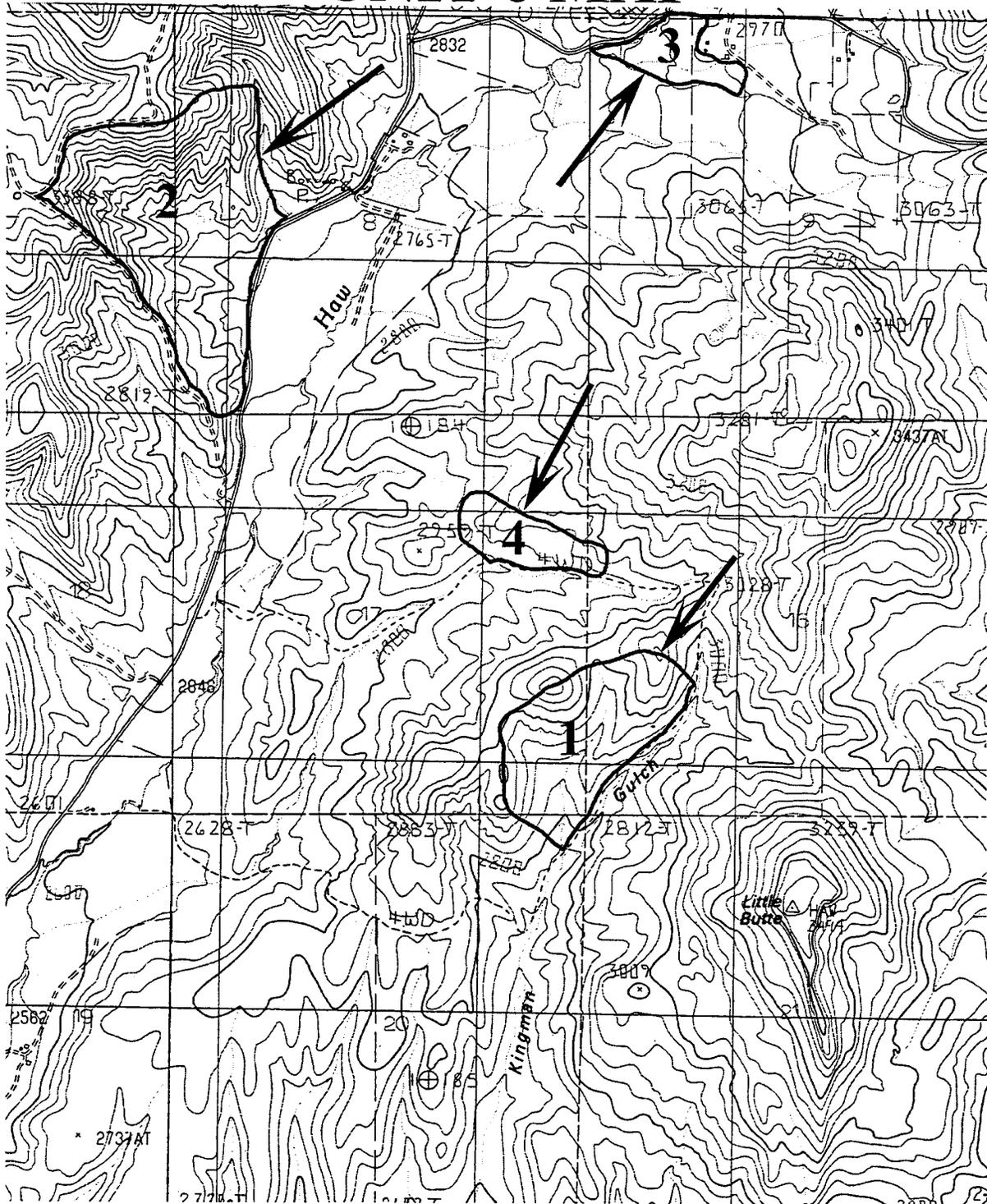
1. _____

2. _____

3. _____

4. _____

UNIT 6 MAP



SCALE 1:24,000

UNIT 7

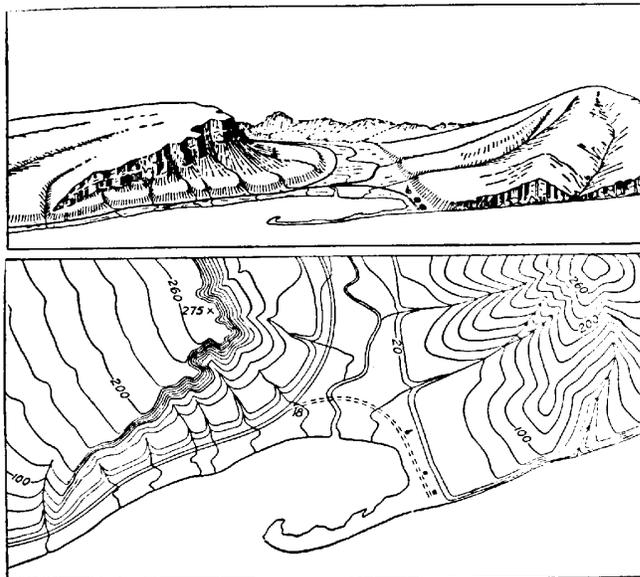
TOPOGRAPHIC RELIEF

7. TOPOGRAPHIC RELIEF

A topographic map is printed on a flat piece of paper. It is, therefore, necessary to use symbols to represent the variation in elevation (relief) of geographic features, such as ridges and valleys, hills, and streams. These ground forms are measured vertically as well as horizontally. Contour lines, colors, and raised areas are symbols that show changes in elevation. Maps with relief show the general shape of the land.

7.1 Contour Lines

A contour line is a line on a map or chart connecting all points of the same elevation. Any point on a contour line is the same elevation as all the other points on the same line. In other words, contour lines connect points of equal elevation.



A. A landscape in perspective and the same landscape in contour lines. Note especially that lines are far apart for level land, almost touch for cliffs.

Contour interval is the difference in elevation between two adjacent contour lines. On U.S.G.S. maps they could be drawn at any elevation, but in practice they are drawn at intervals of 1, 5, 10, 20, 40, and 80 feet. Occasionally you will find a map with a 25 foot contour interval or metric units, but not often.

To make the contours easier to read, every fifth one is printed darker and has the elevation marked every so often in the line. (Every fifth contour on 40' interval maps). This is called the index contour. The thinner or lighter colored contour lines are called intermediate contours.

To find the contour interval on a map check the legend, or, find two index contours adjacent to each other. Read their elevations and find the difference. If the number of spaces between them is 5, divide the difference by 5 to find the contour interval. If the number of spaces between them is 4, divide the difference by 4 to find the contour interval.

For example:

1. Two adjacent index contour lines indicate 250 feet and 300 feet.
2. Find the difference by subtracting 250 feet from 300 feet = 50 feet.
3. Count the spaces between the dark index contour lines; there are 5.
4. Divide 50 feet by 5.
5. 50 divided by 5 = 10 foot contour interval

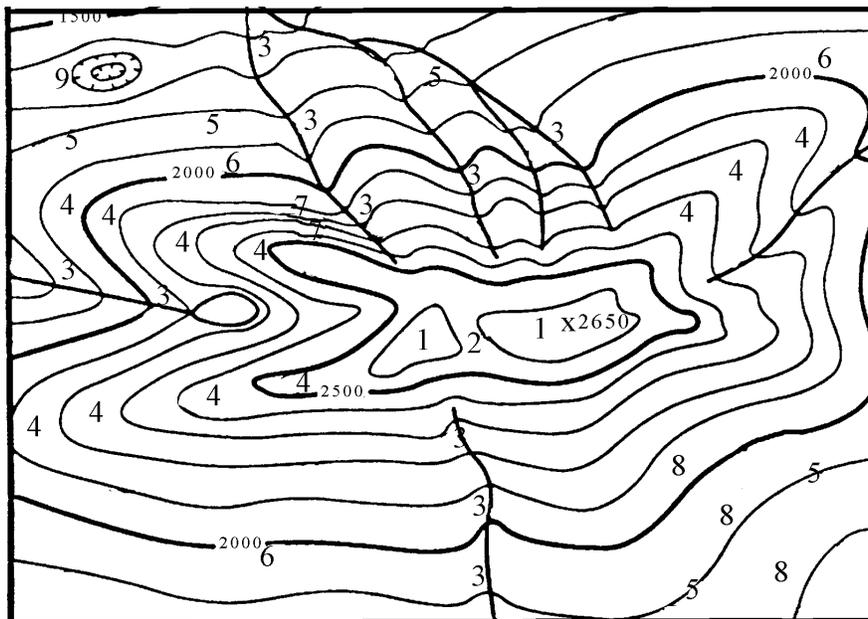
Contours have certain general characteristics. Listed are characteristics which are not rules but guidelines that are helpful in many cases. Contours:

1. Usually have smooth curves. Exceptions are large outcrops of rocks, cliffs, and fractured areas of the earth's surface.
2. Are "V" shaped in stream beds and narrow valleys. The point of the "V" always points uphill or upstream.
3. Are usually "U" shaped on ridges with the "U" bottom pointing down the ridge.
4. Are usually "M" or "W" shaped just upstream from stream junctions.
5. Tend to run perpendicular to streams.
6. Tend to parallel each other, each approximately the shape of the one above it and the one below it.
7. Do not cross or touch. Exception is overhanging cliffs.
8. Do not fork.
9. Never end on the map, only at the map edges and sometimes at overhanging cliffs.
10. Indicate steep terrain by being closely spaced.

11. Indicate a uniform slope by being equally spaced.
12. Indicate depressions or pit by a contour line joined forming a circle having hachures (short lines extending from the contour line at right angles).
13. Indicate elevation in feet above mean sea level in index contours.

Contour characteristic terminology:

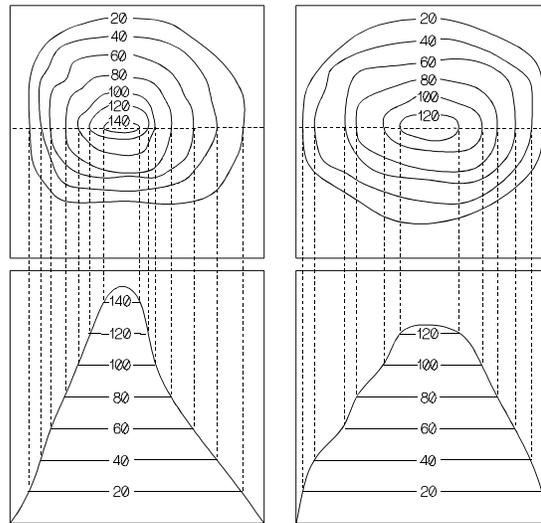
1. Depression - a low place in the ground having no outlet for surface drainage.
2. Hill - a naturally occurring mass of earth whose crest or summit is at a lower elevation than a mountain.
3. Mesa - a flat-topped mountain bounded on all sides by steep terrain.
4. Ridge - long narrow elevation of land, often located on a mountainside.
5. Saddle - ridge between two hills or summits.
6. Valley - stretch of low land lying between hills or mountains and sometimes occupied by a stream.



