Lab 1: Geologic Techniques:
Maps, Aerial Photographs and LIDAR Imagery

Introduction

Geoscientists utilize many different techniques to study the Earth. Many of these techniques do not always involve fieldwork or direct sampling of the earth's surface. Before a geoscientist completes work in the field he/or she will often review maps or remote images to provide important information relevant to a given study area. For example, when a geoscientist is retained to assess landslide hazards for a proposed housing development located proximal to a steep bluff slope, he/or she would certainly want to review topographic maps, geologic substrate maps, and aerial photography prior to completing a field visit to the study area. Since topography and substrate geology play important roles in landslide processes, it is important for a geoscientist to review the slope conditions and the underlying substrate geology to better understand potential landslide hazards for a given study area. Aerial photography, or other remote imagery, may provide the geoscientist with important historical data, such as vegetation age structure or other evidence quantifying the frequency of landslide activity and related hillslope erosion. Geoscientists also utilize maps and remote imagery to record their field data so that it can be synthesized and interpreted within a spatial context and shared with other geoscientists or the general public.

In today's laboratory we will explore map-reading, aerial photo interpretation and remote sensing techniques that are utilized by geoscientists to study the geologic landscapes processes operating at its surface. Many of these techniques will be integrated into future laboratory exercises.

History of Maps

A map is a two-dimensional representation of a portion of the Earth's surface. Maps have been used by ancient and modern civilizations for over three thousand years. The Egyptians, Ancient Greeks, Babylonians and Roman civilizations drew the earliest recorded maps. These earliest maps were largely drawn to denote place names and general directions, often neglecting accuracy and scale. Figures 1-1A and 1-1B illustrate the simplicity of these early maps.[1]

[1] Figure 1-1A taken from *History of Cartography Volume One: Cartography in Prehistoric, Ancient, and Medieval Europe and the Mediterranean*. Edited by J. B. Harley and David Woodward (1987), The University of Chicago Press, Chicago and London. Figure 1-2A redrawn from Erwin Raisz, 1948. *General Cartography*. McGraw Hill.
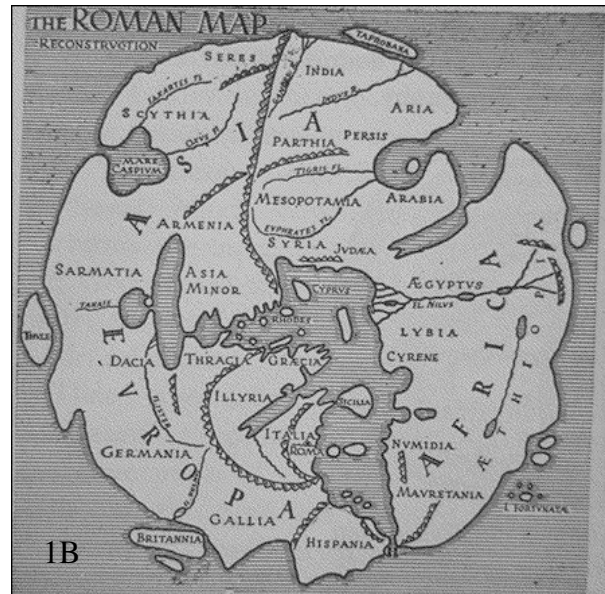
Figures 1-1A and 1-1B: Babylonian map of the world (Fig. 1-1A) drawn on a clay tablet circa 500 B.C. The map represents ancient Babylon, the Euphrates River and surrounding ocean, which today comprises modern Iraq. Fig. 1B is a representation of an original Roman map entitled, *Orbis Terrarum*, drawn by Marcus Vipsanius Agrippa in 20 A.D. The ancient Roman map shows Europe, Asia and Africa surrounding the Mediterranean Sea.

Following the decline of the Roman Empire, near the end of the 5th century A.D., innovation and advancement in cartography declined for almost 1000 years until the start of the *Renaissance Period* in the late 14th century. During the Renaissance Period the *Age of Exploration and Discovery* brought about a need for increased accuracy in maps, particularly for navigational purposes as global trade and colonization increased. Figure 1-2 shows a world map, originally published by the Flemish cartographer Gerard Mercator in 1595, and subsequently published in Henricus Hondius' *Atlas* in 1633 (image taken from the U.S. Library of Congress web site. *An Illustrated Guide Geography and Maps*., URL: **www.loc.gov/rr/geogmap/guide/gmillatl.html**). Such maps provided valuable navigational information, such as latitude and longitude coordinates and the seasonal position of the overhead sun for sea faring explorers and traders.
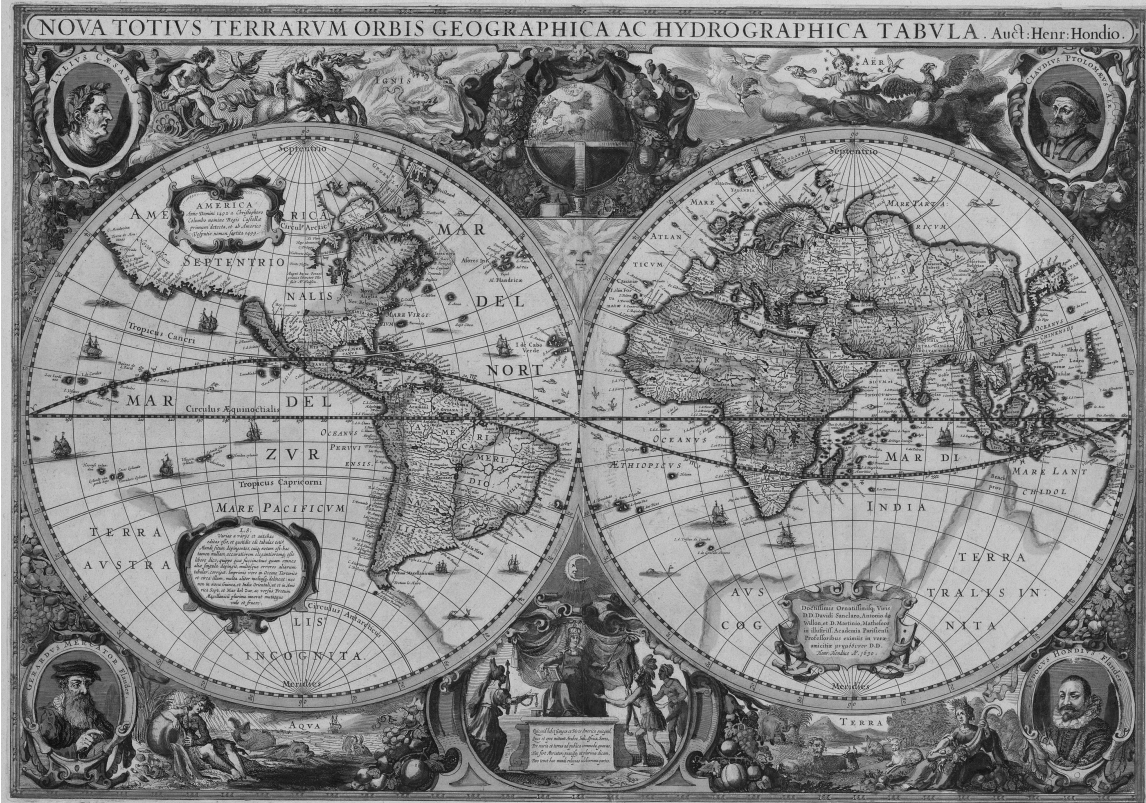
Figure 1-2: Hondius' map of the world was depicted in two hemispheres bordered by the representation of the four elements of fire, air, water and land. Portraits of the Roman Emperor Julius Caesar, Claudius Ptolemy, a 2nd century A.D. geographer, and the atlas's first two publishers, Mercator and Hondius also adorn map's the border.

