USDA
United States
Department of
Agriculture

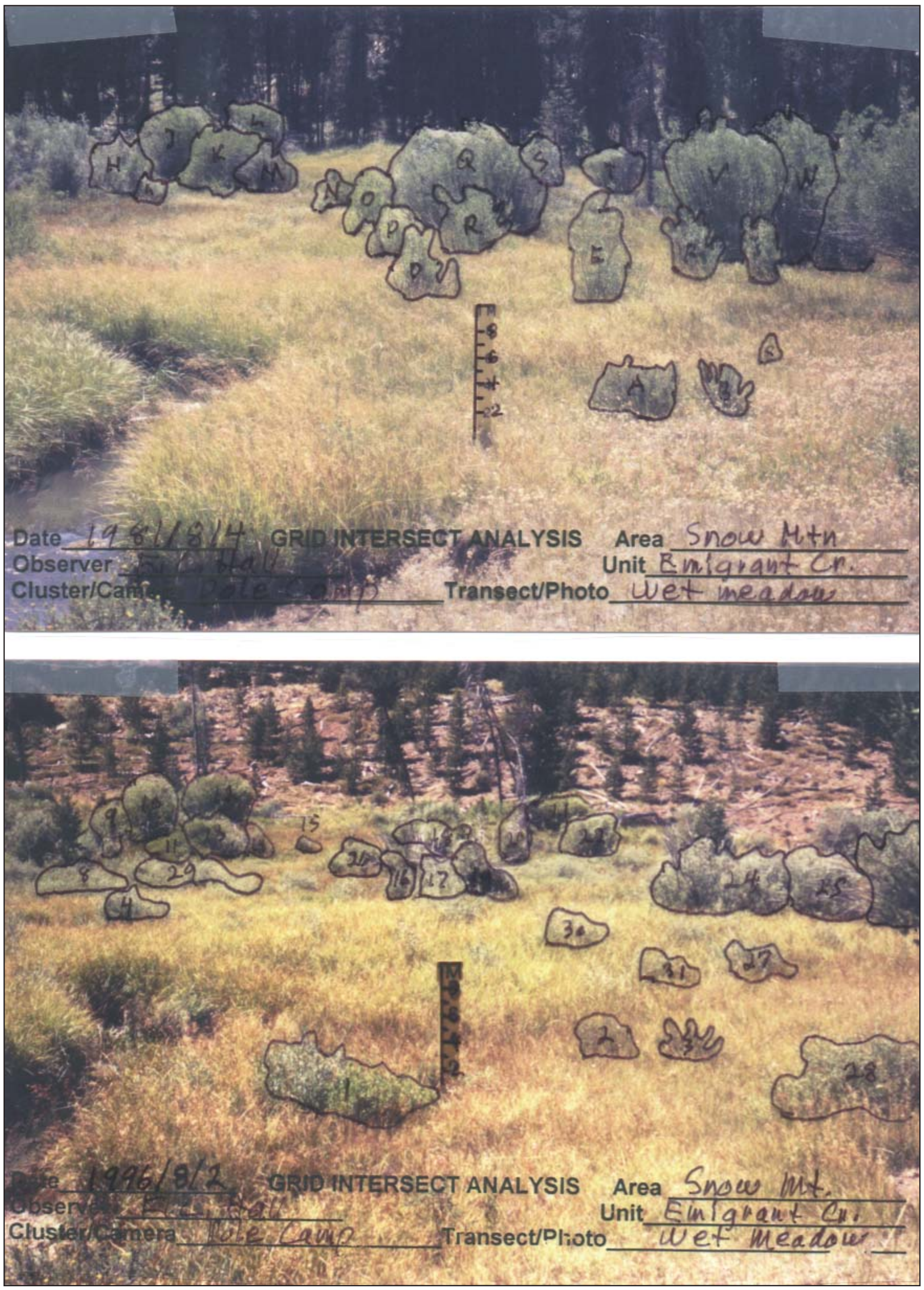
Forest Services

Pacific Northwest
Research Station

General Technical
Report
PNW-GTR-526
March 2002

Photo Point Monitoring Handbook: Part B–Concepts and Analysis

Frederick C. Hall



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Part B contains pages 49–134

Published By:
U.S. Department of Agriculture
Forest Service
Pacific Northwest Research Station
Portland, OR
General Technical Report PNW-GTR-526
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Abstract

Hall, Frederick C. 2001. Photo point monitoring handbook: part B—concepts and analysis. Gen. Tech. Rep. PNW-GTR-526. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 86 p. 2 parts.

This handbook describes quick, effective methods for documenting change in vegetation and soil through repeat photography. It is published in two parts: concepts and office analysis in part B, and field procedures in part A. Topics monitored may be effects of logging, change in wildlife habitat, livestock grazing impacts, or stream channel reaction to land management. Land managers, foresters, ranchers, wildlife biologists, and land owners may find this monitoring system useful. In part B, (1) concepts and procedures required to use photographs for analyzing change in photographs are presented, (2) monitoring equipment specifications are given, and (3) forms for recording information and mounting photographs are provided.

Keywords: Monitoring, photography.

Preface

This handbook is an synopsis of repeat photography principles and photo point sampling from the publication *Ground Based Photographic Monitoring*, PNW-GTR-503, which is based on 45 years experience in repeat photography by the author. During those years, many nuances were discovered that bear discussion and emphasis so that new users can avoid the pitfalls I ran into. The terms *should*, *must*, *will*, and *do not* are used to help users avoid problems and are not meant as rules.

Contents

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Introduction

Photographic documentation of soil and vegetation topics of interest is an essential first step in photo monitoring. But monitoring implies the need to determine change. This determination has two components: (1) the basics of photographic technique; and (2) a method to assess change–in this case, grid analysis, which may be done by hand or with a computer. Appendices provide forms for photo monitoring and analysis as well as equipment specifications.

Basics

Use of photographic equipment is fundamental to photographic monitoring. The equipment may be either film or digital cameras. The purpose of photo monitoring is to document change in a landscape or topic over time. Measuring change requires photographs of good to excellent resolution and color, both of which are influenced by camera and film.

Cameras

Consumer cameras currently are classed into two broad categories: point-and-shoot automatic and single lens reflex (SLR) for either film or digital use. Point-and-shoot cameras usually provide safe exposure in average light conditions to produce nice snapshots. The SLR cameras use a view-through-the-lens system enhancing photographic composition and have various adjustments for fine tuning exposure. They can take superior pictures. Digital cameras are similar, but their quality tends to center on the number of pixels. Pixels are dots of different colors that form an image. Point-and-shoot digital cameras range from 1.1 to 2.4 megapixels and better quality ones usually have 3.4 or more. If measurements on photographs are contemplated, one must use a camera of 2.4 megapixels or higher.

Film and digital camera characteristics—Both camera formats come in two configurations: (1) viewfinder and (2) view-through-the-lens, or SLR. Many digital cameras use SLR principles with a liquid crystal display (LCD). An LCD is a miniature (2.5- by 3.3-centimeter [about 1- by 1.3-in]) computer monitoring screen that displays the image as seen through the lens (Kodak 1999a). With through-the-lens systems, the image is viewed exactly as it will appear. There is no parallax correction and the image will look fuzzy when out of focus. The SLR cameras are more expensive. Viewfinders are parallel with the lens, and there is an outlined box in the viewer (parallax correction) to show what the image will cover when pictures are taken at close range. The image always will appear sharp.

Both film and digital cameras provide for a strobe flash system. Less expensive cameras often have built-in flash that fires straight ahead and is effective up to 9 feet (3 m) for low-light conditions and as fill-in light for up to 16 feet (5 m). More expensive cameras provide a hot shoe to which a more powerful and adjustable flash system can be attached. Additional flash systems add cost to the camera. Some cameras have both an internal flash and a hot shoe.

Zoom lenses have become popular, particularly with the “point-and-shoot” automatic cameras. They are common on many digital cameras. These lenses add flexibility to the camera, but they tend to be less sharp than a fixed lens. Zoom lenses may pose problems in photo monitoring because lenses need to be carefully set to reproduce the original image. This is difficult, if not impossible, with zoom lenses that might range, for example, from 35mm to 100mm focal length for a 35mm film camera and 9.2mm to 28mm for a digital camera. This allows for a threefold difference in photo coverage. See the section on camera format (below) for details.

The lens speed on film cameras is given in f-stops. The “f” indicates how large a hole is open to admit light into the camera. Small f-stops admit much light and large f-stops admit little. For example, under a given light condition, f-8 might require 1/60 second exposure, but f-5.6 would require 1/120 second because it admits twice the light, and f-3.5 would require 1/250 second because it admits four times the light. The f-stop also influences depth of field. The length of in-focus distance increases with increasing f-stops. When a 35mm camera is focused at 30 feet (9 m), f-8 is sharp from 15 feet (4.5 m) to infinity, f-5.6 from 20 to 60 feet (6 to 18 m), and f-3.5 from 25 to 40 feet (7.6 to 12 m). Digital camera speed usually is provided by the processing unit in the camera computer, and faster speed costs more.

Resolution, the sharpness of the image, in film cameras is a function of (1) lens quality, providing that the camera was properly focused; and (2) graininess of the film as determined by an ISO rating. Cost of film between ISO 100 and 400 is not much, but good lenses (low f-stop such as 1.8) are expensive. Film speed, the light required for an exposure, is characterized by an ISO rating. The graininess of an image also is a product of film speed—larger grain with faster film. Common ISO ratings are 100 for medium speed and relatively fine-grained film, ISO 200, which can be shot at twice the shutter speed and has medium graininess, and ISO 400, which can be shot at four times the shutter speed of ISO 100 but is rather coarse grained.

With digital cameras, resolution is determined by maximum dots per inch (dpi) of the camera. Each image is characterized by dpi across the width and a vertical dpi, such as 1200 by 900 dpi for a total of 1,080,000 dpi, which is referred to as 1.1 megapixels (a pixel is one dot). Digital camera equivalents for film ISO ratings are about 1640 by 1460 dpi for ISO 400 (2.4-megapixel camera), 1960 by 1640 dpi for ISO 200 (3.2-megapixel camera), and 2280 by 1800 dpi for ISO 100 (4.1-megapixel camera). To determine the camera rating, multiply the two pixel numbers: 1200*900 = 1.1 megapixels.

As of January 2001, most digital cameras started at about 1.1 megapixels, suitable for 4- by 6-inch (10- by 15-cm) snapshots, and went up to 4.4 megapixels appropriate for 14- by 17-inch (35- by 42-cm) pictures. A 2.4-megapixel camera or higher is required for grid analysis (film speed of ISO 400 or less). Resolution also is enhanced by good quality optical lenses. Most digital cameras offer a choice of three to five resolution levels. For example, a 1.1-megapixel camera might offer its best at 1200 X 900 dpi, midresolution at 900 X 700, and lowest at 600 X 400 dpi. Finer resolution results in fewer images on a digital memory card and slower processing. Quality also is influenced by the kind of compression, if any, used to store the image. Compression permits more images to be placed on a memory card.

Film and digital concepts—The digital camera could be considered a special purpose computer designed to take photographs (Kodak 1999b). This dramatically separates it from a film camera, which physically captures images on a role of film. The images cannot be altered on the film, but they may be altered in the printing process. Digital images are captured on an electronic storage or memory card, which must be processed to produce an image. A digital image can be altered by the camera through different settings. Images are made up of dots called pixels, each composed of three colors: red, green, and blue; intensity of each color can be adjusted. Film and digital storage cards are discussed in the next section.

A camera using slide film exposes an image on film—**period**. Once the exposure is made, there is no recourse through correction. With black-and-white and color negative films there is some recourse through changing print exposure time, selection of paper, and dodging or burning items to be enhanced.

With digital cameras, the image is only one link in the chain to a photograph (Kodak 1999a). This chain is (1) the camera with its dpi, or pixel resolution, lens quality that captures the image, and the camera's ability to modify pixel characteristics; (2) the CPU (the computer) that processes the image with its ability to make major changes in the pixels and thus the image; (3) the monitor with its color projection of the image on the screen, which is used as a basis for changing the image characteristics; and (4) the output device, which either prints the image (printer) or projects it (projector). Resolution (dpi), color quality, and contrast are affected at the camera, CPU, and output device. Best image quality is attained by matching the camera resolution with that of the output device. They may **not** be the same.

Output (a picture) differs between film and digital cameras. Prints are similar because they are an image printed on paper. Prints from color film, black-and-white film, and digital images all share the same end result—a picture one can hold in their hand or mount on a monitoring form.

In contrast, slides made from film and digital images share few common traits. A film image is determined at exposure and can be projected with a slide projector in presentations. A digital image cannot. Generally, the digital image must first be downloaded from the camera and placed into the memory of a laptop computer. Then the laptop must be connected to a digital slide projector for presentation. Recently, cameras have been programmed for download directly to a projector; however, this projects only images in the camera. It does not provide for a presentation using title, data, and instructional images.

Camera focal length—Photo monitoring is greatly facilitated by using the **same** focal length lens for all repeat photos. Use of the same focal length is highly desirable but not essential (Rogers and others 1983). If the same focal length is used, subsequent pictures can be compared side by side. If different focal lengths are used, pictures must be adjusted in size to be compared, which will be discussed in "Camera Format and Distance to Photo Point," below. Conversion from film to digital cameras usually will result in a change of focal length, because the digital camera must be adjusted to match the film camera lens. Digital camera adjustment often is not precise enough to exactly equal the film camera; for example, setting it at 13mm to copy a 50mm lens. Nothing can be done with slides taken at different focal lengths.

Recommendation—Specify the make and focal length of camera(s) to use in the monitoring.