1-Top of hill; 2-Saddle; 3-Streams and bottom of canyon; 4-Ridges; 5-Contour line; 6-2000 on contour line indicates elevation in feet above sea level; 7-Steep slope; 8-Gentle slope; 9-Depression

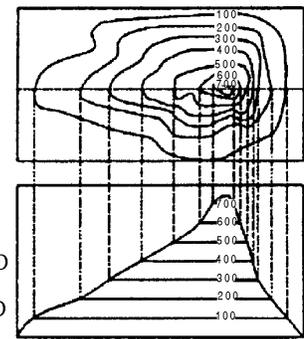
7.2 Cross-sectioning landscape profiles.

When the contour lines are close together at the top of a hill, the hilltop is pointed. The hilltop is flat when the contour lines are widely spaced at the top.



Contour lines widely spaced show a gentle slope; when they are close together, the slope is steep.

HILL AS SHOWN ON MAP



PROJECTION SHOWS HILL AS IT WOULD LOOK FROM THE GROUND

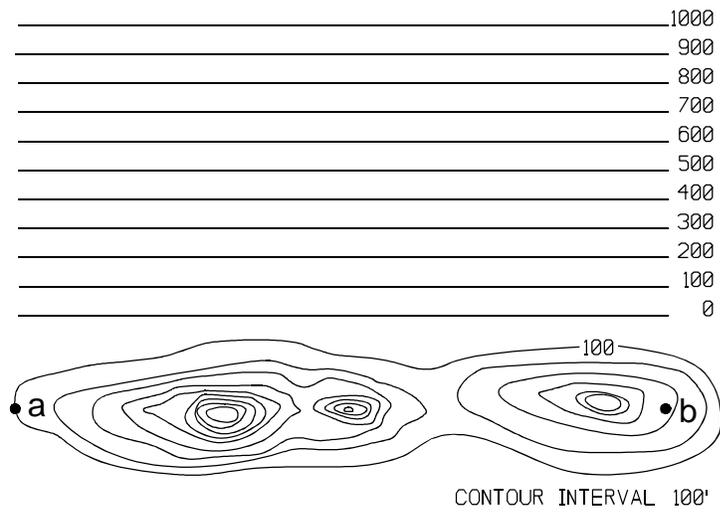
GENTLE STEEP

Remember: A contour line is a brown line on your map that connects points of the same elevation. You can find the contour interval in the margin at the bottom of the map. The heavy brown lines (every fifth one) have the elevation printed on them. You can tell from looking at your map what the slopes, hills, and valleys will look like on the ground.

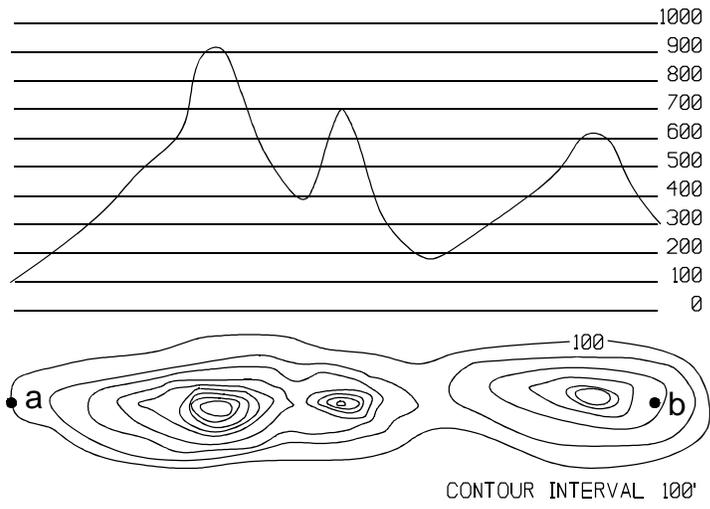
Now that you know how contour lines are interpreted, study the contour drawing on the next page, then draw a profile (similar to a line graph) of the land from point “a” to point “b”. Draw the profile in the space provided with the elevation lines marked in 100-foot increments.

Hint: the elevation rises from the 100-foot contour line. After completing this exercise examine the school solution on page 44.

Draw a profile showing the elevations along a line from a to b.



School solution



UNIT 7
QUESTIONS

1. What is the definition of a contour line?

2. What is the definition of a contour interval?

3. Two adjacent index contour lines on a map are 500 feet and 700 feet, and there are 5 spaces between them. What is the contour interval?

4. Do contour lines ever cross or touch?

5. What do contour lines that are closely spaced indicate?

6. What do hachures on contour lines indicate?

UNIT 7
EXERCISE

On the map on the next page (Page 47) there are five numbered squares with arrows. Locate and write the elevation closest to where the arrow is pointing.

ARROWS:

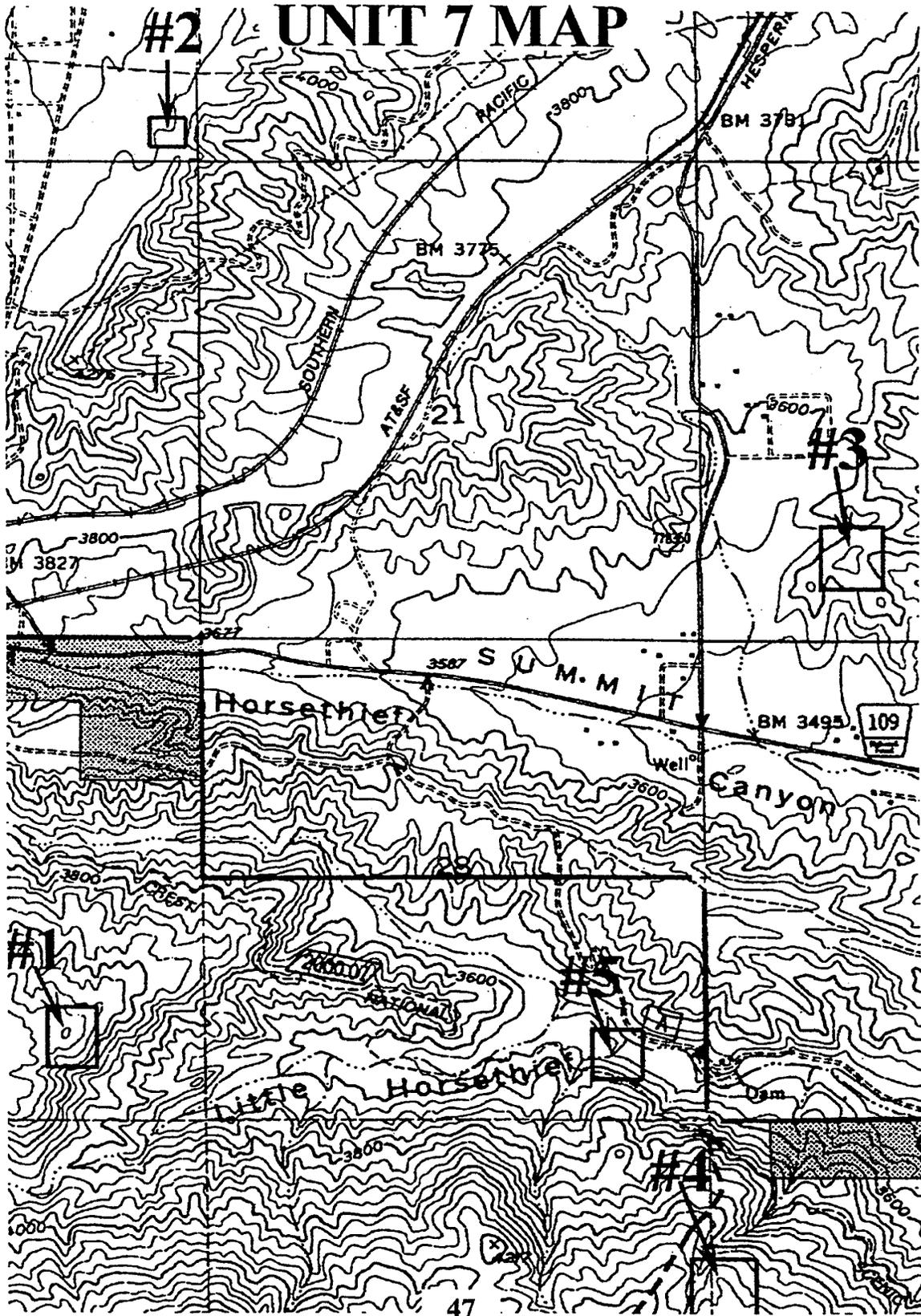
- 1.
- 2.
- 3.
- 4.
- 5.

Using the map on Page 48, identify the topographic feature inside the rectangles numbered 6 - 12. Match the appropriate rectangle with the characteristics listed below:

RECTANGLES:

- | | |
|-----------|---------------|
| 6. _____ | Stream |
| 7. _____ | Hilltop |
| 8. _____ | Steep terrain |
| 9. _____ | Ridge |
| 10. _____ | Depression |
| 11. _____ | Flat terrain |

#2 UNIT 7 MAP



UNIT 8

SLOPE

8. SLOPE and ASPECT

A slope is an inclined ground surface that forms an angle with the horizontal plane (flat ground). The degree of inclination, steepness, is also called *slope*. *Aspect* is the compass direction that the slope is facing.

8.1 Percent Slope

Slope is usually expressed in percent. It is useful in estimating the amount of time it takes to construct a piece of fireline. The estimation of percent slope can help determine whether or not a dozer, engine, or hand crew can work the topographic area. It is also used as an input for making fire behavior calculations. A one percent slope indicates a rise or drop of one unit over a distance of 100 horizontal units. Usually the mapper will be working with feet; therefore, a one percent slope rise would indicate a one foot rise over a 100 foot horizontal distance.

Elevation/Vertical Difference

Slope can be determined in several different ways in the field, or it can be calculated from a topographic map. A number of slope calculation aids are available in the form of tables that show the relationship between map scale and contour interval; contour overlays; and slope indicator overlays or templates. Use of slope calculation aids is limited by map scale and contour intervals, and most are designed to be used with USGS 7-1/2 minute quadrangle maps.

