A. BASIC SLOPE INFORMATION

1. Percentage of Slope
   a. Expresses rise or fall, in feet, for a 100-foot horizontal distance.
   b. Slope may be described as a percentage (%) or by a decimal number (0.XX):
      • 12% slope = 0.12 slope
      • Do not get confused and use both a decimal and the % sign, unless the percentage of slope is less than 1%. For example, 0.12% designates that the slope is less than a 1% slope (twelve hundredths of a percent), not a 12 percent slope. Of course, if the percentage of slope is less than 1%, use both a decimal and the % sign.
      • For accuracy, slopes are typically expressed to the 100th place, such as 5.65% or 0.0565.
   c. REMEMBER THAT SOME CALCULATORS DO NOT GIVE “PERCENTAGES”, THEY ONLY EXPRESS SLOPE IN DECIMALS (i.e., .01 = 1%).

2. There are three basic formulas used to calculate the slope gradient (%), the vertical change of the slope (rise) and the length of the slope (run). The diagram below illustrates the relationship between these elements of a slope.

Source: Site Engineering for Landscape Architects
a. **Rise divided by Run = %** is the basic formula for calculating slopes, where:
   - Rise = the vertical change of the slope.
   - Run = the length of the slope.
   - % = the gradient of the slope.

   Variants of the formula are noted below.

b. To determine **RISE (vertical change)**, use the formula:
   - % of slope $\times$ run (horizontal distance) = rise (vertical change)

c. To determine **RUN (horizontal distance)**, use the formula:
   - $\frac{\text{rise (vertical change)}}{\% \text{ of slope (gradient)}} = \frac{\text{run (horizontal distance)}}{\%}$

3. **Slope Ratio**
   a. A slope ratio expresses the relationship of horizontal distance to vertical distance.
   b. It is written as a ratio, for example, 4:1. The first number represents horizontal distance, the second number represents vertical change (H:V).
   c. The vertical grade change is always described as being 1 foot (for instance, a 4:2 ratio would be converted to a 2:1 ratio).
   d. Use the rise/run formula to convert a ratio to a percentage
      $$\frac{\text{vertical change}}{\text{horizontal distance}} = \%$$

4. **Expressing Slope as “Inches per Foot”**
   a. Architects and contractors most commonly use this designation.
   b. Each 1/8” per foot grade change equals approximately 1%:
      $$\frac{1/8”}{12”} = 1% \text{ (actually it equals 1.04% but round it off for convenience)}$$
   c. 1/8” per foot = 1%
   d. 1/4” per foot = 2%
   e. 1” per foot = 8.33% (the rounding catches up by this point and thus the % is shown to the hundredths place)
B. CONTOUR INTERPOLATION

1. Contour interpolation provides a method for locating whole contours, or the elevation of any point, between two or more given spot elevations.

2. Locations for whole contours can be calculated mathematically if the following are known:
   a. The value of the two spot elevations.
   b. The horizontal distance between the two spot elevations.
   c. The scale of the drawing.

3. Example (see diagram below): Spot elevation “A” is 47.81, spot elevation “B” is 44.37, and the distance between them is 120 feet. The scale of the drawing is 1” = 20.0’’. The whole contour numbers 45, 46, and 47 must be located. The solution is as follows (also see diagram below):
   a. Determine the % of slope between the spot grades using the rise over run formula. To determine the %, the rise and run are needed. The rise equals 3.44 feet (47.81 minus 44.37 = 3.44). The distance is given at 120 feet, so the formula is as follows:
      \[
      \frac{3.44 \text{ feet (rise)}}{120 \text{ feet (run)}} = \% \text{ of slope}, \text{ which calculates to be 2.87\% (round to the 100th place)}
      \]
   b. To find the distance (RUN) to the next whole contour, the rise and % of slope are needed. Determine the vertical change (RISE) between one of the spot grades and the next whole contour. From spot elevation “A” this is 0.81 feet (47.81 minus 47 = 0.81 feet). The % of slope was previously calculated as 2.87%.
   c. Now determine the horizontal distance (RUN) between spot elevation “A” and the whole contour 47 using the rise over run formula:
      \[
      \frac{0.81 \text{ feet (rise)}}{2.87\% \text{ (slope)}} = \text{run (horizontal distance), which equals 28.26 feet}
      \]
      Therefore, the location of the whole contour 47 is 28.26 feet away from spot elevation 47.81. Scale this distance on the plan to locate the whole contour.

4. The final task is to determine the distance (RUN) between the whole contours 47, 46 and 45. To calculate the distance, or RUN, the % of slope and the rise are needed. The % of slope was previously determined to be 2.87%. The rise is 1 foot (47 minus 46). The formula is as follows:
   \[
   \frac{1 \text{ foot (rise)}}{2.87\% \text{ (slope)}} = \text{run (horizontal distance), which equals 34.88 feet}
   \]
This means that for the given criteria in this example, all whole contours would be 34.88 feet apart because all of the factors in the formula remain the same.