Figure 29—A system for combining color and black-and-white photography. Both cameras are connected by strap aluminum 1/8 inch thick and 1 inch wide bent into a “U” with holes drilled for mounting screws to connect the cameras (see app. B for details). The cameras operate independently. Identical cameras simplify the photography because all control settings are adjusted in the same way, which helps in avoiding mistakes. Shown here are cameras with black-and-white film at 400 ISO and color film at 200 ISO.

Double camera system—My photography over the last 45 years used a pair of good quality 35mm SLR cameras and 50mm lenses (about $500.00 each at 2001 prices), one for color and the other for black-and-white film. When both color and black-and-white photographs are to be taken, consider the camera system shown in figure 29. Both cameras are the same make and model to simplify adjustment for lighting and distance. Appendix B has details for constructing the apparatus.

Film and Digital Memory Cards

There are four ways to record images: (1) color slides, (2) color prints, (3) black-and-white prints, and (4) digital. Digital cameras are color and do not use film but, rather, memory cards.

Film—If film is used, both color and black and white are recommended because color film, slide or print, will fade with time and black and white will not. Once an exposure has been made on slide film, nothing can be done to enhance the image. Negative films, for either color or black-and-white prints, offer an opportunity to modify images in the print-making process. Different printing papers may be used, time of exposure can be adjusted, and overexposed or underexposed parts may be "dodged" or "burned" to enhance the image. Similar treatment, by computer manipulation, is available for digital images. But a word of caution, digital images can be so dramatically altered that they may not be admitted in a court of law.

Film comes in various degrees of graininess. This is roughly identified by film speed: the higher the speed, the grainier the film. For example, ISO 100 is relatively fine-grain film whereas ISO 400 is quite grainy. Digital camera equivalents are 4.1 megapixels compared to 2.4 megapixels. Determination of change between photos depends on the precision of measurement that can be made on a photo. Graininess limits precision.

Color rendition of vegetation is influenced by film chemistry. Tones can differ between brands from a single manufacturer, such as Kodak's Kodachrome compared to Ektachrome, and between manufacturers, such as Fuji and Kodak. Film developing may produce different tones from the same kind of film. Color prints from the same negative can differ depending on how the prints were made. Time of exposure and kind of paper are critical. Subtle changes in green as the season progresses might not be captured from one year to another or from one kind of film to another.

Processing of film will influence how well photos can be compared. Most film is sent to a commercial processor where either slides are produced or pictures at a standard size are printed, such as 3 by 5 or 4 by 6-inch (7.5 by 12.5 or 10 by 15 cm). Quality of processing differs. Do not cheapen your product by cutting costs and quality at the final step (Johnson 1991).

Digital memory cards—Digital cameras do not use film but, rather, electronic memory cards (Kodak 1999a). Unlike film, memory cards do not have to be developed; they are processed by computer. Any or all images can be erased and the card reused. The color quality, contrast, and depth can be manipulated. Selected images or all of them can be copied from a memory card to another media, which greatly facilitates their storage and retrieval.

Different makes of cameras use different memory cards. Memory cards come in several configurations: Compact Flash and Smart Media are about half the size of a credit card and about as thick. Some cameras use a 1.44-megabyte floppy (3.5-inch diameter) and others use a 140-megabyte Super Disc floppy.

Memory cards differ in their megabyte capacity. Smart Media offers 2 to 64 megabytes and Compact Flash 2 to 160 megabytes. Many digital cameras are sold with an 8-megabyte card, but larger capacities are usable. Megabyte capacity directly limits the number of images that can be stored. A general conversion from number of pixels in an image to number of images per storage card is a 1:1.2 ratio: a 1-megapixel photo requires about 1.2 megabytes of storage card capacity. For example, an image at 1200 X 900 pixels (1.1 megapixels) would require an entire 2-megabyte card, or 29 photos could be placed on a 32-megabyte card. The same 32-megabyte card would hold 51 photos at 900 X 700 pixels (0.63 megapixels) from a camera's lower pixel setting.

Digital memory cards can be reused. The deleted images, of course, are lost.

Processing memory cards is quite different from film. There are two alternatives: commercial or home processing. Commercial means the memory card is sent to a digital processing laboratory for prints similar to film. Home processing requires use of a CPU with a download system from the camera and a printer. For best image quality, the dpi of the camera and printer should be compatible. Image quality is sacrificed if the printer cannot process the dpi of the camera. And image quality may be sacrificed by color rendition of the printer.

Digital images may be stored in any of three ways: (1) in the memory card used with the camera, (2) by being transferred to a compact disk (CD) or zip disc and the memory card reused, or (3) by being transferred to a computer hard drive with essential information in its file and the memory card reused. If images are stored in a computer, assure that instructions for locating the folder or file are placed in the photo monitoring filing system. Disks should be placed in the monitoring file (see "Filing System" below).

Color prints from film and digital systems are similar in cost; however, slides made from digital memory cards tend to cost more. A negative must be made at about $5.50 and from it the slide for another $2.25, for a total of about $7.75 each. And the need for two steps, from card to negative and from negative to slide, tends to reduce quality of the image.

Recommendation—Specify the brand, type of film, and ISO rating that will be used; for example Kodak Elite Chrome ISO 200 color slide film and TMAX ISO 400 black-and-white film.

Camera Format and Distance to Photo Point

Camera format is the combination of camera body image size and focal length of a lens. Format concepts apply to both film and digital cameras. Exact duplication of camera format is not of critical concern (Rogers and others 1983) when evaluating change in the subject photographed. Images may be enlarged or reduced to a constant area of coverage, printed, and compared.

Concept—With slide film, images taken with different camera formats will project differently on the screen. This is a major concern discussed by Magill (1989) in his analysis of change in campgrounds. He projected slides onto a screen with a grid and adjusted size of the image according to specified criteria prior to analysis.

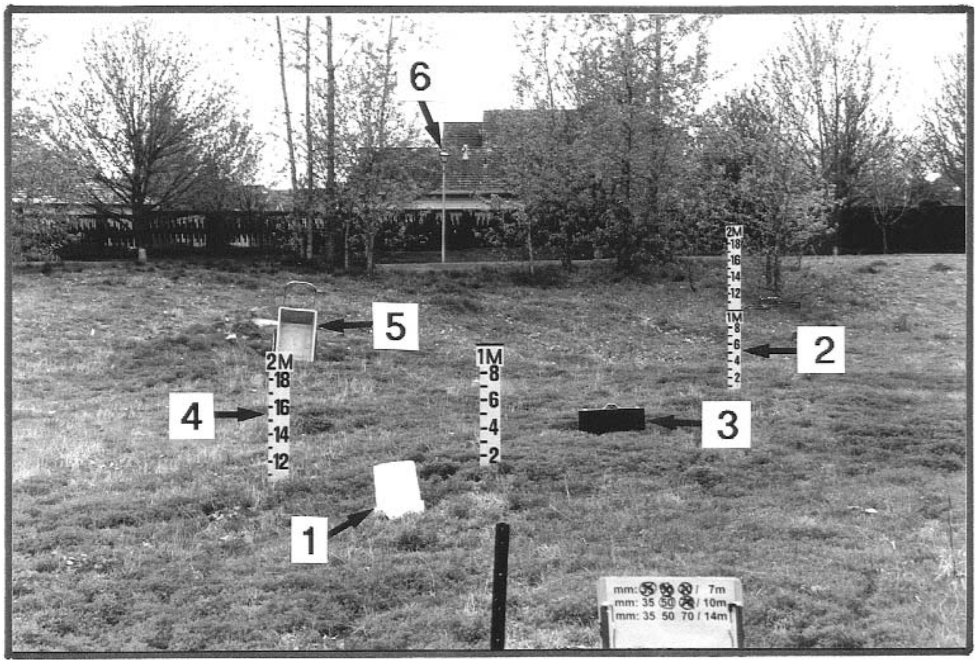


Figure 30—This landscape was used to test effects of camera format (focal length) and distance from camera to photo point (meter board) on determining size and location of objects. Camera format is 35mm image with two focal lengths: 35mm wide angle and 50mm standard. Distances are 23 and 33 feet (7 and 10 m) to the “1M” meter board. Numbered items are outlined and compared: (1) bucket between camera and the “1M” meter board; (2) double meter boards 23 feet (7 m) behind other “1M” meter board; (3) tool box; (4) top of 2-meter board parallel with the “1M” meter board, (5) cart 49 feet (15 m) from the “1M” meter board, (6) lamp pole 164 feet (50 m) from the “1M” meter board. Two situations are evaluated: (A) change both distance and focal length such that the meter board is the same size in both pictures (figs. 31 and 32), and (B) vary the camera focal length at a given distance (figs. 33 and 34). The fencepost at center front marks the 7-meter distance, and the photo identification sheet lists the focal length and distance to identify the negative.

Some examples of common film camera formats that cover about the same area of a landscape are (1) 25- by 35-millimeter (1- by 1.5-in) image size (35mm camera) using a 50mm focal length lens, (2) 2- by 2-inch (50- by 50-mm) image size using a 70mm lens, or (3) a 4- by 5-inch (100- by 125-mm) image using a 128mm lens. All are equivalent to a digital camera at 13mm focal length.

The advent of good quality zoom lenses permits a great variety of camera formats, but zoom lenses have both desirable and undesirable features. A desirable feature is increased flexibility in choosing photographic formats without the need to change lenses. Undesirable features include higher f-stops and no constant focal length when rephotographing monitoring sequences.

Testing in a landscape—The effects of camera format and distance from camera to photo point are shown and discussed in figures 30 through 34. Change in emphasis on a topic through distance is depicted in figure 16 in part A.

Figure 30 is a testing landscape where six objects were positioned, photographed, and outlined to compare their size and location with change in distance and focal length. I used two camera formats with a 35mm camera body; a 35mm wide angle

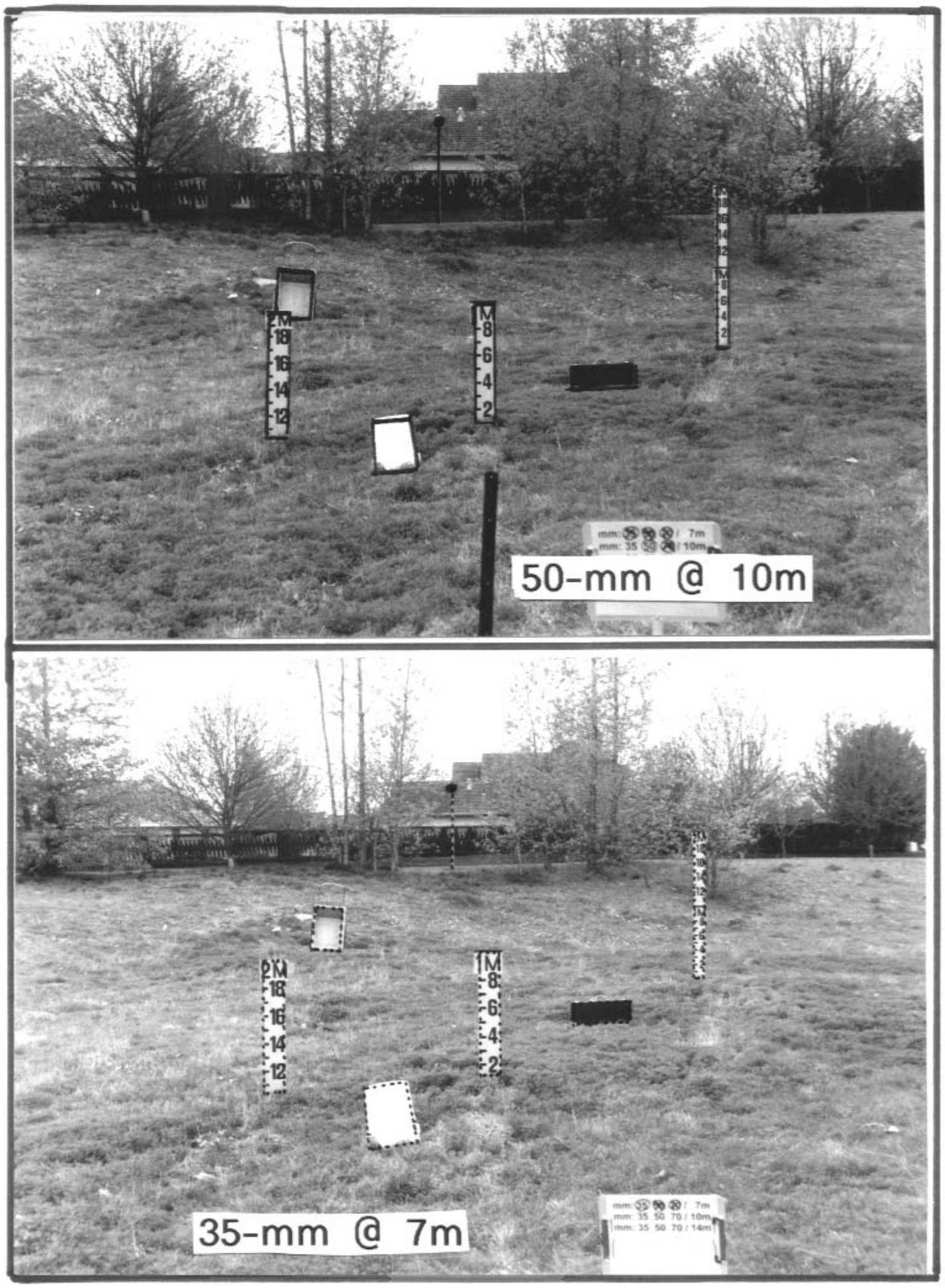


Figure 31—Both focal length and distance to meter board are adjusted to make the meter board the same size in each photograph: 50mm at 33 feet (10 m) and 35mm at 23 feet (7 m). Each of the six items have been outlined on clear plastic overlays as follows: 50mm at 10 meters in a solid line and 35mm at 7 meters in a dotted line. Note differences in backgrounds even though meter boards are the same size. Figure 32 compares the object outlines.

