Basic Recon Line Survey Methods

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PREFACE

This RTC-TH Applied Geography paper provides basic information about line surveys. There are numerous uses for line surveys in geography field mapping. This paper is the start of a series of papers related to line surveys. The specific assessment methods have been adapted from other RTC-TH field survey methods contained in RTC-TH Publication AG-2010-2 Natural Terrain Study Guide. New lessons / adaptations are developed whenever a specific need arises. Survey methods are tools that can be applied to an number of other RTC-TH activities and program.

Various specific adaptations of line surveys follow in the series as a subset of this paper. For example, this RTC-TH publication number is AG-2010-4 Basic Recon Line Survey Methods. Another paper applies line survey methods to determine elevations (leveling) and is numbered AG 2010-4-1 Fast Recon Leveling Surveys. Leveling surveys could be used in the following:

- SOW / SOS: setting markers for terrace grading; soil sampling.
- IFS: determining stream flow head heights for water pumping site assessments
- SOW: determining elevation differences for drip irrigation lines or gravity flow irrigation systems
- BUGS: forest canopy density surveys

RTC-TH Demonstration Farm Programs

Light green shading indicates this lesson can be used in the programs listed above.

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Geography, Line Survey

Basic Recon Line Survey Methods

Community-based Environmental Education for Families and Sustainable Communities

1.0 INTRODUCTION

A line survey is a field data collection method. The line can be straight (line-of-sight) or curvilinear (not straight), short or long, continuous or discontinuous. This paper will discuss the basic types of line surveys on land using low-tech / low cost methods as these are more suitable to rural conditions. Each type of line survey has advantages and disadvantages. The challenge is to find the line survey method best suited to your purpose.

The general rule of thumb is to let the "data" do the talking. Rather than impose pre-conceived notions on the data collection, the field site or natural characteristics of the phenomenon should be your guide.

Any field survey is an exercise in sampling. It is impossible to measure everything in the study area. So sampling (and statistics) becomes significant in determining one of the most critical details of the survey: how many observations are to be made. [**Note:** This paper focuses on "recon" surveys, which are preliminary scouting-type surveys. Legal land description precision and accuracy are NOT the norm for a recon survey. Recon surveys provide a general description of the area and identify sites within the area that may warrant detailed study.]

2.0 LINE SURVEY CHARACTERISTICS

The key line survey characteristics are length, alignment, and orientation.

- ***Length*** is determined using standard measuring tapes. Errors of a 1-3 meters are acceptable for recon survey work. For construction, more detailed surveys / measurements should be made.
- ***Alignment*** is generally straight (or line-of-sight, where you can clearly see the entire length of the survey line from one end point to the other) or curvilinear (where you cannot see the entire length of the survey line from one end point to the other).
- ***Orientation*** is measured using a magnetic compass. Most commonly available compasses (non-survey, non-professional grade) are only accurate to 2-5º. For short distances (on a small farm of a few acres), this will work. Land navigation over longer distances will require much more care in use and / or better quality equipment.

2.1 Length: Generally, survey lines can be short or long. This is a relative and subjective characteristic, so no exact numerical length limits are set. Functionally you can set the distance for a short line based on visual acuity. If you can imagine a perfectly level surface with 2 end points connected by a straight line, this can be the model. You can only see so far. On a clear day, it would be farther than in twilight conditions or fog. In an open grassy field it would farther than in thick, tall brush. The important thing is to know the distance of each survey line, and the total

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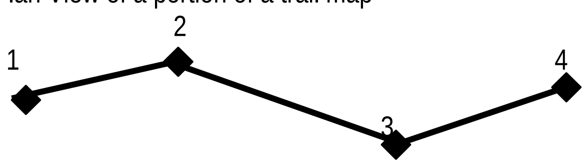
distance for all survey lines in a single study. This is part of the data needed to determine the total number of measurements or “samples” you have for the study.

Measuring Tapes and Data Processing: Computers and digital electronics are basic information age processing tools. This makes decimal mathematics more convenient for field use. Using ISU (international standard units, the metric system) to measure length is very convenient. If using traditional English units (e.g. feet), consider using decimal measuring tapes (tapes that divide the foot into 10 parts rather than the traditional 12 inches).

