edge against the linear course that is to be measured and mark the beginning point at one end of the paper using a sharp pencil.

Align the fold against the course to be followed and mark straight segments successively along the paper's edge, turning the paper to follow the path. Mark the end of the course on the paper when you have completed the final straight section. Now place the folded edge of the paper against a bar or graphic scale to read the distance directly in meters, feet, miles, etc. If you are working with an image rather than a map, the measured distance on the paper may be converted to meters or feet using the RF value following the procedure explained in Chapter 1.

Use of a Map Measurer. There are a number of companies listed in map-related catalogs that manufacture a device commonly called a **map measurer.** (Also referred to as an opisometer or map wheel.) This is a relatively simple instrument that easily fits in your hand and is used to trace an irregular course on a map or photograph. It consists of a small tracing wheel on the end of the instrument which is connected by gears to large dials that may be marked in centimeters, inches, feet, or other units. See Figure 2–1.

Care should be exercised if you use or purchase a map measurer—since they are utilized by architects, planners, foresters, geographers, geologists, and others, the dials are marked in many different units of measure, some of which will not be appropriate for your needs. An inexpensive version can be obtained for less than $10. More precise, sturdier units are available at higher prices.

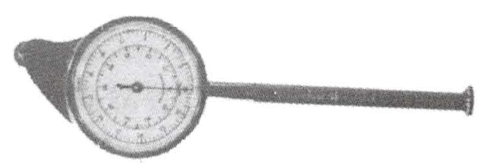

Figure 2–1. Map measurer. Courtesy Avery/Berlin.

Representative fraction (scale)	Meters per centimeter	Centimeters per kilometer	Hectares per square centimeter	Feet per inch	Inches per mile	Acres per square inch
1:1,000	10	100.00	0.01	83.33	63.66	0.16
1:2,000	20	50.00	0.04	166.67	31.68	0.64
1:3,000	30	33.33	0.09	250.00	21.12	1.43
1:4,000	40	25.00	0.16	333.33	15.84	2.55
1:5,000	50	20.00	0.25	416.67	12.67	3.99
1:10,000	100	10.00	1.00	833.33	6.34	15.94
1:15,000	150	6.67	2.25	1,250.00	4.22	35.87
1:20,000	200	5.00	4.00	1,666.67	3.17	63.77
1:25:000	250	4.00	6.25	2,083.33	2.53	99.64
1:50,000	500	2.00	25.00	4,166.67	1.27	398.56
1:75,000	750	1.33	56.25	6,250.00	0.84	896.75
1:100,000	1,000	1.00	100.00	8,333.33	0.63	1,594.22
Method of calculation*	$\frac{\text{RFD}}{100}$	$\frac{100{,}000}{\text{RFD}}$	$\frac{(\text{m/cm})^2}{10{,}000}$	$\frac{\text{RFD}}{12}$	$\frac{63{,}360}{\text{RFD}}$	$\frac{(\text{ft/in})^2}{43{,}560}$

* RFD refers to the representative fraction denominator. After Avery & Berlin, 4th ed.

Figure 2–2. Scale conversions for maps and vertical photographs.

absorption of energy by the Earth's atmosphere. That is, which wavelengths of energy may pass through the Earth's atmosphere to reach the Earth's surface vs. the waves that are partially or completely absorbed by the atmosphere.

The portion of Figure 3–1 labeled **atmospheric transmission** is divided into black areas of attenuation and absorption, and clear areas termed **windows.** These windows are portions of the EMS that allow energy to pass through the atmosphere to be reflected or absorbed at the Earth's surface and then be reflected or emitted at the surface back to space. Since these are the regions of the EMS where reflected or radiated energy may be recorded, these are the wavelengths that have been targeted for use by remote sensing systems. Sections of these windows where different wavelengths may be grouped together are termed **bands.** The bands may be broad or narrow depending upon the objectives for using the imaging system.

This manual will concentrate on several of the most commonly utilized windows. One of these windows is closely related to human vision and is termed the **visible spectrum.** It extends from approximately 0.4 to 0.7 microns (micrometers) and includes the energy that is received by the human eye. This range is included within the broader part of the EMS referred to as the **photographic spectrum** which extends from 0.2 to 0.9 microns (ultraviolet to infrared) and is the collection of wavelengths that may be recorded on film.

The **infrared** region of the spectrum is commonly divided into the **reflected IR** and the **thermal IR.** The reflected infrared extends from 0.7 to 3 microns. Thermal infrared is recorded primarily in two windows, 3 to 5 and 8 to 14 microns. The latter are regions of radiated or emitted energy, referred to in this manual as **TIR.** Reflected infrared energy is compared to visible light later in this chapter and is discussed further in Chapter 7. Thermal IR is pursued in Chapter 10.

Spectral Signatures

All objects and phenomena at the Earth's surface reflect or absorb radiant energy from the Sun. Humans can perceive this reflected radiation within the visible part of the spectrum referred to above. Photographic film may be used to extend the range of the "visible" EMS wherein reflected energy can be recorded and then viewed by using a photographic print or other photo product.

Each Earth surface feature has its own array of reflectance characteristics which are controlled by the nature of the feature. The total amount of sun energy striking an object is the sum of the energy that is reflected, absorbed, and transmitted. The percentage of the energy that is reflected is termed the **albedo** and is a useful characteristic in identification. Objects with a high albedo are bright, e.g. snow, and those with a low albedo are dark as is the case with most wetland and floodplain soils.

