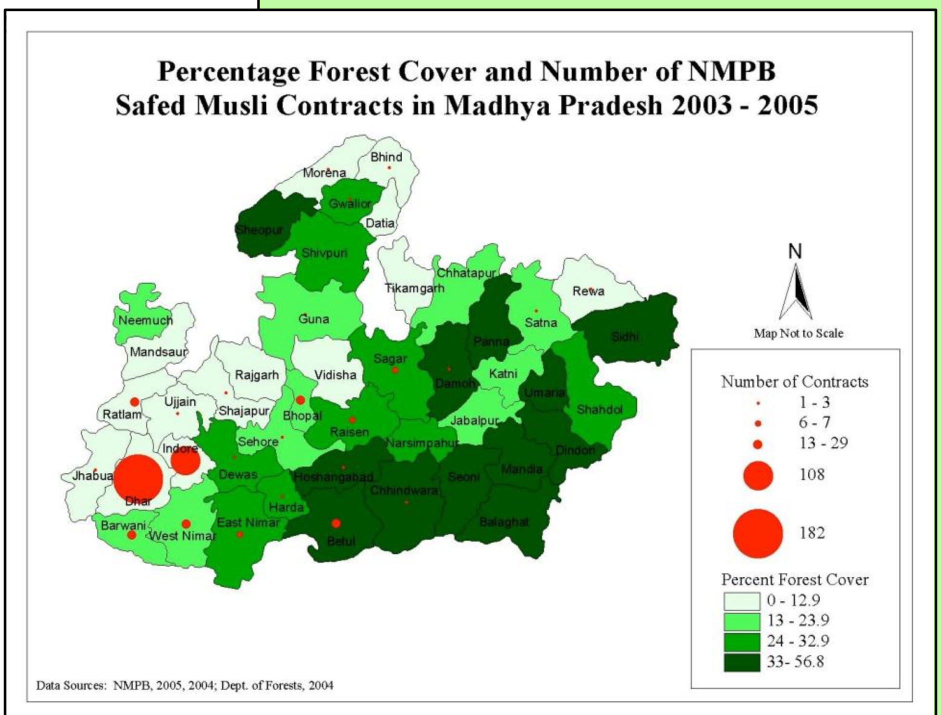
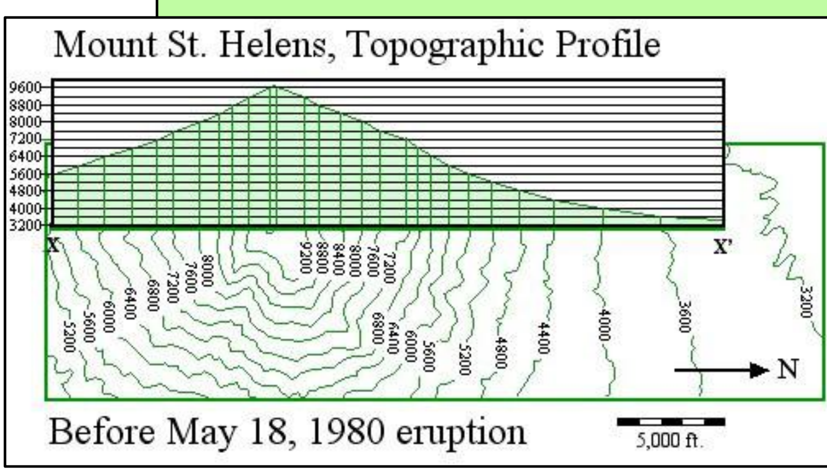
UFVGSH/ part four

Numeracy ~ Graphing ~ Geodesy and Mapping ~ Topographic Profiles

GEOGRAPHIC TECHNIQUES



Numeracy and map reading, construction, and interpretation are skills used by human, physical, and techniques geographers. At the top left, Dr. Garry Fehr's GIS map of contracts to plant Safed Musli (a non-timber forest product) in central India. Below, a topographic profile of Mt. St. Helens. Topographic profiles are used by physical geographers to identify changes in topographic form due to major events, such as volcanic eruptions.



SECTION CONTENTS

BASIC NUMERACY

A: Mathematical Conventions

Symbols

Symbols used in mathematics generally fall into two broad categories: symbols which inform, such as "=", and symbols which instruct, such as "+" and "-", which are also known as operators.

Symbols that "instruct"	Alternate ways of indicating multiplication and division	Symbols that "inform"
+ add - subtract x multiply ÷ divide	*a* multiplied by *b* is the same as *a* x *b* or *a* *b* or *ab* *a* divided by *b* is the same as *a* *b* or *a* / *b* or *a* b^{-1} Under the SI (Systeme International) system *ab*, *a* / *b* , and *a* b^{-1} are the preferred methods for indicating multiplication and division.	= equal to ≠ not equal to ≈ approximately equal to > greater than ≥ greater than or equal to < less than ≤ less than or equal to ~ proportional to

B: The SI System of Units

At the Eleventh General Conference on Weights and Measures of 1960 the metric system (with some modifications) was given the name "International System of Units" and the abbreviation "SI" (for Systeme International). This system has almost universally been accepted as the standard system of measurement for scientific uses. The SI system is based on seven basic units from which a wide variety of other units can be derived.

Basic Units

	SI UNIT	SYMBOL
Length (L)	Meter	M
Mass (M)	Kilogram	Kg
Time (T)	Second	s
Temperature Difference	Kelvin or degrees Celsius	K or °C
Electric Current	Ampere	A
Luminous Intensity	Candela	cd
Amount of Substance	Mole	Mol

Some Commonly-Derived Units

	Dimension	SI Unit
Area	L^2	m^2
Volume	L^3	m^3
Density	$M\ L^{-3}$	$kg\ m^{-3}$
Velocity	$L\ T^{-1}$	$m\ s^{-1}$
Acceleration	$L\ T^{-2}$	$m\ s^{-2}$
Force	$M\ L\ T^{-2}$	$kg\ m\ s^{-2}$ or N (Newton)[a]
Pressure or Stress	$M\ L^{-1}\ T^{-2}$	$kg\ m^{-1}\ s^{-2}$ or Pa (Pascal)[b]
Work or Energy	$M\ L^2\ T^{-2}$	$kg\ m^2\ s^{-2}$ or J (Joule)[c]
Power	$M\ L^2\ T^{-3}$	$kg\ m^2\ s^{-3}$ or W (Watt)[d]
Heat or Energy	$M\ L^2\ T^{-2}$ or Q	J (Joule)[e]
Energy Flux	$Q\ T^{-1}$	$J\ s^{-1}$ or W Energy
Flux Density	$Q\ L^{-2}\ T^{-1}$	$J\ m^{-2}\ s^{-1}$ or $W\ m^{-2}$

[a] 1 Newton is the force required to produce an acceleration of 1 m s^{-2} on a standard 1 kg mass
[b] 1 Pascal is the force of 1 Newton acting on an area of 1 m^2 (N m^{-2}).
[c] 1 Joule is the work done when the application of a force of 1 Newton to a point displaces that point a distance of 1 m in the direction of the force.
[d] 1 Watt is the power required to do 1 Joule of work in 1 second (J s^{-1}).
[e] James Joule (1818 - 1889) demonstrated that it takes about 4.18 units of mechanical energy (Joules) to raise the temperature of 1 g of water 1 k. This is referred to as the mechanical equivalence of heat. Historically heat energy has been expressed in calories (1 calorie = 4.18 J); however modern practice is to use Joules for all forms of energy.

Multiples and Fractions of SI Units

For reasons of convenience and/or convention it is common to use multiples or fractions of the basic SI units. For example using the meter as a unit for expressing long distances is awkward, so its multiple the kilometer (km) is more commonly used, 1 km = 1000 m. Similarly the meter is awkward for describing very small distances so its subdivisions the millimeter (mm) and micrometer (µm) are used, 1 mm = 0.001 m and 1 µm = 0.000001 m. The following table describes prefixes commonly used for expressing multiples and fractions of these metric units.

	Prefix	Scientific Notation	Decimal Notation
P	pico (one trillionth)	10^{-12}	1E-12
N	nano (one billionth)	10^{-9}	0.000000001
µ	micro (one millionth)	10^{-6}	0.000001
M	milli (one thousandth)	10^{-3}	0.001
C	centi (one hundredth)	10^{-2}	0.01
D	deci (one tenth)	10^{-1}	0.1
Da	deca (ten)	10	10
h	hecto (hundred)	102	100

K	kilo (thousand)	103	1000
M	mega (million)	106	1000000
G	giga (billion)	109	1000000000

The "preferred standard form" for expressing SI units is to use a multiplier of 10^{3n} where n is a positive or negative whole number. Terms like centimeter, 10^{-2} m, and decimeter, 10^{-1} m, should be avoided when using the SI system.

It is interesting to note that the basic unit of mass in the SI system is the kilogram (kg) or 1000 grams. This reflects the historical evolution of the SI system from a previous system, the centimeter - gram - second system, in which the gram (g) was the basic unit of mass.

Some Associated Units of Measurement

There are several metric units of measurement that are associated with the SI system. For reasons of convenience or convention these units are commonly used, despite the fact that a SI equivalent exists. Three of these associated units of measurement deserve special mention:

1. The liter (l) is commonly used as a measure of volume, 1 liter is a volume of 10^{-3} m^{-2}.
2. The hectare (ha) is commonly used as a measure of area, 1 hectare is an area of 100 m^2.
3. Degrees Celsius (^oC) are commonly used as a measure of temperature difference.
   As a measure of temperature difference 1^oC is the same as 1 K. For example, the difference between 255 K and 254 K is both 1 K and 1^oC. However, the reference point for these two temperature measurement systems is different. The Kelvin system is referenced to absolute zero, 0K, and the Celsius system is referenced to the freezing point of pure water, 0^oC. As 0K equals -273.15^oC it is easy to convert between the two systems;
   a. to convert from Celsius to Kelvin add 273.15;
   b. to convert from Kelvin to Celsius subtract 273.15.

Converting from Other Non-metric Systems

The SI system is relatively new and although accepted universally by scientists it has not been completely adopted by all countries and all users. Notably, the British or Imperial system is still widely used. The Imperial system uses the familiar units of feet, pounds, miles, acres, gallons, degrees Fahrenheit, etc. Canada has only partially converted over to metric units of measurement and the metric system has yet to be widely used in the United States; consequently it is often necessary to make conversions between the two systems. This is usually a straightforward process of multiplying the measurement to be converted by a conversion factor.

There are two important points to remember when doing conversions:

1. Converting a measurement from one system to another does not change the value of the quantity being measured. For example, 1.00 miles = 5280 feet = 1.61 km = 1610 m. These values all represent the same distance. It would take you the same amount of time to walk 5280 feet as it would to walk 1.61 km.
2. Converting a measurement from one system to another cannot increase the accuracy of the measurement. For example, you have weighed a sack of potatoes using an old fashioned scale. The scale indicates that the potatoes weigh 55 pounds. The conversion factor for pounds to kg is 0.4535. Therefore, 0.4535 kg x 55 pounds = 24.94 kg = 25 kg. When you originally weighed the potatoes you only knew the weight to the nearest pound. If you did not pay attention to the

significant figures the conversion results might suggest that you now know the weight to the nearest milligram. This is an example of a situation where it is very important to be aware of the significant figures.

C: Significant Figures and Orders of Magnitude

Many numbers used in science are the result of measurements and are known only with some experimental uncertainty. The magnitude of the uncertainty depends upon the instrumentation and the skill of the experimenter. It is customary to give an indication of the uncertainty in a measurement by the number of *significant* figures used to express the measurement.

For example, if we measure the length of a table and say that the table is 2.57 m long, we have expressed its length with three significant figures. The last, 7, is referred to as the *doubtful figure*. If we had a more accurate measuring device we might say the table had a length of 2.576 m. In this situation we have expressed the measurement with four significant figures, and 6 is the doubtful figure.

A significant figure is any reliably known digit, excluding zeros, used to locate decimal places. Zero is a significant figure if surrounded by other digits, or if it is specifically indicated as such.

Operations Involving Significant Figures

a) Rounding off a number

Rounding off a number is the process of rejecting (dropping) one or several of its last digits. In rejecting figures, the last figure retained should be increased by one if the figure rejected (dropped) is 5 or greater. The following are examples of numbers been rounded.

Number	Rounded off to:		
	Four figures	Three figures	Two figures
73.589 10,232 329,350	73.59 10,230 329,400	73.6 10,200 329,000	74 10,000 330,000

b) Addition and Subtraction

The number of significant figures of the sum or difference should be rounded off by eliminating any digit resulting from operations on the broken column on the right as shown in the two examples below.