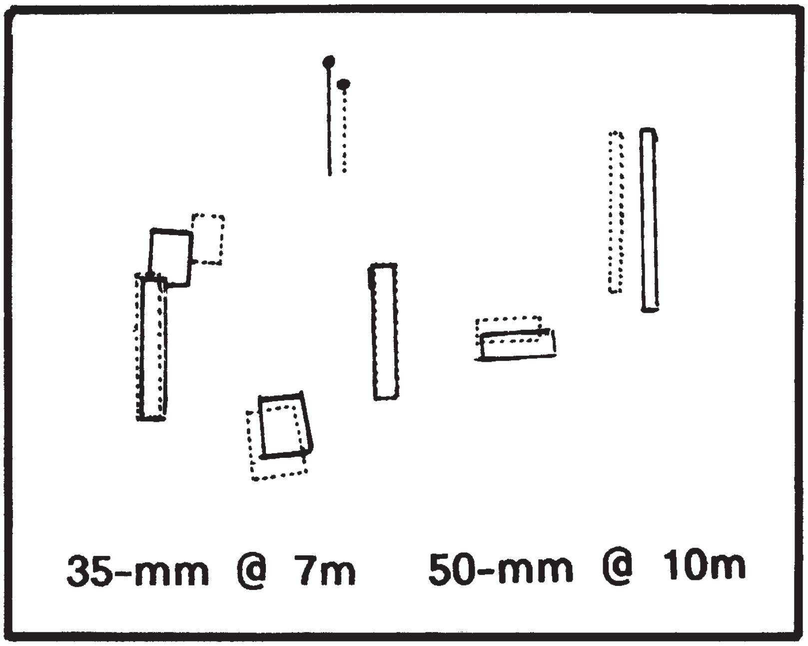


Figure 32—Object outlines from figure 31 overlaid to evaluate the effects of camera focal length and distance from camera to meter board on size and location of objects. The overlays for 35mm at 7 meters and 50mm at 10 meters show both different sizes and locations of objects even though the meter boards are the same size. This is because geometric angles from camera to objects change as distance changes. If objects in photographs are to be measured for change, distance from camera to meter board must remain the same. This is further demonstrated in figures 33 and 34.

lens was compared to a 50mm normal lens as a standard for evaluation. They are equivalent to digital cameras of 9mm and 13mm. The focal lengths were used in conjunction with two distances from camera to meter board: 23 feet (7 m) compared to 33 feet (10 m). Figure 30 illustrates the 50mm lens on a 35mm camera.

Camera format and distance—Both camera format and distance to meter board were adjusted in figure 31 to photograph the meter board at a constant size. The 35mm lens at 23 feet (7 m), dotted outline, gave the same size meter board as 50mm at 33 feet (10 m), solid outline. But note the different backgrounds. Comparison of object outlines in figure 32 shows that all objects are different in both size and location except the meter board. They are different because geometric angles between the camera and objects changed as distance varied from 10 to 7 meters.

Next, focal lengths of 35mm and 50mm were used at a distance of 33 feet (10 m), illustrated in figures 33 and 34. Figure 33 appears to show very different scenes. They are different in what is included within each photo. But when the 35mm image (dotted outline) was enlarged to size the meter board to be equivalent to that taken

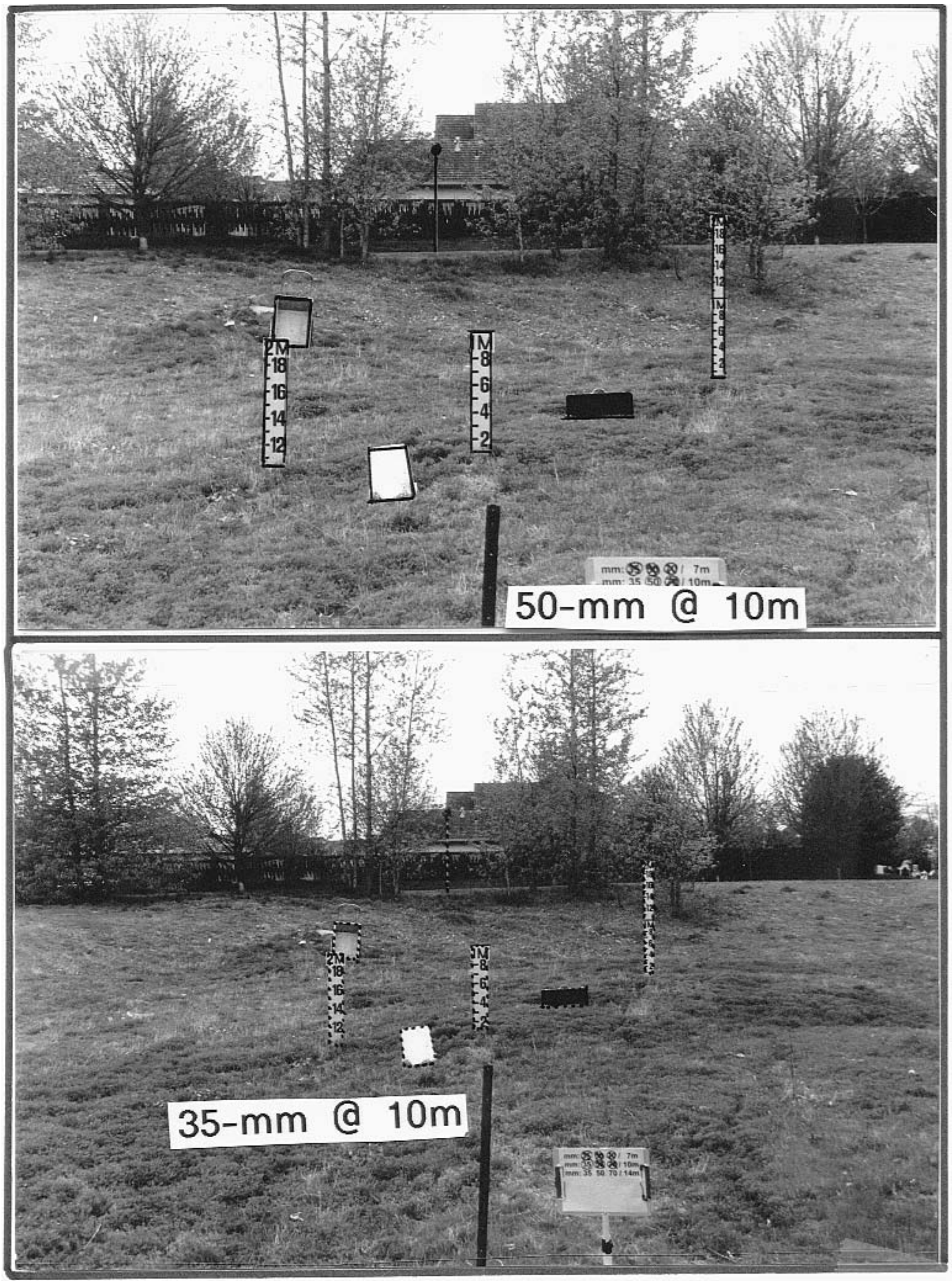


Figure 33—Effects of change in camera focal length of 50mm and 35mm at 10-meter distance from camera to the "1M" meter board. Objects in each photograph were outlined on clear plastic overlays and adjusted in size to the 50mm at 10 meter board as follows: the 50mm at 10 meter "1M" board was measured at 20 millimeters and the 35mm at 10 meter "1M" board at 14 millimeters; the percentage of enlargement was calculated as 20 ÷ 14 = 143 percent. The 35mm at 10-meter outline was enlarged 143 percent. They are compared in figure 34.

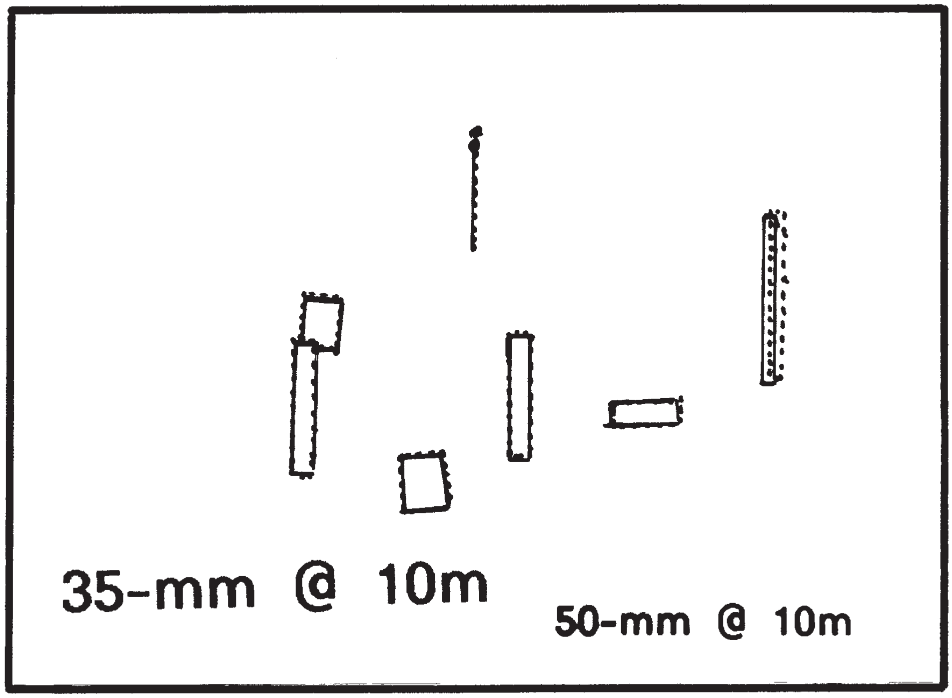


Figure 34—Object outlines for 35mm and 50mm camera focal lengths taken at 10 meters from the "1M" meter board (from fig. 33). Overlaying the enlarged 35mm on the 50mm shows little difference in object size or location. Camera focal length may differ without affecting analysis of photographic items when images are adjusted to a common size meter board. Comparison with figures 31 and 32 clearly demonstrates that distance from camera to meter board must remain the same.

at 50mm (shown in figure 34; solid outline), each object is almost exactly the same size and location. This effect is what Rogers and others (1983) discuss. Figures 31 through 34 clearly indicate that distance from camera to meter board is critical, whereas focal length is not.

Weather

How does current weather compare to conditions of previous photographs (Magill 1989, Maxwell and Ward 1980)? A dense, heavy cloud layer will produce different colors and tones compared to a high, thin overcast, which in turn will be different from full sunlight with attendant deep shadows. Maxwell and Ward (1980) suggest overcast skies to reduce shadows and taking at least three different exposures to achieve comparable color between photos.

Photo Grid Analysis

To quantify changes in vegetation, soil, fuel loading, streambanks, or other photographic topics, outline the selected topic on a clear plastic sheet. Then place a grid under the sheet. Count grid intersects falling on and within the outline, and record. Compare these to counts from previous photographs of the same topic to estimate change. Each plastic sheet with its outlines and associated counts is a set of data and must be identified clearly and then archived.

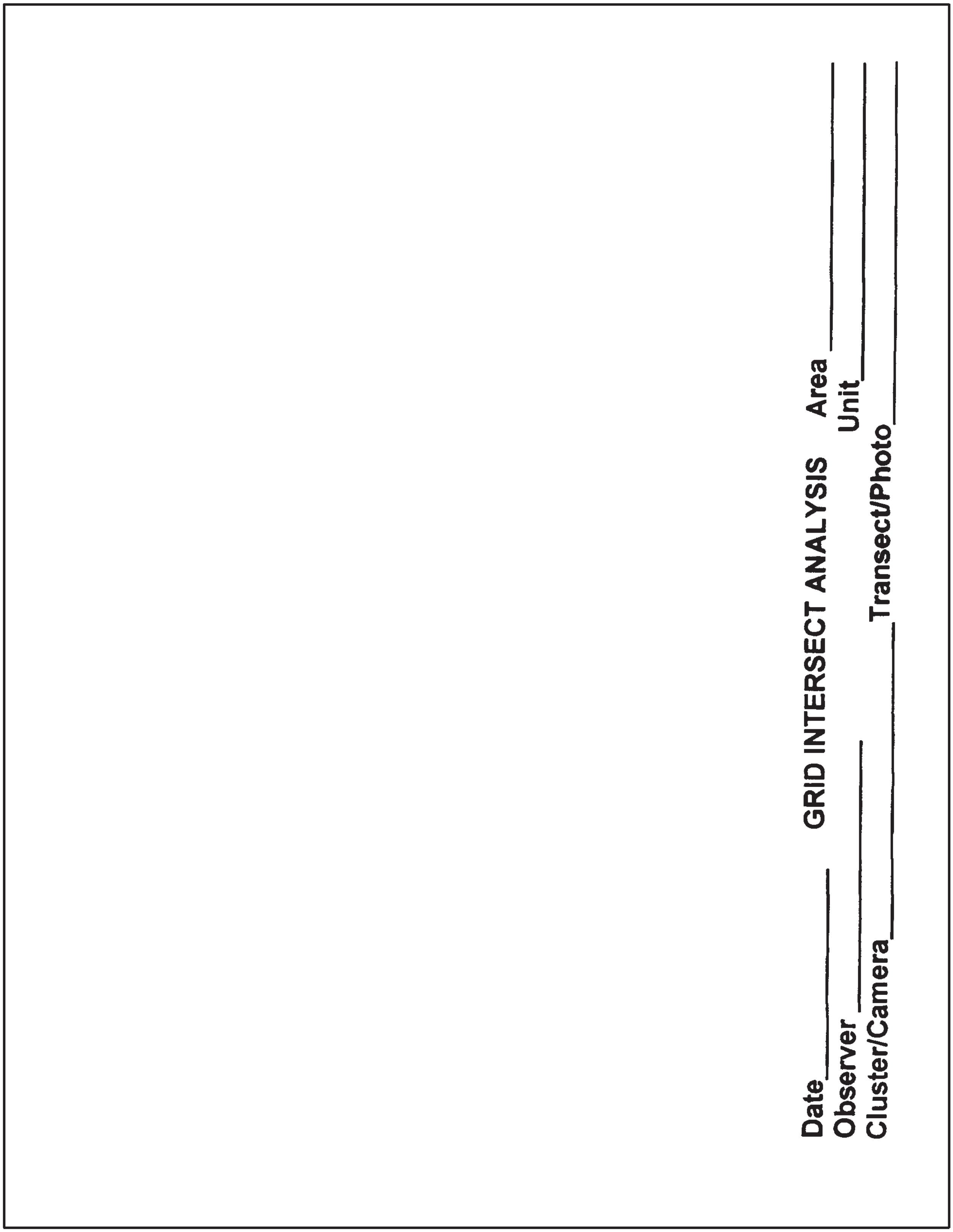
Figure 35—A 1981 view of the Pole Camp wet meadow photo point, which will be used to illustrate grid analysis. This photograph will be compared to one from 1996. The first step is to attach a clear plastic outline form (shown in fig. 36). Fill in the required site information and outline the shrubs (fig. 37).