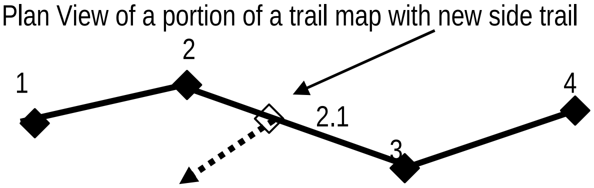
2.1.1 Station Marking Pins: A temporary pin (peg) should be placed at each survey station on the line survey. Each pin should be clearly labeled with the station ID number. Station marking pins should be left in place until the survey is completed. For example, on a trail survey, the survey team moves up the trail placing the marking pins as the trail measurements are taken. On the way back down the trail, the survey team double checks the measurements following the station marking pin identification numbers BEFORE removing the station marking pins. This redundancy in measurements is one way to assure survey accuracy. [**Note:** The distance measurements may be the same, but the magnetic azimuth measurements will NOT be the same. Proceeding up the trail will give a forward azimuth. Returning down the trail will give the back azimuth.

2.1.2 Station ID Numbering: A decimal numbering system for survey stations gives flexibility to add intermediate survey stations later without having to renumber all subsequent stations.

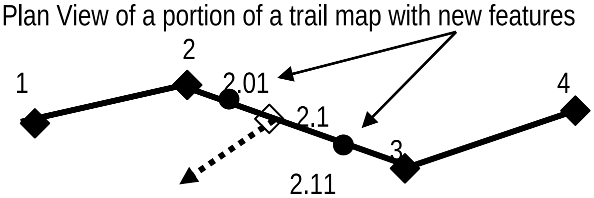
Plan View of a portion of a trail map



Plan View of a portion of a trail map with new side trail



Plan View of a portion of a trail map with new features



Decimal numbering gives flexibility to add station numbers without having to renumber all subsequent station numbers on the line. For example, between station 2 and 2.1 a new trail feature is identified at station 2.01.

2.2 Alignment: Straight lines are easy to work with both in the field and in the office. From geometry, you know that any curved line can be closely approximated by a series of shorter straight lines. In some cases, short survey lines are obviously simple line-of-sight. But the line-of-sight applies to both horizontal and vertical situations. The length of a line-of-sight survey varies depending on the topography and the alignment of the study object. In some cases, the actual ground track of the survey line is approximated using a series of short straight lines, so the straight line-of-sight distance is NOT the same as the actual ground distance for the line survey.

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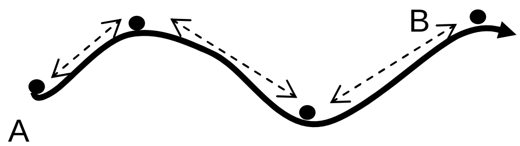
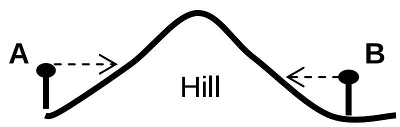
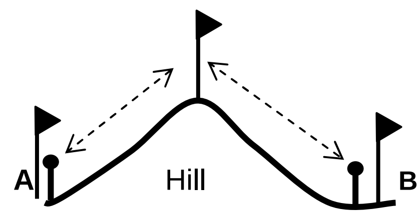
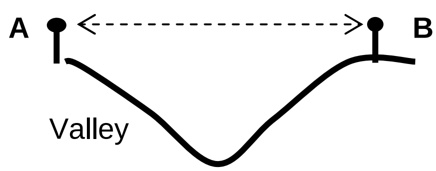
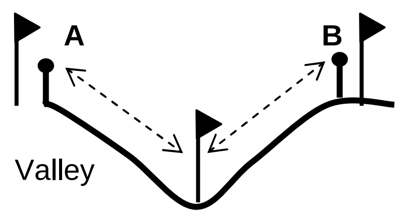
Viewpoint	Straight Line / Line-of-Sight	Curvilinear
Horizontal (Plan View)	Surveyors A and B can see each other.  Straight trail on a plain	Surveyors A and B cannot see each other.  Winding trail on a plain
	Use a series of short, straight lines to approximate the curves of a trail so surveyors can see each other in a series of short straight lines..	
Vertical (Profile View)		
	Use range poles when surveyors A and B cannot see each other.	
		
	Use range poles when surveyors A and B can see each other, but not all points along the survey line.	