Over the subsequent 500 years the accuracy and detail of maps has improved greatly with technological advances in surveying equipment and the advent of aerial and satellite imagery. Most maps used today are **planometric**, which convey data on a two-dimensional surface (Figure 1-3). Planometric maps may provide information about transportation routes, geographic location, nominal data, vegetation patterns or other forms of data requiring spatial representation. The planometric map above spatially represents a portion of the University of Washington campus that includes Johnson Hall.

*ESS 101 field trips this quarter will leave from Johnson Circle. Locate this point on the map below (Fig. 1-3) for future reference.
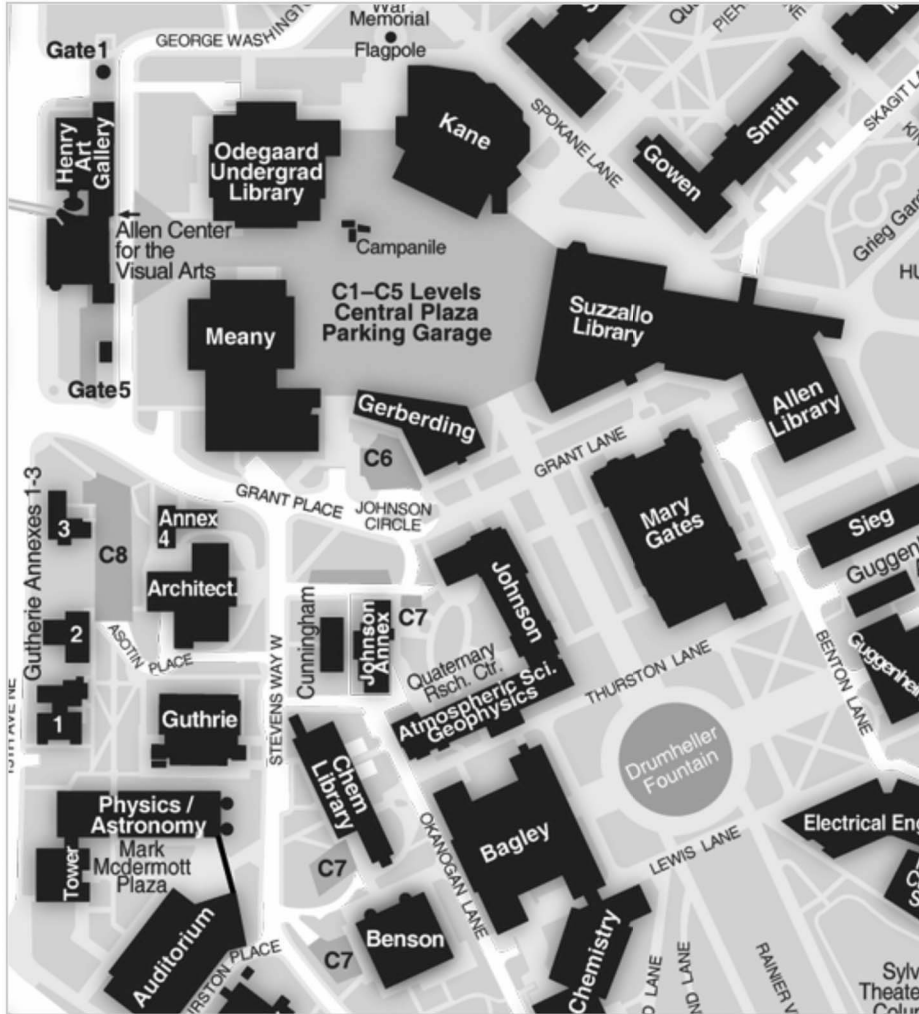
Figure 1-3: The planometric map above spatially represents a portion of the University of Washington campus that includes Johnson Hall.

Topographic Maps

A **topographic map is** a three-dimensional representation of the Earth's surface, where surface elevation or topography is represented by **contour lines**. Topographic maps are used in the earth sciences because they present a reduced view of the Earth's surface and show the size, shape, and interrelationships of the natural landscape. Being able to use topographic maps is an invaluable tool to many different professions, as well as recreational hiking. This laboratory will help acquaint you with the different components of topographic maps and their potential application to geologic problems.

Location

Latitude and Longitude

Most maps have a geographic coordinate grid, which can be used to determine location. The most commonly used coordinate system is latitude and longitude. **Latitude** is an

angular distance measured north or south of the Earth's **equator,** which is 0° latitude. It varies from 0° to 90° north and from 0° to 90° south (Figure 1-4). Lines of latitude encircle the Earth parallel to the equator and are called **parallels** because they are parallel to one another. Lines of **longitude** represent the angular distance measured east or west from the **prime meridian** (0° longitude), which passes through the Royal Astronomical Observatory in Greenwich, England. Lines of longitude range from 0° to 180° east to 0° to 180° west (Figure 1-4). The **international date line** is the line represented by both 180° east and 180° west longitude. Lines of longitude are termed **meridians** and encircle the Earth in a direction perpendicular to the equator. Meridians of longitude converge at the North and South poles; thus, they are neither parallel nor equally spaced except along a given line of latitude. Ground distance represented by a degree or minute of longitude decreases poleward from the equator because of this convergence.