Source: Site Engineering for Landscape Architects

5. There is a much easier way to interpolate the distance between whole contours by using the “proportional method”. In this method, the value between two or more spot elevations is needed but the distance between the spot elevations and the scale of the drawing are unnecessary. The proportional method is based on determining how many units are between two given spot elevations and using those units to count where the whole contour would fall:

a. In the illustration below, the location of whole contour 98 is being determined. The number of units between the spot elevations is 12 (98.50 minus 97.3 = 1.2, or 12 tenths). By using an engineer’s scale, it is possible to physically layout 12 units between the two spot elevations. Since 97.3 is 7 units away from the 98 contour (98 minus 97.3 = .70, or 7 tenths), count 7 units on the scale and locate where the 98 contour falls. Conversely, it is possible to count 5 units down from the 98.50 spot elevation since it is 5 units away from whole contour 98.
b. Although this method is less precise than calculating each contour using the “rise over run” formula, it is used most often to quickly calculate whole contours between spot elevations. For most applications, particularly the early stages of design, the proportional method is sufficiently accurate.

C. BASICS OF TOPOGRAPHIC SURVEYING (LEVELING)

1. When a piece of land is surveyed for topography, two markings are most important for translating a three dimensional relationship into a two-dimensional plan: spot elevations and contours. In a survey, the spot elevations are located first because whole contours are derived by interpolating between spot elevations.

2. The determination of spot elevations is based on having a known location for a benchmark (BM) from which to reference the spot elevations. A benchmark is a stationary point on a permanent object that can be referred to time and time again. It might be a point on a building, a hydrant, or a stone or metal marker. Its vertical elevation is typically related to its elevation above sea level (refer to step 4. below for more information on this).

3. Three steps are taken before the survey work begins:
   a. Establish a survey grid. The spot elevations will be read from the points at the intersection of the grid. This is typically a square grid in increments of 20', 50', etc. The grid is staked in each direction and labeled (letters in one direction, numbers in the other direction).
   b. Set up the survey instrument. This involves leveling the instrument to make sure it is plumb and, properly locating it so the most spot elevations can be read from one place. The best location is typically halfway between high and low points in a location most visible to the points being surveyed. A survey rod, which has feet and inches marked on it, is needed to measure the vertical change of each spot elevation.
   c. Determine the location of the BM. This can be assigned to a permanent stationary object or predetermined from local benchmarks. It should be noted that at this point the elevation of the benchmark is unknown.

4. Once the benchmark location is known, the elevation of the benchmark must be determined. The benchmark can be assigned a grade for reference or it can be tied to a geodesic survey grid used by a town, county, or national standards. For this discussion, the benchmark will be assigned an elevation of 202.58. (See the diagram at paragraph 7., below)
5. Once the benchmark elevation is known, the work of collecting all the other spot grades begins by determining the “height of the instrument” (HI) using a method called “backsighting” (BS). This is necessary because all survey readings, except the benchmark, are determined by their vertical relationship to a known elevation (the HI, in this case). These steps are further described below:

a. The survey rod is placed on the BM and a reading is taken on the rod by peering through the scope of a builder’s level or survey instrument and aligning the crosshairs on a rod marking. The rod reading taken at the BM is called the “backsight” (BS). In this example, the BM would be 202.58 and the BS would be 2.32.

b. To determine the HI, add the BM and the BS (rod reading):
   \[ HI = BM + BS \]
   \[ (202.58 + 2.32 = 204.90 HI) \]

c. Backsight readings are always added to the BM.

d. There is only one backsight reading for a series of spot elevations. Physical limitations sometimes require that the survey instrument be moved (usually the inability to see readings on the rod due to obstructions or topography above the level of the HI). Therefore, there may be more than one backsight reading for an entire survey since the instrument may have to be moved. Every time the instrument is moved, a new backsight is taken. (See the diagram at paragraph 7., below)

5. After backsighting, it is possible to determine the spot elevations at the survey grid intersections. The rod readings taken at the survey grid intersections or at particular point (such as a manhole or top of wall, etc.) are called foresight (FS) readings. (See the diagram at paragraph 7., below)

a. FS elevations are determined by subtracting the FS reading from the HI:
   \[ HI - FS = \text{Elevation of Foresight Point} \]

b. Foresight readings are always subtracted from the HI.

c. There are many foresight readings.

d. Foresight has nothing to do with the direction of the reading. There is no positive or negative direction.

e. Using the example above, where the HI is 204.90, a foresight reading of 7.89 would result in an elevation of 197.01 (204.90 minus 7.89).

f. This procedure is repeated at every grid intersection. The whole contours are then interpolated between the spot elevations.

6. Once the locations of the whole contours are interpolated, connect identical spot elevations to form the contours. The contour interval could be established at the elevation of 1’, 2’, 5’, 10’, or 25’ depending upon the size of the parcel or the scale of work. Planning work may require a larger contour interval and detailed work may need more grading detail and thus a smaller contour interval.
7. The diagram below shows the set up and readings for a topographic survey, where point A is the benchmark and point B is an intersection on the survey grid:

![Topographic Survey Diagram]

Source: Simplified Site Engineering

8. The plan below shows contours interpolated from survey readings:

![Contour Plan Diagram]

Source: Simplified Site Engineering