201.3	201.3
+ 1.05	-1.05
+ 21.76	-21.76
+ 0.0013	-0.0013
=224.1113 or 224.1	178.4887 or 178.5

Note that in both the previous examples the correct result has 4 significant figures, even though some of the values being added and subtracted had fewer than 4 significant figures.

c) Multiplication and Division

When multiplying or dividing, the number of significant figures in the result should be no greater than the least number of significant figures in any of the values used. For example, if you were to use your calculator to multiply 3.74567 (6 significant figures) by 110 (2 significant figures) you might get the following result:

$$3.74567 \times 110 = 412.0237 \approx 410$$

The correct result would recognize that the answer should only have 2 significant figures and should be rounded to 410. Note that in this example the last 0 in 110 and 410 is not a significant figure.

d) Squares and Cubes

The number of significant figures of a square or cube of a number N should be rounded off to the number of significant figures of N. For example:

$$2.13^2 = 4.5369 \approx 4.54 \qquad 2.13^3 = 9.6636 \approx 9.66$$

e) Significant Figures and Significant Notation

The following are examples of numbers with three significant figures expressed in both decimal and scientific notation. Note that in the last example the last 0 is a significant figure because it is not used to locate a decimal point.

Decimal Notation	Scientific Notation
2510000.0	2.51×10^6
163	1.63×10^2
1.15	1.15
0.00360	3.60×10^{-3}

f) Some General Comments

A very common error since the advent of the hand held calculator is to carry many more digits than are necessary. This makes the calculations more cumbersome, increases the possibility of errors and gives a false impression of the accuracy of the results. However, overly strict adherence to the convention of significant figures can also be cumbersome and tiresome. A fairly common practice and one that would be appropriate to use for coursework, is to assume that the values you are working with are known to at least three significant figures.

Orders of Magnitude

Occasionally when doing rough calculations and approximations a value may be rounded off to having only one or even no significant figures.

A number rounded off to the nearest power of 10 is called an *order of magnitude*. For example, the diameter of Pluto, the smallest planet in our solar system, is about 3,000 km, and the diameter of Jupiter, the largest planet, is about 100,000 km. One could say that the order of magnitude for planet diameters in our solar system is 10^4 km, implying that most planet diameters fall between 10^3 and 10^5 km.

Table 1 uses orders of magnitude to compare the energy amounts associated with some phenomena. The values are expressed as an order of magnitude fraction of the daily interception of solar energy by the earth, 1.54×10^{16} MJ.

Table 1. Some energy processes expressed as an order of magnitude fraction of the daily interception of solar energy by the earth (From: Sellers, Physical Climatology).

daily interception of solar energy by the earth	1	100
melting of average world winter snowpack	0.1	10^{-1}
strong earthquake	0.01	10^{-2}
average hurricane	0.001	10^{-3}
hydrogen bomb, April 1954	0.0001	10^{-4}
daily output of Hoover dam	0.00000001	10^{-8}
burning of 7,000 tons of coal	0.00000001	10^{-8}
average lightning strike	1E-13	10^{-13}

D: Scientific Notation and Using Powers of 10

Handling very large or very small numbers is simplified by using powers of 10, or *scientific notation*. Using this notation any number in decimal form can be written as a number between 1 and 10 multiplied by a power of 10, such as 10^2 or 10^{-3}. The power of 10 is called the exponent. Typically scientific notation is used only for numbers greater than 999, or less than 0.01.

Assuming that a number is known to 3 significant figures the conventional format for a number expressed in scientific notation would be $X.XX \times 10^n$.

The following are examples of decimal numbers expressed in scientific notation, assuming accuracy of three significant figures.

$10{,}800{,}000 = 1.08 \times 10^7$
$2{,}370 = 2.37 \times 10^3$
$-481{,}000 = -4.81 \times 10^5$
$0.00171 = 1.71 \times 10^{-3}$

The number 10 is the most convenient base for an exponential scale because conversions can be accomplished by simply moving the decimal. Thus:

$120.0 \times 10^3 = 1.2 \times 10^5$
$0.0150 \times 10^5 = 1.50 \times 10^3$
$378.0 \times 10^{-2} = 3.78 \times 10^0$

Calculations Using Powers of Ten

When adding or subtracting numbers expressed in scientific notation, all of the values must be expressed in terms of the same power of ten, as shown in the following two examples.

$(3 \times 10^2) + (4 \times 10^2) = 7 \times 10^2$

$(3.0 \times 10^2) + (1.7 \times 10^3) = (0.3 \times 10^3) + (1.7 \times 10^3) = 2.0 \times 10^3$

or

$(3.0 \times 10^2) + (17 \times 10^2) = 20 \times 10^2$

When multiplying powers of ten, add their exponents; when dividing, subtract the exponents:

$10^n \times 10^m = 10^{n+m}$

$10^n / 10^m = 10^{n-m}$

By convention, the following hold:

$1/10 = 10^{-1}$

$1/10^n = 10^{-n}$

$(10^n)^m = 10^{nxm}$

$10^0 = 1$

INTRODUCTION TO GRAPHING

A. Types of Graphs

- Generally, there are three main types of graphs that will be used in geography courses: **line graphs, bar graphs** and **scatter plots**. A fourth type, the **Population Pyramid**, is human geography courses.

- A **line graph** shows the changes in a continuous variable along a continuum. A continuous variable is assumed to exist at every point along the continuum against that which it is being plotted. For example, a graph might be created showing the change in air temperature over time. Although the actual air temperature measurements might only be made on an hourly basis, we assume that the air also had a temperature during the intervals between the measurements. Thus, air temperature is a continuous variable and the continuum is time. This information is best presented as a **time series graph**. Typically time is indicated along the horizontal axis and the magnitude of the variable being studied is indicated along the vertical axis.

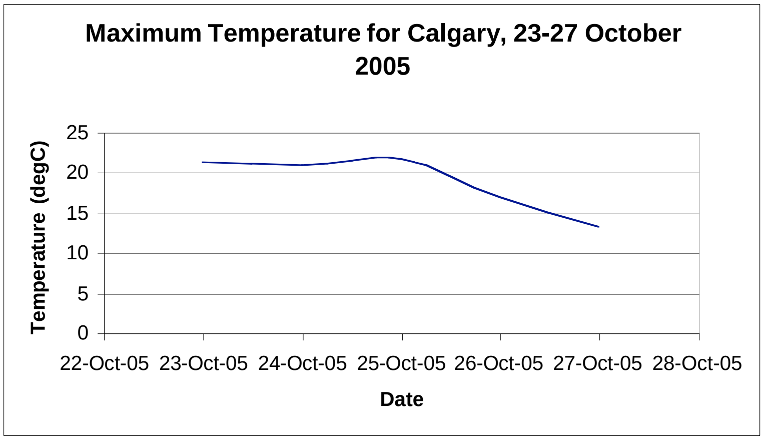


Figure 2: Example of Line Graph

- A **bar graph** is useful for comparing variables or showing changes in variables when the variables are discrete. A discrete variable is one that has been determined or measured so that each measurement of the variable can be assigned to a specific category. For example, rainfall is determined by measuring depth that accumulates in a collection gauge. Typically, these measurements are made at 6 hourly intervals. Every 6 hours the depth in the gauge is measured, recorded, and the gauge is emptied so it is ready to begin collected again. We know how much rain fell between 0-6 hours, 6-12 hours, etc., although we do not know how much rain fell between 9 and 15 hours. The measurement technique has resulted in the variable measurements being assigned into discrete categories of 6-hour periods.

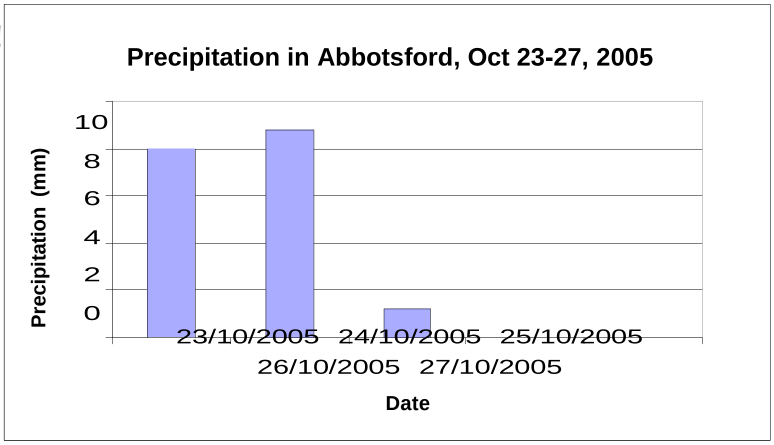


Figure 3: Example of Bar Graph

- A **scatter plot** is useful for identifying if relationships between variables exist (Figure 4). They are often used to compare variables that have no apparent direct connection.

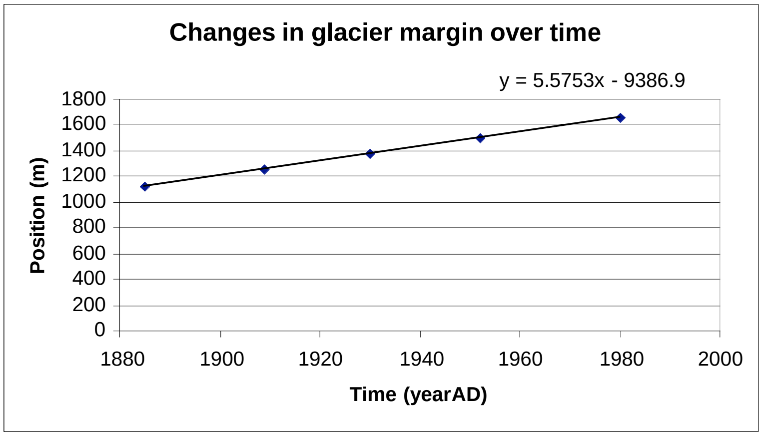


Figure 4: Example of Scatter Plot with trendline and equation shown

- **Population Pyramids** are a type of bar graph used in human geography courses. Population pyramids (Figure 5) are designed to show one specific phenomenon: the distribution, by age and sex, of a population. Unlike conventional bar graphs, population pyramids are 'two-sided', with the bars drawn horizontally along the X-axis, rather than vertically along the Y-axis. The Y-Axis is centered in the graph, rather than located to the right side. Once determining either the total numbers or the percentage of the total population that is made up of males and females in each age group (typically, produced in 5-year increments, beginning with 0-4 years), these values are then charted. Males will **always** be on the left and females will **always** be on the right; this allows for comparison with other population pyramids. When using percentages, the sum of all values plotted should equal 100.

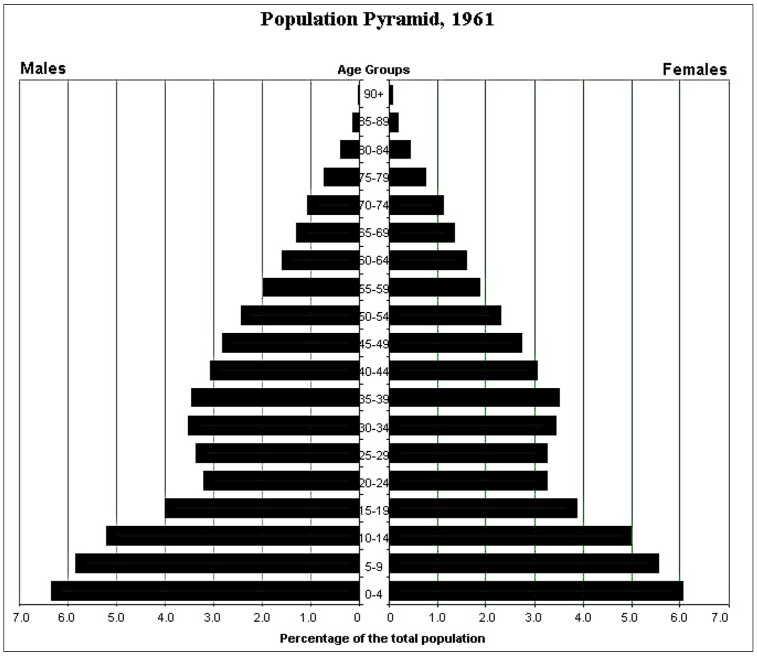


Figure 5: Population pyramid for Canada, 1961 (Govt. of Canada 2008).

While population pyramids can be produced on Excel, your instructor will likely demonstrate how population pyramids are constructed using graphing paper. Each instructor will also specify the format of the population pyramid (e.g. labeling, calculation, etc.).

General Comments

- A graph shows a relationship between two or more variables. It should be neat and legible.
- Use the correct tools. Use proper graph paper (metric is required) and a sharp pencil. Use a ruler when drawing straight lines.
- Print all words and symbols.
- Leave wide margins, unless graph paper already has wide margins.
- Your graph should be large enough to clearly show relationships between variables but does not need to take up the entire page.

The Axes

- It is convention to plot the quantity which you choose to vary (the independent variable—e.g. date and time in Figures 3 and 4) along the horizontal axis and the quantity which results or which you observe (the dependent variable—e.g. precipitation and position in Figures 3 and 4) along the vertical axis.
- The axes do not have to originate at zero.
- Choose axes scales that make both plotting and reading the points easy and make the graph occupy most of the paper.
- Number the major axis divisions from left to right below the horizontal axis and from the base line upward on the left of the vertical axis.
- Name the quantity plotted and the units in which it is expressed along each axis, below the horizontal axis and to the left of the vertical axis.