Units of latitude and longitude are expressed in **degrees** (°), and further subdivided into **minutes** [60 minutes (') = one degree], and **seconds** (60 seconds (") = one minute). For example, Seattle is located at 47° 27' 00" N, 122° 18' 00" W. To accurately convey a specific location on the earth's surface, it is important to state whether its latitude lies north or south of the equator and longitude lies east or west of the prime meridian. By convention, a location's latitude is stated first, followed by its longitude coordinate.
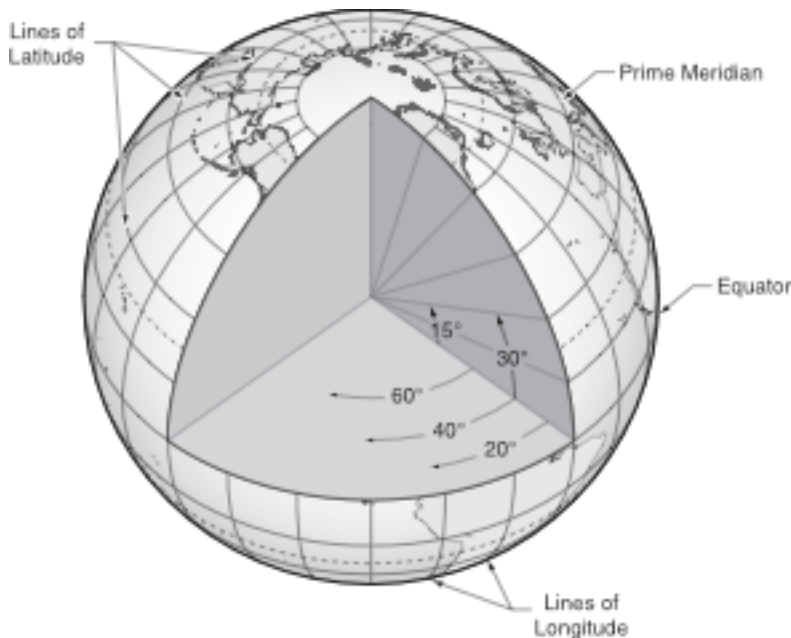

Figure 1-4: World globe showing latitude and longitude coordinates.

U.S. Public Land Survey System (Township and Range System)
In 1785 the U.S. Continental Congress enacted legislation that established a system for surveying lands lying west of the original thirteen colonial states. This public land survey system subdivided the western 2/3 of the United States into squares that could be mapped and subsequently sold to homesteaders migrating west. This grid system is still used today for surveying purposes and to specify locations in all states except the original thirteen colonies, Kentucky, Maine, Tennessee, Texas, Vermont, and West Virginia. This grid system is commonly called **Township and Range.**

Figure 1-5A: The fundamental grid unit is a **section,** a 1 x 1 mile plot of land (640 acres), which are grouped into larger parcels of land termed **townships**. Each township is a 6 x 6 mile plot of land that contains 36 sections. Sections are numbered starting in the northeast corner of a given township as section 1 and then progressing sequentially in a zig-zag pattern ending in the southeast corner as section 36.

Greater specificity of a given location can be provided by subdividing sections into smaller parts, typically, first into **quarter sections,** which are designated by their respective quadrant (e.g., NE, NW, SE and SW)**.** Quarter sections can be further subdivided into quarters or halves. For example, the dot shown in Figure 1-5A, near Enumclaw, WA, is located in the NE ¼ SW 1/4 Sec 29 T20N R6E, which is read as "the northeast quarter of the southwest ¼ of Section 29 in Township 20 North, Range 6 East."
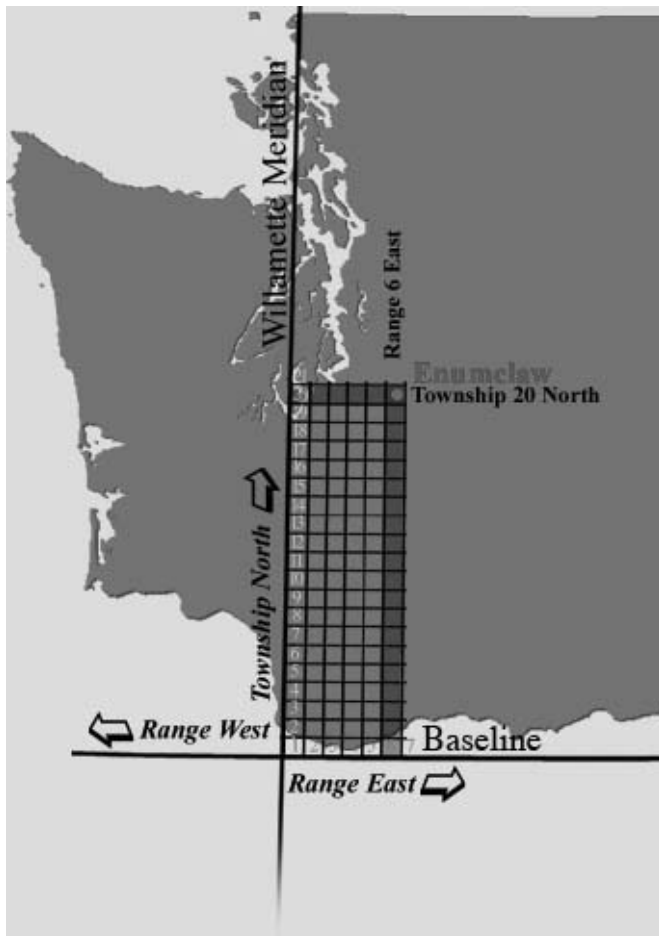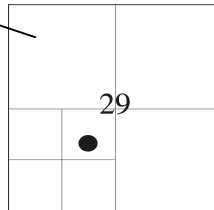

Figure 1-5B: The location of a township is related to its position north or south of an east-west trending **baseline**, similarly, a given range location is defined by its position east or west of the north-south trending **principal meridian** .

In the Pacific Northwest region, the starting point of this grid is defined by the intersection of the **Willamette Meridian** and the **baseline**, located a few miles west of Portland, Oregon. Townships are numbered according to their location relative to the intersection of the baseline and principal meridian. For example, the city of Enumclaw, Washington, is located in 20th row north of the baseline and the 6th column east of the Willamette Meridian or Township 2 North and Range 2 East (commonly written as T.20 N and R.6 E).

Scale

Most maps represent a reduced image of a larger area. The amount of reduction is defined by a map's <u>scale</u> and may be expressed in the following ways:

(1) <u>Graphic Scale</u>: Scale is indicated by a calibrated bar or line. For example, the bar scale shown in Figure 1-6 represents a distance of two kilometers on the Earth's surface.
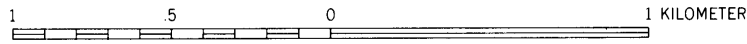

Figure 1-6: Example of a graphic scale from a topographic map.