2.2.1 Range Poles can be used at start / end points of the line survey and at intermediate points when necessary to help surveyors keep aligned. Range poles can be used on very long straight line-of-sight surveys as well as curvilinear survey lines. (See diagrams on the previous page.) When setting up range poles, consider the following points:

- **Securely Anchored:** Make sure the range poles are secured so they are perpendicular to the surface and will NOT blow over or tip out of alignment.
- **Tall Enough:** Make sure the range poles are tall enough to be seen over the terrain and vegetation that exists between the start / end or intermediate points on the survey line.
- **Highly Visible:** Use brightly colored flagging so the range pole is highly visible (especially from a distance).
- **Color Coded Flags:** If more than 2 range poles are used, color code the flags so you can clearly identify the range poles from a distance.

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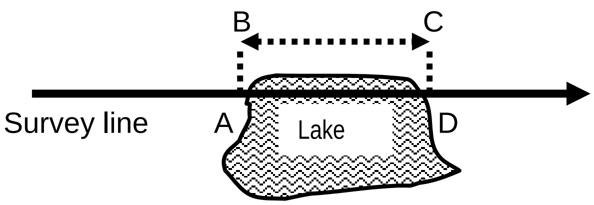
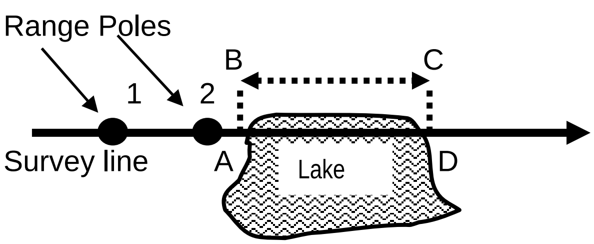
2.2.2 Offsets can be used when obstacles prevent you from surveying in a straight line. This can occur with water bodies, large trees, etc. Traditionally, offsets are a series of right angle (90º turns relative to the alignment of the main survey and supplementary survey lines). Range poles can be used for very large offsets. Be careful when using more than 2 range poles on a single survey line. Make sure you know which range poles you should use to get the correct alignment.

Offset ABCD



The original survey line goes through a lake that the surveyors cannot follow. They do an offset by:

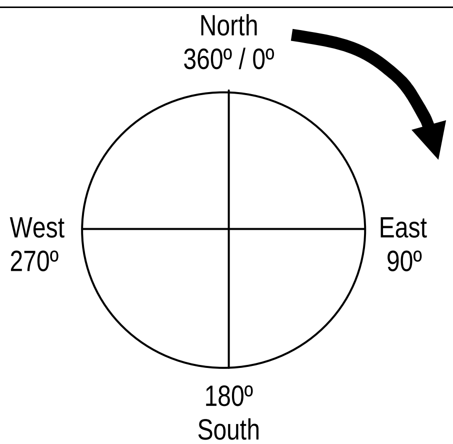
- Turning 90º from line AD to make line AB long enough to skirt the lake.
- Then turning 90º from line AB to make line BC to skirt the lake.
- Then turning 90º from line BC to make line CD to rejoin line AD to continue the survey.



Range poles can be set to assure survey line AD is maintained.

- Range poles 1 and 2 are places along survey line AD using the azimuth for AD.
- Surveyors complete Offset line BC and make a 90º turn and start line CD.
- Line CD ends when the surveyors can look 90º from line CD and see range poles 1 and 2 form a single line.

2.3 Orientation: Directional measurements should be made with a magnetic compass using the azimuth method. It uses a full circle (360º) to specify a horizontal angle for direction. The "0º" (zero) direction line is coincident with the 360º direction line. Azimuth numbers are read going clockwise around the circle. Thus each direction (N, E, S, W and all points in between) is given a unique horizontal angular measurement. This eliminated confusion. The center of the circle represents the occupied station point.



To Measure Azimuth:

Imagine you are standing in the middle of the circle in the picture on the left.

Step 1. Stand on the station looking toward the next survey station.

Step 2. Aim the magnetic compass directly down sighting pole, but keep the compass level so the needle swings freely.

Step 3. Read off the azimuth angle in degrees ranging from 0º (starting at North) going clockwise around the circle.

Step 4. Record the azimuth number. Take a total of 3 azimuth readings.

Do Not Correct for Magnetic Declination while in the field.