Plotting the Data

- Plot all the observed data carefully and accurately.
- If the data being plotted is continuous put a smooth line or curve through all data points. If more than 2 variables are being compared you will have to use different forms of lines to distinguish them.
- If you are constructing a bar graph comparing more than two variables, you will have to use different forms of bars to distinguish them.
- If you are creating a scatter plot, put in a **best-fit line** or curve. This is an averaging process. Strive to have as many plotted points above the line as below it.

Legend

- If more than two variables are being compared you will have multiple curves, lines or bars. The legend should clearly indicate to the reader which data series is represented by which line.
- The legend should be labeled “Legend”.
- The legend should not obscure the plotted information.

Title, Notes and Other Labels

- All graphs should have a title. The title should clearly indicate to the reader what variables are being compared, and where and over what time period the data was collected.
- Place the title on the upper part of the graph paper.
- Occasionally, it may be necessary to draw the reader's attention to some specific attribute of the plotted data. This should be done with a neat label and an arrow pointing from the information to the pertinent feature.
- Place your name on the lower right hand corner of the graph.

INTRODUCTION TO GEODESY & TOPOGRAPHIC MAPPING

A. Map Projections

Because the Earth is a sphere, **distortion** occurs when it is projected onto a flat piece of paper (map). A globe is the best representation of the earth's surface because there is no distortion of areas, shapes or angles. For maps, a cartographer selects the type of map projection (distortion) depending on the map's purpose. **Equal area** map projections preserve the property of equal area but distort shapes and angles between meridians (lines of longitude) and parallels (lines of latitude). Examples of equal area projections include sinusoidal projections and Albers projections (used often for US maps). **Conformal** projections preserve shape and angle but distort area. Examples of this type of projections include Mercator and the Lambert conic projections. Some large-scale maps (1:50,000)—which show a smaller area of land—preserve neither angle nor area but the distortion is minimal because such a small surface area is represented.

Most maps used in our geography classes are ***Transverse* Mercator** projections that preserve shape and direction at the expense of area. (Actually they are Universal Transverse Mercator, or UTM, projections). On a world map, notice how Greenland often appears larger than South America. This is the effect of a conformal projection like the Mercator. Large countries (like Canada) often use the UTM projection as it best represents the country with the least distortion. The Transverse Mercator projection system operates somewhat like rectangular grid system. First, the world is 'divided' into strips that are oriented north to south (vertically on the map below), and numbered from 1 to 60 starting at 180° EW (the International Date Line). Each strip is then further divided into 20 zones (each approx. 8° of latitude) spanning east to west and given letters (Figure 6). Canada is covered by strips **7 to 22** and zones **U to X** (Figure 7; Government of Canada 2006). If a person was looking for maps of southern British Columbia that were created using UTM projections, then they would look for grid zone **10U**.

The UTM grid used on topographic maps is a measure of actual distance (metres) from a fixed point. Grid lines are the standard measurement tool when using UTM maps (seen as a blue grid on 1:50,000 maps). Vertical (north-south oriented) lines on UTM maps run parallel to the central meridian of a particular zone and are referred to as **eastings**. (See Figure 8.) The central meridian of a given zone has the location 500,000mE. Locations to the west of this line will have a lower value, while locations to the east will have a larger value. Note that every UTM zone uses this numbering system. Horizontal (east-west oriented)

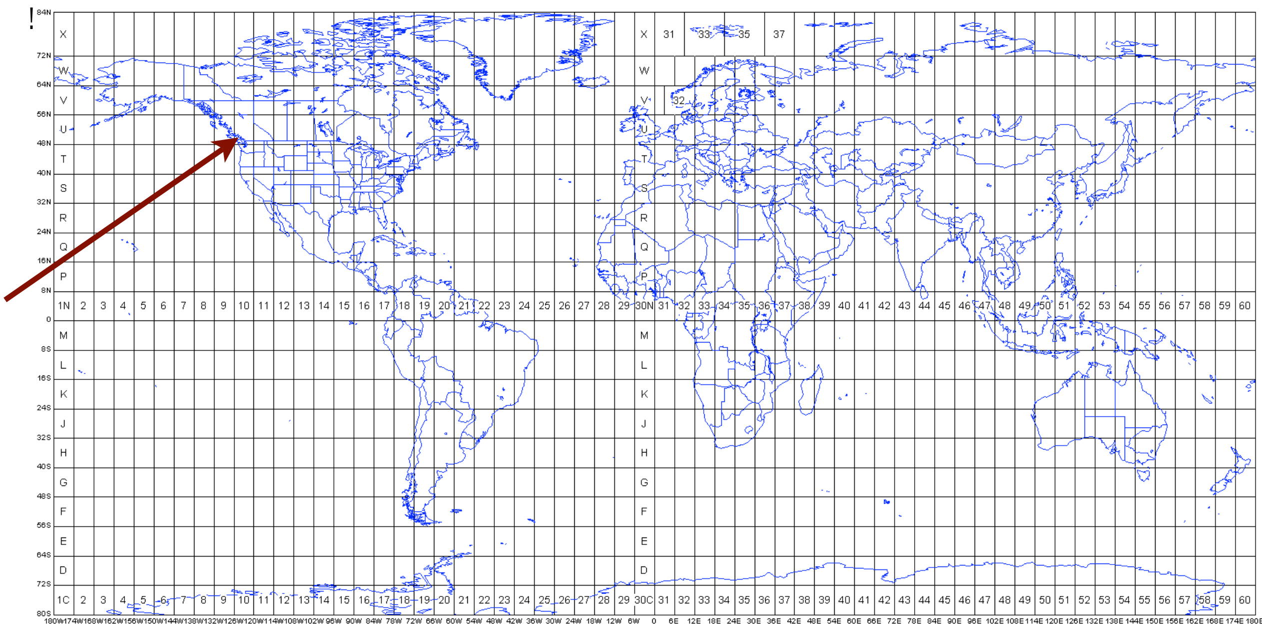


Figure 6: **UTM Grid Designations** (Morton 2006; http://www.dmap.co.uk/utmworld.htm). The arrows point to Southwest BC's UTM grid zone, 10U.

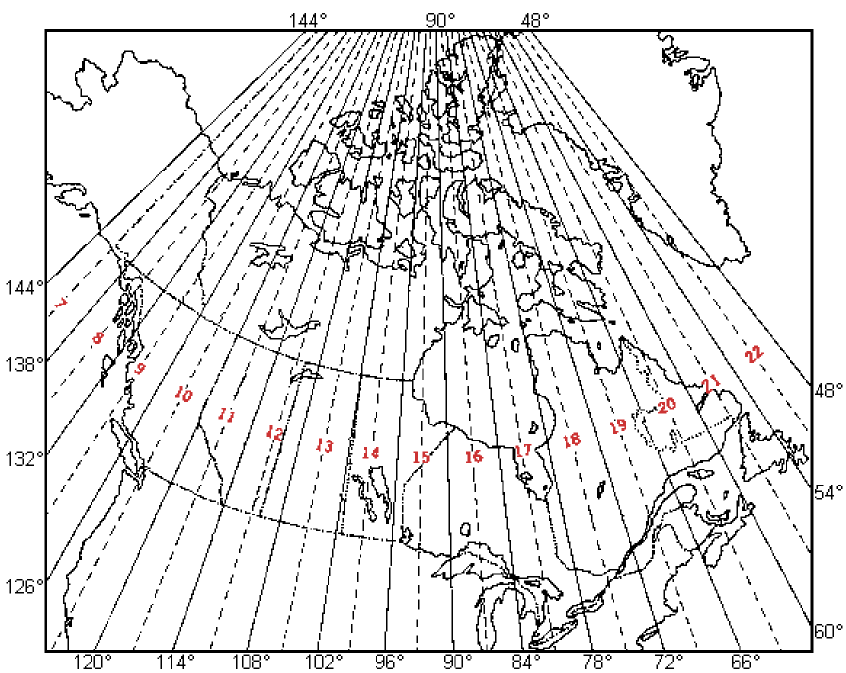


Figure 7: UTM Zones in Canada, © 2006. Produced under licence from Her Majesty the Queen in Right of Canada, with permission of Natural Resources Canada. (Image can be found at: http://maps.nrcan.gc.ca/topo101/)

lines on UTM maps run parallel to the equator and are known as **northings**. Note that the lines representing northings and parallels of latitude are NOT in parallel due to map distortion. Northings represent the distance to a location from the equator and are unique to a particular point. (See Figure 3).

The basic grid lines representing eastings and northings are 100,000m (100km or 62 miles) apart. This system is then subdivided into 10,000m, 1000m or 100m grids based on the map scale. For example, 1:50,000 maps show a 1000m grid. When using UTM coordinates it is important to give the grid zone designation (eg. 10UEK) as the coordinates are not unique to individual areas. See *Section D: Absolute Location* below for information on obtaining UTM coordinates.

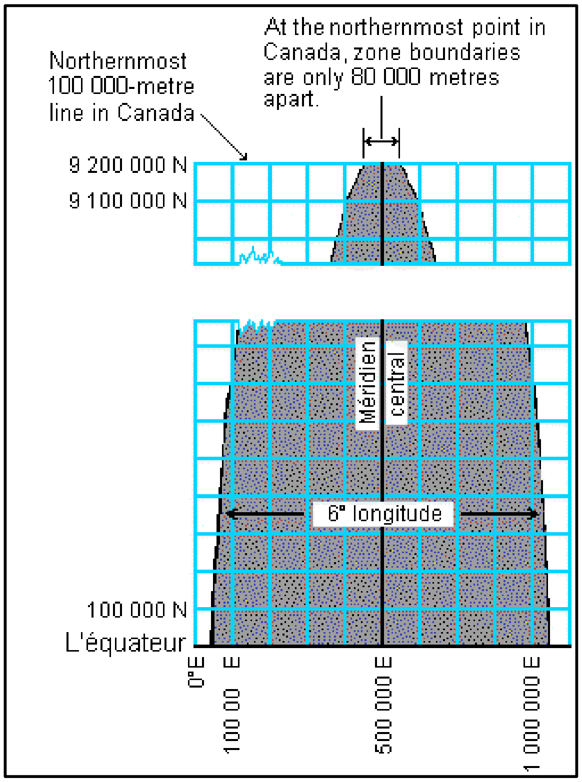


Figure 8: Division of UTM strip into 100,000m grid, © 2006. Produced under licence from Her Majesty the Queen in Right of Canada, with permission of Natural Resources Canada. (Image can be found at*:* http://maps.nrcan.gc.ca)

B. Topographic Maps

A topographic map is a paper representation of the features of a portion of the Earth's surface, drawn to scale. Topographic maps depict detailed relief, drainage patterns, roads, settlements, woodland and many economic features of the land surface. See *Section G: Interpreting Topographic Maps*.

Canadian National Topographic System

Canada has been systematically mapped since 1923 when several federal agencies involved in mapping were brought together under the Board of Topographical Surveys and Maps. It was not until 1946, however, that a standard projection, the Universal Transverse Mercator projection was adopted. Scales chosen for Canada's topographic maps vary from small scale, 1:1,000,000, to large scale, 1:25,000. Canada is divided into 117 quadrangles that are produced as 1:1,000,000 map sheets. The Canadian National Topographic System can be explained as follows (Figure 9):

74 A primary quadrangle at a scale of 1:1,000,000. Almost all of Canada is mapped at this small scale. Sheet 92 covers the SW British Columbia mainland and Vancouver Island.

74SE A sheet of the 1:500,000 series. All of Canada is covered at this medium scale. Map sheet 92SE covers SE Vancouver Island eastward to Princeton.

74D A sheet of the 1:250,000 series; 918 sheets cover the whole of Canada. Map sheet 92G, for example, shows Nanaimo eastwards to Chilliwack and north to Garibaldi.

74D/NE A sheet of the 1:125,000 series. This medium scale was originally intended to cover areas of interest to the tourist and hunter. Only three map sheets are available in western Canada.

74D/1 A sheet of the 1:50,000 series. All settled areas of Canada, as well as locations of economic importance, are covered at this large scale. Map sheet 92G/2 covers New Westminster, Surrey, Langley and White Rock areas.

74D/1a A sheet at 1:25,000 scale. These large-scale maps were only produced for densely-settled areas. Map sheet 92G/2f covers North Surrey.

A topographic map shows landforms with **contour lines –** lines that connect equal elevation (above mean sea level). Topographic maps show a three-dimensional surface in two dimensions. In order to visualize three-dimensional landforms, you will have to practice reading and working with maps of different scales. The most common map you will use in your geography experiences is the 1:50,000 topographic map.