An alternative method is digital analysis by computer. The computer cannot differentiate between pixels on the topic and those behind the topic that are of similar color (fig. 35). A plain colored backdrop is needed behind the topic (Reynolds 1999).

Concept

Grid analysis is based on standardized geometric relations between photograph, camera, and meter board. Having the same focal length lens, distance from lens to meter board, height of camera above the ground, and photograph size simplify the analysis. A set distance between camera and meter board for the initial and all subsequent photographs of a specific topic is a **must**. Different distances may be used for different topics (fig. 16 in part A). A standard camera height is desirable, but it is not essential unless the grid is used to track change in position of items over time, a tenuous procedure. Use of the same camera format, such as 50mm lens on a 35mm camera body is recommended but not required. Grids are designed to encompass a view limited to 13 to 15 degrees both horizontally and vertically. This limit is emphasized by heavy lines surrounding the grid see (fig. 39, below).

Obtain a color 8- by 12-inch (20- by 30-cm) photograph of the topic (see fig. 35), for easy viewing. Attach to the photograph a clear plastic sheet with the form “Grid Intersect Analysis” printed on it, for information on date, site location, and topic (fig. 36). This is used to outline objects. Then measure the meter board to calibrate the grid (distance between grid points and area of grid cells). Use a copy machine to precisely adjust grid cells to match the dimensions of the meter board: each grid cell



GRID INTERSECT ANALYSIS

Date ______ Area ______

Observer ______ Unit ______

Cluster/Camera ______ Transect/Photo ______

Figure 36—Form used to identify photographic outlines. Print the form on clear plastic overhead projection sheets. This form has been reduced to 85 percent of the size in appendix A. The full sized form is suitable for 8- by 12-inch color photographs. Use of the clear plastic overlay is illustrated in figure 37.

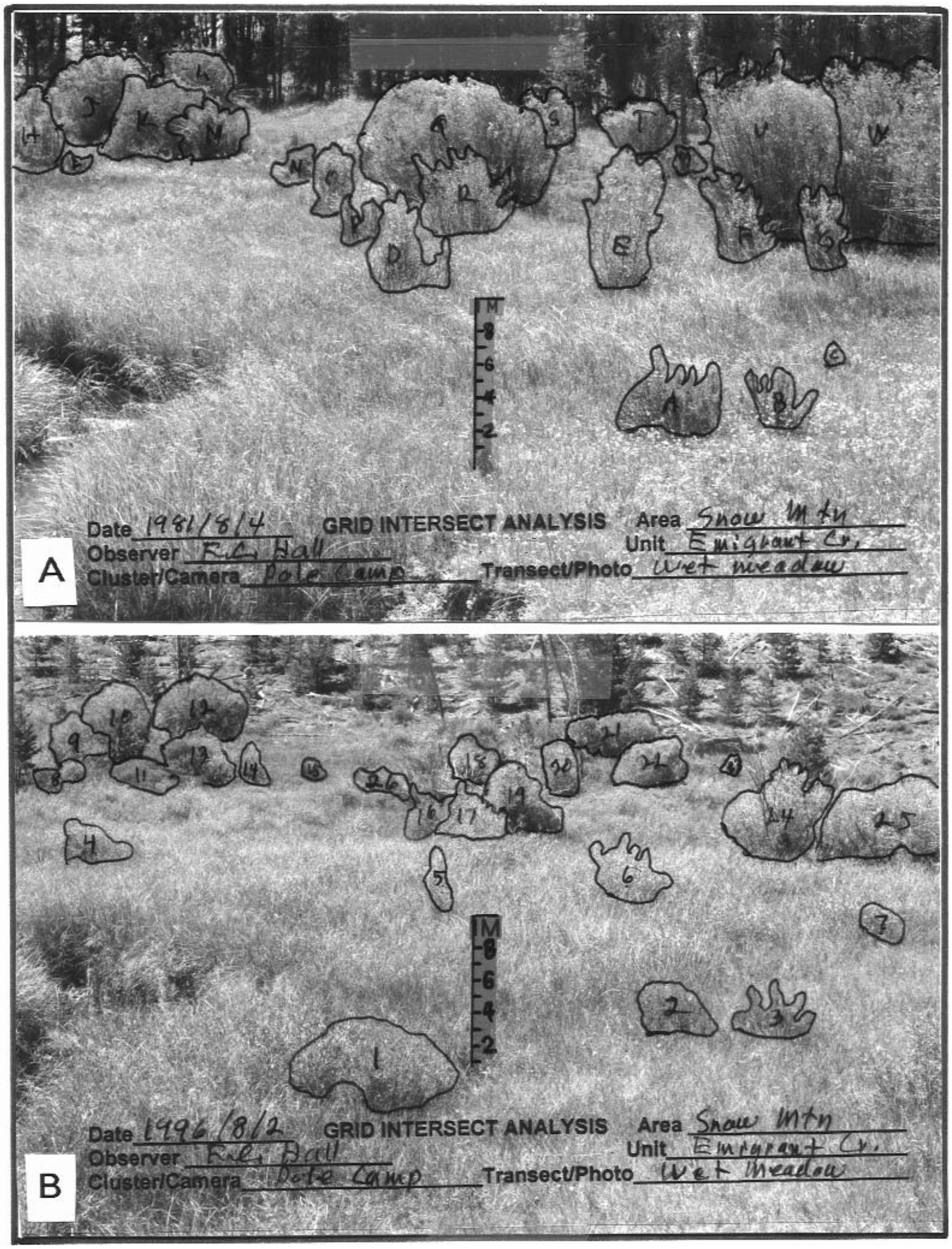


Figure 37—Photographs to be evaluated by grid analysis: (A) 1981 (from fig. 35), and (B) 15 years later in 1996. Clear plastic overlays (fig. 36) have been taped to each photo. Each overlay is a data sheet and therefore must have all information entered to identify the outlines. Date is the **photograph** date, not when the outline was drawn. First the meter board is outlined on its left side and top. Then each visible decimeter line on the meter board is marked and the decimeter number written on the overlay. Finally, each shrub is carefully outlined and given either a letter or number identification. The next step is size adjustment of the analysis grid (figs. 38 and 39).

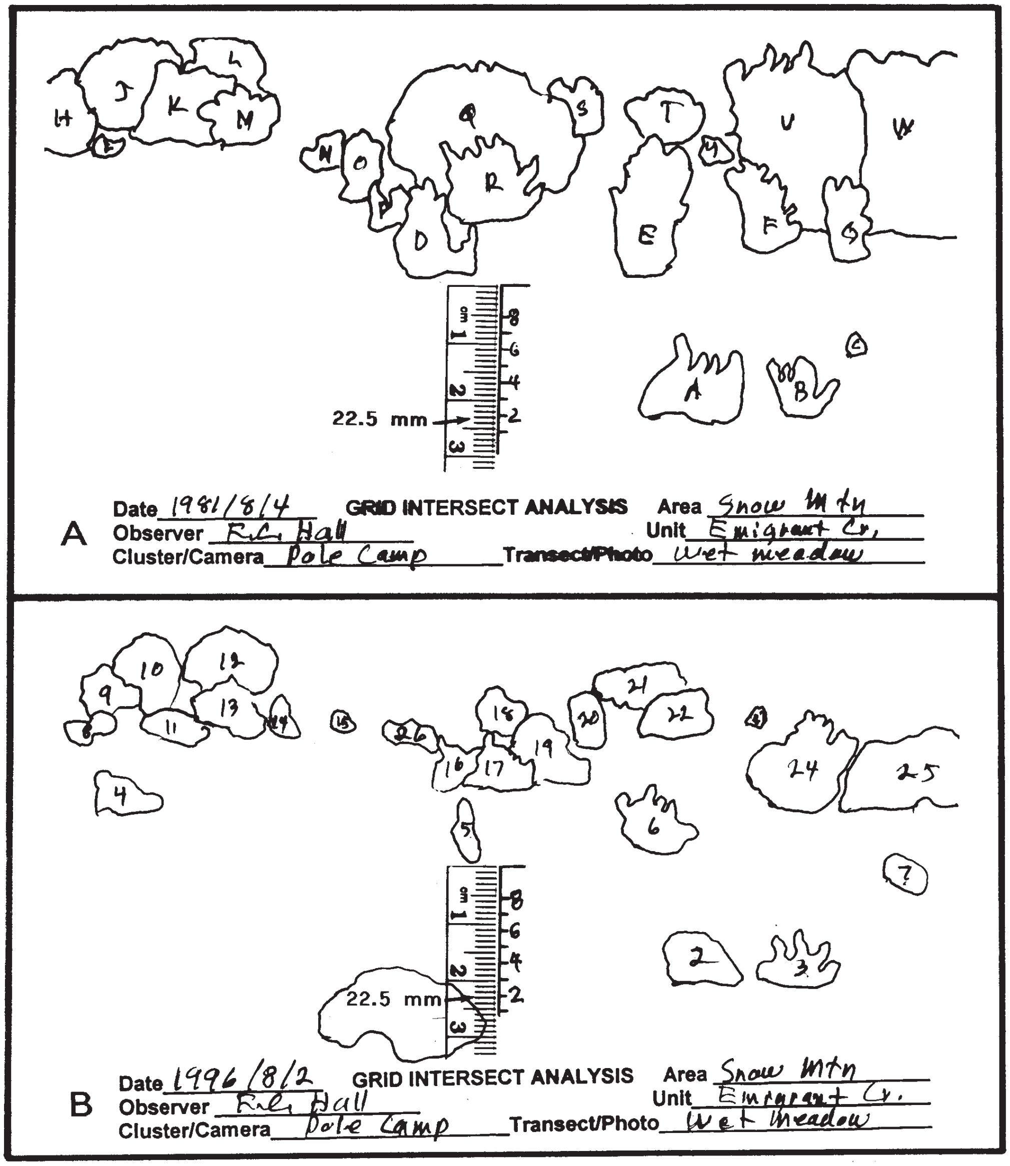


Figure 38—Measure meter boards for size adjustment of analysis grids: (**A**) 1981 and (**B**) 1996. Measure from the top down to the lowest visible decimeter mark to the nearest 0.5 millimeter, in these photos the 2-decimeter mark. Both measurements are 22.5 millimeters, which indicates that both are the same distance from camera to board and there was consistent enlargement of the photos. The analysis grid (fig. 39) will have to be reduced in size to exactly match the size of the meter boards in these outlines. An exact match is required for consistency in measurement between photographs.

should span 4 inch (1 dm) on the meter board. Print the adjusted grid on white paper. Outline the meter board and topics of interest in the photo on the clear plastic (fig. 37). For precise grid calibration, the meter board height should be at least 25 percent of the photograph height, preferably 35 to 50 percent. Each individual picture must be measured for grid adjustment. Tape the outline form onto the grid, carefully match the outline meter board with that on the grid, and count grid intersects that fall on and within each outlined topic.

Setting the Stage

Photography suitable for grid analysis includes the following:

1. Camera location and photo point (meter board) must be permanently marked so that exact relocation is possible. Stamped metal fenceposts driven 2 feet (0.6 m) into the ground work well.

2. Choose a distance from 16 to 65 feet (5 to 20 m), appropriate to the topic, for each site. Place a size control board (a 1-meter board or a double, 2-meter board; see figs. 21 and 35 in part A) such that the visible part of the board occupies at least 25 percent of the picture height. Then the meter board can be used to orient the photograph and adjust size of an analysis grid.

   With a 50mm lens on a 35mm camera, a single meter board set 33 feet (10 m) from the photo point would span 25 percent of the photo height (figs. 31 and 33); at 23 feet (7 m), 36 percent. A double meter board, 7 feet (2 m) tall (app. B), spans 25 percent of photo height at 66 feet (20 m).

   When grid analysis is planned, clip vegetation away from the front of the meter board to expose the bottom decimeter line. This will provide for maximum precision in grid adjustment.

3. When photographing, aim the camera view at the meter board. Place the ring in the viewfinder on the “1M” and focus (fig. 18 in part A). This provides for (1) reorientation of all subsequent photographs, (2) a sharp image at the topic marked by the meter board, and (3) an optimum depth of field.