0º & 360º = North	90º = East	180º = South	270º = West
45º = Northeast	135 – Southeast	225º = Southwest	315 = Northwest

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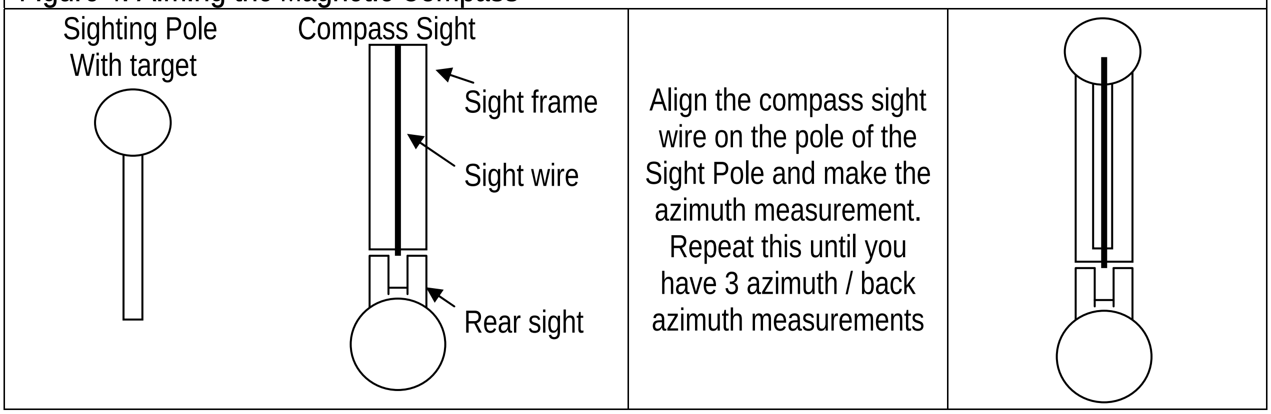
To make magnetic azimuth measurements, place the compass on top of the sighting pole. Make sure the compass dial / needle moves freely. Align the sights of the compass so the compass sight wire is lined up on the pole of the sighting pole at the survey station you are measuring and also centered in the notch of the rear sight on the compass. Then carefully look at the azimuth number lined up with the compass sights.

> ***CAUTION:*** Keep magnetic compasses away from metallic fence posts, wire fences, metal guy wires, and other metal objects (including your personal items you may be wearing) when using the magnetic compass to take readings.

Figure 4: Aiming the Magnetic Compass



> All field measurements should be referenced to Magnetic North.
> ***<u>It is highly recommended not to correct for magnetic declination in the field.</u>***
> Any errors in the field data may be very difficult or impossible to correct later.
> Make declination corrections in the office.

2.3.1 Finding True North: Use the "Shadow Stick" method to find True North. (See Appendix 1 for details for details on finding True North.) This requires nearly a full day of clear sky, bright sunlight conditions, and a large open space that will not be shaded by trees, buildings, or the surrounding terrain. Finding True North is necessary to determine the presence of local magnetic anomalies that can adversely affect the magnetic compass. It is also a check on the local magnetic declination if you don't have any other way to get this data (e.g. updated topographic maps, on-line sources).

> ***CAUTION:*** Magnetic declination information 10 or more years old is not useable. Published data 5-7 years old may be useable, but have larger inherent errors than current on-line data at http://www.ngdc.noaa.gov/seg/geomag/jsp/Declination.jsp

2.3.2 Magnetic Declination Adjustment should be made to all survey data in the office at the same time. This prevents inadvertent erroneous declination adjustments in the field that can corrupt field measurements. You should also check the current magnetic declination relative to the scale precision of the magnetic compass used for the survey. (See Appendix 2 for details on declination adjustments.)

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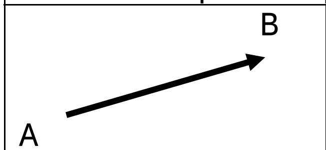
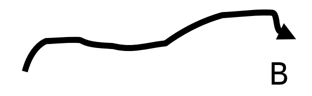
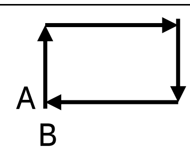
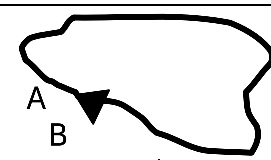
3.0 LAYING OUT THE SURVEY LINES

Planning the line survey begins with map studies in the office before going to the field. Thorough understanding of the phenomenon to be mapped is critical to the success of the map. For example, soils tend to be gradational. The boundary may not be as distinct as the boundary made by the edge of a paved road and bare soil. To detect the presence of a phenomenon (e.g. a soil boundary), the survey lines should be oriented at right angles to the suspected alignment of the boundary. This increases the chance for the survey data to reveal a change / contrast over a minimal horizontal distance to help pinpoint the boundary.