(2) <u>Fractional Scale</u>: Scale is expressed as a fixed ratio between a distance measured on a map and an equal distance measured on the Earth's surface. This ratio is termed the <u>representative fraction</u>. For example, a fractional scale of 1:24,000 indicates that one distance unit on the map (inches, feet, centimeters, etc.) equals 24,000 of the same distance units on the surface of the Earth.

(3) <u>Verbal Scale</u>: is used to verbally convey the map scale, but is rarely written on the map. For example, a verbal scale of "1 inch equals 1 mile" represents a fractional scale of 1:63,360, as 63,360 inches equals one mile.

Magnetic Declination

On the surface of the earth the **magnetic north pole** (where a compass needle will point) is not the same location as the "true" or **geographic north pole**, which defines the earth's axis of rotation. The angular distance between geographic and magnetic north at a given location represents its **magnetic declination.** Because magnetic declination varies over time and space, a symbol and explanation is provided on the lower margin of most U.S. Geological Survey (USGS) topographic maps. This symbol shows the magnetic declination for the center area of a topographic map at the time it was published or revised.

Within the conterminous United States, magnetic declination varies between 20° west in Maine and 20° east in Washington state (Figure 1-7). Up to date magnetic declination measurements provide important information in order to determine accurate directions when mapping and navigating over large distances. Geoscientists and backpackers, alike require accurate magnetic declination data to set their compasses appropriately when using base maps.

Up to date declination data within the conterminous United States can be acquired using an online declination calculator found on the National Geophysical Data Center's (NGDC) web site: ***http:www.ngdc.noaa.gov/geomag/declination.shtml.***

Isogonic Lines Show The Pattern of Magnetic Declination
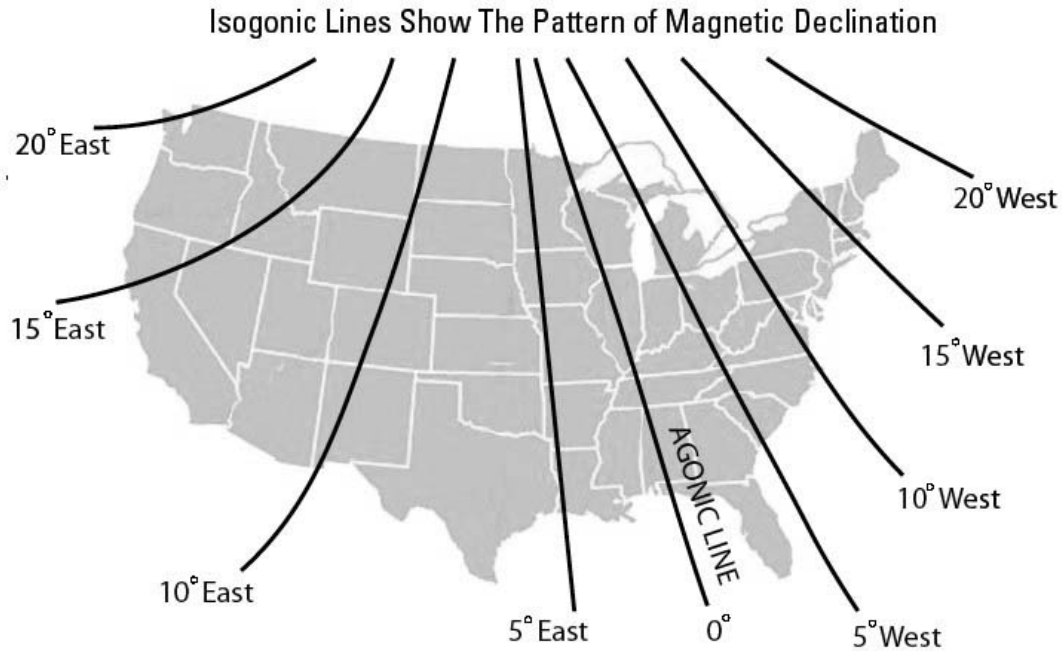
Figure 1-7: Map of magnetic declination for the conterminous United States *(U.S. Geological Survey)*.

Contour Lines

Topographic maps are important tools used by earth scientists because they show the three-dimensional configuration of the Earth's surface by means of **contour lines**, which connect points of equal elevation. Contour lines may be visualized as the intersection of a series of equally spaced, horizontal planes with the Earth's surface. The relationship between a topographic map and the land surface it represents is illustrated in Figure 1-8.

Figure 1-8: Block diagram illustrating the relationship between a topographic map and the land surface it represents.

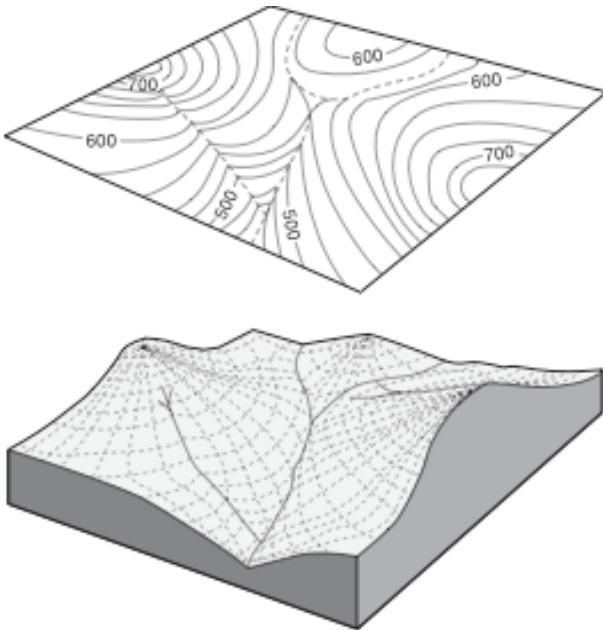There are some simple rules to follow when reading or constructing topographic maps. Figure 1-8 graphically illustrates how these rules apply to contour maps.

(1) Contour lines connect points of equal elevation.
(2) Contour lines do not cross (except in the rare case of an overhanging cliff).
(3) Contour lines never diverge.
(4) Contour lines do not end except at the edges of a map or by closing on themselves.
(5) The spacing of contour lines is related to the steepness of a slope: Widely spaced contour lines characterize gentle slopes and closely spaced contour lines indicate steep slopes.
(6) A rounded hill is represented by a concentric series of closed contours.
(7) A "closed depression" is represented by a concentric series of closed contours that have hachure marks (tick marks) on the downhill side.
(8) Contour lines form V's which point upstream when they cross stream valleys.