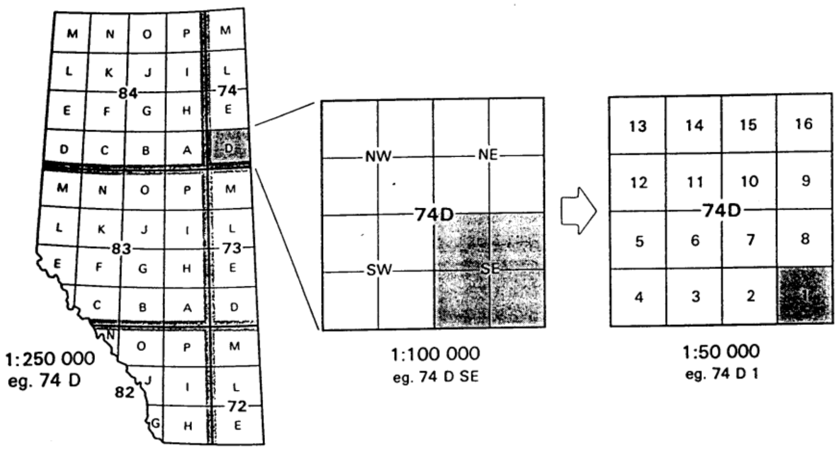


Figure 9: Canadian National Topographic System Grid Reference - Alberta example

C. Map Scales

The scale of a particular map should be printed in the margin of the every map. **Map scales** are used to show the relationship between the distance on the map and the actual ground distance that the map represents. Map scales are usually given as **representative fraction scales** or **ratio scales** (1:100,000 on Figure 10), **graphic scales**, or as **verbal scales**. Each of these map scales is shown on Figure 9.

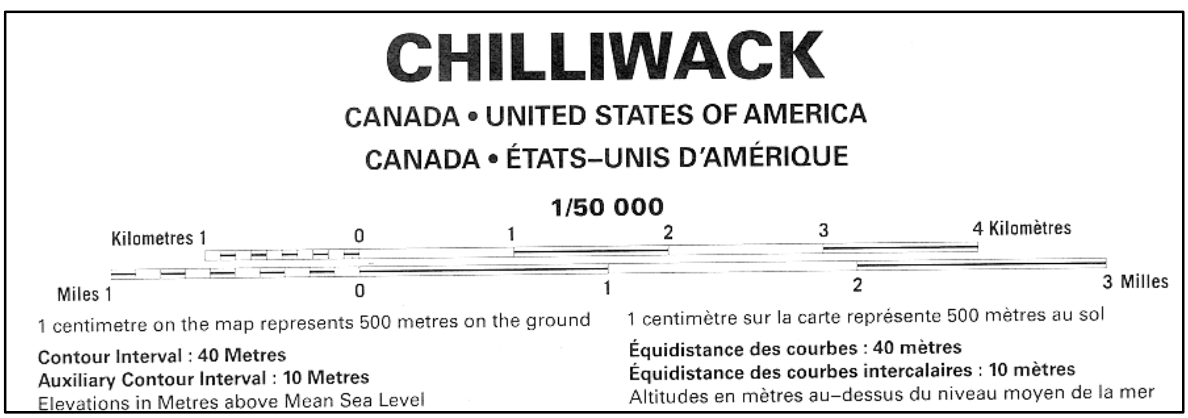


Figure 10: Portion of the margin from the Chilliwack Lake topographic map (92H/4) showing the scale and contour interval © 1992. Produced under licence from Her Majesty the Queen in Right of Canada, with permission of Natural Resources Canada.

A **graphic scale**, or **linear scale**, displays a length of line divided into numbered segments. The graphic scales in Figure 9 present distances in kilometres as well as miles.

A **representative fraction scale (RF scale)** is dimensionless (it has no units of measurement attached) and indicates the relationship between map distance and ground distance as a fraction or ratio. This means that on a map, a given unit of measure (centimetre, inch, etc.) represents some number of the same units of measure on the ground. Conversion to equivalent ratios of centimetres to kilometres is left to the map-reader to compute.

A 1:50,000-map scale (shown in Figure 9 as 1/50,000) would indicate that one unit measured on the map would be equivalent to 50,000 of the same units measured on the ground. Therefore, if one centimetre were measured on a 1:50,000 map, it would represent 50,000 cm, or 500 metres (500 m = 50,000 cm), on the ground (real-life distance).

A **verbal scale** uses the written word to convey the information. Therefore, a RF scale of 1:50,000 (or 1/50,000) would be written as "1 centimetre on the map represents 500 metres on the ground" as verbal scale. Keep in mind that meaningful units must be used; i.e. 50,000 centimetres does not mean much to most people; however, 500 metres does. Since there are 63,360 inches in one mile, a verbal scale of "I inch represents 1 mile" would be expressed as 1:63360 or 1/63360 as a RF.

Table 2: Symbols and Equivalents for Metric Distances

Symbol	Unit	Equivalents			
mm	millimetre	10 mm =	1 cm	1 cm =10 mm	1000 mm =1 m
cm	centimetre	10 cm =	1 dm	1 cm =1 cm	100 cm =1 m
dm	decimetre	10 dm =	1 m	1 cm =0.1 dm	10 dm =1 m
m	metre	10 m =	1 Dm	1 cm =0.01 m	1 m =1 m
Dm	decametre	10 Dm =	1 hm	1 cm =0.001 Dm	0.1 Dm =1 m
hm	hectometre	10 hm =	1 km	1 cm =0.0001 hm	0.01 hm =1 m
km	kilometre	1000 m =	1 km	1 cm =0.00001 km	0.001 km =1 m

Reading down the columns, the units get larger.

Converting a Representative Fraction (RF) scale to a Verbal Scale

Example 1: Restate 1:250,000 as a verbal scale.

A verbal scale of "1 cm represents 250,000 cm" is unacceptable in that no one can visualize 250,000 cm. The centimetre-value must be reduced to a larger unit—metres or kilometres. In order to produce a ground distance in kilometres, divide 250,000 centimetres by 100,000 (because there are 100,000 centimetres in one kilometre).

Therefore, the verbal scale would be:

One centimetre on the map represents 2.5 km on the ground

Converting a Verbal Scale to a RF scale

How can the scale '1 cm represents 1 km" be written as a representative fraction? Following the general rule, write the information as follows:

$$\frac{\text{Map Distance}}{\text{Ground Distance}} \quad \text{so that} \quad \frac{\text{1 cm on the map}}{\text{1 km on the ground}}$$

However, both the numerator and denominator must be in the same units, therefore, convert the denominator to cm by multiplying by 100,000 cm/1km.

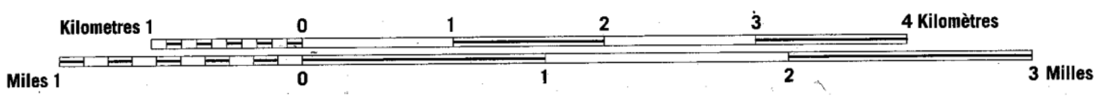
$$\frac{\text{1 cm on the map}}{\text{100,000 cm on the ground}}$$

Similar units in the numerator and denominator cancel each other, leaving the representative fraction:

$$\frac{1}{100000} \quad \text{or} \quad 1{:}100{,}000$$

Converting from a Graphic Scale to a RF scale

Given the graphic scale shown below, determine the fractional scale.



The solution to this problem requires a metric ruler. To minimise error, measure the exact length of the entire graphic scale. Record your results in the following form:

$$\frac{\text{(measured map distance)}}{\text{(ground distance)}} \quad \text{so that} \quad \frac{\text{10 cm}}{\text{5 km}}$$

Convert ‘5 km’ to centimetres by multiplying by 100,000 cm/1km (remember there are 100,000 cm in one km), then reduce to a simple fraction:

$$\frac{\text{10 cm on the map}}{\text{500,000 cm on the ground}}$$

The units in the numerator and denominator must be the same in order to cancel out and produce a representative fraction scale:

$$\frac{1}{100000} \quad \text{or} \quad 1{:}100{,}000$$

When using scale it is important to use the same units in your calculations. By converting everything to centimeters or meters, you will avoid simple errors. You should be comfortable converting between all parts of the metric scale.

Millimeters to centimeters	Multiply by 10
Centimeters to meters	Multiply by 100
Meters to kilometers	Multiply by 1000

Using scale to calculate distances

If the map scale is 1:50,000 and the map distance is 10cm, then the ground distance can be calculated as follows:

$$\text{Map scale (RF)} = \frac{\text{(measured map distance)}}{\text{(ground distance)}}$$

$$\frac{1}{50000} = \frac{10\text{cm}}{\text{(ground distance)}}$$

Using simple cross-multiplication, we can determine that:

$$1 * \text{ground distance} = 10\text{cm} * 50{,}000\text{cm}$$

Therefore:

$$\text{Ground distance (cm)} = 500{,}000\text{cm (or 5 km)}$$

D. ABSOLUTE LOCATION: THE LOCATION OF PLACES ON A MAP

In Canada, four systems are commonly used to locate places:

1. Latitude and Longitude coordinate system
2. Universal Transverse Mercator (civilian UTM) system
3. Military Grid system
4. Township and Range system

1. Latitude and Longitude

A spherical geographic reference grid of *parallels of latitude* (which are equally spaced lines running in an east-west directions, parallel to the equator) and *meridians of longitude* (which run north-south, converging at the poles) circle the globe (Figure 11).

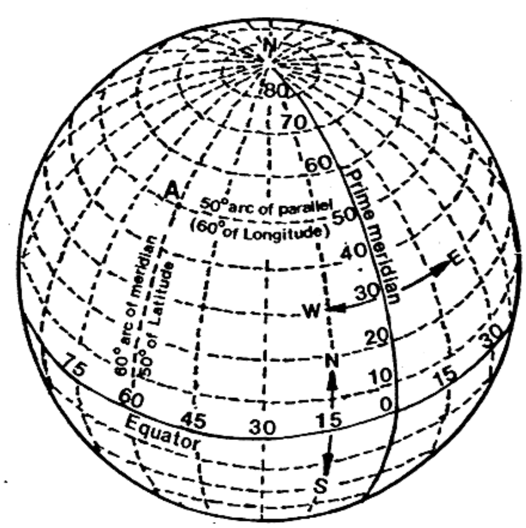


Figure 11: Latitude and Longitude

a) Parallels of Latitude

You should know that:

1. Latitude is the angular distance north and south of the equator—and is numbered 0°NS (e.g. 62°S);
2. A parallel of latitude is an imaginary line drawn around the Earth parallel to the equator and at

constant angular distance from it;
3. The equator is the only line of latitude which is a great circle (a great circle passes entirely around the globe and its centre coincides with the centre of the Earth); and,
4. All parallels of latitude are small circles drawn around the Earth - parallel to the equator.

b) Meridians of Longitude

You should know that:

1. Longitude is distance measured east and west of the Meridian Greenwich—the Prime Meridian—and is numbered 0°EW (e.g. 141°W);
2. Each meridian is exactly half a great circle with its end points at the North and South Poles;
3. Meridians are NOT parallel to one another: they are spaced farthest apart at the equator and converge northward and southward to meet at the poles; and,
4. Meridians always intersect parallels at 90° angles.

All references using latitude and longitude are relative to two lines, the equator (for latitude, 0°NS) and the prime meridian (for longitude, 0°EW). Latitude is used to measure the angular distance (degrees) from the centre of the Earth, north or south of the equator. It ranges from 0° at the equator to 90° north or south at the poles. If the Earth were a perfect sphere, the length of 1° of latitude (a one-degree arc of a meridian) would be a constant value everywhere on the Earth. However, since the Earth is slightly compressed at the poles and slightly bulged at the equator, a degree of latitude changes slightly in length from equator to poles. The length of 1° of latitude at the equator is 110.6 km; at the poles it is 111.7 km.

The longitude of a site is the arc (in degrees) of a parallel between the site and the prime meridian, also known as the Greenwich meridian, which has a value of 0° longitude. Longitude is the measure east or west of the prime meridian, whichever is the shorter arc, and values range from 0 to 180° (east or west).

Point A in Figure 10 above is at 50°N, 60°W. To be more precise, we also use minutes and seconds when specifying locations. In one degree there are sixty minutes and in one minute there are sixty seconds.

The relationship between degrees, minutes and seconds is as follows:

1 degree = 60 minutes [1° = 60‘]
1 minute = 60 seconds [1’ = 60”]
1 degree = 3600 seconds [1° = 3600‘]

To determine the latitude and longitude of a position on a **topographic map**, simply follow the procedure detailed below (Figure 12). The process is different if using a map in an **atlas**. Check with your instructor if this is the case.

1. Determine which hemispheres the map is located in: north or south for latitude and east or west of longitude. Canada is always north and west.

2. If using a topographic map, use the white and black bars around the border to determine the latitude and longitude. Begin by identifying the coordinates listed at the bottom-left corner.