Materials

Materials and equipment required for grid analysis are as follows:

1. Photographs of the setting. Print all photographs to be compared at the same size, preferably about 8 by 12 inches (20 x 30 cm), and in color for best differentiation of items to analyze. Figure 35, for example, is the wet meadow photo point at Pole Camp as taken in 1981. It will be compared to a photo taken in 1996 to appraise change in shrub profile area (fig. 37).

2. Clear plastic sheets used for overhead projection, such as 3M or Labelon Overhead Transparency Film. Film is designed specifically for various copy machines, such as inkjet, plain paper, or laser. Imprint these sheets with site information by using the form in figure 36 (“Grid Intersect Analysis”) from appendix A.

3. A grid master form, which is shown in figure 39 (form is in app. A). Adjust the grid in size to precisely fit each picture and the outlined meter board as shown in figure 39. Instructions for grid size adjustment are given below.

4. Photo Grid Summary form (fig. 41 and app. A).

5. Permanent markers, such as Sanfords Sharpie Ultra Fine Point Permanent Marker, for drawing on clear plastic. Use different colors to aid in differentiating items when their outlines overlap, figures 38 and 40. Black, red, and blue work well together.

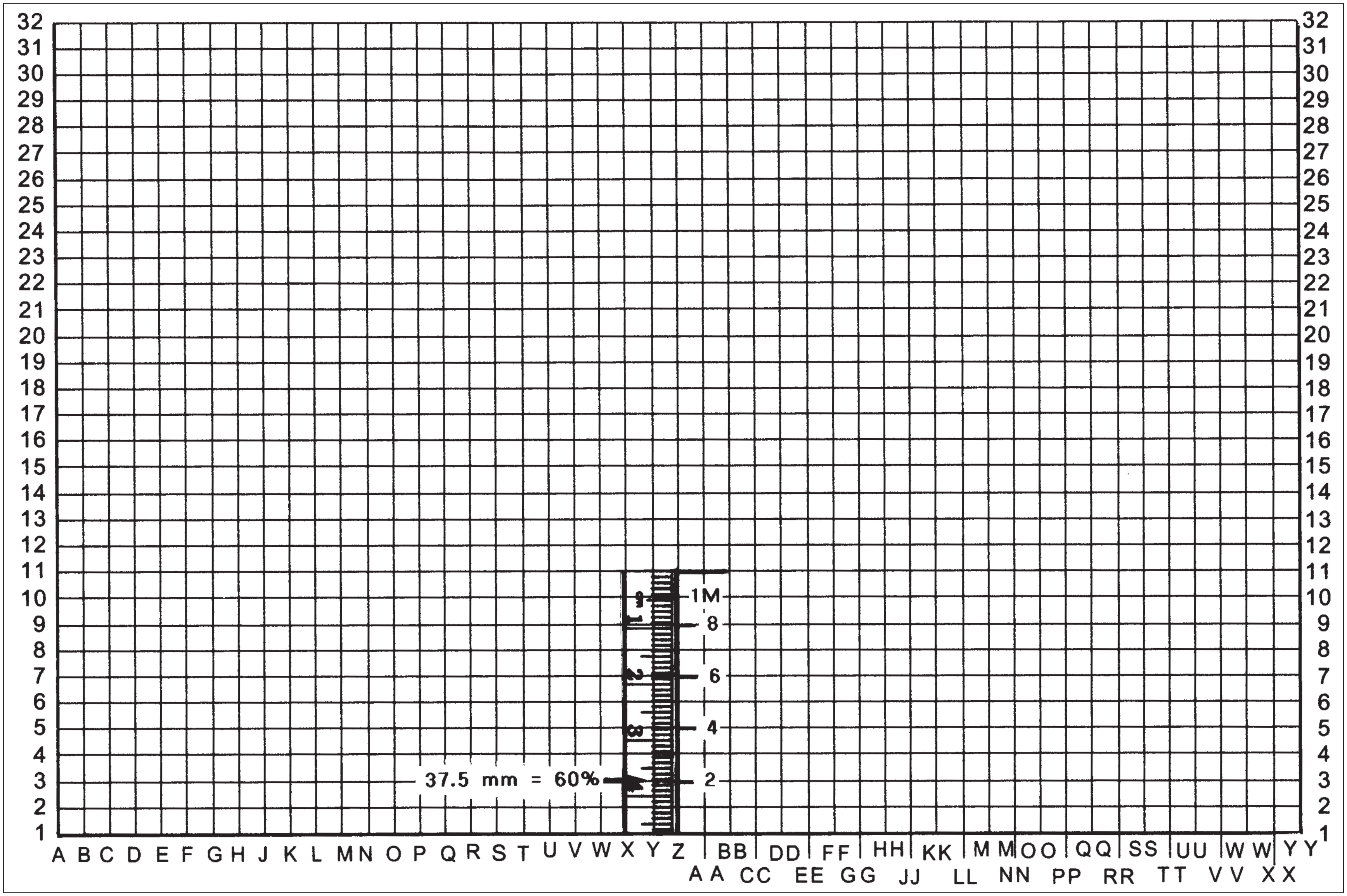


Figure 39—The master analysis grid is in appendix A. Measure from the top of the meter board to the 2-decimeter mark used in the outlines. This measurement is 37.5 millimeters. Divide 22.5 millimeters from the outlines in figure 38 by 37.5 for a reduction to 60 percent of the grid. Print the grid on white paper at 60 percent of its original size. The outline is laid over the reduced grid to check alignment of the meter board marks. Minor adjustments in grid size are made so that marks of the overlay and grid meter boards match exactly (fig. 40).

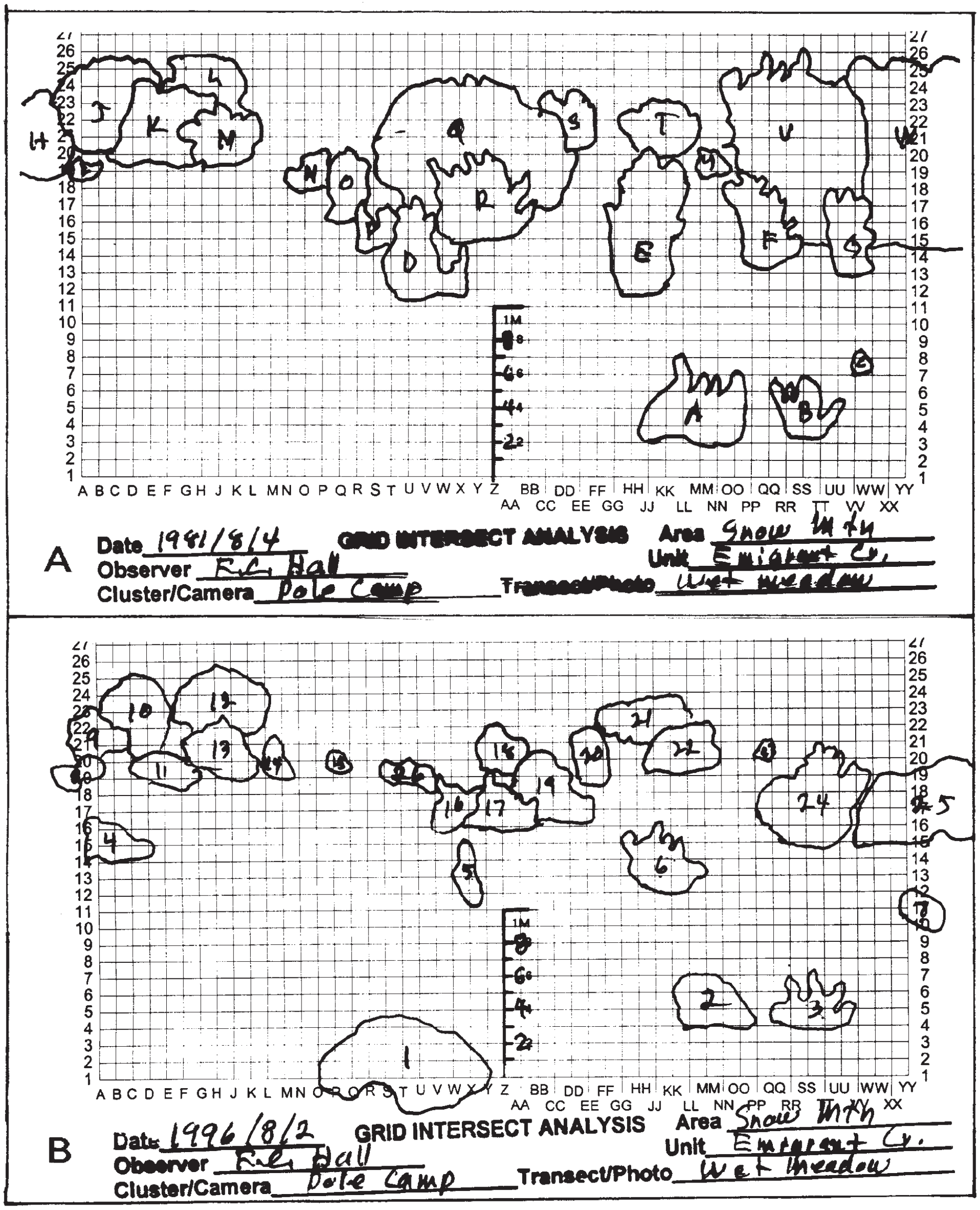


Figure 40—Outline overlays are placed on analysis grids for (**A**) 1981 and (**B**) 1996. The next step is to count grid intersects on and within each outline. When an outline crosses a grid intersect, such as between shrubs 17 and 19, AA-18 in photo (B), count the intersect for the shrub in front (number 17). Also count intersects along the grid edge, such as the five intersects in shrub 25 on line YY, photo (B).

6. Good quality hand lens to identify the periphery of items being outlined, in this case shrub profiles.

7. A copy machine that will produce clear plastic overhead projection copies and can adjust the size of the master grid to fit the photographs. Many copy machines can reduce to 50 or enlarge to 200 percent. Tape one grid, adjusted for size and printed on white paper, under each outline for analysis (fig. 40). Precisely align the outline meter board with the grid meter board.

1999/2/19

PHOTO GRID SUMMARY

Date 1996/8/14 Observer F. C. Hall

Area Snow Mtn Unit Emigrant Cr.

Cluster/Camera Pole Camp Transect/Photo Wet meadow

Item #	Date 1981	Item #	Date 1996	Item #	Date
Shrub A	22	Shrub 1	32		
B	11	2	14		
C	2	3	12		
D	18	4	7		
E	33	5	5		
F	15	6	13		
G	12	7	1		
H	—	8	1		
I	2	9	7		
J	18	10	14		
K	20	11	6		
L	9	12	18		
M	14	13	11		
N	7	14	5		
O	8	15	1		
P	7	16	7		
Q	60	17	11		
R	24	18	7		
S	7	19	12		
T	13	20	7		
U	4	21	11		
V	61	22	11		
W	34	23	2		
		24	28		
		25	16		
	401		259		
	401		259		

$\frac{259}{401} = 0.648 = 65\%$

Figure 41—The filing system form “Photo Grid Summary” where number of grid intersects by outline are recorded. In figure 40A, shrub “A” has 22 intersects; 22 is entered for shrub “A” under 1981. The primary purpose for identifying each outline is to aid in recording the number of intersects. Note that three more shrubs were identified in 1996 than in 1981, even though only 65 percent as many intersects were recorded. Total the intersects: 401 in 1981 and 259 in 1996. Determine the percentage of change: 259 ÷ 401 = 0.65, or 65 percent.

Grid Adjustment

Outline interpretation requires use of a grid whereby each grid intersection on and inside an outline is counted and recorded. The grid must be adjusted in size based on the meter board outlined on each overlay.

1. Measure height of the meter board as it appears on the overlay to the nearest 0.5 millimeter. If the bottom line on the board is not visible, measure to the lowest visible decimeter mark. In figure 38 it is 2 decimeters, and measures 22.5 millimeters from top to 2 decimeters. Similar measurements between the 1981 and 1996 photographs indicate that distance from camera to meter board was the same and that both pictures were enlarged identically.

2. Next, measure height of the meter board on the grid. In figure 39 it is 37.5 millimeters from top to the 2-decimeter grid line (second from the bottom).

3. Determine the percentage of change required for the master grid: 22.5 ÷ 37.5 = 60 percent. On a copy machine, reduce the grid to 60 percent and print on plain paper. Overlay the outline on the grid to determine any additional size adjustment (fig. 40). This usually requires two or three trials.

4. Place the clear plastic overlay with its outlines on the grid and ensure that grid divisions exactly match those on the overlay meter board. Orient the overlay on the grid by using the left side of the meter board outlines (fig. 40). When both overlay and grid meter board marks match exactly, tape the overlay to the grid.

Note the borders on the grid (fig. 39). These mark the maximum 12- to 15-percent angle useful for grid analysis.

Analysis of Photographs

Select a topic—For this example, change in willow profile area is the topic, thus, no other item—grasses, sedges, forests, or water—is outlined. Decide if individual shrubs will be evaluated or if all shrubs will be lumped together. In this case, individual shrubs will be evaluated. Proceed as follows.

1. Fill out all information on the clear plastic overlay (“Grid Intersect Analysis,” app. A). It becomes the permanent data record and must be identified (fig. 36). Date is the **photograph** date, not the date of the outline.

2. Attach the plastic overlay to the photo at one edge, such as the top, so that it can be lifted for close inspection of the photograph and then replaced exactly (fig. 37).

3. With use of a straight edge, mark the left side of the meter board and its top on the overlay of each photo (fig. 37). Next, mark each decimeter division on the meter board and identify even-numbered decimeter marks by their number, such as 2, 4, 6, and 8 (figs. 38 and 40).

4. Select the topic; for example, shrub profile area. Start in front and work from left to right. Outline each element of the topic (shrub in this case) and label it with a letter or number (fig. 37). Labeling ensures that grid intersects on and inside an outline are not repeated or missed when recording data.