The vertical distance of separation between adjacent contour lines is called the **contour interval**. Selection of a contour interval is a function of map scale and the extent of topographic variation within an area. Typically, the greater the vertical relief that is represented on a map, the greater the contour interval. The contour interval, shown at the bottom of the map, remains constant throughout the map area.

On most topographic maps, every fifth contour line is printed darker for easy recognition and is labeled with its elevation. These **index contours** appear dark brown on U.S. Geological Survey topographic maps. **Intermediate contour** lines are lighter brown and elevation data are not given. Elevations of intermediate contour lines may be determined by interpolating between the nearest index contour and adding or subtracting the appropriate elevation as determined by the map's contour interval. If a point lies between two contour lines, then its elevation must also be interpolated. Elevations of specific points (tops of peaks, survey points, etc.) are sometimes indicated directly on the map. The notation "BM" denotes the location of a **benchmark**, a permanent marker placed by the U.S. Geological Survey or other governmental agencies at the point indicated on the map. Elevations are usually given for benchmarks.

Slope and Gradients
Topographic maps permit measurement of the **slope,** defined as the change in vertical distance divided by the horizontal distance (rise over run). For example, to calculate the slope of a hill that has a vertical rise of 80 feet and a horizontal run of 800 feet:

$$Slope = \frac{rise}{run} = \frac{80\ ft}{800\ ft} = 0.10\ or\ 10\%$$

Note that the units of measurement (in feet) cancel each other out; thus, the calculated slope is dimensionless. To calculate the slope in degrees you would take *arctangent* of rise over the run and convert radians to degrees.

The **gradient** of a slope is most often expressed as a change in vertical height (measured in feet or meters) compared to the horizontal length of the sloping surface (measured in miles or kilometers). Measurement of the gradient requires accurate determination of elevations and effective use of map scales. For example, if two separate points have elevations of 182 and 118 feet respectively, and are separated by a distance of 1.8 miles, the gradient between the two points may be calculated as follows:

$$gradient = \frac{difference\ in\ elevation\ (ft)}{horizontal\ distance\ on\ map\ (mi)}$$

$$gradient = \frac{64\ ft}{1.8\ mi}$$

$$gradient = \frac{35\ ft}{mi}$$

Stream and river gradients may be calculated in a similar fashion; however map distances must be measured along stream channels, rather than as a straight line. This can be facilitated by using a piece of string and measuring along the course of the stream channel.

Relief refers to the difference between the highest and lowest point in a given area. Relief can be expressed either numerically (e.g. a mountain has 865 ft of relief above the valley floor), or in a relative sense (e.g. a plain would have low relief while a mountain range would have high relief).

Topographic Cross-Sections
To better visualize topography, it is often advantageous to construct a **topographic** profile, which presents a "side-view," or cross-section, of the Earth's surface. Construction of a topographic profile is not difficult if the following guidelines are followed:

(1) Place a strip of paper along a selected profile line (Figures 1-9A and 1-9B).
(2) Mark on the paper the exact location where each index contour line, hill crest, and valley crosses the profile line. Label each mark with its elevation (Figure 1-9B). For very steep topography, where contour lines are very close together (e.g., a steep cliff), you may decide to only label the base of steep cliff and its top elevation before continuing to label the index contours.
(3) Make a vertical grid on graph paper. The horizontal axis should show units of horizontal distance along the profile line and be the same length as your profile line. The vertical axis should show elevation units ranging from the lowest to highest points on your profile line.
(4) Place the paper strip above the vertical grid and project each marked topographic feature downward to its proper elevation (Figure 1-9C).

(5)   Connect all the points on the grid with a smooth line, which is consistent with topographic trends. The result is a silhouette of the topography along the profile line (Figure 1-9C).
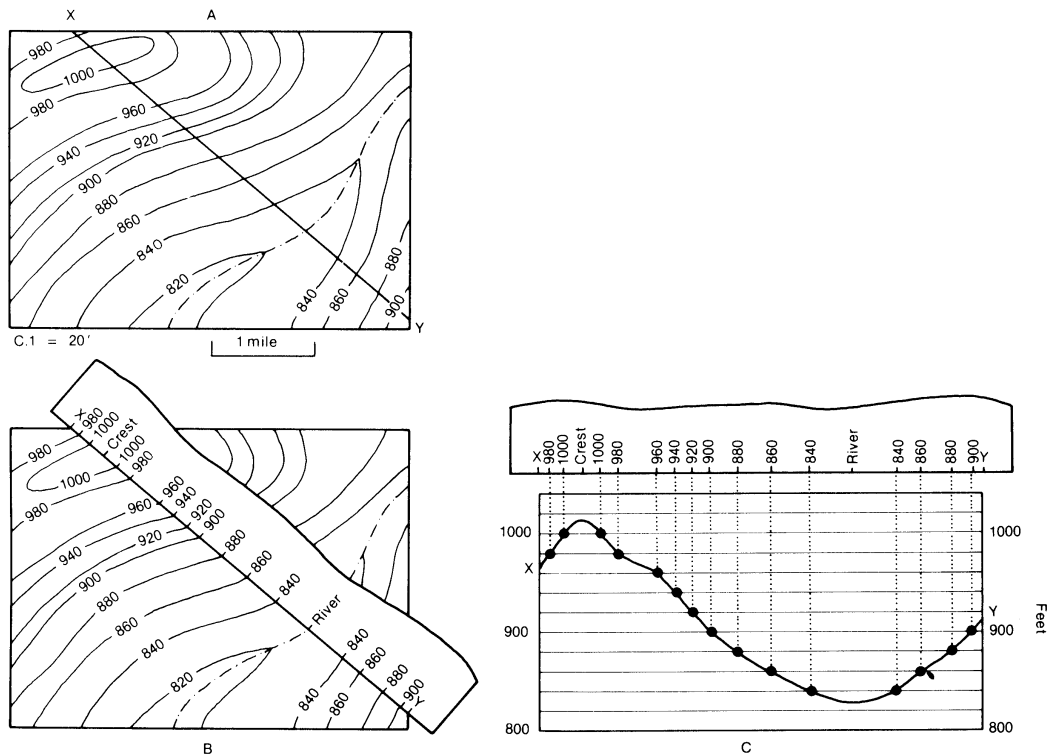
Figure 1-9A-C. Constructing a topographic profile.

Map Symbols

In the lower right corner of most U.S. Geological Survey topographic maps, a legend is given that shows a few of the important symbols used on the map. The U.S. Geological Survey has adopted standardized map symbols and color-coding to represent physiographic, cultural and survey features shown on the map. A complete list of these symbols will be provided by your lab instructor.