3.1 Open or Closed Surveys: Line surveys can be open-ended or closed. Open-ended surveys are often exploratory in nature, scouting into “unknown” areas. Closed surveys are often used to delineate areas or the limits of areas under study.

Open or Open-Ended		Closed	
 Regular	 Irregular	 Regular	 Irregular
The end points of the survey line or survey do not meet or coincide.		The end points of the survey line or survey meet, and the survey line forms a polygon that encloses an area.	

3.2 Other Considerations: Numerous factors influence the planning of line surveys. Some considerations are:

- **Study site geometry:** In some cases, the shape or terrain of the study area lends itself to an obvious survey line alignment or pattern. For example, it is easier and safer to lay out survey lines parallel the only single road in the area so surveyors don’t have to frequently cross the road when gathering data. Straight survey lines projected across a lake pose a problem for land-based surveyors. Following a hiking trail obviously calls for a single, irregular line survey.
- **Sampling density / frequency** relative to mapping accuracy: As in statistics, the larger the sample size, the better the results. But collecting more data means more costs for time, labor, materials / supplies, and post processing. Most projects will be a balancing act between time and costs to meet project specifications.
- **Time constraints** for the survey will affect the sampling density / frequency and accuracy. Another dimension of time are seasonal patterns (which also involves site field conditions).
- **Site field conditions** such as terrain / topography, weather / climate, vegetative cover, land use / restrictions, regulations / permits, wildlife migrations, etc. can affect the access to the area as well as the mobility of the surveyors. All of these can impact the time constraints, sampling density / frequency, and site geometry.
- **Inherent nature** of the phenomenon being mapped: Line surveys are best suited for continuous phenomenon or features that gradually change spatially (e.g. soils, vegetation, etc.). These tend to have a linear or areal dimension to them. Spot or point phenomenon may be detected using line / pattern surveys. But other search criteria specific to the phenomena may be more cost effective (e.g. look for a

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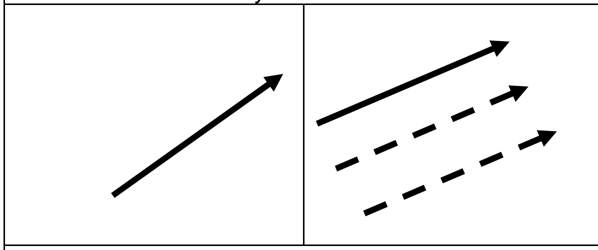
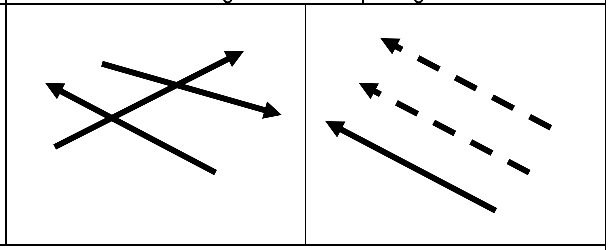
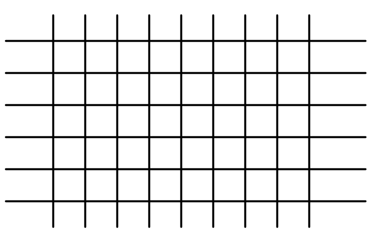
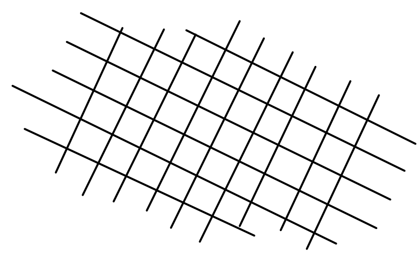
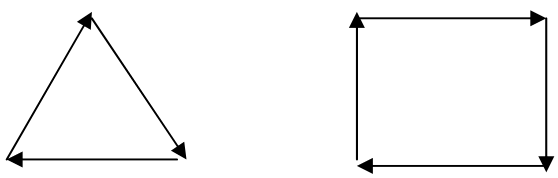
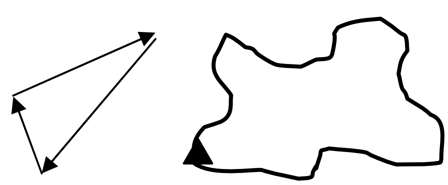
specific bird species based on nesting habits rather than surveying the entire valley).