In order to obtain a slope percent from a topographic map, determine the difference in elevation between two different points in the area of concern. First determine the elevation of each location. To find the elevation of a point, locate the index contour nearest the point, then count contour lines up or down to the point. Some computer software, like BEHAVE, will do the arithmetic automatically.

Next, subtract one elevation from the other, and the difference is the vertical difference (rise).

Estimating slope is a simple mathematical process. The Formula is:

$$\text{PERCENT SLOPE} = \frac{\text{VD} \times 100}{\text{HD}} \quad \text{or} \quad \frac{\text{RISE} \times 100}{\text{RUN}}$$

VD or RISE = Vertical Distance (difference in elevation between two points; subtract one point in elevation from the other point).

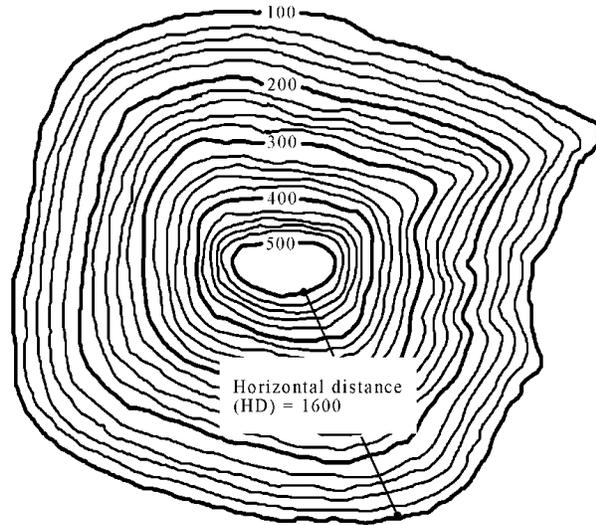
HD or RUN = Horizontal Distance measured with ruler on a map, from one point to the other)

Given: RISE is (500' - 100') = 400'

RUN is 1600'

$400 \div 1600 = .25$

$.25 \times 100 = 25\%$



8.2 Slope Measurements from Field Observations

Determining slope with a clinometer:

Obtain a clinometer graduated in degrees and percent. Abney, Suunto, and Spiegelrelaskop are examples. Ask for assistance on how to use it if you are confused by the following instructions.



Read the dial on the left side of the clinometer to determine how it is graduated, or look into the hole and tilt your head back so that the clinometer is at the top of the scale. The inside scale units should be readable in this position. A degree scale is usually indicated by a "o" symbol and a percent scale is usually indicated by a "%" symbol. (To confirm the degree/percent graduations, 45 degrees on the right will equal 100% on the left.)

Stand so that you are facing directly up or down the slope. While keeping both eyes open, use one eye to read the scale inside the hole and the other eye to sight on an object that is about the same height above the ground as your eye level height. Read the appropriate scale and record your data in the proper units. A common mistake is to read the degree scale and record it as percent slope, or vice versa. Remembering that percent is always greater than degrees will help to prevent this error.



The Silva Ranger CL-15 compass has a built-in clinometer. This scale is only graduated in degrees, and there is no convenient conversion factor. Read the instructions that accompany this compass on how to use the built-in clinometer.

UNIT 8
QUESTIONS

1. What can the estimated percent slope help you determine ?

2. How is slope expressed ?

3. A one foot rise over 100 foot horizontal distance indicates what?

4. What is the percent slope formula ?

5. What is the definition of slope ?

UNIT 8
EXERCISE

Solve the following slope problems using the map on the next page. The map scale is 1:24,000:

1. What is the contour interval on the map on the next page ? _____

Calculate Slopes between the following points on the map on the next page:

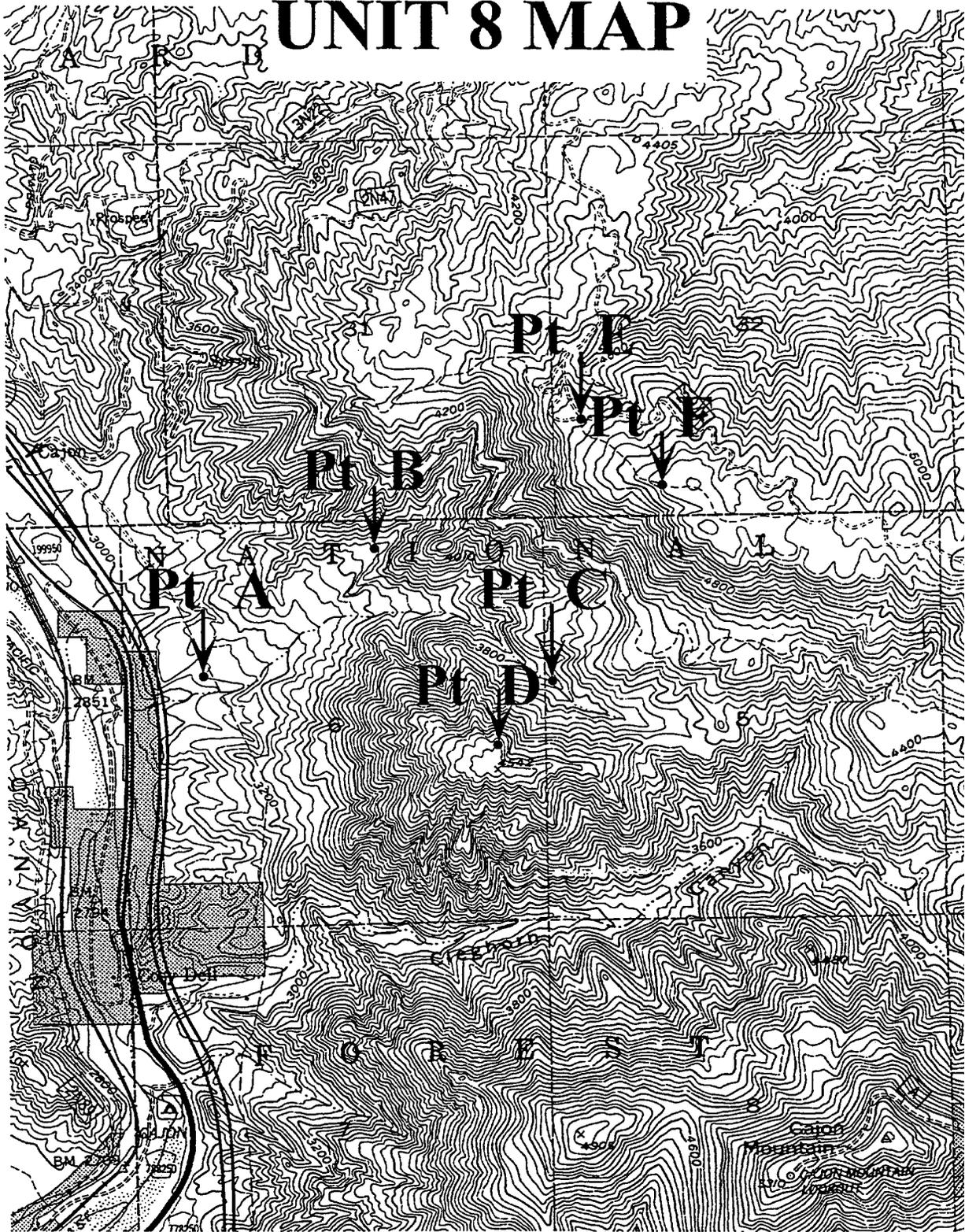
2. A to B _____

3. C to D _____

4. E to F _____

5. Traveling from Point F to Point E, is the direction of travel upslope or downslope?

UNIT 8 MAP



UNIT 9

DETERMINING DISTANCE

9. DETERMINING DISTANCE.

There are various methods of determining distance along the ground. Since it is not usually very practical to measure long distances on uneven terrain with a measuring tape, pacing, estimating by eye, and in some cases vehicular odometer readings along roadways, have become methods of preference.

9.1 Pacing

A mile equals 5280' feet because 1000 double-steps of the average Roman soldier of Caesar's time covered approximately that distance. The Latin phrase for 1000 double-steps or paces, *mille passus*, was later abbreviated into our English "mile" .

The pace we measure is a Roman pace, two steps of normal stride. Since everyone's "normal stride" is different, everyone's pace is unique to him or her. A pace is the distance on level ground between the heel of one foot and the heel of the same foot where it next touches the ground; that is, at the end of two normal steps.

To determine the distance of pace:

1. Lay out a pre-measured course of 100' feet on level ground.
2. Step off the course counting paces (each double-step).
3. Divide number of paces into measured distance to arrive at average pace.
4. Repeat the process a number of times to get a more accurate pace distance.

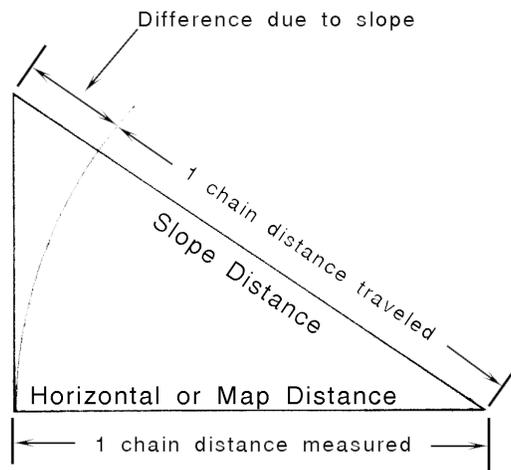


To determine the distance between two points on the ground by pacing, count the number of paces as you walk between the two points. Then multiply the number of paces by the length of your average pace.

Pacing long distances can lead to error, especially in uneven or rough topography. Decide how you will record your pacing distances so that the information can be used, i.e., make pencil marks for every 100 paces.

9.2 Determining your pace on sloping ground.

Steepness of slope affects pacing in two distinct ways. First, the natural length of step varies in walking or climbing up or down the slope. The second effect of slope is that land surveys are based on horizontal distances, not slope distances. To measure a 100 foot horizontal distance, a person must travel more than 100 feet when walking on a slope. Whether going uphill or down, the difference between horizontal and slope distance will increase as the percentage of slope increases. It is therefore essential to compensate for these variations of pacing intervals on slopes.



In general:

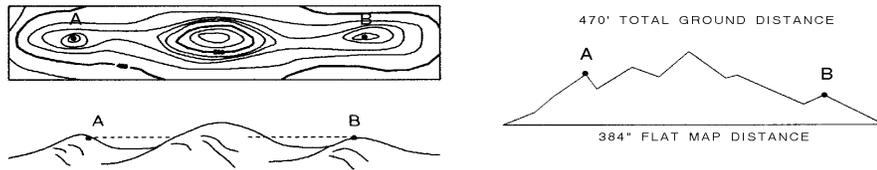
Your pace lengthens on moderate downgrades and shortens on the upgrade or very steep downgrades;

Walking into strong winds causes the pace to shorten; walking with a tail wind causes it to lengthen;

Soft surfaces such as sand and gravel tend to shorten the pace.