3. Determine how many minutes each bar represents; on a 1:50,000 map each bar represents one minute.

4. Locate the feature on the map.

Mike Lake

- 49°16’24”N, 122°32’25”W
- Zone 10 533500mE 5457950mN
- PH 335578

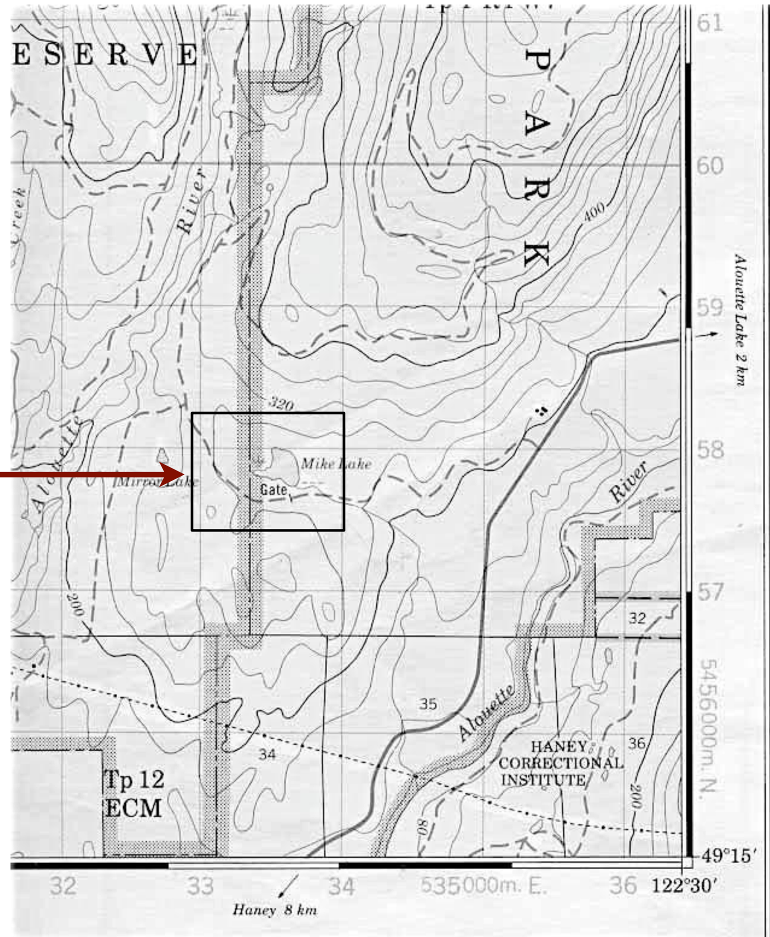


Figure 12: Coordinates for Mike Lake, Port Coquitlam map sheet 92G/*7*, © 1992. Produced under licence from Her Majesty the Queen in Right of Canada, with permission of Natural Resources Canada.

5. Determine the latitude of the feature by identifying the number of degrees and counting the number of full black and white bars to determine the number of minutes. On Figure 12, Mike Lake is located at 49°16’N. To determine the number of seconds to the feature, measure the distance (in mm) from the start of the relevant bar to the point. Using algebra, convert this to seconds as follows:

$$\frac{\text{Distance representing 1' (mm)}}{\text{60secs}} = \frac{\text{Measured distance to location (mm)}}{\text{X seconds}}$$

$$\frac{\text{37mm}}{\text{60 secs}} = \frac{\text{15mm}}{\text{X seconds}}$$

Then using simple cross-multiplication, we can solve for the unknown seconds:

$$37\text{mm} * X \text{ secs} = 15\text{mm} * 60 \text{ secs}$$

Therefore,

$$X \text{ secs} = \frac{15\text{mm} * 60 \text{ secs}}{37 \text{ mm}}$$

Therefore,

$$X \text{ secs} = 24 \text{ secs}$$

6. Therefore, the latitude of Mike Lake is 49°16’24”N.

7. Follow step 4 to determine the longitude of the feature but remember to measure the distance represented by 1 minute of longitude as it is different from latitude.

8. The full latitude and longitude coordinates for Mike Lake are 49°16’24”N, 122°32’25”W. Latitude is always listed before longitude.

2. Civilian Grid Reference System (full UTM coordinate system)

As discussed in *Section A: Map Projections*, transferring a spherical Earth onto a flat map involves distortion, and the Universal Transverse Mercator projection is one solution to the problem. To determine the UTM coordinates for a feature, use the blue grid on the map and follow these steps (Figures 12, 13):

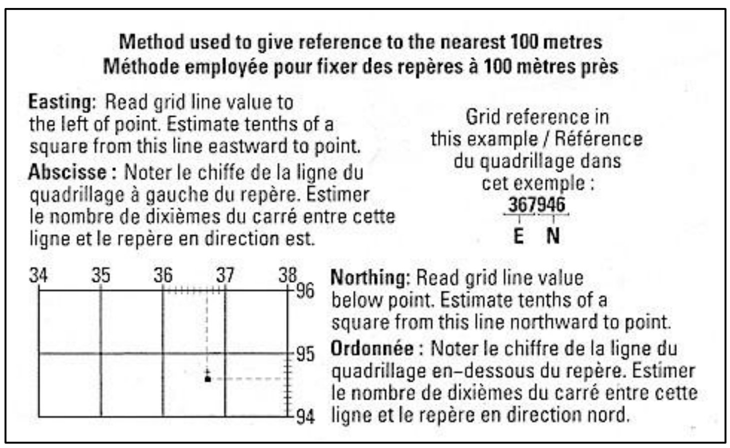


Figure 13: Estimating coordinates to nearest 100 meters, © 1992. Produced under licence from Her Majesty the Queen in Right of Canada, with permission of Natural Resources Canada.

1. Determine the grid zone designation for the map (SW British Columbia is in Zone 10).
2. Identify the feature of interest.
3. Determine the eastings (horizontal coordinate) for the feature, reading from left to right along the bottom axis. REMEMBER to use the blue grid. Identify the grid square that contains the feature. Mike Lake is in square 533. This means that is between 533000mE and 534000mE.
4. Estimate the tenths of a square to the feature’s position. Mike Lake is 500m east of 533000mE. Therefore the full easting coordinate is Zone 10, 533500mE.
5. Follow the procedure to determine the northing component of the coordinate.
6. The complete UTM coordinate for Mike Lake is Zone 10, 533500mE 5457950mN.

3. Military Grid System (modified Universal Transverse Mercator)

This system is based on the Universal Transverse Mercator system and is commonly used by the Canadian military. It also uses the blue grid superimposed on 1:50,000 map sheets but is a simplified system. It is very important to provide the grid zone designation system when giving coordinates as they are repeated every 100km (Figures 12, 13). Follow the procedure below for determining location under a military grid system:

1. Identify the UTM grid zone information on the topographic map alongside the UTM zone information (often shown in blue text). Use the last 2 letters as the start of your coordinate (e.g, PH). If there is ambiguity as to your location, then the full UTM designation as found on the map should be used (10U PH). See *Section A* and *Section D.2* for more information on UTM grid zones.
2. First determine the eastings coordinate by reading across the base of the map from left to right, and finding the square containing the required point (e.g., Mike Lake is in square 33).
3. Then dividing the square into tenths (Figure 13), determine the distance from the square edge to the required point (e.g., Mike Lake is 5/10 of the way across square 33. Therefore the full easting coordinate is 335.
4. Repeat the procedure for the northings reading from bottom to top against the left hand edge of the map (Mill Lake is at 578).
5. The full military grid coordinate for Mill Lake is: PH335578 (or 10UPH335578 if necessary).

4. Township-Range

The Township-Range survey system (otherwise known as the Public Land Survey System in the US and the Dominion Land System in Canada) operates somewhat independently of the above types of map location systems. For one, it uses imperial (e.g. feet and inches) measurement rather than metric. Second, it is only used in North America. Third, its primary purpose was to aid settlement in central, western, and northwestern North America, and it was never intended as a system of universal measurement. However, the township-range survey system is based upon astronomical measurements of latitude and longitude.

Beginning in the 1780s in the US, and the 1870s in Canada, Township-Range was the primary survey system used to divide and allocate public lands in as of yet undeveloped areas. This includes most of the US lands west of the Appalachian Mountains, excluding Texas and Hawaii, and most of western Canada. It does not include northern or eastern Canada, or most areas east of the Appalachians in the US. The reasons for this are simple. Most eastern areas were already settled by the time Township-Range was developed. Texas eventually adopted a blended system, based on pre-existing Spanish survey systems and township-range; Hawaii also used an older, pre-colonial system.

While physical geographers do not often use Township-Range, human geographers, as well as ranchers, farmers, recreationalists, hunters, and real estate purchasers do. Thus, it is important to understand the basics of Township-Range should you yourself buy property, hunt, fish, or hike in areas with unmarked but privately-owned property, or if you should study the settlement geography and landscape development of the North American West.

Township-Range is a relatively simple grid system to understand. In a nutshell, lands that were to be settled were divided into **townships** of 36 square miles (6 by 6 miles) each. Each township was then further divided into **sections** of 1 square mile—or 640 acres—each. Each section was than divided into half-sections—of 320 acres—and quarter-sections of 160 acres. These half- and quarter-sections were further divided to meet the needs of settlement in a particular area.

Surveyors would begin their survey at the **initial point**, or junction, of a **baseline** and a **principle meridian**. A baseline was an east-west line that spanned the length of a territory, state, or province, while the principle meridian was a north-south line. Because the lands being surveyed were sparsely settled (by European settlers), if at all, the lands were usually part of a territory (state/ provincial designation came later). In Canada, the principal baseline is 49°N, while in the US, the baseline for each state was usually a significant line of latitude. Often, a baseline or meridian would become the boundary between two provinces or states.

- In Canada, new baselines were drawn approximately 24 miles north of the previous base line. In the US, new lines, called *standard parallels*, were also drawn at an approximate 24-30 mile interval. These new lines would be used to make corrections in measurements (required, as the meridians converge toward the poles, therefore creating a ‘narrowing’ of the townships toward the north).
- In Canada, seven principal meridians were surveyed. Lands are given a notation based on which meridian they fall to the west of. For example, W3 means west of the third principal meridian (western Saskatchewan). Only lands falling east of the first principal meridian are given an E notation.

Starting at the junction of the baseline and principle meridian, surveyors would work outward, measuring and marking townships.

- In the US, townships would be numbered according to their position north *and south* of the baseline and east and west of the principal meridian (Figure 14).
- In Canada, townships were only measured north of the baseline and usually only west of the principal meridian (except in eastern Manitoba). They were numbered beginning at the Canada-US border, from 1 to 129 (Figure 14). Ranges were numbered from 1 to 35. (At this point, a new meridian was surveyed.)

Township notation (T) is used to denote land division north and south, while *Range* (R) is used to denote land division east and west. Thus, T3S is three townships south of the baseline, while R4E would indicate the fourth township east of the principal meridian. Township-Range notation in this case would read T3S, R4E (Figure 14a).

	T3N R1W				
	T2N R1W				
R2W	T1N R1W	T1N R1E	T1N R2E	T1N R3E	T1N R4E
	T1S R1W				
	T2S R1W				
	T3S R1W				

Figure 14a: Section T3S, R4E, under the Township-Range survey—US Public Lands Survey

Correct Notation Format--Canadian and US differences

The US and Canadian systems differ somewhat in their township and range notation. Because the Canadian survey began at the Canada-US border and moved *north*, there is no need to include the “N” notation for North in a Canadian township and range location. Second, because each survey generally only measured to the *west* of a principal meridian, there is no need to include the “W” notation.

Canadian Township and Range notation:
T15, R32

U.S. Township and Range notation:
T15N, R32W

The following notation would be an American notation:

T22S, R13E

Why? Because the location is *south* of the base line, and *east* of the principal meridian. Canadian surveyors measured to the north and west.

Sections

Each township is further subdivided into 36 sections of one square mile each (Figures 14b and 15).

- In Canada, these 36 sections are numbered beginning in the lower right-hand corner (Figure 15, next page).
- In the US, sections are numbered from the upper right-hand corner (Figure 14b).
- Section 11 of each Canadian township and Section 16 of each US township was given over to the building of schools. Other sections were granted to railways in exchange for or to offset or compensate for construction costs.