If identifying change in specific shrubs is desirable, each shrub identified in the initial photo will have to be identified in all subsequent photos, and the letter or number used initially will have to remain exclusive to the shrub or to the location where the shrub used to be. Any new shrubs will require their own exclusive new identification, such as shrub 1 in figure 37B.

5. When outlining, pay particular attention to the periphery of the shrub by following as carefully as possible the foliage outline. Do not make a general line around the outside of the shrub. Mark directly **on** the foliage, not outside of it. Check outlines by lifting the overlay to check the foliage and inspect with the hand lens.

6. Work back into the photograph. Overlapping shrubs are identified by the letter inside the front shrub outline (fig. 37). Overlapping outlines may be enhanced by using different colored marking pens. Intersects often will occur under an outline; count them for the shrub in **front** only (do not count the intersect twice).

   Do not count intersects on outlines outside the grid.

7. On the filing system form "Photo Grid Summary" (fig. 41), fill in the required information and enter the year of the photograph in the "Date" column. This is the date on the plastic outline. List shrubs by letter or number in the "Item #" column. The form provides space for recording intersects for three photographs. Note that items, shrubs in this case, are not required to have the same identification. Here, shrubs from 1981 are letters and those from 1997 are numbers, because exact relocation of shrubs was not possible.

8. Starting in front and working from left to right, count the number of grid intersects on and within each outline. An intersect is where a horizontal and vertical grid line meet (intersect). Many times, the outline will separate two shrubs. When the outline covers an intersect, count it for the shrub in front. Do **not** count the intersect twice. See figure 40A: intersect BB-18 is on shrub "R" outline with shrub "Q" behind it. Record the intersect only for shrub "R." This is why outlining **on** rather than outside of shrub foliage is important. Do not try to count intersects of the shrub behind when they cannot be seen; for example, in figure 40A, intersects of shrub "Q" behind shrub "R." Count intersects on the edge of the grid but not beyond even though the shrub or outline might extend beyond the grid. The grid, not the photo coverage, defines the area of analysis.

9. Record the intersects for each shrub beside its letter or number (fig. 41). Recording by shrub letter or number is designed to simplify record keeping. One may stop or be disturbed at any time and still know what shrubs they have recorded and where to begin again. When finished, sum all the intersects.

Important note—Each picture is produced by enlargement of a negative. Seldom are two enlargements made at exactly the same scale even though the negatives might be precisely sized. Therefore, grids must be sized **independently** for each photograph (fig. 37).

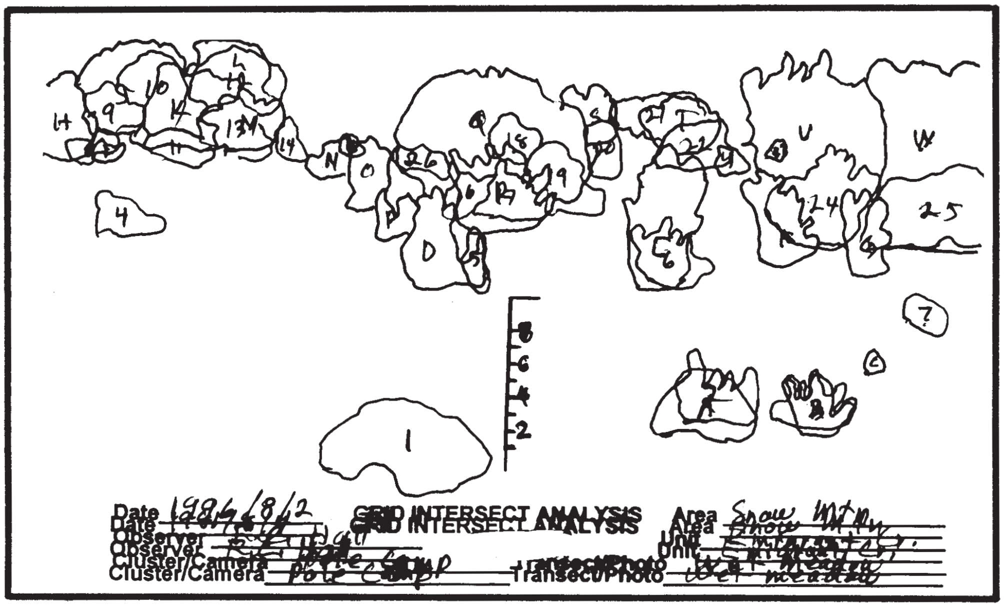


Figure 42—Outlines from 1981 (letters) and 1996 (numbers) overlaid for comparison of change in shrub profile. There were major changes in shrubs “Q”, “V” and “W”, and a new shrub shown as 1. The dramatic reduction in shrub height of “Q”, “V” and “W” from 1981 to 1996 was caused by beavers cutting the largest stems for dam construction.

Figure 40 compares outlines from 1981 and 1996. Visually, there is a difference in shrub profile area. These outlines are overlaid in figure 42 as one way to interpret change. The next section deals with analysis of change given two factors: grid precision and observer variability. This grid monitoring system provides an opportunity to overcome both problems, which primarily result from differences among observers. Let each observer do grid analysis on all photographs and interpret the results. The same personal idiosyncrasies will be applied in object outlining, grid sizing and placement, and interpretation of grid intersects, thereby greatly reducing between-observer differences that affect interpretation of change.

Analysis of Change

Analysis of change is influenced by correct grid sizing and different interpretations among observers. Areas within successive grid outlines may be digitized and compared; however, the data are entirely dependent on exact duplication of the outline of the meter board.

Grid precision—Percentage of photo height represented by the meter board is an important factor in precise fit of grids. The minimum is 25 percent and the optimum is 35 to 50 percent. A 35-percent meter board is 1.3- times more precise than a 25-percent board for grid adjustment. Precise means how carefully one measures a distance.

With a single meter board at 33 feet (10 m; fig.35), 25 percent of photo height, a 0.02-inch (0.5-mm) difference in measurement at the meter board, (for example 0.90 vs 0.92 in [22.5 vs. 23.0 mm]; fig. 38), results in a 2.2-percent change in grid

Table 1—Effect of camera-to-meter-board distance on grid coverage at distances of l0, 20, 30, and 60 meters (33, 66, 98, and 198 ft) from the camera

Distance from camera to meter board	Ratio	Angle	Grid size at distance from camera of: 10 m	20 m	30 m	60 m
Meters		*Percent*	*Decimeters*			
5	1:50	2.0	2.0	4.0	6.0	12.0
7	1:70	1.4	1.4	2.8	4.2	8.4
10	1:100	1.0	1.0	2.0	3.0	6.0

height. Grids 2.2 percent larger in height are also 2.2 percent wider, which results in a 4.4-percent increase in outlined area. Thus the number of intersects on and within an outline can change by 4.4 percent.

A meter board occupying 33 percent of photo height would measure 1.2 inches (30 mm) in figure 38. A 0.02-inch (0.5-mm) difference here is only 1.7 percent change in grid size. The 1.7 and 2.2 percent represent measurement-precision errors.

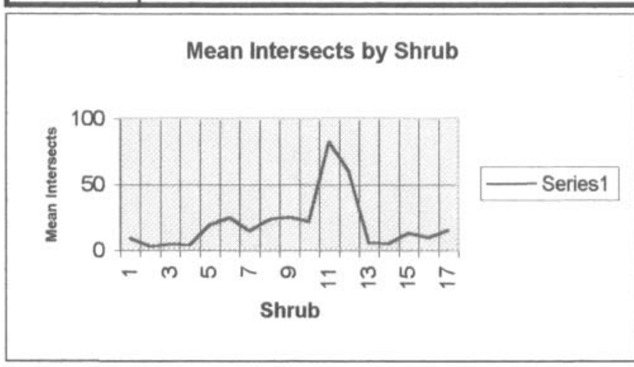
Distance from camera to meter board also affects precision of measurement on items beyond the meter board. Table 1 illustrates the effects of three distances between camera and meter board and how they affect grid precision at various distances beyond the meter board. Because grids are adjusted to size at the meter board location, each grid is 4- by 4-inch (1 by 1 dm) in size at that location but changes as distances increase.

A grid adjusted to a meter board 16 feet (5 m) from the camera measures 8 inch (2 dm) between grid lines at 33 feet (10 m) from the camera. This is two times greater than a grid adjusted at 33 feet (10 m) from the camera. At 98 feet (30 m) from the camera, a grid adjusted to a board 16 feet (5 m) from the camera will cover an area 24 by 24 inches (6 by 6 dm). When adjusted to a meter board set 33 feet (10 m) from the camera, it will cover an area only 12 by 12 inches (3 by 3 dm)—one-half the dimensions and one-quarter of the area—a significant improvement in precision. Monitoring objectives help determine the optimum distance from camera to meter board when grid size adjustment and outline precision are being balanced.

Observer variability—“Perfect” outlines are influenced by three kinds of differences among observers.

1. Size adjustment of grids is influenced by observer skill. With a meter board at 25 percent of photo height, 0.02-inch (0.5-mm) measurement difference of the meter board can mean as much as 2.2 percent difference in grid dimensions and 4.4 percent difference in area. Meter boards closer to 33 percent of photo height and larger photographs help to reduce this error. I recommend 8- by 12-inch (20- by 30-cm) color photographs. A meter board at 33 percent of an 8- by 10-inch photo height would measure about 2.6 inches (66 mm). A 0.02-inch (0.5-mm) measurement difference would be only a 0.8-percent error.

Shrub	FCH	CE	DE	SE	MR	CQ	MN	Mean	Std.Dev.	5% CI	CI%Mean
A	10	9	12	8	13	8	7	9.571429	2.22539	0.8242813	8.611894322
B	4	3	5	2	4	3	2	3.285714	1.1126973	0.8242813	25.08682259
C	6	5	6	5	5	4	3	4.857143	1.069045	0.7919439	16.30472673
D	3	3	7	2	10	4	1	4.285714	3.1471832	2.3314196	54.39979127
E	22	13	26	22	23	17	15	19.71429	4.7509398	3.5194755	17.85241217
F	28	24	28	25	32	21	19	25.28571	4.4614753	3.3050415	13.07078572
G	17	12	18	14	19	15	11	15.14286	3.0237158	2.2399555	14.79215911
H	24	23	26	22	26	24	22	23.85714	1.6761634	1.2416946	5.204707832
J	30	23	26	24	30	25	21	25.57143	3.4086724	2.5251297	9.874808968
K	23	24	28	13	34	13	21	22.28571	7.6095178	5.6370978	25.29466952
L	86	81	79	91	82	81	77	82.42857	4.6853368	3.4708772	4.210769515
M	65	58	59	72	43	68	56	60.14286	9.5118973	7.0463722	11.71605833
N	6	6	5	6	6	6	5	5.714286	0.48795	0.3614713	6.325747193
O	7	4	5	4	6	5	5	5.142857	1.069045	0.7919439	15.39890858
P	14	14	14	12	16	13	13	13.71429	1.2535663	0.9286365	6.771307827
Q	9	12	11	11	7	14	9	10.42857	2.2990681	1.7031397	16.33147648
R	17	16	20	14	18	9	15	15.57143	3.5050983	2.5965616	16.67516637
S	24	23	22	16	22	24	21	21.71429	2.75162	2.0383881	9.387313837
TOTAL	395	353	397	363	396	354	323	368.7143	28.347335	20.999583	5.695353784
								MEAN	3.2249101	2.3432062	15.4060848



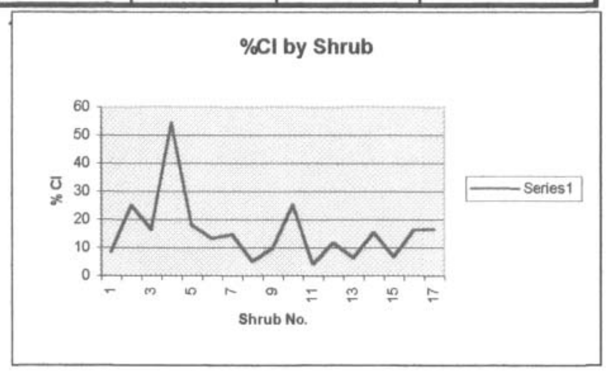


Figure 43—Summary of seven observers determining grid intersects on 18 shrubs in the same photograph. Variation among observers is characterized by the 5-percent confidence interval (5%CI) and expressed by dividing the 5%CI by the mean intersects by shrub and multiplying by 100 (CI%Mean). The mean and CI% Mean are graphed by shrub below the summary data.

2. The grid must be oriented exactly along the left side of the meter board as viewed (that is, the observer's left side) and precisely at the top and bottom or lowest clear decimeter mark. Orienting precision is subject to observer skill.

3. Interpretation of what constitutes the periphery of a shrub profile is subject to observer variability. One must make choices about where to place an outline and how precise it will be, particularly on overlapping shrubs. Note that an intersect is counted if the outline crosses it. The desirability, good or bad, of the topic being outlined tends to influence a person's willingness to include or exclude marginal parts. Outlining on clear plastic without grid lines tends to reduce observer bias.