3.3 Survey Lines and Patterns: Survey lines / patterns can be distributed in the study area in a regular, random, or subjective way. Random lines / patterns are used to minimize subtle and subconscious biases sometimes associated with regular line / patterns. Subjective survey lines / patterns are usually based on localized site conditions and the expertise / experience of the surveyor.

	Survey Line Distribution	
	Regular	**Irregular / Random**
Simple Lines	Single Traverse or Parallel Lines Usually pre-planned in the office on maps prior to arriving in the field. Parallel lines are set at a pre-determined spacing / distance that would be standard for the duration of the survey	Random Line(s) or Parallel lines Often done on site. A marker is thrown over the shoulder to randomly pick a starting point. The azimuth is also picked at random. Parallel lines laid out relative to the first random line using a standard spacing
		
	Numerous factors need to be considered in planning line surveys: site geometry, sampling rate, time constraints, site conditions, and the inherent nature of the object of study.	
Basic Patterns	Regular Grid Grid patterns can generate mountains of data. Careful attention is needed to properly identify each survey line so the data are properly portrayed.	Irregular / Random Grid The grid orientation is randomly determined as for the random line / parallel line survey.
		
	Regular Shapes Good for assuring uniform area coverage or search pattern for an area. Outward spirals provide increasing search radius in searches.	Irregular / Random Shape Often used to adapt the survey to local site conditions and geometries.
		
Line spacing for parallel lines and grids should be equal to or smaller than the smallest dimension of the phenomenon of interest. For example, if a certain type of endangered plant grows in patches 8 m / 24 ft in diameter, the line spacing should be 6-8 m / 18-24 ft. This will increase the chance that a survey line will cross a part of a patch of the vegetation. Some basic patterns are summarized below.		

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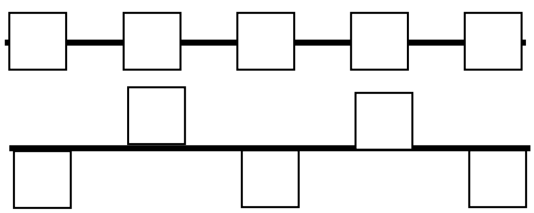
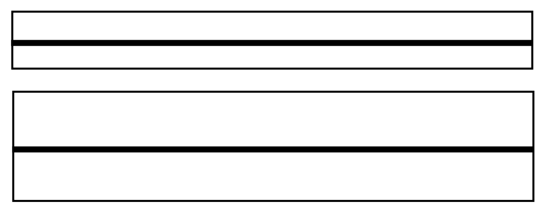
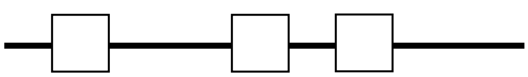
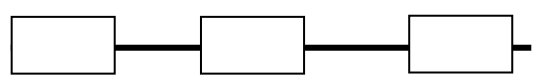
4.0 SAMPLING FREQUENCY AND PATTERN

The number of samples collected, measurements taken, or observations made along a survey line determine the level of detail or accuracy of the survey. This also affects the data volume, survey time, and post-processing time. All of these affect project costs.

The data collection can be point-interval spot sampling or continuous sampling along the survey line. These basic methods can be modified to be binary (yes / no; 0 or 1), small / spot area sample (quadrat; See Appendix 3 for a description), belt / swath, and randomized.

Point / Interval	Continuous
	
Point / Interval Line Survey Observations are made and data are recorded at regular intervals along the survey line whether or not the items of interest are present.	***Continuous Line Survey*** Observations are made continuously all along the survey line with data recorded as items of interest are encountered.
	
Quadrat Line Observations are made and data recorded at regular intervals along the survey line inside a quadrat frame (typically an area 1 sq m) rather than for a spot / point.	***Belt / Swath or Line-Area Survey*** Observations are made continuously inside a swath or belt on both sides of the survey line. The belt width can be wide or narrow
	
Random Quadrat Line A modified quadrat line survey where placement of the quadrat frame is determined by randomly tossing a marker along the survey line. Observations and data are made only inside the quadrat frame.	**Interrupted Belt / Swath Survey** A modified belt / swath line survey where observations and data records are made only inside the designated swath area (typically larger than a quadrat frame) that can be at regular intervals or at randomized intervals.
Other sampling patterns can be created to suit the particular needs of the survey and site conditions. Whatever sampling pattern you create, be sure to document the rational for the pattern and the detailed procedures used.	