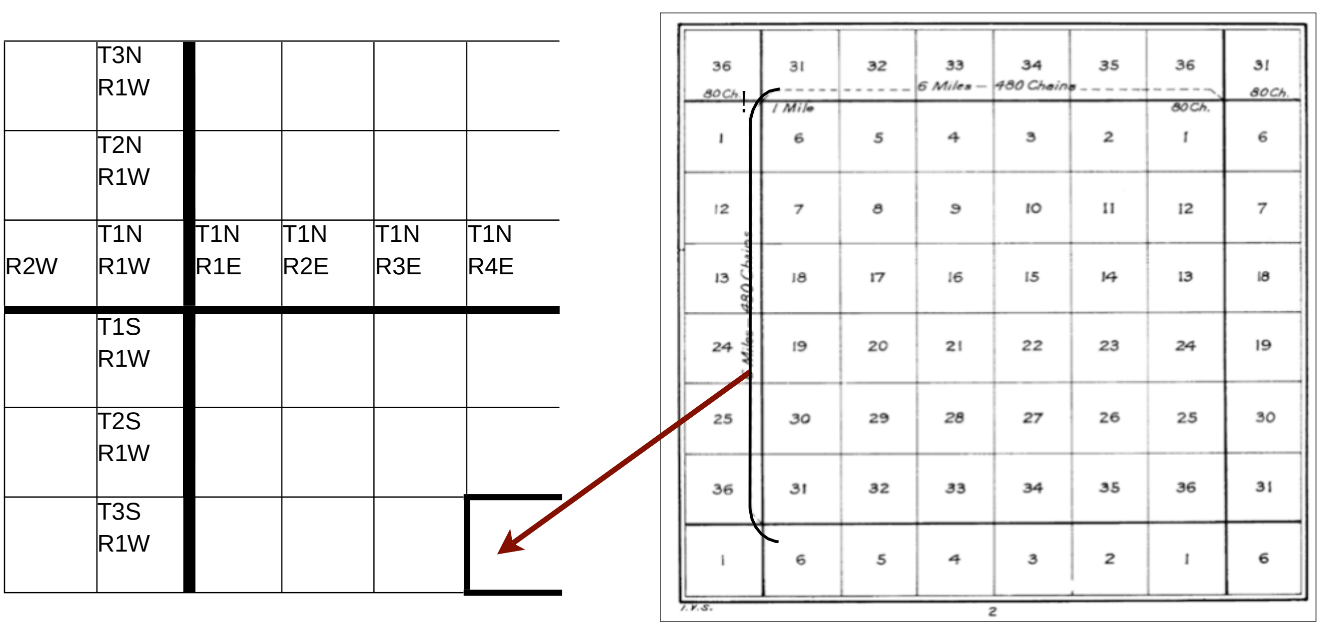


Figure 14a and 14b: Section T3S, R4E, and subsequent section division, under the Township-Range survey—US Public Lands Survey

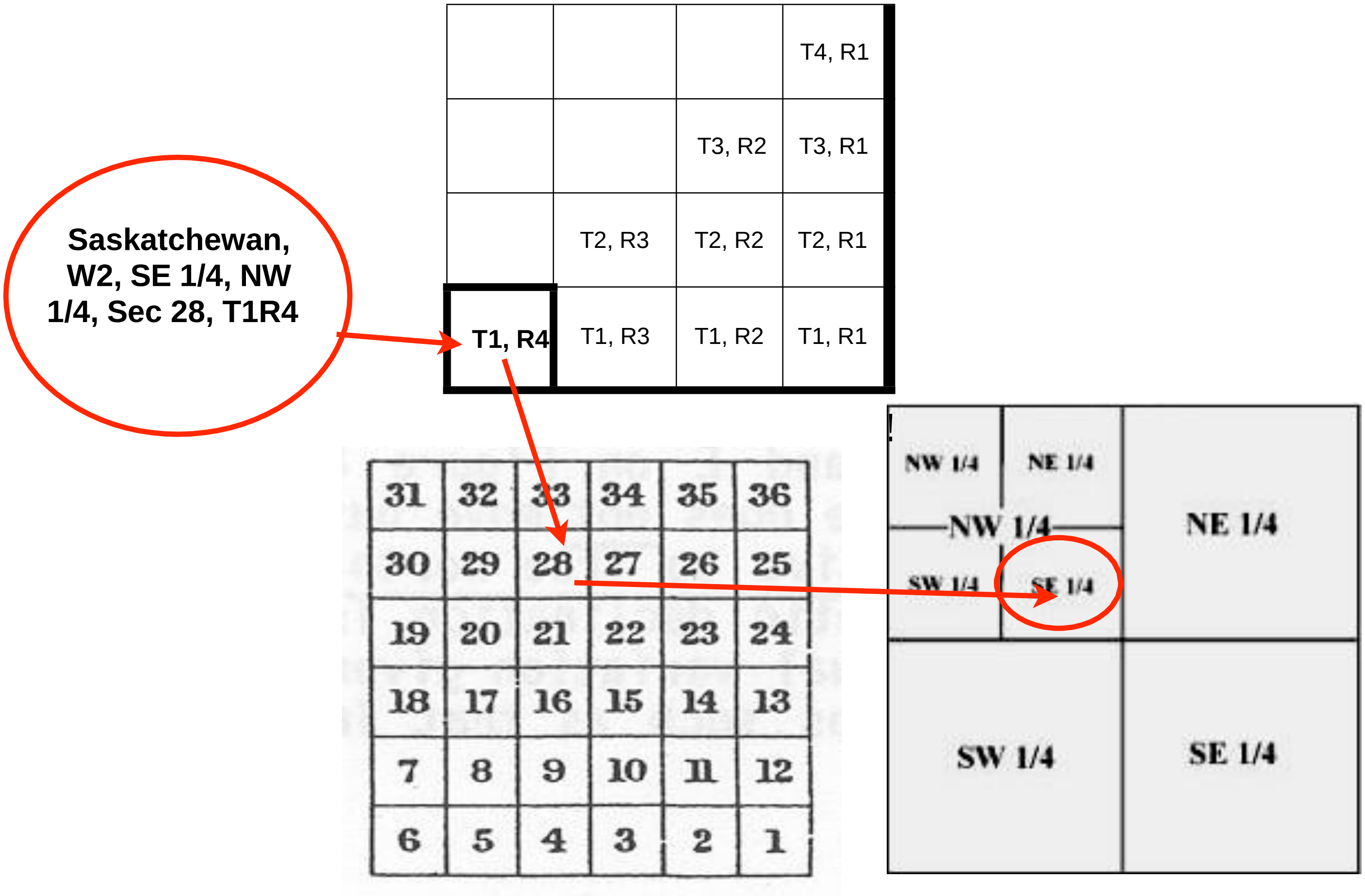


Figure 15: Township-Range and section location and numbering—Dominion Land Survey, Canada. W2 refers to those townships west of the second (principal) meridian. This location would be found in far SE Saskatchewan.

Individual sections were further divided to accommodate settlement. Initially, lands were divided into quarter and half-sections, but as populations became more densely settled in many areas, further divisions would be made (see Figure 15). Division can take place multiple times. Thus, it would not be unrealistic to see the following location notation:

Alberta, W4, SW, NW, NE, SW, SE, Sec. 22, T34R16

In other words…

The SW 1/4 of the NW 1/4 of the NE 1/4 of the SW 1/4 of the SE 1/4 of Section 22, of Township 34 N, Range 16 W, West of the Fourth Principal Meridian in Alberta

(Phew!)

Can you figure out how large a parcel this is? (Hint—one section is 640 acres; begin your division from this. See the answer at the end of this section.) If it sounds a bit unwieldy, it is, but it was and is a simple to understand system of both land division and map reading.

On **US** topographic maps, Township-Range is shown. Section lines are red, and cross the map, and Township-Range numbers are found on the margin. Such notation is not found on newer Canadian topographic maps.

This system can be used to measure **rough distance**. Because each township is 6x6 miles, and each section 1-mile square, one can estimate how far south, north, east, or west of the baseline or prime meridian one is by counting townships and sections.

Human geographers and history students will at some point encounter Township-Range, particularly if their interests involve rural and/or Prairie settlement. Travelers too often encounter Township-Range without realizing it. Do you ever wonder why roads in rural areas suddenly take a 90° turn? It is because they follow township lines. Look at a road map at Alberta to see this over a large area. And if you were buying the parcel notated above?

By the way, did you figure out the size of the parcel located at Alberta, W4, SW, NW, NE, SW, SE, Sec. 22, T34R16? Remember, prior to subdivision, Section 22 was 640 acres. It was subsequently subdivided five more times. (The “W4” notation is not a subdivision; it indicates that this area is west of the fourth principal meridian in Alberta.) The parcel is .625 of an acre--or roughly the size of a lot found in a lower density residential area in a suburb.

E. Directions

True North, Grid North, and Magnetic North

True North is the cartographic direction of the North Pole, the point where the meridians of longitude converge to a single point. True North is NOT the same as Magnetic North and compasses do not point to True North.

Magnetic North is determined by the alignment of the Earth's magnetic field. The Earth acts like a bar magnet and it is believed that the circulation of magma in the Earth’s molten outer core produces the effect. The strength and alignment of this magnetic field have fluctuated throughout geologic time. An important effect of the magnetic field is that a freely swinging magnet on the Earth's surface will align itself with the magnetic field. This is the basis of the compass.

The compass consists of a freely swinging magnet (needle) suspended over a card upon which the points of a compass are labelled. An important concept to understand when using a compass is that the compass needle points to Magnetic North, the point on the Earth's surface that attracts the compass needle.

Grid north is determined by the alignment of the military grid system on a map. Usually it is only slightly different than True North.

Magnetic Declination

Remember that the magnetic poles do not coincide with the true poles of the Earth's rotational axis. To further complicate the situation, the magnetic poles 'wander'. Fortunately, polar wandering can be predicted reasonably well. Currently, the north magnetic pole is located near Prince of Wales Island in the Canadian Arctic.

To use a magnetic compass in Canada you must be aware of the difference between True North (geographic) and Magnetic North. Figure 16 shows the relationship between True North (T.M.) north on the grid system and Magnetic North, as shown on a topographic map. The angle between True North and Magnetic North is called **the magnetic declination** or angle of declination, and it may be to the east or the west of True North.

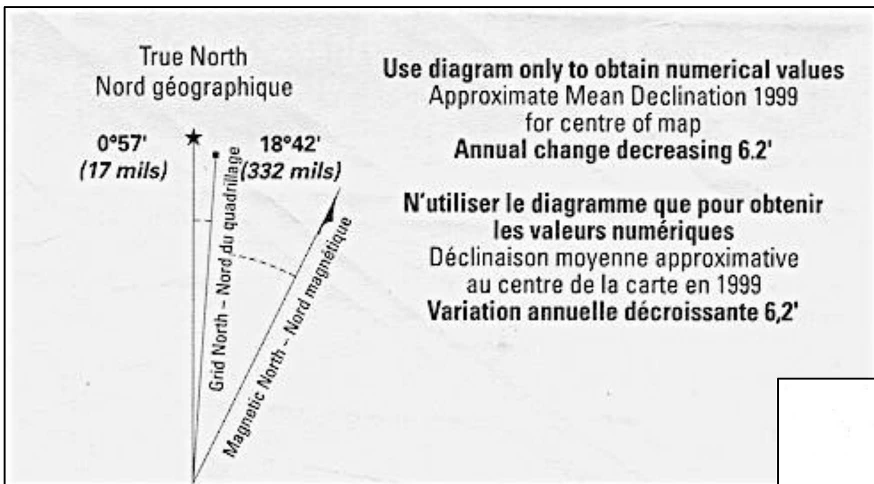


Figure 16: Magnetic Declination for Chilliwack, BC, © 1992. Produced under licence from Her Majesty the Queen in Right of Canada, with permission of Natural Resources Canada.

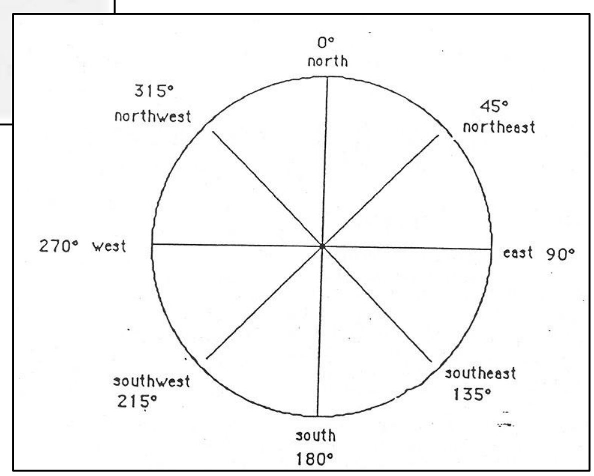


Figure 17: Four cardinal and four intermediate points of the compass and their angular equivalents

The direction of travel from one point 'A' to another point 'B' is called a **bearing**. The directional system familiar to most people is that of compass points. The compass rose, Figure 17, has four cardinal points—in a clockwise directions—north, east, south, and west, separated by four intermediate points: NE, SE, SW, and NW.

Grid azimuth bearing is expressed in degrees from grid north and measures between 0-360°, where 0° (or 360°) is north, east is 90°, south is 180° and west is 270°. To determine a bearing:

1. Draw lightly in pencil a line 'A-B' through the two points (Figure 18). The line 'A-B' should intersect one of the bold lines running grid north-south.