In wet, rainy, or icy conditions, the pace tends to shorten.

When you set up a course to determine the length of your pace, include moderate and steep slopes, and measure uphill as well as downhill. This will ensure a more accurate measurement.



As shown in the above drawings, if you were to travel from Point A on the top of the hill on the left, to Point B at the top of the hill on the right, you would actually travel much farther than the flat map distance appears.

9.3 Visually estimating distance and other methods

Occasionally you will encounter a stream too deep to wade or a slope too steep to cross, and the distance must be estimated. In rough country or dense brush, it is more convenient to estimate a short distance to some object than it is to pace the distance. First, practice estimating the units of paces, and then increase the estimate to units of chains or 100-foot increments. Verify each estimate by pacing the distance during practice. Continue practicing until the desired accuracy is reached. In terrain that is drivable or where perimeters are bounded by roads, the vehicle odometer, measured in tenths of a mile, may be useful. This method would be especially useful over long distances.

UNIT 9
QUESTIONS

1. How many steps does a pace actually have at normal stride?

2. Are paces on upgrade slopes shorter or longer than on even ground?

3. How do you determine a distance using the pace?

4. Why is a vehicle odometer a good tool to use for determining distance?

5. In the field, how will you record/remember how many paces you've traveled?

UNIT 10 COMPASS FAMILIARITY

10. COMPASS FAMILIARITY.

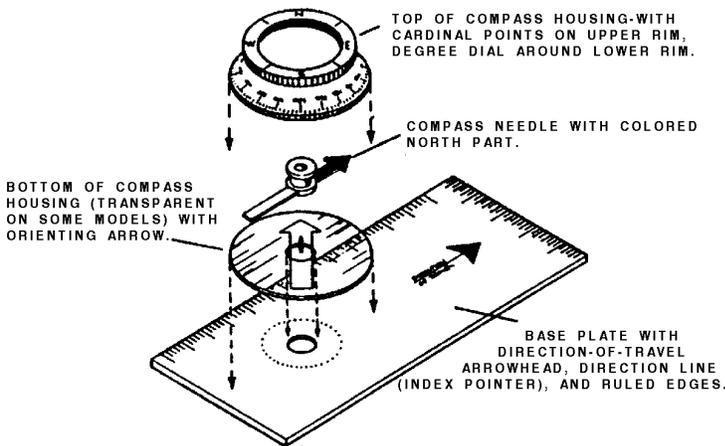
The compass is an instrument which indicates magnetic north. The compass needle consists of a strip of magnetized steel balanced on a pinpoint and free to swing in any direction. One end of the needle, usually marked by an arrow or luminous dot painted red, is the north-pointing end. When the compass is laid or held horizontally, the red end of the needle will always point to magnetic north. Unfortunately, *Magnetic North* and the geographic *True North Pole* do not coincide. Magnetic North is located about 1,400 miles south of True North. The significance of this will be explained later.

10.1 Parts of a compass

The compass consists of three basic parts:

1. The magnetic needle - always points to Magnetic North - if is not disturbed by a nearby metal object.
2. A revolving 360° dial which is a graduated circle that shows the cardinal points (being at least north, east, south, and west, and sometimes divided into four or twelve additional points), sometimes called the compass rose. The dial's upper rim has degree indentations, and the lower transparent plate has orienting north/south lines and an arrow.
3. A transparent "base plate" - has direction of travel arrows and ruled edges.

Parts of a Compass

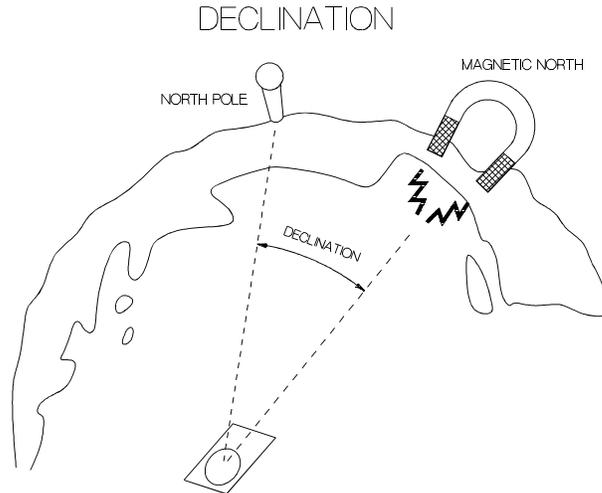


The Mariner's Compass Rose

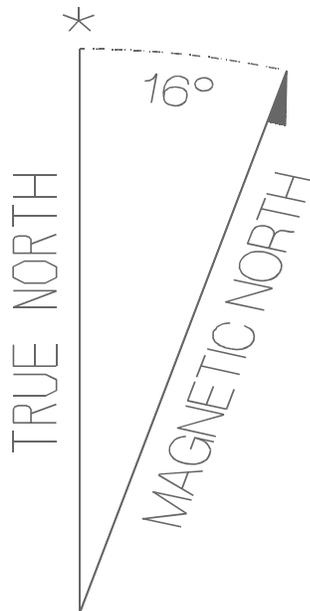


10.2 Magnetic Declination

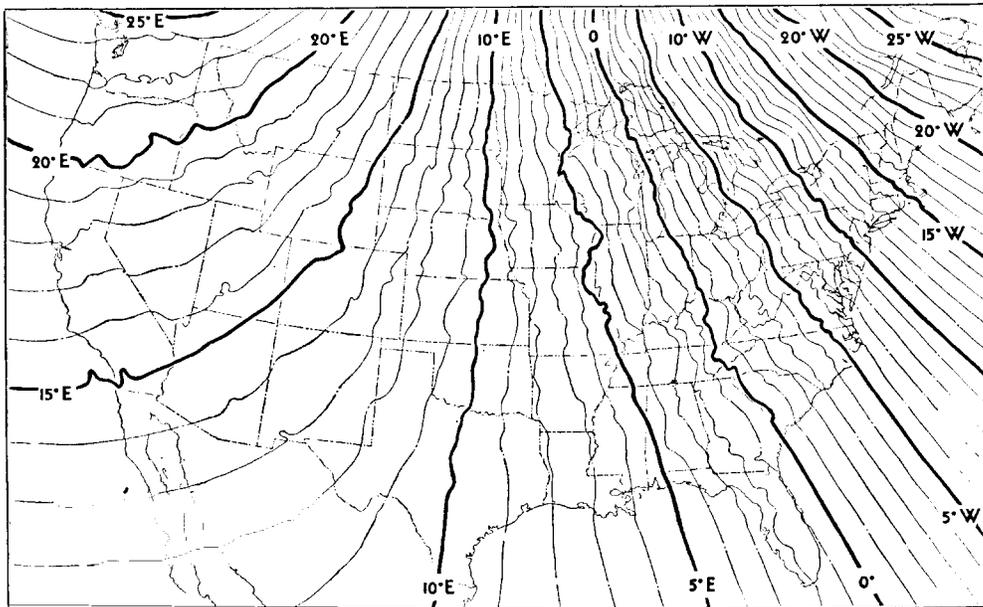
Compass directions usually refer to true north, but the compass needle always points toward magnetic north. The difference (angle in degrees) between true north and magnetic north is called **magnetic declination**, or simply the **declination**. Declination is sometimes also referred to as “compass error”, but is not the same thing as “compass deviation” .



On USGS topographic maps, the declination diagram (degrees of declination for an area) is located on the bottom margin of the map.



Map bearings are true bearings and uncompensated compass bearings are magnetic. This means that all topographic maps are drawn in reference to true north, but the compass does not point to true north unless a magnetic declination adjustment can be made on the compass. Adjusting for magnetic declination can be very confusing, because the declination can be either east or west of true north, depending on your location. At any area in the United States where your compass points east of true north - as in California, for example - you must correct for “Easterly Declination”; conversely, where the compass points west of true north - as in Maine - you must correct for “Westerly Declination”. The line of zero declination (where true north and magnetic north are the same) passes through Michigan to Georgia. This line of zero declination is NOT associated with any geographic feature, and in fact changes position over time, which accounts for the differences in declination you will find on topographic maps of the same area but with different publication dates.



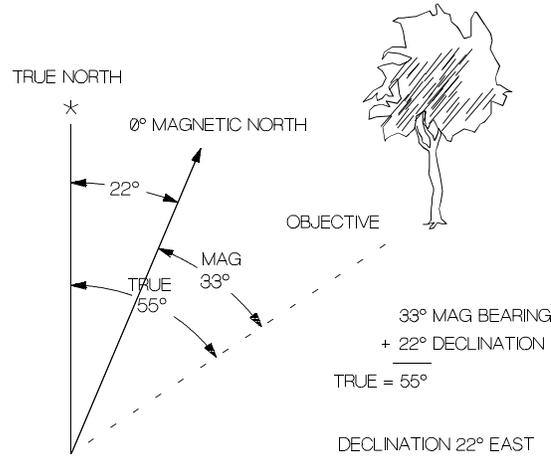
DECLINATION CHART OF THE UNITED STATES *circa* 1955

Declination requires adjustments in readings when mixing true readings from the map with magnetic readings from the compass.

East declination: To adjust a compass bearing for **east** declination (in the western U.S.), do the following:

1. Determine the declination for your map’s location. We will use Seattle, Washington as an example, with a declination of 22 degrees east.

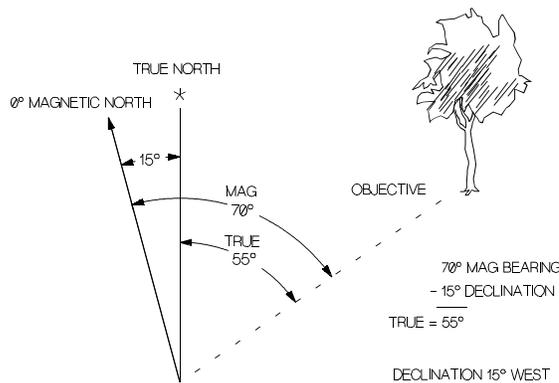
2. **ADD** the amount of east declination to the compass reading. This will give you the true bearing. For example, if your magnetic bearing (from the compass) is 33 degrees, add the declination (22 degrees) to it to determine the true bearing of 55 degrees. See the picture below.



For **West Declination**: To adjust a compass bearing for a west magnetic declination (in the eastern U.S.), follow these steps:

1. Determine the declination at your map's location. For this example, we will use Cape Cod, Massachusetts, which has a declination of 15 degrees west.

