Lesson 8:  
Surveying the Forest

TEACHER: ____________________________

SCHOOL: ____________________________

GRADE LEVEL: 9-12

**TASKS/COMPETENCIES**

ANR8046.172 Set up and operate a transit level and rod.

ANR8046.173 Read a rod and a level to calculate slope.

ANR8046.174 Use a transit level to lay out level and sloping contour lines on a sloping land.

ANR8046.175 Explain the parts of a field map.

**OBJECTIVES AND GOALS**

- The student will define surveying.

- The student will list the purposes of surveys.

- The student will take accurate field notes.

- The student will identify and use surveying equipment correctly.

- The student will determine location of points on a land surface.

- The student will run a closed traverse.

- The student will determine area of a closed traverse.

- The student will use Reddi Mapper to determine area.

**SOL CORRELATIONS**

**Mathematics**

A.7 (determine slope)

G.8 (quadrilaterals)

G.9 (angles of polygons)

G.13 (area and volume of three-dimensional objects)

G.14 (proportional reasoning to solve practical problems)

**EQUIPMENT, SUPPLIES, AND MATERIALS NEEDED**

- Field note forms
- Steel tapes
- Surveyor’s tape
- Compass
- Abney level
- Planimeter
- Reddi Mapper
- Topographic maps
- Aerial photographs
**ACTIVITIES**

**Preparation**

**Lesson approach**

- Surveys are performed for several different purposes, but the primary reasons for surveys of forestland are to determine boundaries of tracts and to determine the acreage of a given piece of forestland.
- Harvesting operations are often arranged with approximate descriptions of the woods to be cut. To protect the forest owner and logger, exact boundaries should be established. The most precise method of determining boundaries is by survey.
- It is essential in effective forest management to know the acreage of tracts to be used, improved, or harvested.

**General situation**

- Land is sometimes bought and sold without reference to its actual location on maps or aerial photographs. The same lack of specificity often applies to forest products.
- Boundary disputes often arise between neighbors and municipalities.
- Surveys, used alone or in conjunction with existing maps and aerial photographs, are performed to solve problems arising from inexact descriptions or boundary disputes.
- Surveys are used to create and update maps, to locate roads, and to determine land configurations.

**Local situation**

- Determine if any students (or their families) have had their land surveyed; if so, find out the purpose of the survey.
- Determine if there is new road construction underway in the local area, and point this out as an example of the use of survey.
- Review elements of map and aerial photograph interpretation before embarking on a study of surveying.

**Application**

- Arrange a field trip so students can observe a survey crew in action.
- Arrange access to a tract of forestland and have groups of students survey the tract by running a closed traverse.
  - Have selected students prepare field notes.
  - Have students compute the area within the closed traverse by using one or more methods (cross-section squares, triangulation, or by planimeter).
- Have students make and use a Reddi Mapper.


Presentation: Forest Surveys

Definition of surveying
Surveying is the art of locating points of lines on or near the surface of the earth by measuring angles, directions, and distances.

Types and purposes of surveys
• Control surveys determine horizontal position and elevation.
• Topographic surveys determine ground configuration.
• Surveys determine the direction and length of lines.
• Boundary surveys determine the position of property lines and enclosed areas.
• Construction surveys determine the position of buildings, roads, dams, and other structures.

Accuracy and precision
Regardless of the type of survey, a good surveyor must produce accurate and precise results. Before starting any survey, the surveyor or forester must decide on the accuracy desired for a project (usually based on cost). Many forestry applications do not require precise instruments; for example, less precise instruments such as a compass to measure angles and directions, taping or pacing to measure horizontal distances, and an abney level or clinometer to measure differences in elevation and vertical heights are satisfactory for many surveys. If greater accuracy is desired, more precise instruments such as transit or theodolite to measure angles, directions, or elevations and a steel tape with temperature and tension corrections to measure distances are often used.

This unit will concentrate on the use of less precise instruments that are much simpler and faster to use, but still provide the required accuracy for many forest surveying situations.

Field notes
Field notes are permanent written records of surveys taken at the time the work was done in the field. Field notes must be neatly and clearly written so that anyone can easily read and interpret them. Field notes usually consist of numerical values, sketches, and explanatory notes, such as those shown below.