For a 100 m / 300 ft survey line, measurements made every 4 m yields 25 measurements. Collecting data every 2 m yields 50 measurements, double the data volume when sampling every 4 m. If you were to make continuous measurements, there is no way to tell what the data volume will be. Essentially for a continuous survey, if you looking for a specific plant species, you would walk along the survey line and record the location of every single plant of that species as it occurred along the survey line.

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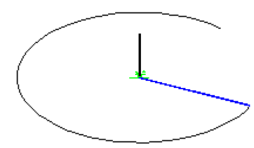
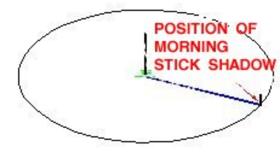
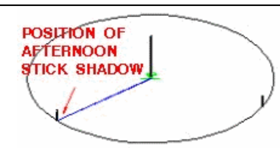
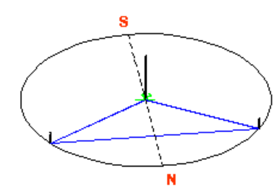
Appendix 1: Finding True North Using a Shadow Stick

This should be done BEFORE starting the line survey and requires clear skies, bright sunlight conditions, and a large open area.

Requirements	Weather	Clear skies, bright sunlight casting distinct dark shadows all day long.
	Time	• **Set up:** 15 minutes. • **Solar Observation:** The better portion of a day, starting in the morning and going until mid-afternoon.
	Space	Large open space exposed to bright sunlight all day long.
	Equipment	• 1 stick about 1 m / 3 ft long • 2 long pieces of string or a long tape measure • 2 short marker pegs

These procedures are applicable for the northern hemisphere.

Step 1. Get a stick 2 or 3 feet long and drive it a few inches into the ground as straight as you can. This means you might want to use a plumb bob made from suspending a pocketknife or other weight on a length of string. **Step 2.** Tie a piece of string at the base of the pole.	
Step 3. Use the piece of string to draw on the ground a circle whose radius is the length of the pole's shadow in the morning. This may mean adjusting the length of the string until it just matches the length of the sun's shadow. **Step 4.** Now drive in a short stick at the point on the circle that the shadow just reaches.	
Step 5. As the sun rises and the hours progress during the day the shadow will get shorter, but in the afternoon the shadow will again touch the circle. Mark that point with another small stick.	
Step 6. Stretch a length of string between the two short sticks to measure their distance apart. Fold the string in half to find the center point and mark that point.	
Step 7. Scratch a line on the ground from the tall stick to the centerline (or halfway) point just located and you have your north-south line. The direction north is AWAY from the tall stick Toward the halfway point.	
Step 8. Placing the magnetic compass at the center stake and measure the angular difference between the True North line of the shadow stick to the Magnetic North indicated by the compass determine local Magnetic Declination.	
Diagrams from http://www.bluebirdobs.org/observatorytools/SunPosition.html	

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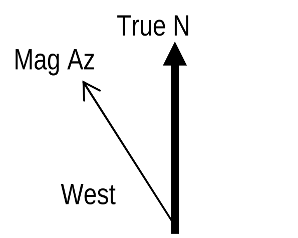
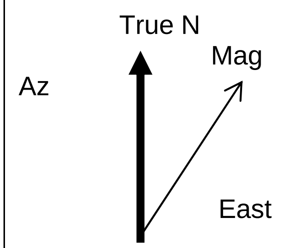
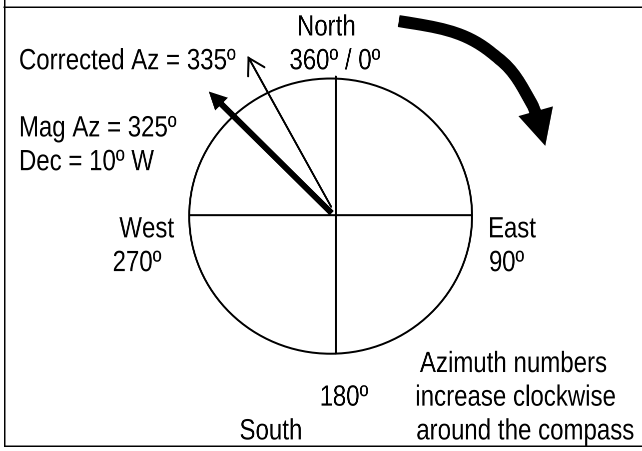
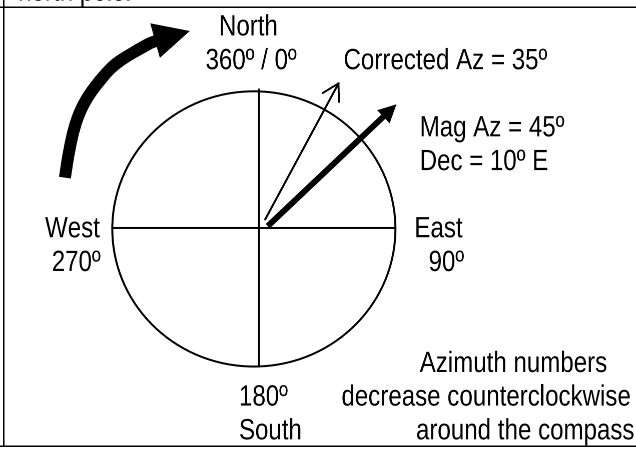
Appendix 2: Magnetic Declination Adjustment