2. **SUBTRACT** the amount of declination from the compass bearing. For example, your magnetic bearing (compass reading) to an object is 70 degrees. Subtract the declination (15 degrees in our example) from the bearing to determine the true bearing of 55 degrees.



The rules for correcting magnetic bearings to true:

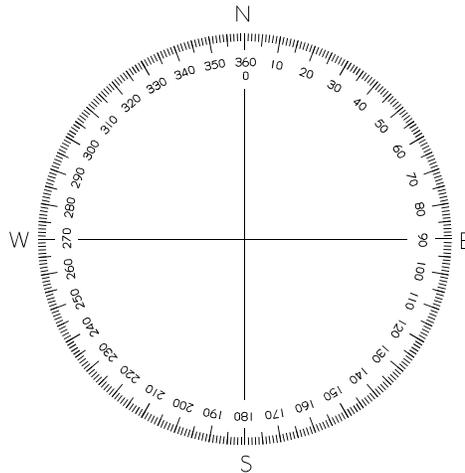
For **EAST** declination, **ADD** the declination to the compass reading.

For **WEST** declination, **SUBTRACT** the declination from the compass reading.

Note: Some compasses (like the Silva Ranger) allow an internal adjustment which automatically corrects for declination. To avoid the declination problem entirely, use one of those.

10.3 Using Your Compass

Imagine yourself in the center of a circle that has been divided into 360 equal parts or degrees. This enables you to measure any direction. In map reading we refer to a direction as an Azimuth. This azimuth circle is divided into 360 degrees. The degrees are numbered in a clockwise direction, the zero point being north, east 90 degrees, south 180 degrees, west 270 degrees, and north 360 or 0 degrees.



For correct readings, always hold the compass level so that the needle swings freely. Bend your elbows close to your side so the compass is steady. The compass should be at a height that allows you to take a line of sight reading on the 360 degree dial and also allows you to turn the 360 degree dial without unnecessary movement of the needle. Do not move your head, but raise and lower your eyes. Stand away from metal objects.

To determine which direction is North:

- a. Set 360 degrees on the 360^o dial in line with the direction of travel arrow and index line.
- b. Hold the compass and turn your body until the magnetic needle lines up with the direction of travel arrow. The direction you are facing is Magnetic North.

To determine the direction of an object:

- a. Hold the compass and align the direction-of-travel arrow with the object.

- b. Turn the 360⁰ dial until the needle is aligned with the north index pointer. Hold the base plate steady.
- c. Read the azimuth where the index line meets the 360⁰ dial.

To follow an azimuth:

- a. Determine the direction to be walked by checking your compass.
- b. Set the azimuth on the compass by turning the degree dial until the desired azimuth lines up with the direction-of-travel arrow.
- c. While holding the compass in front of you, turn until the needle lines up with the orienting arrow.
- d. Sight along the edge of the baseplate toward a distant object.
- e. Walk to the object without looking at the compass.
- f. When you arrive at the object check the accuracy of your walk.
- g. Repeat steps “a” through “g” .

It is difficult for some people to learn how to use a compass by reading about it. Find a knowledgeable person to show you these skills and practice them repeatedly on different objects.

Precautions to take when using a compass:

Be sure that the correct declination is set on the compass, or that you adjust for the declination mathematically.

When running lines always follow the line of sight, not the direction of the needle.

The compass is a delicate instrument; handle it carefully.

Always follow the line indicated by the compass rather than relying on judgement as to the direction.

Remember the tree, rock, or other object sighted on your line of sight. When in doubt, take another reading.

Keep articles containing steel or iron (ferrous metals), or which generate a magnetic field (such as radios) far enough away from the compass to avoid influencing it.

Do not attempt to repair the compass except in emergencies.

10.4 The compass as a protractor

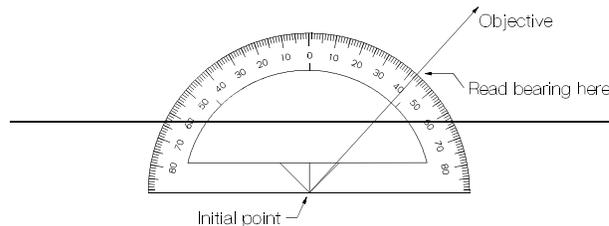
A compass can also be used as a protractor for determining map directions. The compass dial with its 360 degree markings becomes the protractor, the base plate with its straight sides your ruler, and the compass needle plays no part.

First, place the compass on the map where one edge of the base plate touches both your initial point and your object of destination, with the direction of travel arrow on the base plate pointing in the direction of the destination.

Second, turn the 360⁰ dial until the north sign and orienting lines on the 360⁰ dial point to north on the map (parallel the orienting lines with the closest north-south meridian on map).

Now look at the azimuth on the 360 degree dial where the index line touches it. This is the direction in degrees and the true azimuth.

With a true compass reading and a distance from a given point, a line can be drawn on a map and a location on this line can be found. Although this method will suffice when you have no protractor available, it is always better to use a protractor if you have one; it is easier to read.



10.5 Orienting a map with a compass

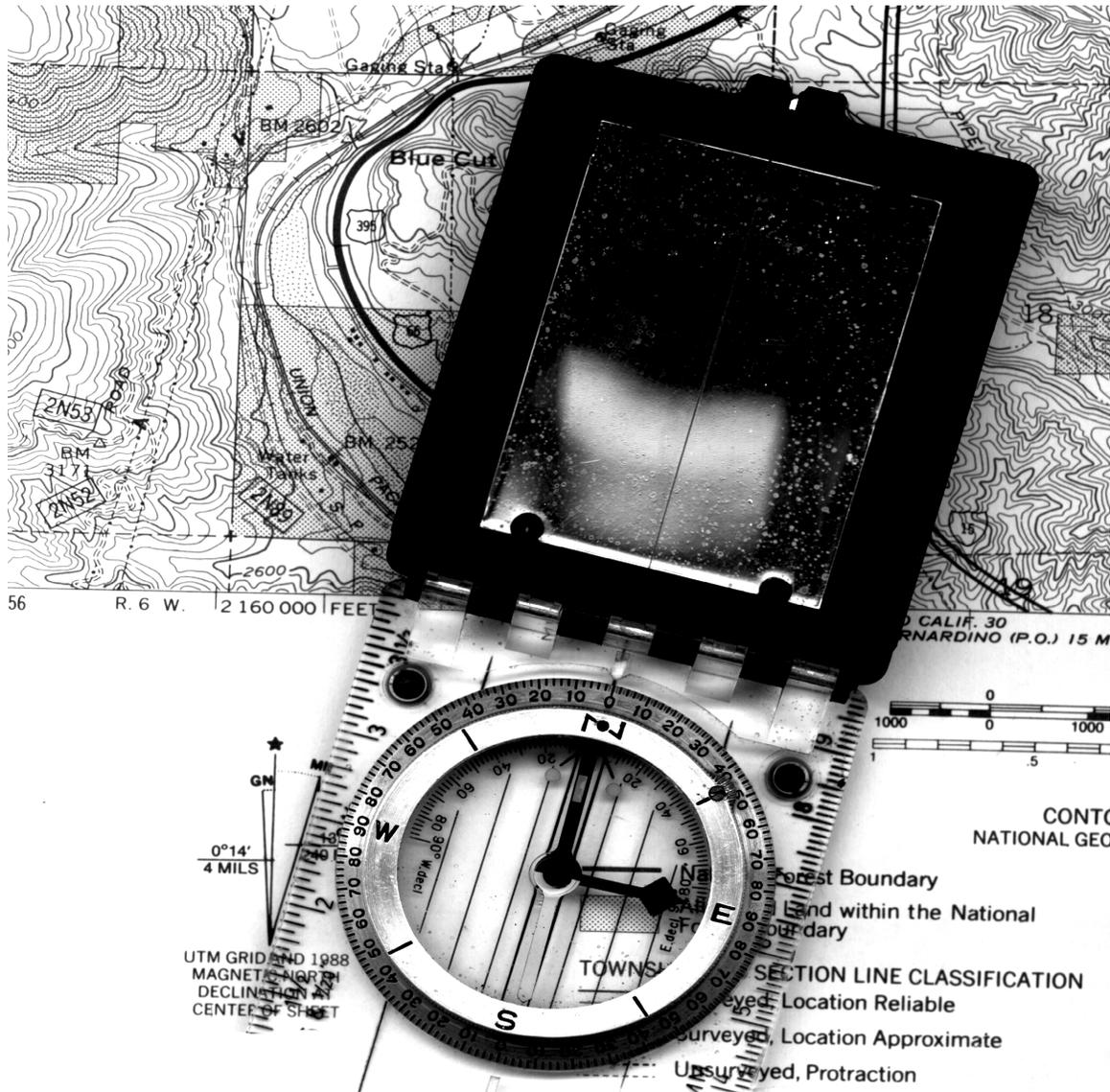
Listed are two ways to cope with the problem of orienting the map and declination:

1. Orienting the map - Topographic orientation
 - a. Find your approximate location on the map.
 - b. Select two prominent landmarks visible to you and shown on the map.
 - c. Turn the map until the map landmarks are in proper relation to the actual landmarks.
 - d. The map is now oriented generally to true north. This is referred to as terrain association - associating the map to fit the terrain.

2. Orienting with the compass and the magnetic north arrow on the map.
 - a. Lay the map out flat.
 - b. Set the 360⁰ dial with north at the index line.
 - c. Lay the compass down with the edge of the base plate parallel with *magnetic north arrow line* pictured at the bottom of a topography map.

- d. Carefully rotate the map and compass *together* until the needle points to north on the 360 degree dial.
- e. The map and compass are now oriented with the terrain.

(See the illustration of a properly oriented map below.)



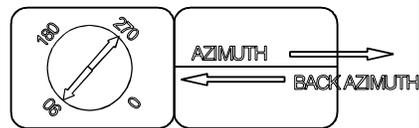
Proper orientation of map with compass
to correct for magnetic declination.

10.6 Back Azimuth and Backsight

A back azimuth is the projection of the azimuth from its origin to the opposite side of the azimuth circle. The back azimuth of a line differs from its forward azimuth by exactly 180° .

A back azimuth is calculated by adding 180 degrees to the azimuth when it is less than 180 degrees, or by subtracting 180 degrees if the azimuth is more than 180 degrees. For example:

If the azimuth is 45 degrees, add 180 degrees to find the back azimuth. Our back azimuth would be 225 degrees. If the azimuth is 270 degrees, subtract 180 degrees. The back azimuth would be 90 degrees.