In later chapters the spectral signatures of Earth surface features will be shown to vary depending upon the bands of the EMS used to record the features. That is, the spectral signature of an object in one band may be quite different in another band since reflection and absorption characteristics vary with wavelength. For example, growing vegetation reflects strongly within the near IR region and considerably weaker within the visible bands of EMS.

This variation in spectral reflectance is a powerful tool in the use of multispectral satellite imagery. Comparison of spectral signatures by band allows for the identification of a feature or its elimination from consideration once signatures are known.

Figure 3–2 on the following page displays a number of aerial views of small parts of the Earth's surface that have been impacted by human activities. Such artifacts are referred to as examples of **culture** to distinguish them from totally natural landscapes. Note that there is a decided variation in albedo within the photos and from one photo to another. That information will be used as an aid in exercises at the end of this chapter.

chapter 4

PHOTOGRAMMETRIC CONSIDERATIONS

TERMINOLOGY

photogrammetry
vertical airphoto
oblique airphoto
fiducial marks
principal point (PP)
nadir
parallax
sidelap
forward overlap
stereovision
stereopair
low oblique
high oblique
pocket stereoscope
mirror stereoscope
corresponding principal point (CPP)
average photo base length (P)
differential parallax (dp)
stereogram
contact prints
A,B,C location method

PHOTOGRAMMETRY DEFINED

The art and science of obtaining reliable measurements from photographs is termed **photogrammetry.** In carrying out the interpretation of airphotos and other remotely sensed images, it is often of value to know the scale of the image, distances between points shown thereon, and the altitude at which the image was acquired. All of these values are interrelated in a series of photogrammetric relationships that may be expressed as mathematical formulae or in graphic diagrams. Some of the more important aspects that impact image interpretation are discussed below.

VERTICAL VS. OBLIQUE AIRPHOTOS

An aerial camera can be positioned to photograph the ground from any angle above the horizon. In Figures 4–1 and 4–2 some of the characteristics of a **vertical airphoto** are illustrated. Such photos are acquired with the camera pointing vertically down to the Earth's surface on a line which, if extended, would reach the center of the Earth. This is a view that is utilized in airphoto analysis most frequently as it allows for the greatest data extraction based upon photogrammetric principles. For the average person an **oblique photo,** in which the view of the ground is other than vertical, is more familiar and more easily comprehended. However, in oblique photography photo scale is constantly changing from the foreground to the distant background. **Low oblique photos** are those where the camera position is closer to a vertical view, whereas **high oblique photos** usually include the horizon and the camera angle is approaching a horizontal line of sight. The emphasis in this manual is on the use of vertical photography due to the greater amount of information that may be extracted through measurement as well as interpretive techniques.

are sometimes difficult to obtain. Establishing changes that have occurred over time is one of the most powerful capabilities of airphoto study.

It requires approximately fifteen minutes to create and then mount a stereogram on card stock after you become familiar with the procedure. You may modify the following steps to suit your needs.

1. Using two or more overlapping 9″ × 9″ contact airphotos, establish the flight line path by locating the Principal Point (PP) and the Corresponding Principal Point (CPP) on the prints. Mark these locations just dark enough to see. A more precise method is to put a tiny needle hole at the two locations on each photo.

2. Measure the photo base length on each photo so that you can obtain the average photo base length. Measure to the nearest 1/50th inch.

$$\frac{(\text{PP} - \text{CPP photo A}) + (\text{PP} - \text{CPP photo B})}{2} = \text{P}$$

3. Draw two lines perpendicular to flight line 2.2″ apart that will enclose the area to be viewed. (One such strip from each photo will frequently provide for two stereograms.) Enclose the same area on each photo. Remember that these are two different views of the same surface area. (A stereogram produced from two copies of the same print does not yield any three dimensional effect.)

4. Record all information printed on the airphotos before using scissors to cut along both sets of lines. (The information may be included on the stereogram card—see Figure 4–11.)

5. Align one strip with the left margin of the stereogram card's inside margin being careful not to cover any letters or numbers in the margin. (See Appendix C for an example of this type card.) Mark the portion of the strip to be cut to a size of 2.2″ wide and 3.9″ high. Cut it and paste it in the left area of card. Shadows should face bottom of card if possible. **Note!** If photos are aligned on the stereogram card in reverse of the order in which they were photographed, it may result in topographic inversion—rivers become ridges, etc. View strips side by side before pasting to achieve the proper alignment.

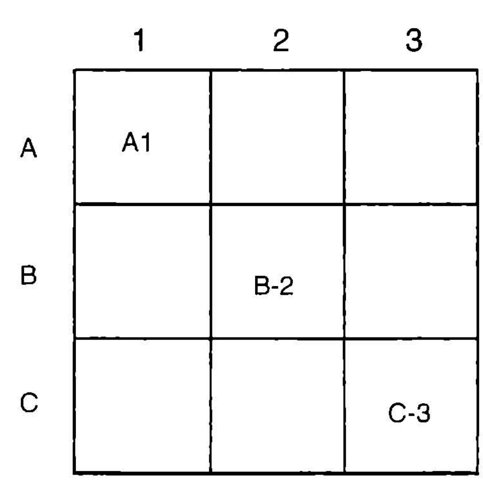

Figure 4–13. Communicating image location.