Note: If the magnetic declination data is more than 10 years old or comes from an unknown or undocumented source, find true north using a shadow stick (See Appendix 1.)

<table>
<tr><th colspan="2">Declination West of True North…</th><th colspan="2">Declination East of True North…</th></tr>
<tr><td>…add the declination to the magnetic azimuth to get to True North</td><td>
</td><td>
</td><td>… subtract the declination from the magnetic azimuth to get to True North</td></tr>
<tr><td colspan="2">Mag Az + Mag Dec = True North</td><td colspan="2">Mag Az – Mag Dec = True North</td></tr>
<tr><td colspan="2">When the magnetic azimuth is pointing west of True north, you must turn toward the north pole going clockwise to get to True North. Since the azimuth numbers increase in a clockwise direction around the compass circle, this is like adding magnetic declination to the magnetic azimuth in order to get to the north pole.</td><td colspan="2">When the magnetic azimuth is pointing east of True north, you must turn toward the north pole going counterclockwise to get to True North. Since the azimuth numbers decrease in a counterclockwise direction around the compass circle, this is like subtracting magnetic declination to the magnetic azimuth in order to get to the north pole.</td></tr>
<tr><td colspan="2">
</td><td colspan="2">
</td></tr>
</table>

On-line declination calculator. http://www.ngdc.noaa.gov/seg/geomag/jsp/Declination.jsp Requires Lat / Long (either decimal degrees or degrees, minutes, seconds) and the calendar date for the calculation. Output is the magnetic declination adjustment and the annual declination change. (Note: Annual declination changes are valid for about 5-7 years.)

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Appendix 3: Quadrat Frame

A quadrat frame is a tool for sampling an area. The size can vary, but a 1 m square is common for recon surveys. The quadrat frame is 1 m x 1 m (inside dimensions of the frame). It is subdivided into cells, each 0.25 m x 0.25 m.

A	B	C	D
1			
2			
3			
4			

- The cells in the quadrat frame are uniquely identified by row and column indexing.
- Item counts are made and recorded for each cell.
- A summary total for all items and all cells is compiled for the frame at each sampling location.
- Relative % are calculated for the survey items for each quadrat frame / sampling point.
- An area composite summary is tallied to characterize the survey area

Quadrat frames can be made in various sizes. They can also be nested within larger quadrat frames. Quadrata frames can be portable, semi-permanent, or permanent as needed.

Sample counts are taken for the ground surface contained inside the quadrat frame. The sample counts can be quantitative (numerical) or qualitative (descriptive terms describing the relative occurrence of an item; abundant, frequent, occasional, rare). Counts are tabulated for each cell, then summarized for the quadrat frame. Relative % for each category (e.g. plant species, rock type, etc.) can be readily calculated. Qualitative terms can be used based on relative frequency counts in the area (which could be the entire study area or a subunit in the area).

Abundant	Most frequently occurring in the area.
Frequent	Regularly occurring, but not as numerous as to be predominant in the area.
Occasional	Found in the area but not as often as “frequent”.
Rare	Not usually found in the area.

After compiling the statistics from your survey, you can assign % range values to these descriptive terms

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