A test was made in January 1998 of observer variability in outlining the shrub profile area shown in figures 35 and 37A. Results of the seven observers are given in figure 43. Color prints, 6 by 9 inches (15 by 22 cm) with properly sized grids, were provided. Observers placed the grids, outlined shrubs, and summarized intersects

Outline Analysis - 2 photos, 99/3

Photo	FH1	FH2	EC	DR	DF	MN	SE	CQ	Mean	Std.Dev.	Cof.Var.	Max.	Min.	Range	% Range	5%CI	CI%mean
1975	376	364	394	473	386	330	359	393	384.38	41.59305	10.82096	394	330	64	0.1665041	28.8219	7.49839184
1995	201	241	255	232	208	152	263	196	218.5	36.53961	16.72293	263	152	111	0.5080092	25.3202	11.5881706

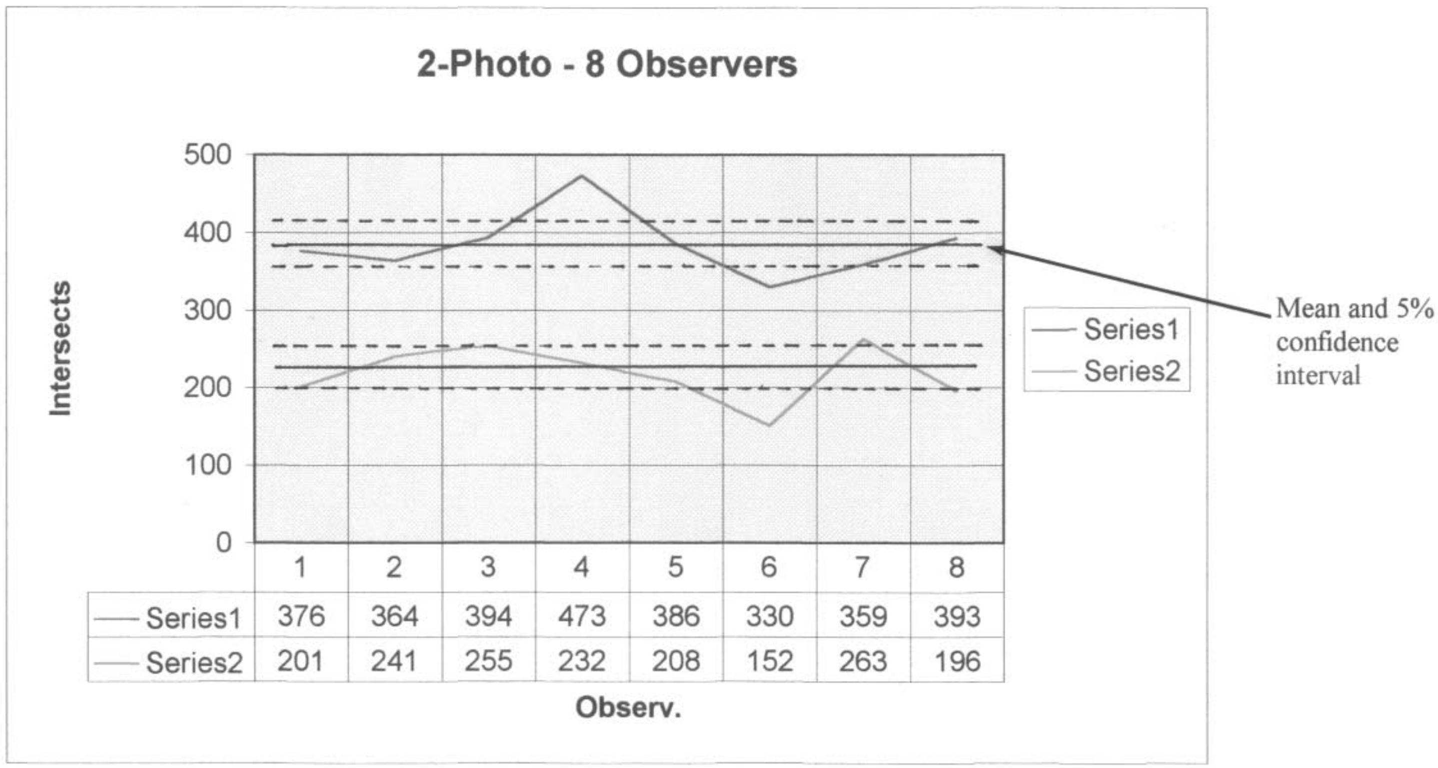


Figure 44—Outline analysis test for variation among eight observers in estimating shrub profile intersects. Photographs from 1975 (series 1) and 1995 (series 2) at the Pole Camp wet meadow photo point were compared. The 5%CI for 1995, 11.6 percent of the mean, is used to determine a significant change in shrub profile. FH1 and FH2 were observations by the same observer made 2 months apart to illustrate single-observer variability.

within each outline. Variation among observers was measured by the 5-percent confidence interval (CI). The CI also was calculated as a percentage of the mean: CI divided by the mean times 100 equals the CI% for each shrub, total of all shrub intersects, and an average CI. Low CI%, such as 5 percent (shrub H), is interpreted as low observer variability and that a change of more than 5 percent in intersects probably is a significant difference. High CI%, such as 25 percent (shrub B), means high observer variability and greater than 25 percent change is required.

The percentages for confidence intervals ranged from 4.2 percent (shrub L) to 54.4 percent (shrub D, fig. 43). The average CI% among the observers was 15.4 percent, which suggests that, to be significant, a change of more than 15 percent in intersects is required owing to observer variability. However, the CI% for total intersects of all shrubs combined was only 5.7 percent, indicating good concurrence between observers for the entire scene, a relation tested in 1999 and reported below.

The number of intersects in an outline seems to influence the CI%. Graphs at the bottom of figure 43 show higher CI% with lower intersects per shrub.

Differences in shrub profile area are rather clear in figures 41 and 42. Profile area in 1996 was 65 percent of that in 1981. Change in shrub profile is illustrated in figure 42. However, the reader may wish to test this for observer variability. Count the shrub profile intersects in figure 40 and compare to the data in figure 41.

Because CI% was rather high for individual shrubs, another observer variability test was conducted in winter 1999. Eight observers were provided with two photographs, one from 1975 and another from 1995, and asked to count total intersects of shrub profile. The CI% for 1975 was 7.5 percent and that for 1995 was 11.6 percent (fig. 44). The 1995 photo was more difficult to interpret.

The graphs in figure 44 illustrates the mean, 5-percent confidence interval, and observer variability by year. Using the largest CI%, 11.6 percent, the averages are significantly different at the 1-percent level of probability. Considering a maximum of 12-percent observer variability here and 15 percent for total individual shrubs, a value greater than 12 percent of the average intersects is proposed as being significant at the 5-percent level of confidence for observer variability. For example, a mean of 384 intersects must change by more than 46 to say that the change was real and not due to observer variability at the 5-percent level of confidence (384*0.12 = 46.1). This may be expressed as 384 ± 46 and thus intersects greater than 430 or less than 338 may be considered a real change.

Studies, such as at Pole Camp where photographs are taken every year, are amenable to regression analysis of grid intersects. If the outlines are done by the same person, observer variability is reduced. Figure 45 illustrates regression on shrub profile intersects at Pole Camp from 1975 to 1997. Regression for the entire data set showed a decline at -0.63. However, when data were selected for the time when beavers were in the area, 1983 to 1994, the regression was at -0.90, highly significant. Trend lines such as these seem very useful.

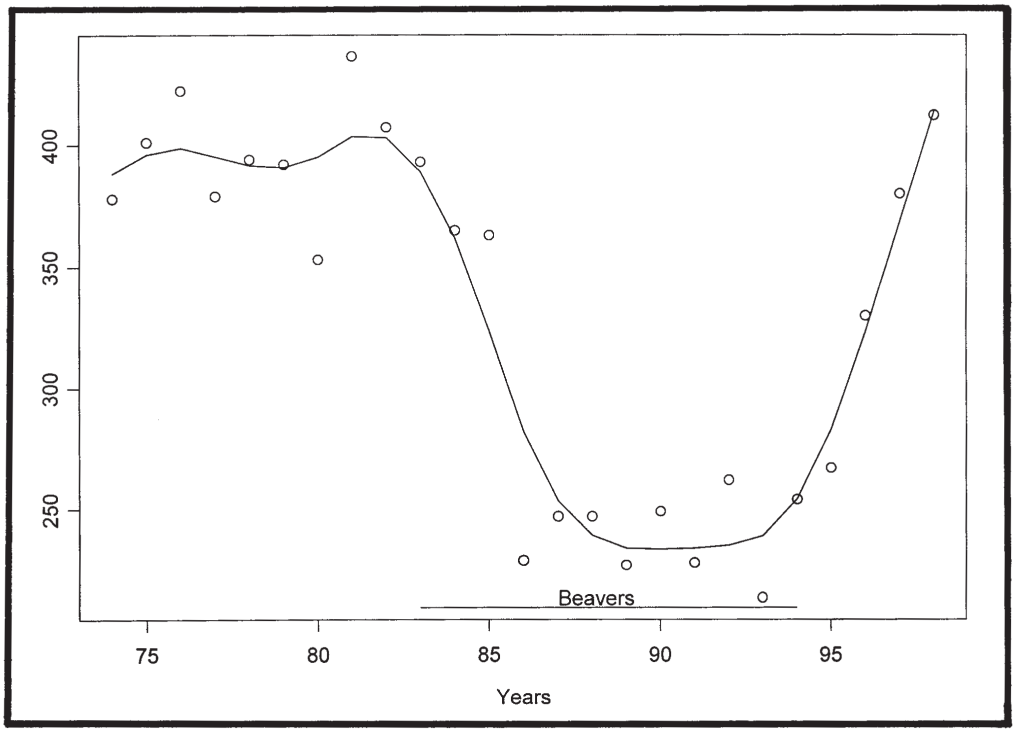


Figure 45—Regression of outline intersects from 1975 through 1997 for shrub profile changes at the Pole Camp wet meadow photo point. One observer made all 25 grid measurements. Intersects are totals from inside the grid area. Circles are the yearly total shrub intersects. The line is a smoothing spine regression. A note at the bottom of the graph indicates years when beavers were present.

Analyzing Location

Documenting change in position of items on a photograph requires precise photography. Three kinds of precision are required: (1) distance between camera location and meter board must be the same for all repeat photos, (2) height of camera above the ground and placement over the camera location stake must be the same for all repeat photos, and (3) sizing and orientation of the grid must be precise.

These variables do not consider observer interpretation. They do suggest that attempts to use photographs for monitoring change in position of objects is questionable if they are distant from the meter board. Table 1 illustrates effects of distance on grid precision. If documentation of position change is desired, place the meter board near the topic of interest, such as a streambank, and measure on the ground from the meter board to the object of interest.

Shrub Profile Grid Analysis

A review of photo grid analysis is required for this evaluation. Only highlights specific to shrub grid interpretation are presented here.

Photograph the shrubs from two directions as illustrated in part A, “Shrub Profile Photo Monitoring.”

Print the photographs to be analyzed at 8- by 12-inches (20 by 30 cm) and in color for good resolution.

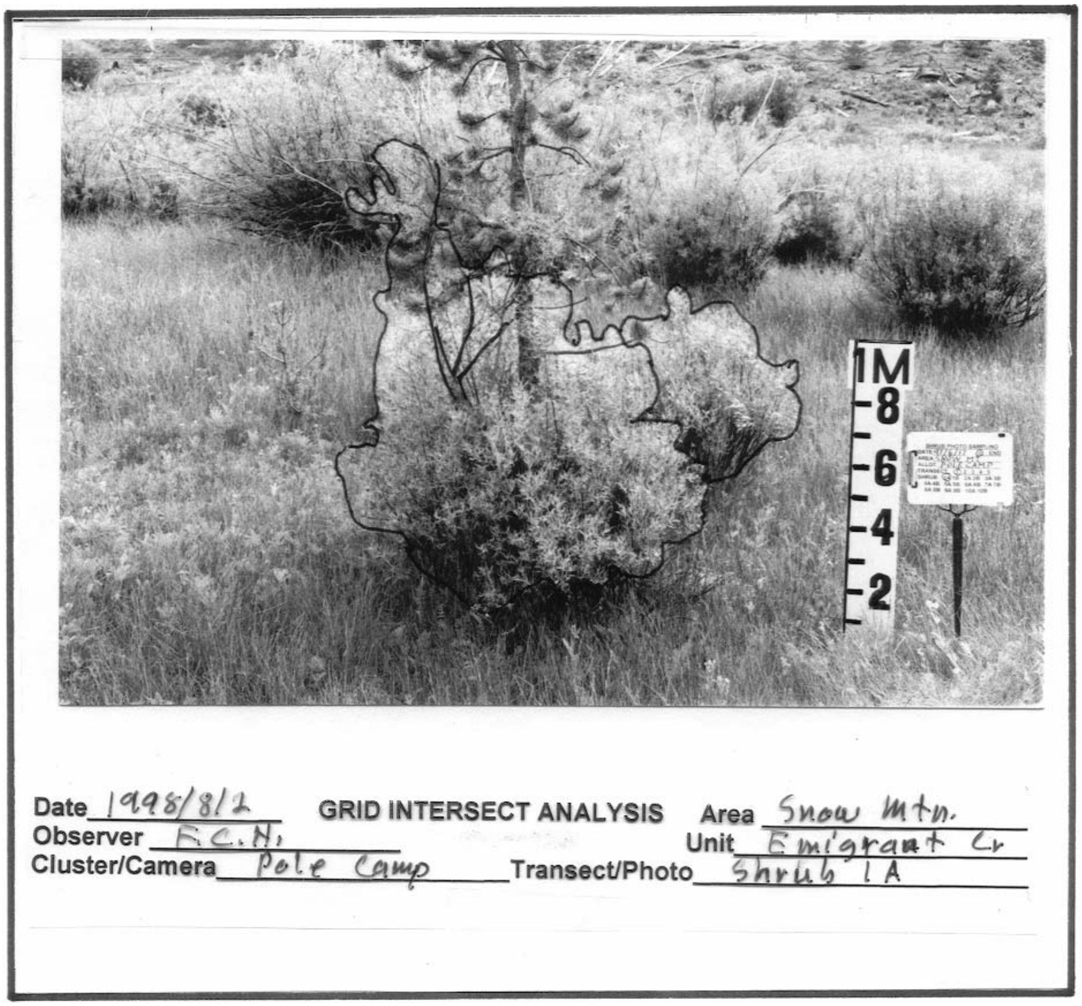


Figure 46—Grid analysis of shrub 1 on the Pole Camp shrub profile transect (see map, fig. 23, part A). This view is “1A” of the two photos of shrub 1 (1A and 1B, figs. 23 and 25) Both photos of shrub 1 are shown in figure 25, part A. The “Grid Intersect Analysis” outline form has been placed on the photo, information filled in, and the meter board marked. Outline as carefully as possible the shrub profiles. Do the same for the other photo of shrub number 1 (figs. 25, 1B, part A, and 47).