Use the 7.5 minute topographic map of Mt. Rainier West Quadrangle, Washington to answer questions 1 to 9.

1. When, and by whom, was the map published?

2. List the bounding parallels of latitude (i.e. the latitude lines at the limits of the map area, shown at the top and bottom corners of the map).

3. List the bounding meridians of longitude (i.e. the longitude lines at the limits of the map area, shown at the top and bottom corners of the map).

4. Which is closer to this map area: the prime meridian or the international date line? (circle one).

5. Why is this topographic sheet called a 7.5' (seven-and-a-half-minute) quadrangle?

6. Horizontal bar scales at the bottom of the map are provided in what units?

7. The horizontal scale of this map is also given as a representative fraction, or ratio, of 1:24,000. This scale indicates that one inch on the map represents _____ inches on the Earth's surface. Using this ratio, 1 **inch** on the map represents _____ **feet** on the Earth's surface. Show all calculations.

8a. What is the distance (in miles) represented by 7.5 minutes of angular distance of latitude on this map? _____ miles

8b. What is the distance (in miles) represented by 7.5 minutes of angular distance of longitude on this map? _____ miles

8c. Are these values the same distance? _____ If not explain your answer below.

9. What is the contour interval of this map? _____.

10. Make simple sketches to show how contour lines represent the following features. Use a 100-foot contour interval, and **label all contour lines and benchmarks.**

a. A steep cliff, rising 800 feet above a nearly flat plain.

c. A meteorite impact crater (closed depression), 500 feet deep located 2500 feet a.s.l.

b. A rounded hill, rising 500 feet above sea level.

d. A southward-flowing stream and stream valley, showing the "rule of V's" with at least 4 contour lines.

Compare Mt. Rainier National Park and Mt. Rainier 7.5 minute topographic map to answer questions 11 to 13.

11. Look at the scales of both maps.

11a.   How many feet does one inch represent on the Mt. Rainier National Park map?

11b.   How many feet does one inch represent on the Mt. Rainier 7.5 minute quadrangle map?

12a.   Is the scale of the Mt. Rainier National Park map larger or smaller than the scale of the Mt. Rainier 7.5 minute map? (Remember numeric scales are like fractions).

12b.   On which map does one square inch represent a larger area on the surface of the Earth?

13a.   What is the magnetic declination for each map?
         Mt. Rainier National Park _____   Mt. Rainier _____

13b.   Why are the two values different for each map?

Study the Leavenworth-Icicle Creek map. It is a composite map comprised of portions of several 7.5 minute U.S. Geological Survey topographic maps. The Leavenworth and Icicle Creek area represents a spectacular landscape created by the actions of glaciers, rivers, and mass wasting processes (landsliding).

14a.   What major topographic feature is located at approximately latitude 47°32'24" N and longitude 120°39' 00" W?

14b.   What is the elevation of this feature?

14c. What is the local relief of this feature relative to Peshsatin Creek (located near the southeast (lower right) corner of the map)?

15a.   Calculate the stream gradient of the Wenatchee River in feet/mile from the fish ladder on the south end of Jolanda Lake (located latitude 47°36'30" N and longitude 120°W 43' 30") to Icicle Creek Road bridge (located ~1 mile SSW of Leavenworth and directly southwest of the golf course). Use a string to measure the horizontal change over

the measured portion of the river. **To save time have each group at a table calculate one stream gradient and compare your results.**

       Vertical change: _____
                              (altitude of river at fish ladder – altitude of river at bridge)

       Horizontal change: _____
                              (follow stream channel)

       Gradient: _____
                              (follow stream channel)

15b.   Calculate the stream gradient of the Wenatchee River in feet/mile from the Icicle Creek Road bridge (located ~1 mile SSW of Leavenworth) to a point where Possy Creek (Possy Canyon) flows into the Wenatchee River (located ~1mile east of Leavenworth). Use a string to measure the horizontal change over the measured portion of the river.

       Vertical change: _____
                              (altitude river at bridge-altitude of river at Possy Creek)

       Horizontal change: _____
                              (follow stream channel)

       Gradient: _____
                              (follow stream channel)

15c.   Compare the results of the two groups and decide which reach of the river would be the best location for whitewater rafting.

16a.   Compare the valley profiles of the lower Tumwater Canyon section of the Wenatchee River and the lower Icicle Creek drainage. Use the graph paper provided to construct a topographic cross-section for one of these two transects (A-A', B-B'). To save time, have each group at your table complete only one of the transects. Following completion of the cross-section the two groups should compare their results.

16b.   Glaciers tend to carve "U-shaped" valleys while streams carve "V-shaped valleys. What agent, glacier or river, was responsible for eroding the Tumwater Canyon section of the Wenatchee River (Cross-section A-A')?

16c.   What agent, glacier or river, was responsible for eroding the lower Icicle Creek drainage (Cross-section B-B')?

16d.   Look at the glacial reconstruction of the Icicle Creek-Lower Wenatchee River region, published by Porter and Swanson, 2008. According to Porter and Swanson (2008), which of these two drainages were glaciated during the last glacial cycle. Are your reconstructions consistent with Porter and Swanson's (2008) interpretation?

B. Aerial Photographs

Aerial photographs are an important supplement to topographic maps. They provide detailed views of the Earth's surface and, when viewed **stereoscopically** (in three dimensions), show subtle topographic features, vegetation patterns, and textural differences, which cannot be expressed simply by contour lines.

Vertical aerial photographs are usually taken sequentially along a predetermined flight line (Figure 1-10A). Photographs are taken frequently, and each photograph includes a portion of the land area shown on the previous picture. Flight lines try to attain approximately 60% photographic overlap. When a portion of the overlap area is viewed through a **stereoscope**, each eye sees exactly the same area, but at different angles and on different photographs (Figure 1-10B). The view through the stereoscope approximates that of an observer suspended over the original landscape. As a result, the two photographs merge into one, thereby creating a three-dimensional effect (Figure 1-10B).
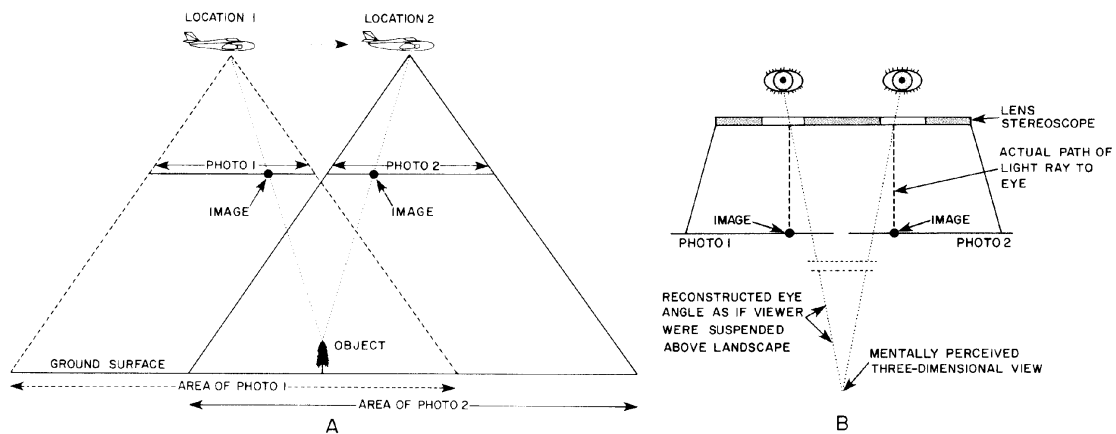