Backsight is a method of sighting using a compass bearing taken backwards, in an opposite direction from the original heading. It is the practical application of back azimuth.

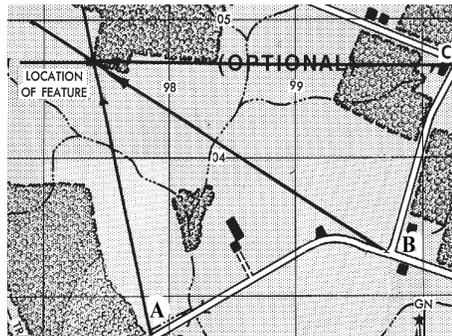
Backsighting uses the azimuth sight of your first destination and turns it around so you can find the way back to your original starting position. To keep on track to a destination use the backsight to check the line of sight back to the starting point. When traversing with a compass, a mistake of a few degrees will result in a significant distance over a long traverse.

Keeping on track requires you to periodically check the backsight of your position. While your starting point is still in view, calculate your back azimuth. Look along the line of sight to determine if it bisects your starting point. If your line of sight aims to the left of your starting point, this means you will have to move to your right in order to get back on your original line of sight.

10.7 Intersection

The method of locating a point on a map by intersecting lines from two known landmarks is called **Intersection**. Distant or inaccessible objects can be located on a map by intersecting lines from two known landmarks. For example, magnetic azimuths from two different mountain tops to a distant point are converted to true azimuths and drawn on a map. Where the two lines intersect on the map is the location of the distant point.

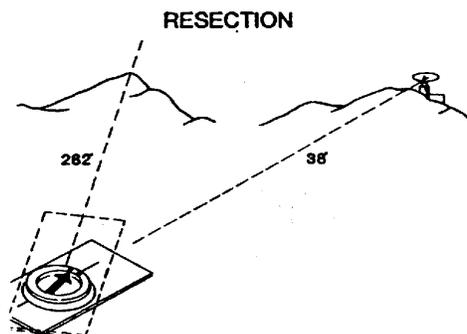
1. The first step of the intersection process is to take magnetic azimuths from two known landmarks (points A and B) to the object.
2. Convert these magnetic azimuths to true azimuths by adjusting for declination.
3. Draw the lines of azimuth on the map from each point well past the object.
4. Where the two azimuth lines intersect on the map is the location of the distant or inaccessible point.



10.8 Resection

The method of finding one's own (unknown) position by sighting on two known landmarks is called **Resection**.

1. The first step in resection is to locate two or more objects on the ground that can be identified on the map.
2. With the compass, measure an azimuth to each of the landmarks on the ground. (Example: 282° , 38°)



3. Convert these magnetic azimuths to true azimuths by adjusting for declination. (If east declination add; example $282^{\circ} + 15^{\circ} = 297$ and $38^{\circ} + 15^{\circ} = 53^{\circ}$)
4. Convert to back azimuths. ($297^{\circ} - 180^{\circ} = 117^{\circ}$ and $53^{\circ} + 180^{\circ} = 233^{\circ}$)
5. From the two known landmarks on the map, draw the lines of the back azimuths until the lines intersect.
6. The point where these two lines cross is your position.

UNIT 10
QUESTIONS

1. List the three basic parts of the compass:

2. How should you hold the compass to get correct readings?

3. A back azimuth is calculated by adding 180 degrees to the azimuth when it is _____ than 180 degrees, or by subtracting 180 degrees if the azimuth is _____ than 180 degrees.

4. What is Intersection?

5. When using the resection method to find your position on a map, can you sight on two landmarks such as a tree and a large rock ? Why or why not?

UNIT 10
EXERCISE

Using the map on the next page and your protractor, determine the degree reading between the following points:

1. From the borrow pit in Section 8 to hilltop 3160 in the SW 1/4 of Section 9.

2. From the intersection of roads in the SE 1/4 of Section 18 to the fork in the road in the NW 1/4 of Section 7.

Using the map on the next page and your compass, determine the specified azimuth taken from one landmark to another (assume a magnetic declination of $13\frac{1}{2}$ degrees east):

3. The back azimuth from the top of Little Butte to the top of hill 3009.

4. The true azimuth from the cluster of buildings in the NE 1/4 of Section 8 to the cluster of buildings in the NE 1/4 of Section 9.

5. On a given map, the easterly declination is 14° . If the true azimuth from a highway intersection to a water tank is 54° , what is the magnetic azimuth?

Determine the back azimuth of the given forward azimuth:

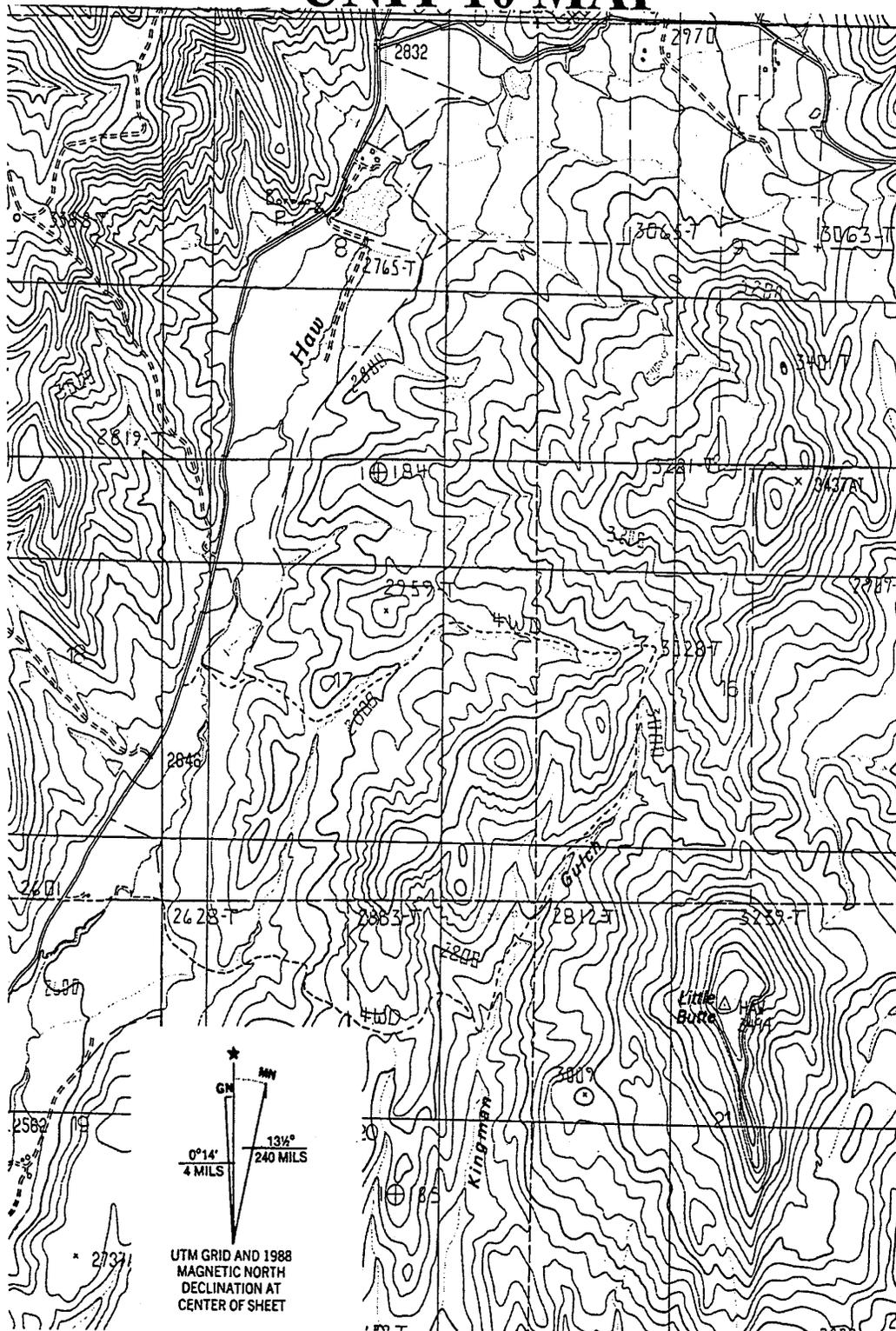
6. 35° _____

7. 340° _____

8. 210° _____

9. 125° _____

UNIT 10 MAP



SCALE 1:24,000.

GLOSSARY

AXIS

A straight line about which an object turns or seems to turn. The axis of the earth is an imaginary line through the North Pole and South Pole.

AZIMUTH

Horizontal angle or bearing of a point measured clockwise from true (astronomic) north.

BACK AZIMUTH

Angle or bearing 180 degrees opposite of azimuth.

BACKSIGHT

Using a compass, a sight taken backwards; the practical application of back azimuth.

BASE LINE

An imaginary line on the ground running east-west (horizontal) measured with special accuracy to provide a base for surveying.

CARDINAL POINTS

The four principal points of the compass; north, south, east, and west.

COMPASS

An instrument used for showing direction, consisting of a magnetic needle swinging freely on a pivot and pointing to magnetic north.

CONTOUR LINE

A line on a map or chart indicating elevation in feet, and connects all points of the same height above sea level.

DECLINATION

The angle formed by a magnetic needle with the line pointing to true north. It is also the difference in degrees between true north and magnetic north.

DEGREE

A unit of angular measurement equal to one-360th part of the circumference of a circle. The entire globe contains 360 degrees, each degree contains 60 minutes, and each minute contains 60 seconds.

DEPRESSION

A low place in the ground having no outlet for surface drainage.

GRAPHIC SCALE (G.S.)

A graphic scale is a line marked off on a map which compares map distances to the ground distance in "different" units of measurements. It indicates that so many inches or millimeters equal so many feet, kilometers, chains, or miles on the ground. A graphic scale of 1" to 5 miles means that 1 (one) inch on the map represents 5 miles on the ground. It is also called a comparison scale.

GRID

A network of evenly spaced horizontal and vertical bars or lines intended for defining areas. When placed over a map a system is created which helps you find a specific location.

GRID NORTH

The north that is established by the grid lines on the map. In the declination diagram of a map, grid north is symbolized by the letters "GN" at the apex of a line.

GUIDE MERIDIANS

Imaginary north-south lines established in a similar manner as the principal meridian. They are located at intervals of 24 miles east and west of the principal meridian only at the starting point and then they converge because of the curvature of the earth.

HACHURES

A series of short, nearly parallel lines used in map making to represent a sloping surface. Representing a depression or pit, the contour line is joined forming a circle with the hachures on the inside of the circle.

HILL

A naturally occurring mass of earth material whose crest or summit is at a lower elevation than a mountain.