2. Orientate the protractor such that the 0-180° marks are aligned exactly where the grid line intersects the traced line through the two points (you may need to extend the line drawn to read the angle on the protractor).
3. Read the angle in a clockwise direction. Remember that any bearing eastward of a meridian will be between 0-180° and any bearing west of a meridian will be between 180-360°.
4. Adjust your bearing for magnetic declination if required.

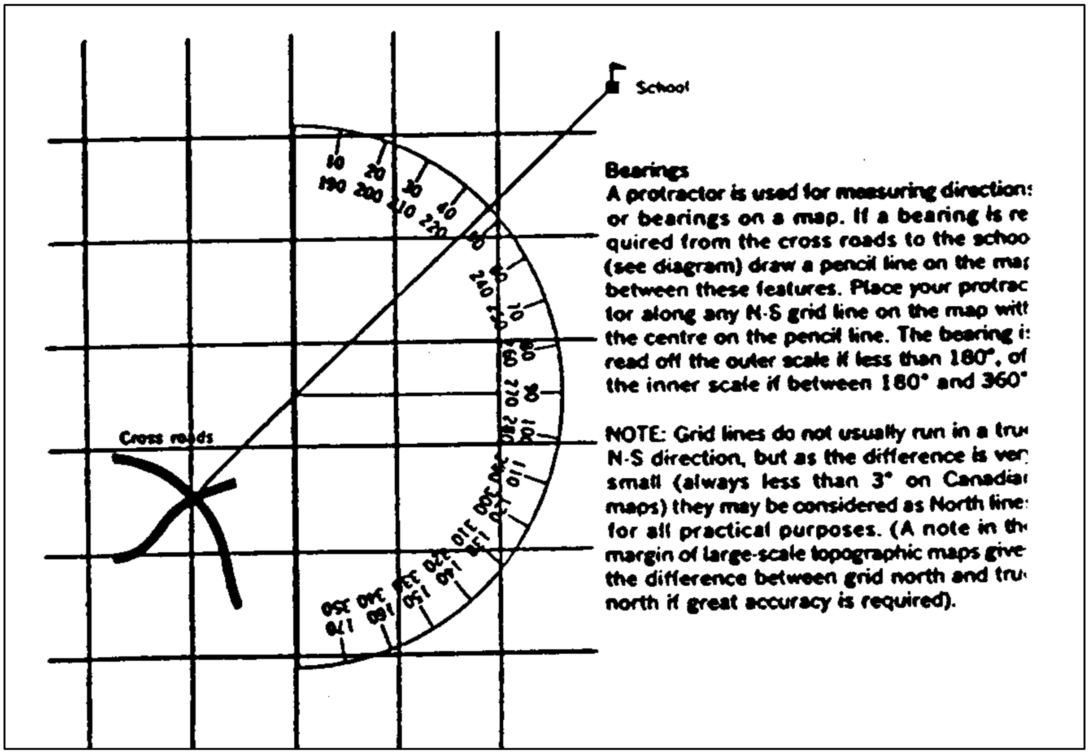


Figure 18: Taking a bearing from a map.

F. Slope

Slope (or gradient) is a measure of the steepness of a slope between two points. On a topographic map, the spacing of the contour lines indicates the steepness of the slope. Steep slopes are recognized by closely-spaced contour lines. Slope can be expressed as a percentage (%), an angle (°) or as meters per kilometer (m/km). Use this procedure to calculate the steepness of a slope:

1. Identify the required points on the map (or choose 2 points over which you will calculate the slope).

2. Using the map scale, calculate the real distance (meters) between A and B.

3. Calculate the difference in elevation between A and B using the contour information.

4. For example, calculate slope as a percentage if the distance (run) is 1200m and the elevation difference (rise) is 200m. Note that the rise and run must be measured in the same units:

$$\text{Slope (\%)} = \frac{\text{Rise}}{\text{Run}} * 100$$

$$\text{Slope (\%)} = \frac{200\text{m}}{1200\text{m}} * 100$$

$$\text{Slope (\%)} = \mathbf{16.7\%}$$

5. To calculate the slope as an angle (°) and make sure your calculator is measuring in degrees (not radians):

$$\text{Slope (°)} = \frac{\text{Rise}}{\text{Run}} * \tan^{-1}$$

$$\text{Slope (°)} = \frac{200\text{m}}{1200\text{m}} * \text{tan-1}$$

$$\text{Slope (°)} = \mathbf{9.5°}$$

6. To calculate the slope in meters per kilometer (m/km):

$$\text{Slope (m/km)} = \frac{\text{Rise}}{\text{Run}} * 1000$$

$$\text{Slope (m/km)} = \frac{200\text{m}}{1200\text{m}} * 1000$$

$$\text{Slope (m/km)} = 0.16666\ldots * 1000$$

$$\text{Slope (m/km)} = \mathbf{166.7m/km}$$

G. Interpreting Topographic Maps

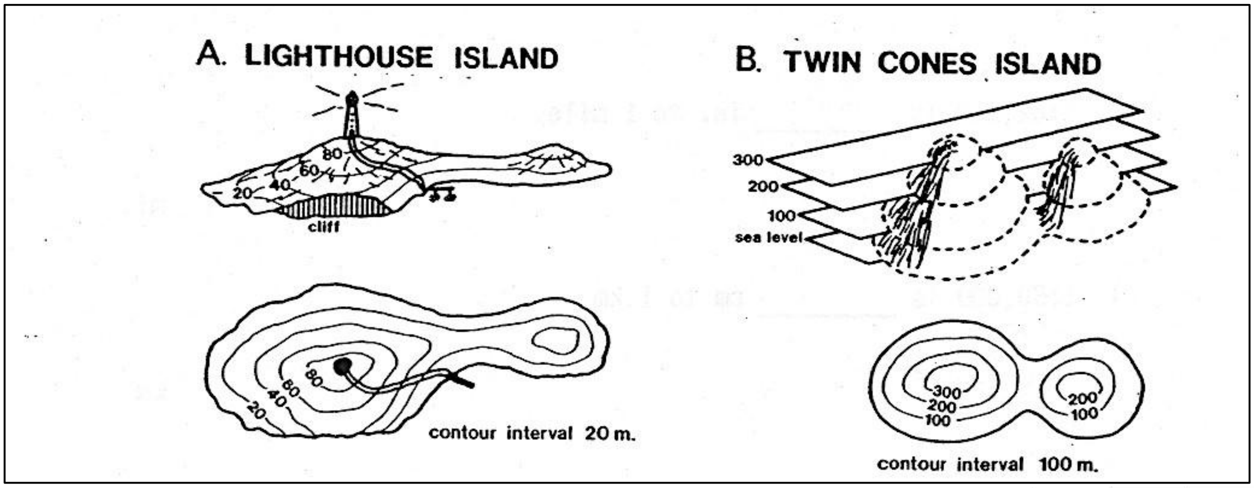
One of the problems constantly faced by physical geographers is how to graphically portray the data that they have collected. Data is commonly shown using **isopleth maps**. **Isopleths** are defined as lines that join points of equal value. Topographic maps showing contour lines are a form of isopleth map, where the contour lines connect points of equal elevation (thereby demonstrating physical relief). Other examples of isopleth maps are **isotherm** maps that show temperature distributions, **isobaric** maps that show atmospheric pressure variations and **isohyet** maps that show precipitation distributions.

Contour Lines

On topographic maps contour lines take a number of different forms. There are 1) **contour lines**, 2) **indicator contours,** and 3) **depression contours**. In each case the term **contour** can be defined as a line joining locations of equal elevation above mean sea level (Figure 19).

Maps are designed to present a great deal of detail and labeling every contour line would obscure other information. As such, only certain contour lines are labeled (see Figure 19).

In order to find elevations quickly, every fifth or tenth contour is labeled with its correct elevation and is represented with a bold line. These contour lines are called **indicator contours**. To find the elevations of the unlabeled contours, count up or down, from the closest indicator contour using the contour interval. The **contour interval** is the vertical distance between successive contours (Figures 19 and 20).



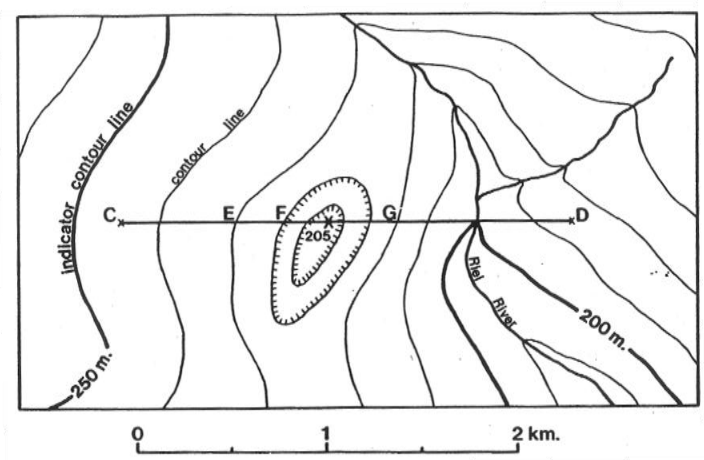


Figure 19: Maps and diagrams illustrating topography through the use of contour lines

Figure 20: Topographic map showing different contour types and contour vee-ing

Contour Vee-ing

Note how contour lines bend when they cross the rivers on Figure 21. This is called contour **vee-ing**. If a person crossed a stream, they might simply walk down to it, ford it and climb up the other bank. However, contour lines do not change elevation. When a contour line crosses a stream, it remains parallel to sea level and moves up the stream valley along points where the stream is exactly the same elevation. The contour then moves back out the other side of the valley. A plan view of this contour would be a **V** pointing upstream. Contours <u>always</u> **V** upstream.

Contours also V, or point, downslope when they cross a sharp ridge. This is similar to the contour crossing the river valley except that, in this case, the valley is inverted to form a ridge.

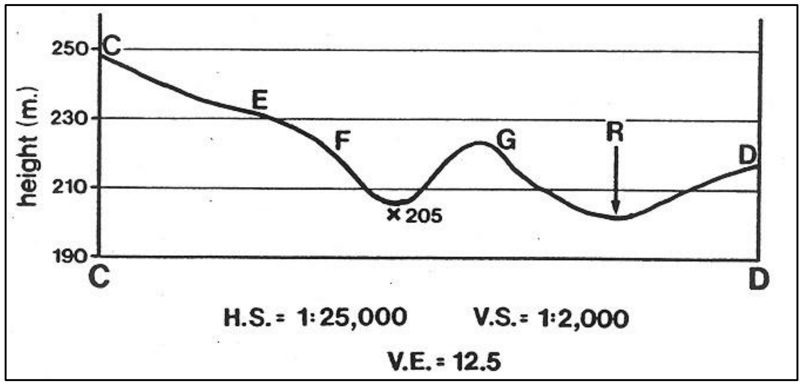


Figure 21: Topographic profile of Line C-D on Figure 20

Construction of Contour Maps (and other isopleth maps)

The following should be considered when constructing a contour map:

1. The data is plotted at its appropriate location on the map;
2. A suitable interval for the isopleths is determined; and,
3. The lines are drawn on the map.

The drawing of the lines on the map is usually the major difficulty. Frequently a decision will have to be made as to where to place a line between two points. This decision-making process is referred to as **interpolation**.

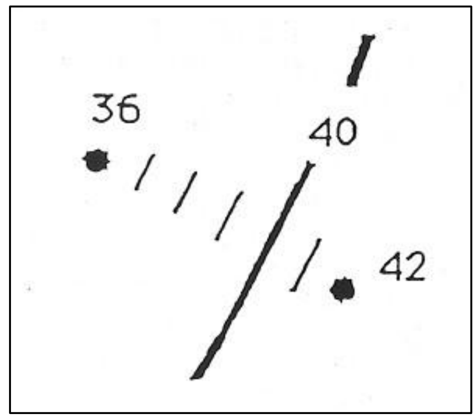


Figure 22: Interpolation on a contour map

Figure 22 illustrates the proper method for determining the location of an isopleth. In the example the problem is to locate the 40 isopleth between two plotted data points that have values of 36 and 42. First, the distance between the two points should be divided equally as shown. Six units separate these two points. The location of an isopleth for the value 40 is shown in its correct position.

However, time constraints and the nature of the data do not allow always for such an exact approach (measuring the distance between every pair of adjacent points on a map). In such situations, the cartographer must exercise judgement and "eyeball" an appropriate location for the isopleth.