Figure 1-10A & -10B. Diagrams illustrating vertical aerial photography and stereoscopic viewing. (A) The photograph taken over location 1 covers the ground area indicated. The photograph taken over location 2 includes about 60% overlap with the

area covered by photograph 1. (B) A stereoscope is used to restore original angular relationships and obtain a three-dimensional view of area of overlap.

Scale
Vertical aerial photographs are contact prints usually produced from 9" X 9" film negatives. The scale of the aerial photograph is related to the flying height of the airplane and the focal length of the camera lens. If both are known then the average scale of the photograph can be determined using the formula below:

Scale = focal length of lens (ft or m)/flying height (ft or m)

It is important to note that the focal length and flying height must given in the same measurement units.

In many cases we do not know the focal length of the lens or the flying height of the airplane and the scale can only be estimated by comparing the length (or distance) of a feature on the photograph with its actual length, either measured on the ground or from an accurate map. Using this information the scale can be estimated using the formula below:

Scale = distance on photograph between points/ground distance between points

Again, the units of measurement must be the same for the distance shown on the photograph and actual distance on the land.

D. LIDAR (LIght Detection And Ranging) Imagery

LIDAR mapping, also described as Airborne Laser Swath Mapping (ALSM), utilizes an airborne scanning laser rangefinder to produce detailed topographic surveys. This relatively new mapping technique produces more comprehensive and precise topographic data than traditional methods. One of its unique properties is that airborne laser altimeter data can be used to accurately measure topography even when vegetation growth is extensive, such as forested terrains.

Accurate topographic data is acquired by precisely timing the round-trip travel time of a pulse of laser light from the airplane to ground surface and back. The travel-time is converted to distance from the ground to the plane knowing that the laser pulse travels at the speed of light. Laser transmitters fire thousands of pulses per second, which provides very detailed distance data of the surface below. The airplane's location at the time that a given set of laser pulses is emitted is accurately determined using a global positioning system (GPS). The distance measurements and GPS data are then converted to detailed map coordinates and elevation data coincident with individual laser pulses.

Large surface areas are mapped by flying many parallel flight lines ensuring that there is adequate overlap for complete coverage. Newer laser technology can measure multiple reflected returns so that vegetation cover can be identified and "removed" from the

mapped surface by comparing the multiple returns with the "last return" (inferred to be from the actual ground surface). High resolution LIDAR imagery has many applications important to the geo- and environmental sciences, as well as urban and rural planning.

For more detailed and complete information regarding LIDAR imagery, techniques and applications refer to the Puget Sound LIDAR Consortium's web site at:

http://pugetsoundlidar.ess.washington.edu

Use the three images (provided by your lab instructor) of Possession Point, Whidbey Island, WA to compare the attributes of LIDAR imagery (Fig. 1-11A) to conventional topographic maps (Fig. 1-11B) and aerial photography (Fig. 1-11C). You will use LIDAR imagery in later laboratories to map and interpret geologic structures and features.

17. Look at the three images shown in Figures 1-11A-11C. List the common and different types of information and features that are shown on each image.

Fig. 11A. LIDAR imagery:

Fig. 11B. 7.5 minute topographic map:

Fig. 11C. Vertical aerial photograph:

18. Study the LIDAR imagery shown in Fig. 1-11A. Compare the east-facing shoreline of Possession Point to the west-facing shoreline. If Island County Public Works hired you as a geo-consultant to assess shoreline retreat rates, and to determine building setbacks from the bluffline, what assessment and recommendations would you make regarding the west-facing versus east-facing shorelines of Possession Point?

19a. Observe the incised stream channels on the west side of Possession Point. Do they terminate at modern sea level?

19b. Propose your own hypothesis to explain how and when these channels formed based on their spatial distribution and termination elevation above modern sea level.

D. Geologic Maps

Geologic maps show the **lithology** (rock or sediment type) exposed at the Earth's surface. These maps depict information such as rock type and age, orientation of rock layers, and geologic structures, such as folds or faults. This type of information is not only of academic interest, but it is also necessary for locating economic resources (petroleum, ores, water, etc.) and determining potential geologic hazards (earthquakes, landslides, etc.) of a given area.

Geologic maps typically show contour lines, so the geology can be interpreted in the context of the topographic landscape. Geologic cross-sections may also be provided. It is imperative to carefully read the legends, explanations, and other important information provided on the geologic map. Geologic maps also show chronologic information which is important to infer the geologic history of the mapped area. Standard symbols for designating the age of rock or sediment units on geologic maps are shown below (Table 1-1). An updated, comprehensive geologic time scale, is provided on the inside back cover of this lab manual (produced by the Geological Society of America, 1999).

Era	*Period*	*Symbol*
Cenozoic	Quaternary	Q
	Tertiary	T
Mesozoic	Cretaceous	K
	Jurassic	J
	Triassic	Ŧ
Paleozoic	Permian	P
	Pennsylvanian	ℙ
	Mississippian	M
	Devonian	D
	Silurian	S
	Ordovician	O
	Cambrian	€
Precambrian		p€

Today's lab will introduce you to the use of geologic maps and the basic geologic units and structures that are represented. We will look at geologic maps in further detail during the petrology (rock identification), geologic time and geologic structures laboratories.

Use the geologic map of Washington State provided by your lab instructor to answer questions 20 to 22.

20.   Look at the Explanation, or map key. How is the legend of this map arranged?

*Most geologic maps are arranged chronologically from youngest to oldest sediment/rock units.

21a.   What lithologic unit is represented by the brown/tan color that covers much of eastern Washington forming the Columbia Plateau?

21b.   What lithologic unit (rock type) represents the summit region of Mt. Rainier?