INITIAL POINT

A point indicating the base where the Rectangular Land Division initiates its surveying. There are 31 of these "Initial Points" in the conterminous U.S.

LANDMARK

A feature in the landscape which can be readily recognized - anything from a prominent tree or rock, to a church or a lake.

LATITUDE

Angular distance, measured in degrees, creating imaginary lines circling the earth's globe. The lines extend in an easterly and westerly direction, parallel with the equator, which is 0 degrees latitude. The degrees of latitude increase as one proceeds from the equator toward either north or south poles where the latitude is 90 degrees.

LEGEND

A key accompanying a map which shows information needed to interpret that map. Each type of map has information represented in a different way relating to its subject matter. The legend can explain map scales, symbols and color.

LONGITUDE

Angular distance, measured in degrees, creating imaginary lines extending from north pole to the south pole which identify geographical positions on the earth's globe. The lines are based from the Prime Meridian of 0 degree longitude which runs through Greenwich, England, extending 180 degrees westward and eastward.

MAGNETIC NORTH

The direction toward which a magnetic needle of a compass points. In a declination diagram of a map, magnetic north is symbolized by a half arrowhead and the letters "MN" at the apex of a line.

MAP

A line drawing, to some scale, of an area of the earth's surface. It shows objects and features by conventional signs.

MAP SCALE

Indicates the ratio or proportion of the horizontal distance on the map to the corresponding horizontal distance on the ground.

MERIDIAN

A great circle of the earth passing through the geographical poles and any given point on the earth's surface; either half of such a circle between the poles; or any of the lines of longitude running north and south on a globe or map, representing such a half circle.

MESA

A flat-topped mountain with steep sides.

ODOMETER

An instrument for measuring the distance traveled by a vehicle.

PACE

A unit of linear measure, equal to the length of a step or stride. The pace is measured from the heel of one foot to the heel of the same foot in the next stride. The two steps (double-step) are walked at normal stride which will give the pace a general length of 5 feet.

PLANIMETRIC MAP

A map that shows the positions of features without showing the elevations of all hills and valleys of the land. It can include rivers, lakes, roads, boundaries, or other human-made symbolic features.

PERCENT SLOPE

The ratio between the amount of vertical rise of a slope and horizontal distance, expressed in percent. One hundred feet of rise in 100 feet of horizontal distance equals 100 percent.

PRINCIPAL MERIDIAN

An imaginary line on the ground running north-south which is accurately laid out to serve as the reference meridian in land survey.

RANGE LINES

The series of lines, 6 miles apart, which extend north and south similar to the Principal Meridian.

RECTANGULAR SYSTEM

The United States System of Surveying the Public Lands, which was established in 1784 by the Continental Congress and has survived until today with only minor modifications.

REPRESENTATIVE FRACTION (R.F.)

A scale that expresses the ratio of the map distance to the ground distance in 'SAME' units of measurements. It is usually written as a fraction or ratio.

RIDGE

A long narrow elevation of land; a steep slope or a similar range of hills or mountains.

SADDLE

A depression or pass in a ridgeline.

SECTION

An area of land one mile square and containing 640 acres, more or less, which is one of 36 parts of a township.

STANDARD PARALLELS

Imaginary horizontal lines established in the same manner as the base line and located at intervals of 24 miles north and south of the base line.

SLOPE

An inclined ground surface that forms an angle with the horizontal plane (flat ground). The degree of inclination (steepness) is also called slope.

TOPOGRAPHIC MAP

A map that shows the positions of features and also represents their vertical position in a measurable form.

TOWNSHIP

An area of land divided by township lines and range lines which is approximately 36 miles square. Each township is divided into 36 parts, each approximately one mile square, called sections.

TOWNSHIP LINES

The series of lines, 6 miles apart, which run east and west parallel to the Base Line (and also parallel to lines of latitude).

TRUE NORTH

A line from any position on the earth's surface to the geographic north pole. In a declination diagram of a map true north is symbolized by a line with a star at the apex.

U.S.G.S

United States Geological Survey of the Department of the Interior, an organization established by Congress which is engaged in topographic and geologic mapping and in collection of information about the public lands.

VALLEY

A stretch of low land lying between hills or mountains which is sometimes occupied by a stream.

ANSWERS

to

EXERCISES and UNIT TESTS

UNIT 1 TEST
ANSWERS

1. A map is designed for the purpose of permitting you to visualize a portion of the earth's surface with pertinent features properly positioned to facilitate planning and organizing operations.

2.
 - A. Maps are not absolutely accurate because they represent curved and uneven surfaces on a flat piece of paper.

 - B. Inaccurate local information sources, name changes, or new names and features are added in an area.

3. Because of basic human error, difficult working conditions, and inadequate survey procedures implemented by the initial surveyors.

UNIT 2 TEST
ANSWERS

1. Planimetric maps
Topographic maps
Orthophoto maps
2. Common road maps
Specific area maps
Agency maps
3. Contour maps
Shaded-relief maps

ICS SYMBOLS EXERCISE
ANSWERS

Q1:  _____ Incident Command Post

Q2:  _____ Incident Base

Q3:  _____ Spot Fire

Q4:  _____ Mobile Weather Unit

Q5:  _____ Uncontrolled Fire Edge

Q6:  _____ Division

Q7:  _____ Branch

Q8:  _____ Staging Area

Q9:  _____ Water Source

UNIT 3 TEST
ANSWERS

1. A legend shows information needed to interpret a map.

2. A represented fraction is a scale that expresses the ratio of the map distance to the ground distance in LIKE units of measurements.

If map distance is 1" representing 24,000" ground distance the ratio would be 1:24,000.

3. A graphic scale is a line marked off on the map that expresses the ratio of map distance to the ground distance in DIFFERENT units of measurements.

A graphic scale of 1" to 5 miles means that one inch on the map is proportioned to five miles on the ground.

4.

Black	Most cultural or human-made features
Blue	Water features such as lakes and swamps
Green	Vegetation such as woods, orchards or parks
Brown	All relief features, contours and fills
Red	Main roads, built-up areas, boundaries

5. No, because symbols may change from map type to map type.

6. Top is North
Bottom is South
Right is East
Left is West

UNIT 4 TEST
ANSWERS

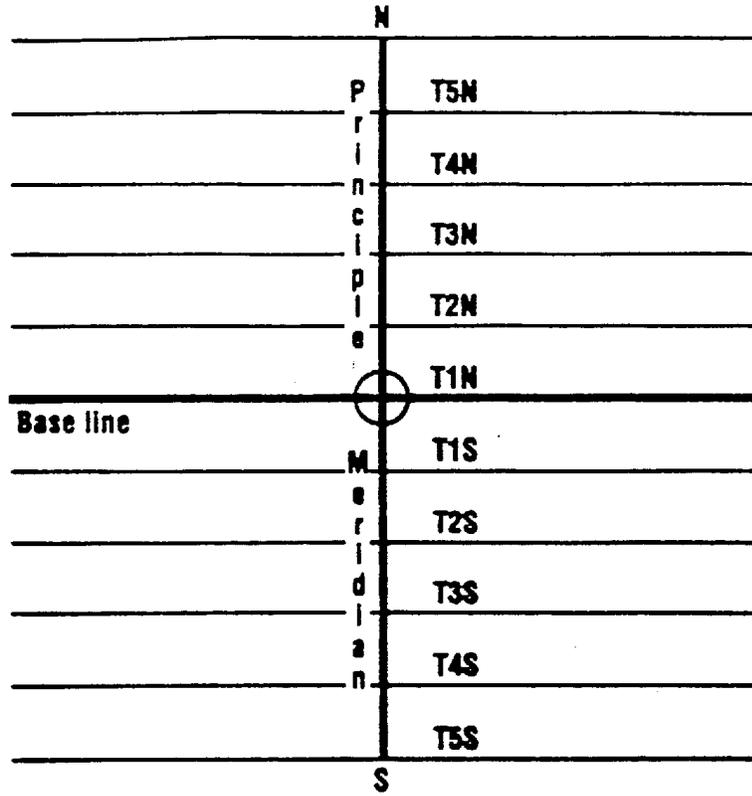
1. A grid placed over a map creating a system which helps find a specific location on the map.
2. With the matching of horizontal and vertical identifiers placed along the edge of the grid.
3. To direct you to a location on a map.
4. It is an artery map of the entire area covered by the atlas.
It designates the most direct route from one community to another and it shows all the individual map pages together.

UNIT 5 TEST
ANSWERS

1. Initial or Reference Point
2. Base Line
3. Principal Meridian
4. 36
5. A section
6. 640
7. North and south
8. Parallel to the equator, east and west
9. Township
10. Range

UNIT 5
EXERCISE 1 ANSWERS

1.