Sample Note Form
Measurement of horizontal distances

Units of length
The basic units of length used in the United States for forestry applications are the foot (ft), meter (m) and the surveyor’s or Gunter’s chain, measuring 66 feet. The foot is used in English-speaking countries and the meter has become the adopted unit for international and scientific usage.

For foresters, the chain is a convenient and popular dimension of horizontal measurement. The unit of land measurement is the acre, standardized at 1/8 mile (660 feet) in length and 1/80 mile (66 feet) in width. When using a 66-foot chain, an acre becomes 10 chains long and 1 chain wide, or 10 square chains in area. Areas expressed in square chains can be easily converted into acres by dividing by 10.

Listed below are the equivalents of the different units.

- 1 mile = 5280 feet = 1760 yards = 320 rods = 80 chains
- 1 chain = 66 feet = 4 rods
- 1 meter = 39.37 inches = 3.2808333 feet = 1.0936111 yards
- 1 acre = 43,560 square feet = 10 square chains

Instruments and methods
Measurement of horizontal distances is essential to the inventory forester, who often must retrace old property lines, survey new tract boundaries, or determine land areas. Distances can be determined by several means, but pacing and measuring with steel tapes are the methods most often used.

- **Steel tapes**
  - Engineer tapes are made of metal and come in 100-, 200-, and 300-foot lengths. Most tapes are graduated at every foot, with the first and last foot subdivided in 1/10- or 1/100-foot increments for measurement of fractional distances. Engineer tapes also can be further divided into adding and subtracting tapes, which have extra graduations beyond the zero mark. When using an adding tape, the fractional part is added on to the measurement held by the rear chainer. With a subtracting tape, the fractional part held by the head chainer is subtracted from the measurement held by the rear chainer.
  - A surveyor’s tape (or Gunter’s chain) is also a steel tape, but with different graduations. Generally 2 chains, or 132 feet long (plus trailer), the tape is divided into links that are 1/100 of a chain (0.66 feet or 7.92 inches).

- **Pacing**
  Pacing is the least accurate method for distance measurement, but accurate pacing is a valuable asset to the timber cruiser working alone. Pacing is commonly defined as the average length of two natural steps. For best results, a natural walking gait is recommended because it can easily be maintained under rough terrain conditions. Pacing uniformly is difficult in hilly terrain because slope distance rather than horizontal distance is being measured. When pacing uphill or downhill, compensations for slope must be made by adjusting or skipping a pace at certain intervals.

For instruction in pacing, a horizontal course (5 to 10 chains) should be measured and staked out on level ground. After establishing a consistent gait, the student should pace the measured course several times until an average number of paces per chain can be determined.

- **Measuring level ground with steel tapes**
  Accurate measurement (also called chaining or taping) of distances with a steel tape requires a two-person survey crew consisting of a head chainer and a rear chainer. On level ground, chaining is a simple operation using 11 chaining pins and a steel tape. Beginning at the point of origin, a chaining pin is placed after the “zero” point and the head chainer moves ahead with the remaining 10 pins. When the end of the tape approaches, the rear chainer shouts out, “Chain!” Both crew members pull the tape taut until the rear chainer calls out, “Stick!” After marking the point with a pin, the head chainer replies, “Stuck!” The procedure is repeated until the desired measurement has been taped. As chaining proceeds, the rear chainer keeps the head chainer on a straight course and also collects the chain pins until a 10-chain interval has been measured.
• Measuring slope with steel tapes
Since acreage is always measured by horizontal distance, in rough and mountainous terrain, horizontal distances may be measured by one of two methods. The first method is called “breaking chain” because only short sections of the tape are used to maintain and measure a level line.

In the second method, foresters may use a 1- or 2-chain trailer tape and an abney level with a topographic scale graduated in percentages of 66 feet. The head chainer moves up or down the slope until the full length of the tape is reached. The rear chainer determines the slope percentage (using the abney level) between his or her position and the head chainer’s. Using the slope percentage correction table (or slope correction graduations on the tape), a correction adjustment is made by adding the proper number of links from the trailer tape. The tape is again stretched tight, a new pin is set, and the correct horizontal distance is marked and recorded.

Measurement of direction
A fundamental purpose of surveying is to determine locations of points on the land surface. In order to fix the position of a point, angles and directions, as well as distances, must be determined. Horizontal angles are the basic measurements for determining bearing and azimuths.