21c.   How does the age of volcanic rocks near the summit of Mount Rainier compare to the age of the Columbia Plateau volcanism?

22a.   Where are the oldest lithologic units located in Washington State?

22b.   How old are the lithologic units on south Whidbey Island, Washington?

Answer Sheet for Laboratory 1: Geologic Techniques

Group Members: _____, _____, _____,

_____, _____, _____,

Use the 7.5 minute topographic map of Mt. Rainier West Quadrangle, Washington to answer questions 1 to 9.

1. When, and by whom, was the map published?

2. List the bounding parallels of latitude (i.e. the latitude lines at the limits of the map area, shown at the top and bottom corners of the map).

3. List the bounding meridians of longitude (i.e. the longitude lines at the limits of the map area, shown at the top and bottom corners of the map).

4. Which is closer to this map area: the prime meridian or the international date line? (circle one).

5. Why is this topographic sheet called a 7.5' (seven-and-a-half-minute) quadrangle?

6. Horizontal bar scales at the bottom of the map are provided in what units?

7. The horizontal scale of this map is also given as a representative fraction, or ratio, of 1:24,000. This scale indicates that one inch on the map represents _____ inches on the Earth's surface. Using this ratio, 1 **inch** on the map represents _____ **feet** on the Earth's surface. Show all calculations.

8a. What is the distance (in miles) represented by 7.5 minutes of angular distance of latitude on this map? _____ miles

8b. What is the distance (in miles) represented by 7.5 minutes of angular distance longitude on this map? _____ miles

8c. Are these values the same distance? _____ If not explain your answer below.

9. What is the contour interval of this map? _____.

10. Make simple sketches to show how contour lines represent the following features. Use a 100-foot contour interval, and **label all contour lines and benchmarks.**

a. A steep cliff, rising 800 feet above a nearly flat plain.

c. A meteorite impact crater (closed depression), 500 feet deep located 2500 feet a.s.l.

b. A rounded hill, rising 500 feet above sea level.

d. A southward-flowing stream and stream valley, showing the "rule of V's" with at least 4 contour lines.

Compare Mt. Rainier National Park and Mt. Rainier topographic map to answer questions 11 to 13.

11. Look at the scales of both maps.
11a.   How many feet does one inch represent on the Mt. Rainier National Park map?

11b.   How many feet does one inch represent on the Mt. Rainier 7.5 minute quadrangle map?

12a.   Is the scale of the Mt. Rainier National Park map larger or smaller than the scale of the Mt. Rainier 7.5 minute map? (Remember numeric scales are like fractions).

12b.   On which map does one square inch represent a larger area on the surface of the Earth?

13a.   What is the magnetic declination for each map?
        Mt. Rainier National Park _____   Mt. Rainier _____

13b.   Why are the two values different for each map?

Study the Leavenworth-Icicle Creek map. It is a composite map comprised of portions of several 7.5 minute U.S. Geological Survey topographic maps. The Leavenworth and Icicle Creek area represents a spectacular landscape created by the actions of glaciers, rivers, and mass wasting processes (landsliding).

14a. What major topographic feature is located at approximately latitude 47°32'24" N and longitude 120°39' 00" W?

14b. What is the elevation of this feature?

14c. What is the local relief of this feature relative to Peshsatin Creek (located near the southeast (lower right) corner of the map)?

15a. Calculate the stream gradient of the Wenatchee River in feet/mile from the fish ladder on the south end of Jolanda Lake (located latitude 47°36'30" N and longitude 120°W 43' 30") to Icicle Creek Road bridge (located ~1 mile SSW of Leavenworth and directly southwest of the golf course). Use a string to measure the horizontal change over the measured portion of the river. **To save time have each group at a table calculate one stream gradient and compare your results.**

       Vertical change: _____
                                     (altitude of river at fish ladder – altitude of river at bridge)

       Horizontal change: _____
                                     (follow stream channel)

       Gradient: _____
                                     (follow stream channel)

15b. Calculate the stream gradient of the Wenatchee River in feet/mile from the Icicle Creek Road bridge (located ~1 mile SSW of Leavenworth) to a point where Possy Creek (Possy Canyon) flows into the Wenatchee River (located ~1mile east of Leavenworth). Use a string to measure the horizontal change over the measured portion of the river.

       Vertical change: _____
                                       (altitude river at bridge-altitude of river at Possy Creek)

       Horizontal change: _____
                                       (follow stream channel)

       Gradient: _____

(follow stream channel)

15c.   Compare the results of the two groups and decide which reach of the river would be the best location for whitewater rafting.

16a.   Compare the valley profiles of the lower Tumwater Canyon section of the Wenatchee River and the lower Icicle Creek drainage. Use the graph paper provided to construct a topographic cross-section for one of these two transects (A-A', B-B'). To save time, have each group at your table complete only one of the transects. Following completion of the cross-section the two groups should compare their results.

16b.   Glaciers tend to carve "U-shaped" valleys while streams carve "V-shaped valleys. What agent, glacier or river, was responsible for eroding the Tumwater Canyon section of the Wenatchee River (Cross-section A-A')?

16c.   What agent, glacier or river, was responsible for eroding the lower Icicle Creek drainage (Cross-section B-B')?

16d.   Look at the glacial reconstruction of the Icicle Creek-Lower Wenatchee River region, published by Porter and Swanson, 2008. According to Porter and Swanson (2008), which of these two drainages were glaciated during the last glacial cycle. Are your reconstructions consistent with Porter and Swanson's (2008) interpretation?

Use the three images (provided by your lab instructor) of Possession Point, Whidbey Island, WA to compare the attributes of LIDAR imagery (Fig. 1-11A) to conventional topographic maps (Fig. 1-11B) and aerial photography (Fig. 1-11C). You will use LIDAR imagery in later laboratories to map and interpret geologic structures and features.

18. Look at the three images shown in Figures 1-11A-11C. List the common and different types of information that are shown on each image.

Fig. 11A. LIDAR imagery:

Fig. 11B. 7.5 minute topographic map:

Fig. 11C. Vertical aerial photograph:

18. Study the LIDAR imagery shown in Fig. 1-11A. Compare the east-facing shoreline of Possession Point to the west-facing shoreline. If Island County Public Works hired you as a geo-consultant to assess shoreline retreat rates, and to determine building setbacks from the bluffline, what assessment and recommendations would you make regarding the west-facing versus east-facing shorelines of Possession Point?

19a. Observe the incised stream channels on the west side of Possession Point. Do they terminate at modern sea level?

19b. Propose your own hypothesis to explain how and when these channels formed based on their spatial distribution and termination elevation above modern sea level.

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