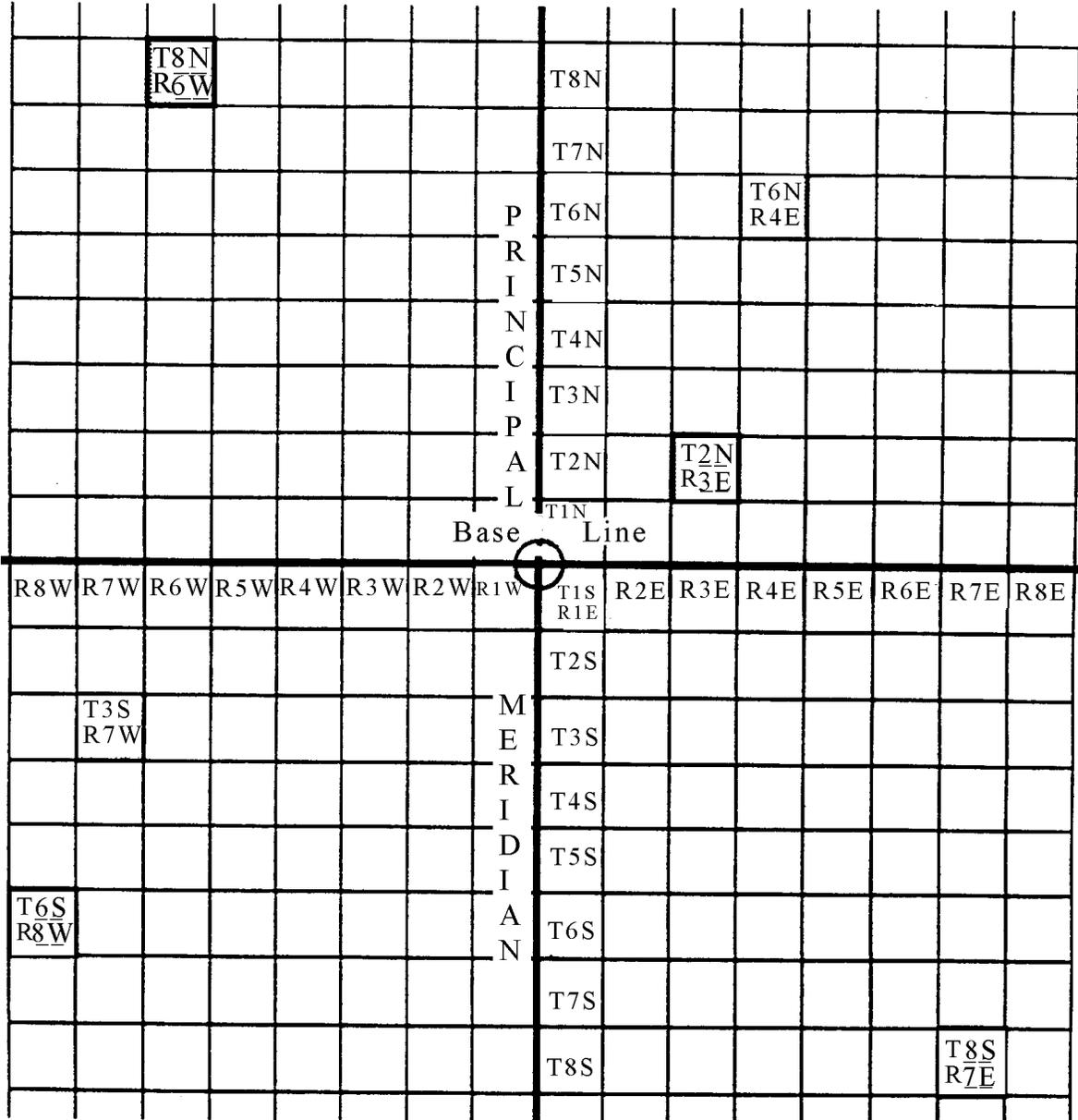


2.

6	5	4	3	2	1
7	8	9	10	11	12
18	17	16	15	14	13
19	20	21	22	23	24
30	29	28	27	26	25
31	32	33	34	35	36

UNIT 5
EXERCISE 2 ANSWERS

3.



UNIT 6 TEST
ANSWERS

1. Length x Width = Area
2. 200 chains
3. 33 yards
4. 5.5 miles
5. 6 acres
6. 1.5 acres
7. 1
8. 4 1/2 acres
9. 80 acres
10. 80 acres

UNIT 6
EXERCISE ANSWERS

1. 82 acres
2. 150 acres
3. 21 acres
4. 26 acres

UNIT 7 TEST
ANSWERS

1. A contour line is a line on a map or chart connecting all points of the same elevation.
2. Contour interval is the difference in elevation between two adjacent contour lines.
3. $700 \text{ feet} - 500 \text{ feet} = 200 \text{ feet}$
 $200 \text{ feet} \text{ divided by } 5 = 40 \text{ feet}$
40 foot interval
4. Yes, but only when indicating sheer or overhanging cliffs
5. Steep terrain
6. Depressions or pits

UNIT 7
EXERCISE ANSWERS

1. 4160'
2. 4120'
3. 3640'
4. 4160'
5. 3520'
6. Hilltop
7. Flat terrain
8. Steep terrain
9. Ridge
10. Depression
11. Stream or drainage

UNIT 8 TEST
ANSWERS

1. Whether or not a dozer, engine, or hand crew can work in the area.
2. Slope is usually expressed in percent
3. One percent slope rise
4. $\text{PERCENT SLOPE} = (\text{RISE divided by RUN}) \times 100$
5. Slope is an inclined ground surface that forms an angle with the horizontal plane (flat ground).

UNIT 8
EXERCISE ANSWERS

1. 40'

2. Vertical distance = 400'
Horizontal distance = 3000'
 $400 \div 3000 = .13$, or 13%

3. Vertical distance = 640'
Horizontal distance = 1200'
 $640 \div 1200 = .53$, or 53%

4. Vertical distance = 330'
Horizontal distance = 1400'
 $330 \div 1400 = .24$, or 24%

5. Downslope

UNIT 9 TEST
ANSWERS

1. Two steps
2. Shorter
3. Multiply the number of paces by length of your pace
4. It can save many paces over along distance.
5. Notebook marks, tally whacker, etc.

UNIT 10 TEST
ANSWERS

1. The magnetic needle
A revolving 360⁰ dial
A transparent base plate

2. Always hold the compass level
Bend your elbows close to your side keeping it steady
Hold it at a height where you have a line of sight and can turn the dial; do not move your head, but raise and lower your eyes.

3. Less
More

4. The method of locating a point on a map by intersecting lines from two known landmarks is called Intersection.

5. No, You have to locate landmarks that can be identified on the map.

UNIT 10
EXERCISE ANSWERS

1. 96°
2. 345°
3. 61°
4. 78°
5. 68°
6. 215°
7. 160°
8. 30°
9. 305°

4. The next five questions refer to the basic colors used on a topographic map. Briefly explain what features the colors represent.

A. Black

B. Blue

C. Green

D. Brown

E. Red

5. Draw the ICS display symbol for the following items:

A. ICP

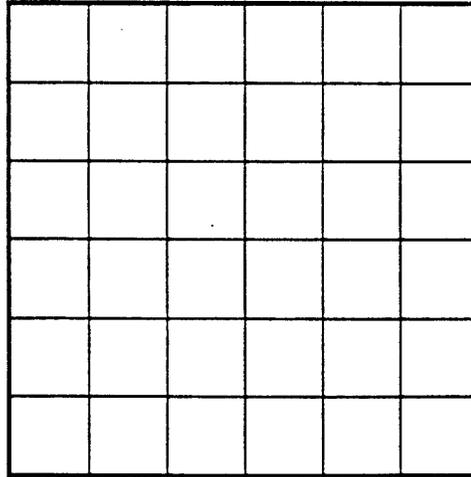
B. Uncontrolled perimeter

C. Origin

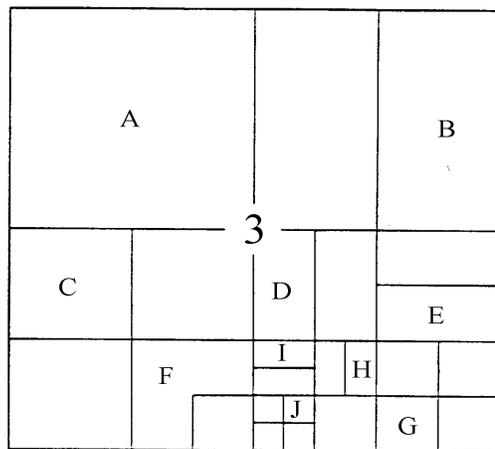
D. Staging area

E. Ridge

6. Number the sections in this typical township.



7. Using the sketch below and assuming the area within the overall square represents a typical section, show how many acres is represented in the following areas:

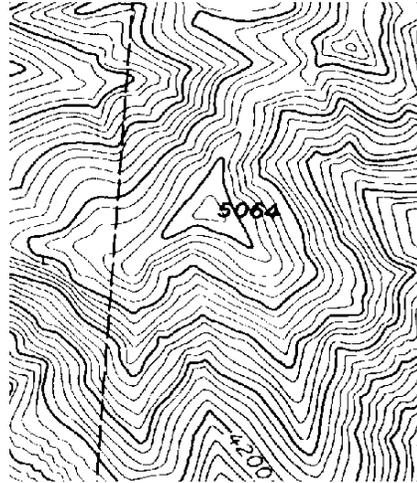


Section 3, Township 2 South, Range 4 E

- A. How many acres in area "A"?
- B. How many acres in area "C"?
- C. How many acres in area "J"?

8. What does a compass do?

9. What topographic feature is depicted in the sketch below?



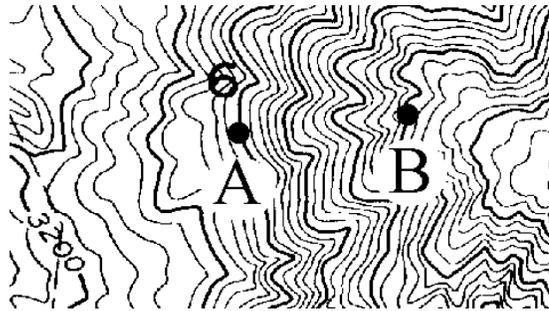
10. What is the elevation at the top of the feature in the sketch above?

11. What information can you determine from the topographic map feature shown in the sketch below?

1	2	3	1. NORTHEAST EMMETT 2. MONTOUR 3. HORSESHOE BEND 4. SOUTHEAST EMMETT 5. CARTWRIGHT CANYON 6. STAR 7. EAGLE 8. BOISE NORTH
4	PEARL	5	
6	7	8	

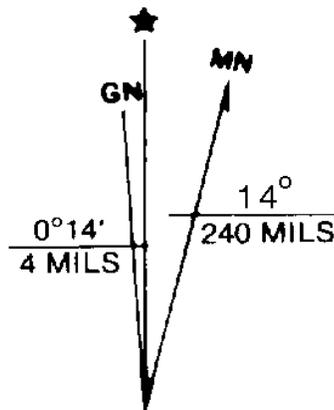
12. Does the above feature appear on all USGS topographic maps?

13. Refer to the sketch below. Assuming the map scale is 1:24,000 and the contour interval is 40 feet, what is the slope in percent from Point “A” to Point “B”?



14. What does a clinometer do?

15. What information can you gain from the map feature indicated below?



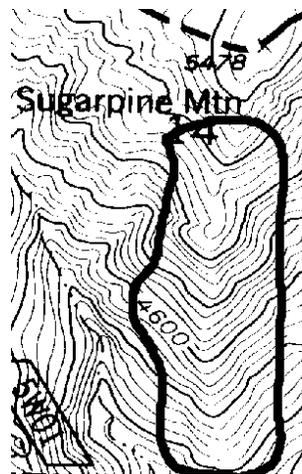
16. In the illustration above, what do the letters “MN” stand for?

17. On a USGS topographic map, where will you find the feature shown in question 15 above?

18. You are traversing the perimeter of a fire, and determining its length by pacing. You have just paced up a long ridge in which the average slope was 45%. If your pace is five feet, and you counted 200 paces, have you traveled:

- A. 1000 horizontal feet?
- B. less than 1000 horizontal feet?
- C. more than 1000 horizontal feet?

19. What is the topographic map feature indicated in the outlined area in the sketch below?



20. A. What is the grid location of Point "A" in the illustration below?

B. What is the grid location of Point "B" in the illustration below?