• Bearings
The use of bearings is one system of representing directions of lines. The bearing of a line is the acute horizontal angle between it and a reference line (meridian). The angle is always measured from north and south to east or west, dividing the circle into quadrants of 90 degrees each. Bearings never exceed 90 degrees and are always referenced to one of the quadrants of the compass (NE, SE, SW, NW). (See figure on next page.)

• Azimuths
Another system of designating directions is the azimuth, which varies from 0 to 360 degrees. An azimuth is the angle a line makes with the true north-south line (meridian) and is always measured in a clockwise direction from due north. The relationship between bearings and azimuths can be seen on the next page. Azimuths are generally true or magnetic, depending upon the meridian used.
Magnetic declination and local attraction
The angular difference between magnetic north and true north is called declination. Because the earth acts like a magnet, corrections are necessary (for either east or west declinations) to compensate for compass distortions caused by the earth’s magnetic field. The amount of magnetic declination changes from place to place and from year to year. Isogonic charts are issued periodically and used to determine exact declinations.

Compass readings used in establishing and retracing property lines are generally recorded as true bearings or azimuths. Therefore, adjustments for magnetic declination can be made by setting the correct allowance directly on the compass. As long as the declination does not change, all compass readings will be in true bearings (and azimuths) rather than magnetic.

Other local magnetic attractions may also cause a compass to read incorrectly. When surveying is being done near ore and mineral deposits, fence lines, or electrical transmission lines, care must be taken to keep these “local attractions” from affecting compass readings.

Lines of Declination in the United States
Instruments and use

For most forestry applications, the compass is still the main instrument used for angle measurements. A compass consists of a magnetized steel needle (which points toward magnetic north), mounted on a pivot at the center of a circle which is graduated in one-degree units. There are many types and brands of compasses, but foresters commonly use either the hand compass or the staff compass.

- **Hand compass**
  The hand compass is held with both hands about chest high. Bearings are determined by sighting along the desired line through a notched site in the compass box. The bearing of the line is then determined by reading the degrees shown on the compass dial when the needle and the orienting arrow correspond. A viewing mirror aids in sighting the bearing line and turning the compass dial simultaneously.

- **Staff compass**
  A staff or surveyor’s compass is a box compass very much like the hand compass, but instead of being hand-held, it is supported by a wooden “Jacob’s” staff (or tripod). The staff is placed firmly in the ground and the compass box is attached and leveled, using a circular leveling vial. The compass also has a device for clamping the needle securely (for transporting) and an exterior screw for changing the declination. Bearings are determined by sighting through two vertical sighting vanes that are aligned on the north-south axis. Direct readings of bearings (in degrees or half degrees) are shown on a circular scale at the outer rim of the compass box. Accuracy of the staff compass, when used in conjunction with a steel tape, is approximately 1/300. (For more exact surveys where greater accuracy is required, a vernier transit should be used.)

Boundary surveys and traversing

**Boundary surveys**

Foresters survey the boundaries of a timber tract to establish exact property lines, to locate timber-cutting areas, and to determine the area of a tract. Occasionally, land surveys are used to locate fences and firebreaks; to plan for logging roads, skid trails, and log loading areas; to locate water drainages, culverts, and bridges; and to map timber types, soil series, watersheds, or recreational areas.

**Traversing**

A surveyor traverse is defined as a “series of consecutive lines whose lengths and directions have been determined by field measurements.” There are two basic types of traverses: closed and open. A closed traverse begins and ends at the same point and forms a closed polygon of an undetermined area. An open traverse generally begins at a known point and consists of a series of connected lines that terminate at an unknown position.

![Open Traverse](image1)

![Closed Traverse](image2)

**Method of running a traverse**

Most boundary surveys or closed traverses require a three- or four-person crew. The crew generally consists of a party chief who serves as a compass operator and note keeper, two people who chain horizontal distances, and the fourth person who handles the range poles at each compass setup.