Other points to remember when drawing or interpreting contour or other isopleth maps are:

1. The contour interval should be selected so that the value of the contours is evenly divisible by the interval;
2. Contours never cross or split;
3. Whenever a contour joins itself to form a closed loop or circle, all the data values within the circle must either be greater *or* less than the-value of the contour;
4. Contours are generally shown as fine brown lines (except on a glacier surface where they are either dashed or blue);
5. Every fifth contour line is thickened (index or indicator contours) to facilitate reading;

6. Usually indicator contours are broken and labeled, while intermediate contours are unlabeled to avoid clutter;
7. Contour labels are generally oriented so that they read "uphill" (the top of the number is on higher ground than the bottom);
8. Contours tend to parallel adjacent contours;
9. Contours tend to parallel major river courses;
10. There are always two contours marking the lowest part of a valley or the highest part of a ridge;
11. Contour lines of different elevations meet or merge only at cliffs;
12. Spot heights are indicated on maps by a dot or other symbol with the elevation in digits beside the symbol; spot heights often are located on hill tops and roads, although they may be found anywhere on a map;
13. Points inside a closed-depression contour are lower than those outside and the land slopes downwards towards the enclosed area; depression contours are shown with hachures perpendicular to the contour;
14. Evenly-spaced contour lines indicate an even slope while the closer the contour lines, the steeper the slope; the further apart the contours, the more gentle the slope;
15. Contour lines approaching a river valley always bend, or V, upstream (Figure 23);
16. Contour lines approaching a ridge or spur of a hill bend, or V, downhill;
17. If the contours are approximately circular they indicate a conical hill, e.g. volcanic cone, dome, or if they are depression contours, a basin, e.g. crater, kettle hole.

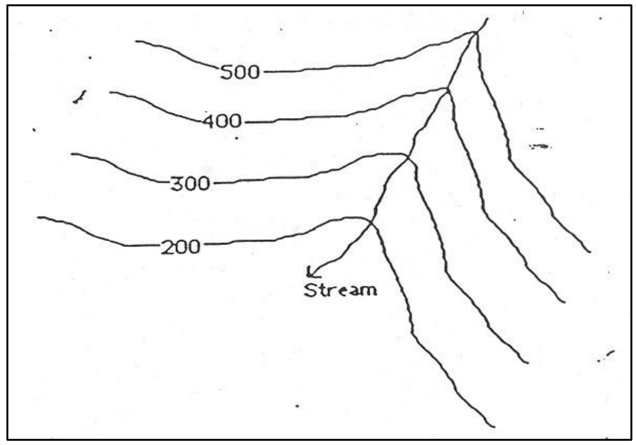


Figure 23: Interpreting contour vee-ing

The Topographic Profile

Topographic maps present us with the picture of the landscape in “plane view or aerial view”, i.e., looking straight down on the land surface. A topographic profile allows us to visualize the relief of a land surface as it would appear in silhouette. A topographic profile is a “side view” showing the rise and fall of the land surface along a selected line crossing the map (Figures 20-24).

The simplest way to construct a topographic profile is to think of it as a graph in which the vertical axis represents elevation and the horizontal scale is the distance across the map. Figure 24A shows part of a topographic map with a river, ridge, and lake. Below this map are topographic profiles to illustrate the profile route.

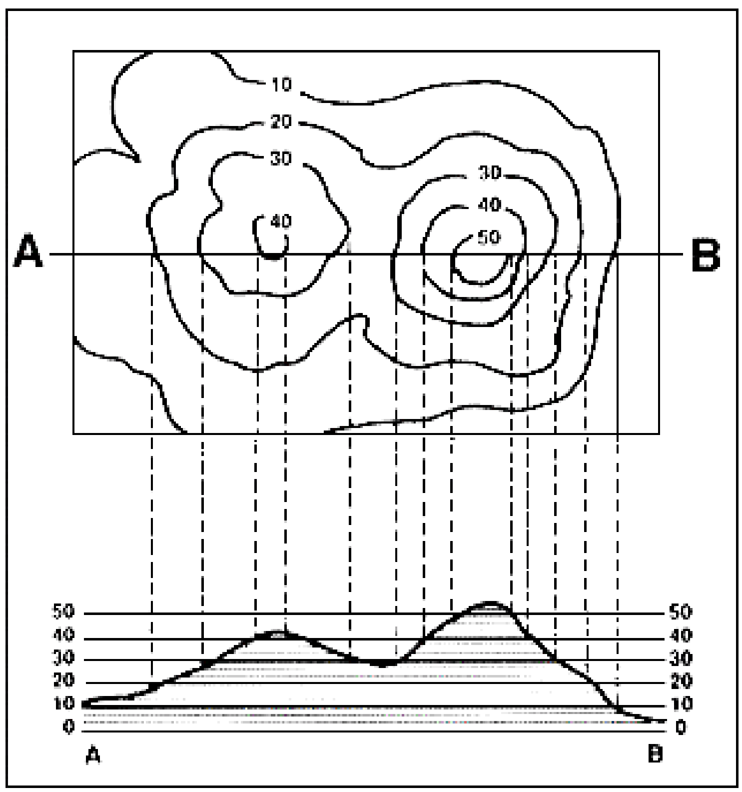


Figure 24: Creating a topographic profile.
Source: USGS Learning Web n.d.

These profiles are drawn with a vertical scale that exaggerates relief. To draw the profile correctly, follow these seven steps. Use a pencil, not a pen, in all steps.

1. On the map, locate the two points that will be the ends of your profile.

2. Place the edge of a sheet of paper along the profile route. On the paper, mark and LABEL the two ends of the profile. Where each contour line crosses the paper, draw a line and label it with its correct elevation. Also mark and label any other topographical features, such as lakes or rivers, which should appear on the profile (see Figure 25A).

3. The profile information is then transferred to a profile outline on a piece of graph paper. **The horizontal scale is automatically the same as that given on the map**. Label the X-axis with the horizontal scale (Figure 25B).

4. If a vertical scale is not provided in a lab exercise, construct a suitable vertical scale (for example, one centimetre represents 100 metres (1:10,000). The vertical scale depends on the difference in elevation to be shown (highest elevation minus lowest elevation) and the height of the graph paper. The vertical scale does not need to start at sea level but should start just below the lowest elevation to be shown. Label the vertical axis (Y-axis) with the vertical scale.

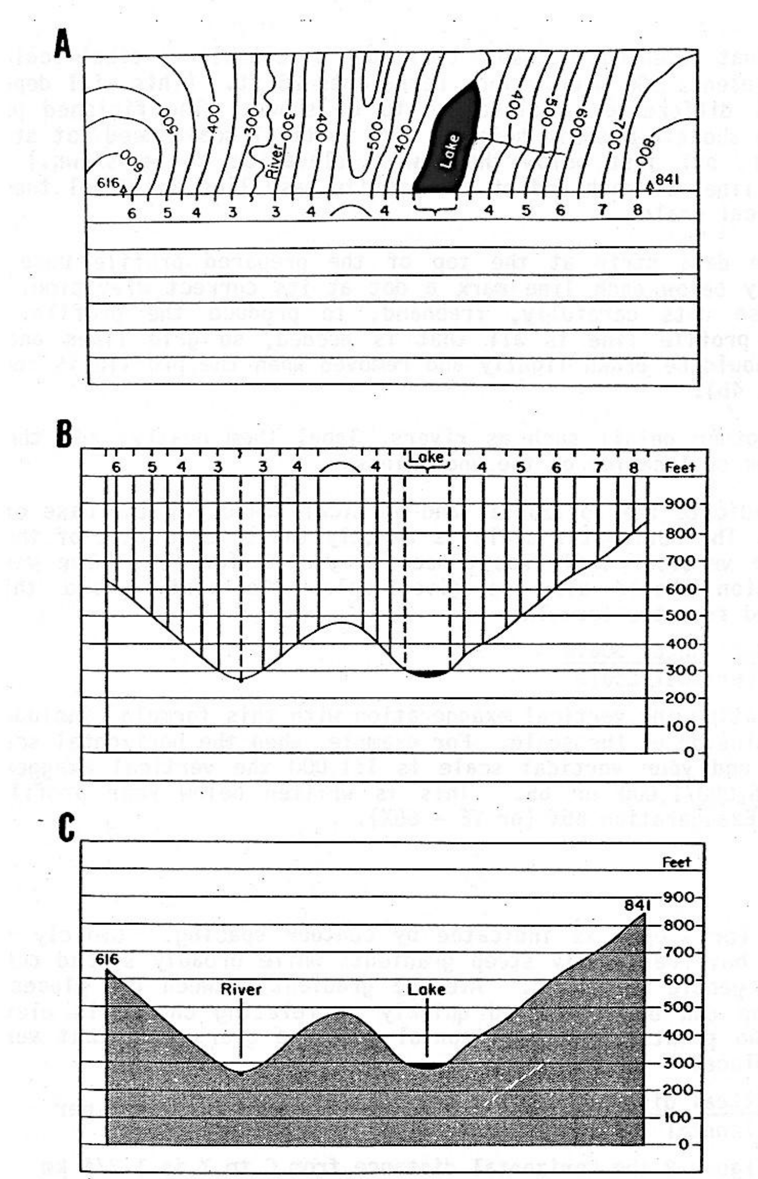


Figure 25: Stages in the construction of a topographic profile.

5. Use the data strip (the piece of paper that was marked with the contours and their elevations) to construct a profile of the land surface. Starting at the left edge of the profile, line up the left end of the data strip with the Y-axis. At the appropriate elevation, mark a dot that coincides with the left end of the profile. Continuing placing dots at the appropriate elevations and distances (moving to the right) for each dot represented on the data strip.

6. After placing a dot on the profile for each contour line marked on the data strip, join the dots carefully, with a smooth line, to produce the profile. The finished profile line is all that is needed, so data points (and grid lines) should be drawn lightly and removed when the profile is complete (see Figure 25C, 26). Erase all working marks, leaving only the profile line.

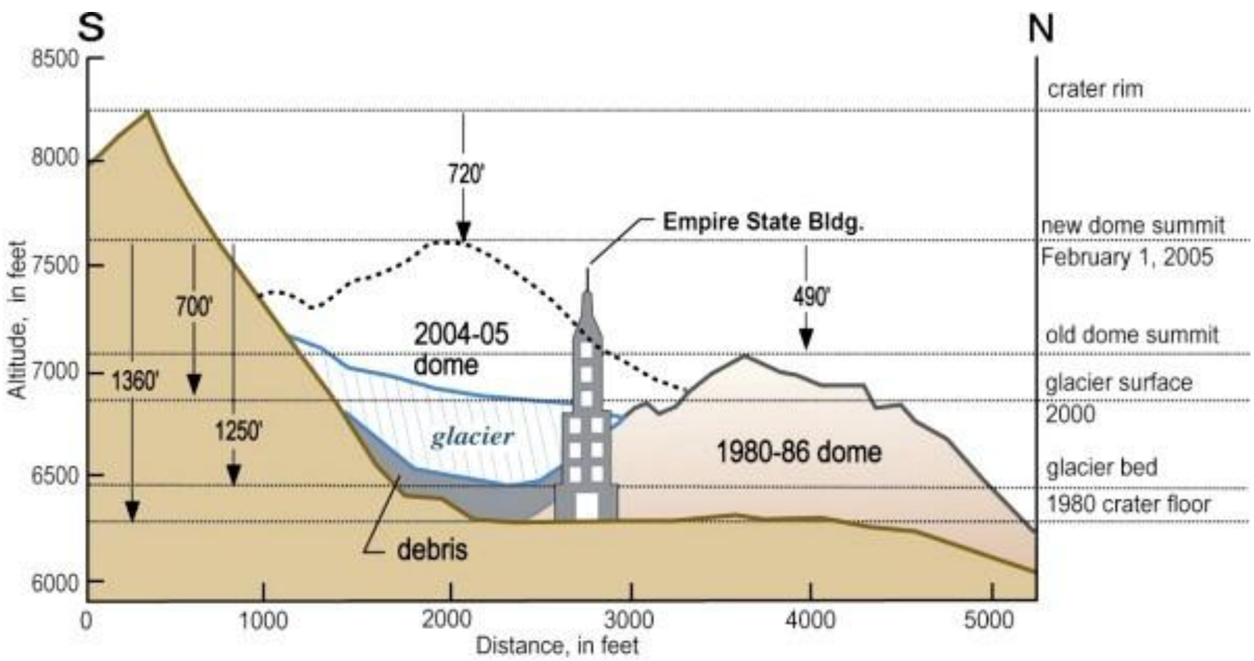


Figure 26: A completed--and embellished--topographic profile. Source: Major et al 2005, available as USGS Fact Sheet FS2005-3036.

7. Add any other detail such as rivers, lakes, and roads. Label them neatly; add the locations of the end points and their orientation (relative to one another).

8. Provide a legend (if required), orientation, title and scale.

9. Always provide the horizontal and vertical scales of the profile. The horizontal scale is the same as that of the map, while the vertical scale was chosen by you or given to you. The **vertical exaggeration** should also be given below the profile and this is determined from the formula:

VE = Vertical Scale / Horizontal Scale

For example, when the horizontal scale is 1:50,000 (1 cm represents 500m) and your vertical scale is 1:10,000 (1cm represents 10,000) the vertical exaggeration is calculated as follows:

$$VE = \frac{VS}{HS} = \frac{1/10,000}{1/50,000} \quad \textbf{VE = 5X}$$

10. Vertical exaggeration should not exceed 5X except in very flat terrain.