Beginning at a known corner (A), the surveyor’s compass is set up and a compass bearing (foresight) is made to the next corner (B). The compass operator records the foresight (nearest degree), and the two chainers tape the distance between points A and B. At point B, the compass is again set up and a bearing reading back to point A is taken. This is termed a backsight and is used to check for local attraction and accuracy of the foresight. The survey from point B to point C and other points in the traverse are made in the same way as from A to B. All foresights, backsights, and distances are recorded in the field notebook. Normally, the fourth person in the survey party places a range pole at each point, which acts as a temporary marker until a wooden stake can be driven into each corner station. Each traverse station is designated as A, B, C, D, and so forth.
Field Notes and Plotted Area for a Closed Traverse

After the traverse is complete, the interior angles and distances should be plotted on standard cross-section paper. If the bearings have been properly taken, the sum of all interior angles should equal \((n - 2) \times 180^\circ\), where \(n\) is the number of sides in the traverse. After the interior angles are checked, the traverse should be plotted at a convenient scale. If the horizontal distances have been chained correctly, the plotted traverse should appear to “close.”

**Determination of area**

After the closed traverse is plotted, several methods can be used to compute the area enclosed within the survey boundaries.

**Cross-section squares**

Assuming the traverse is plotted correctly, the enclosed area can be determined graphically by computing the area of the small squares found on the cross-section paper. The total acreage can be easily found by counting all the small squares enclosed within the plotted traverse.

**Triangulation**

Most tracts can be divided into triangles by connecting the various plotted points. Having done this on the plotted traverse, the area of each triangle is computed by the formulas \(A = \frac{1}{2} (a + b + c)\). The sum of all the areas of the triangles is the total tract area.
**Planimeters**

Polar planimeters are instruments used to trace the outline of the plotted traverse area. As the boundaries are traced, the planimeter mechanically records the area in square inches and is read directly from the vernier scale. With this information, the total area of the traverse can be determined by converting the square inches to the scale of the map.

**Reddi Mapper**

This is a very simple, inexpensive tool to use. It can be made or purchased. The azimuth (compass) portion can be tracing paper or plastic material that will accept pencil marks. The azimuth degrees are printed around the outside edge of a 12- to 14-inch piece of transparent plastic or paper. Some bookstores sell paper with the azimuth printed in the margin. The exact center is noted.

This unit is then mounted on a piece of hardboard on which is glued cross section paper (10 lines to the inch). The center of the hardboard should have a pin or nail on which the plastic unit is centered. The top centerline (directly above the nail) on the graph paper is marked north. This is the orientation point to use when recording the compass reading and distance.

To use the Reddi Mapper system, all that is needed is a pencil, ruler, compass, and knowledge of pacing. The surveyor selects the starting point, estimates the area, chooses a scale so that the map will fit on the plastic sheet, and takes a compass reading from A to B. The distance from point A to point B is paced and the plastic sheet is pivoted on the nail until the azimuth reading on the plastic reads the same as the compass reading over the north mark at the top of the board. The distance is then drawn on the plastic to scale. The points are marked A and B, with the compass reading and distance recorded in a notebook.

The surveyor then moves to point B and gets the compass reading and distance to point C. The plastic is pivoted until the azimuth reads the same as the compass reading, always orienting the azimuth (compass reading) with the orienting north mark on the graph paper. The surveyor then follows the same process to the next points. Eventually the traverse closes. The final task is to determine the area in the traverse, by the cross-section squares method.

**ADDITIONAL ACTIVITIES**

- Discuss the types and purposes of surveys.
- Have students list reasons for accuracy and precision in surveying.
- Display surveying equipment and explain the function of each instrument.
- Display samples of field notes and discuss the importance of neatness and accuracy in these records.
- Have students work problems requiring conversion from one basic unit of length to another, e.g., acres of miles to chains.
- Arrange demonstration of and have students participate in the surveying of a particular forest tract that includes both level ground and slope.
- Demonstrate and have students run a closed traverse and determine the area of the traverse.
- Demonstrate and have students practice using a Reddi Mapper.

**SUGGESTIONS FOR STUDENT EVALUATION**

- Students may participate in a survey crew.
- Students may determine acreage to nearest hundredth of an acre.

**SUGGESTED RESOURCES**

- *Elementary Forest Surveying and Mapping*, Robert L. Wilson
- *Elementary Surveying*, Russell C. Brinker and Paul R. Wolf
- *Forest and Forestry*, David A. Anderson and William A. Smith
- *Forest Measurements*, Eugene T. Avery
- *Fundamentals of Surveying*, Milton O. Schmidt and William H. Rayner