From appendix A, select the “Grid Intersect Analysis” form and duplicate on clear plastic. Fill out all information at the bottom of the form. “Date” is date of the **photograph**, not when the outline was made. The completed outline will become a basic data file and must be identified. Tape the outline form to the photograph along one edge such that the outline may be lifted for close inspection of the photo and then replaced exactly.

Outline the shrub or group of shrubs in the photo. Two shrubs are shown in figures 46 and 47. They have been separated for illustration purposes. Do not try to guess the outline of a shrub hidden behind another. Outline only what can be seen. Be as precise as possible. In figures 46 and 47, large willow branches have been marked on the overlay. The branches are clearly shown in figure 25 in part A.

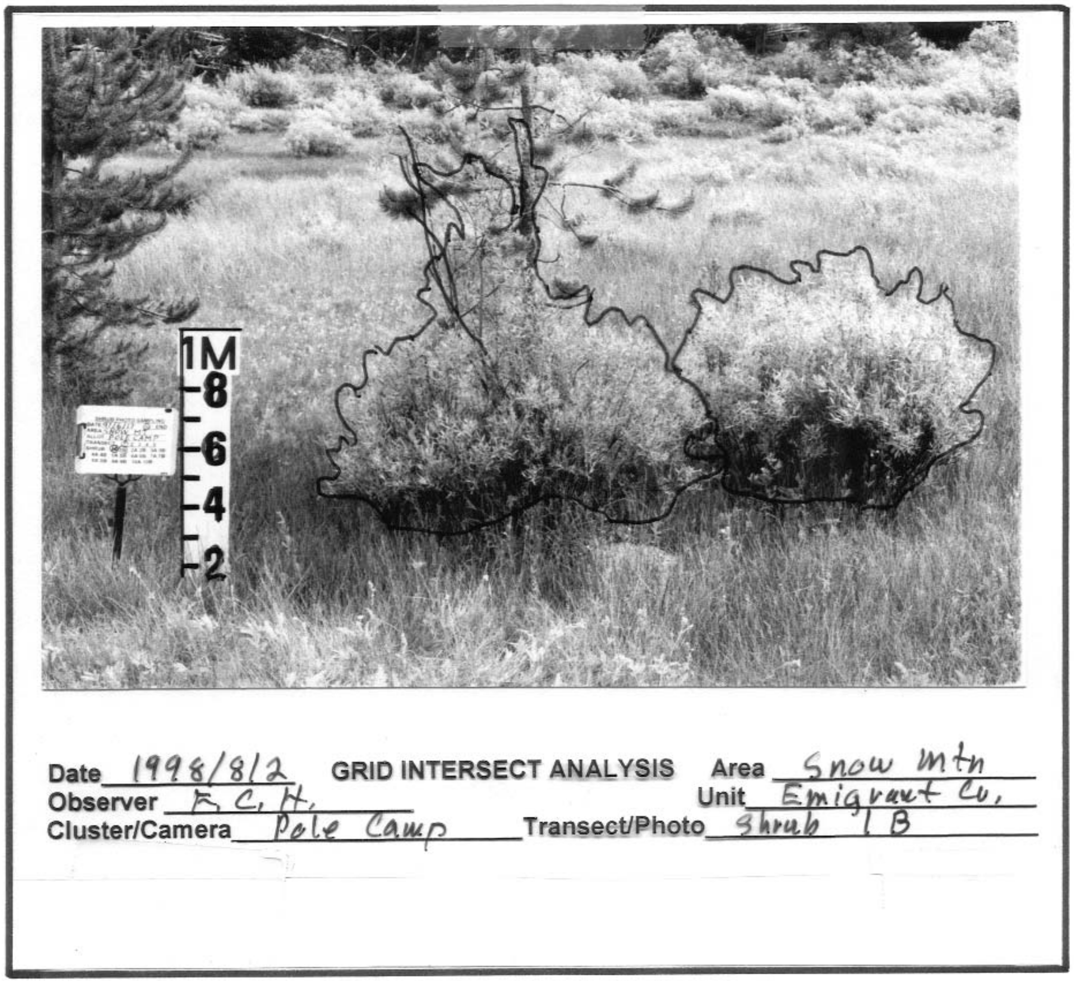


Figure 47—Outline of the second photo of shrub 1 (1B, fig. 25, part A), on the Pole Camp shrub profile transect. When two shrubs are present, separate their outlines as shown. Information at the bottom of the clear plastic overlay must be filled in for each photo. Remember to outline and mark the meter board. Outline **on** the foliage, not around it, to increase precision.

Next, adjust the shrub analysis grid, the one with meter boards at each side (app. A), to exactly match the outline meter boards as discussed in “Photo Grid Analysis,” above. Tape the outline form to the adjusted grid (fig. 48).

Count intersects within each outline including those falling under an outline (fig. 48), and enter on the filing system form “Photo Grid Summary” (fig. 49). Refer to the section “Analysis of Change, Observer Variability,” above, for a discussion of what constitutes a significant change in shrub profile area.

The reader may wish to test observer variability. Count grid intersects in figure 48 and compare to the results shown in figure 49. Expect a difference of three to six grid intersects.

Text continues on page 80.

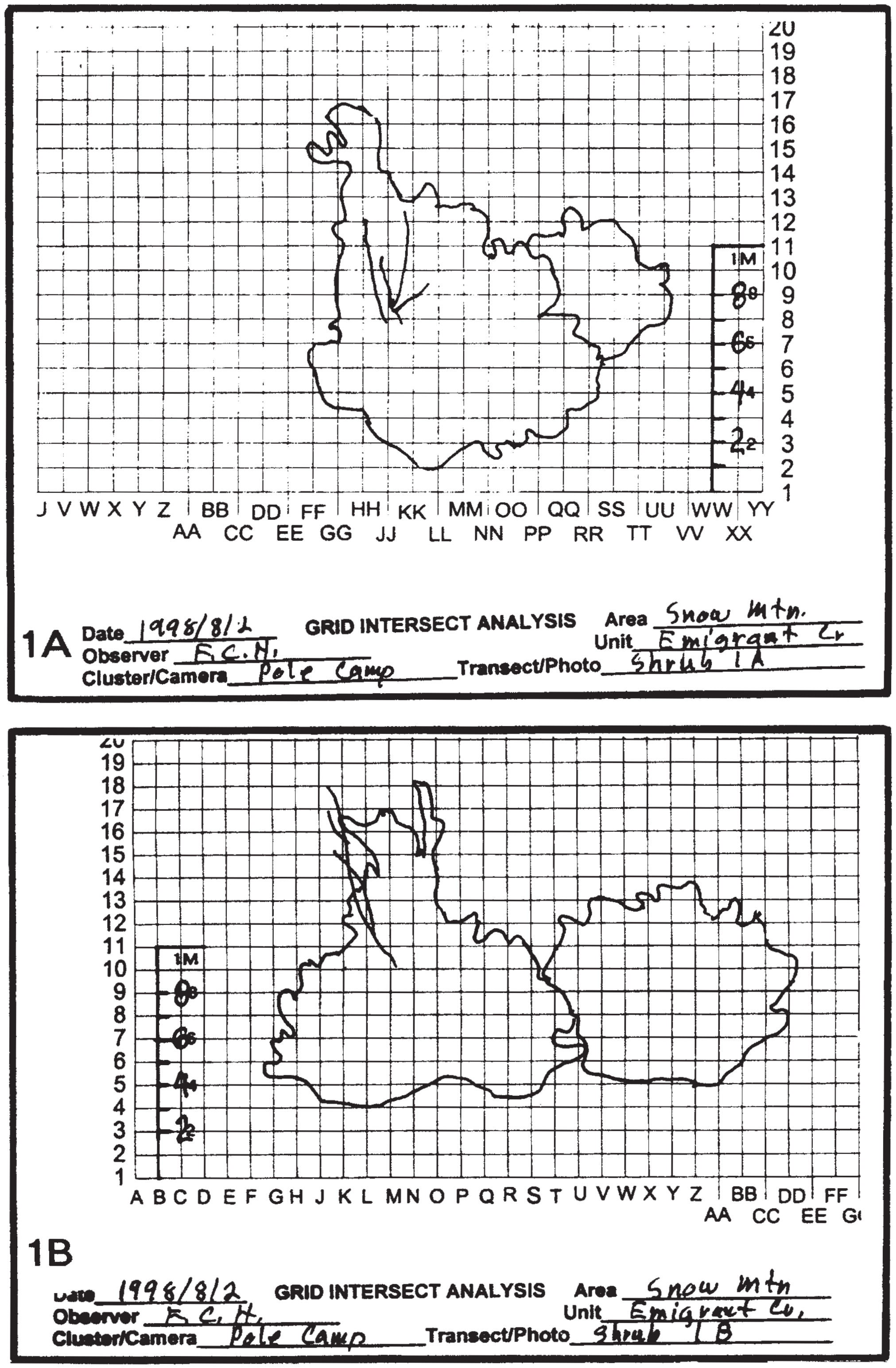


Figure 48—Grid outlines for shrub 1, photos (**1A**) and (**1B**) (figs. 46 and 47), on the Pole Camp shrub profile transect. Grids have been adjusted for size by the outlined meter board. Outlines are then taped to the grid. Count grid intersects and record on the filing system form “Photo Grid Summary (fig. 49).

1999/2/19

PHOTO GRID SUMMARY

Date 1998/8/14 Observer F. C. H.
Area Snow Mtn Unit Emigrant Cr.
Cluster/Camera Pole Camp Transect/Photo Shrub transect

Item #	Date 1998/8/14	Item #	Date	Item #	Date
1A	131				
1B	129				
2A	162				
2B	188				
3A	119				
3B	127				
4A	131				
4B	138				
5A	152				
5B	141				

Figure 49—Filing system form “Photo Grid Summary” for the Pole Camp transect. Future data on these shrubs may be compared for change as discussed in “Photo Grid Analysis,” above.

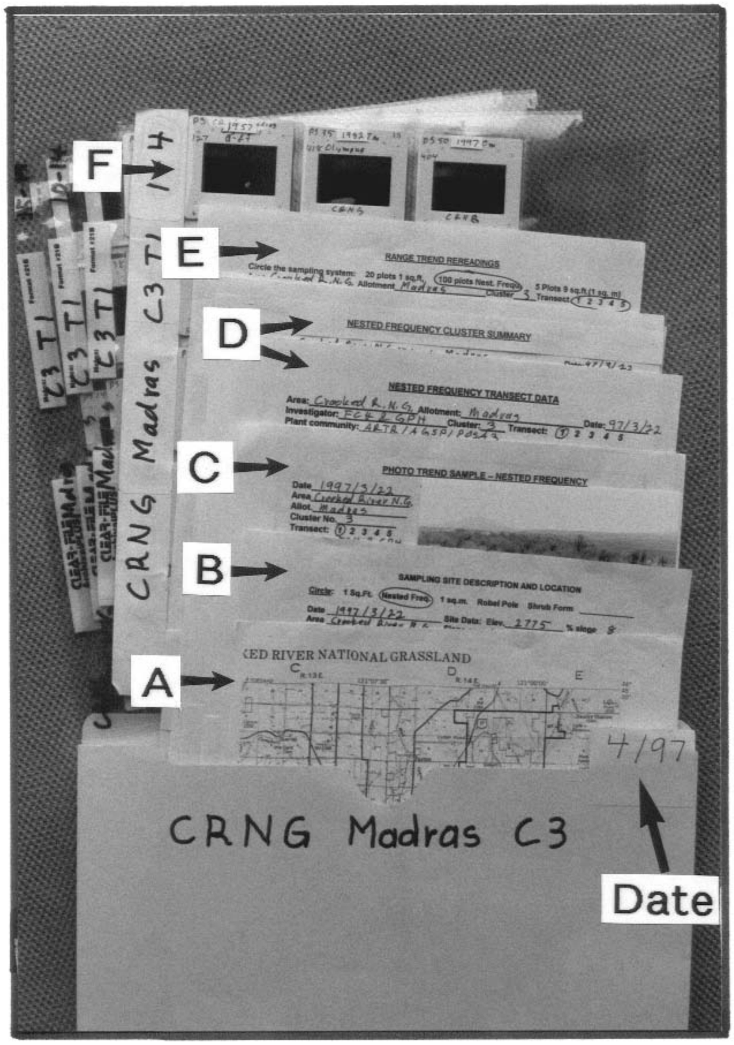


Figure 50—File folder contents for the Crooked River National Grassland trend cluster C3. Several sizes of expanding folders may be used: two-fold shown here, four-fold, or eight-fold to fit the file size. Each folder is labeled and the last date of sampling is attached to the upper right corner (arrow). All items pertaining to the sample location are included in the file: (**A**) general area map (fig. 5); (**B**) the form "Sampling Site Description and Location" for a plot layout map (fig. 6); (**C**) a form for attaching photographs and recording data shown here as the "Photo Trend Sample - Nested Frequency," similar to figure 11; (**D**) data summary forms shown here as "Nested Frequency Transect Data" and "Nested Frequency Cluster Summary"; (**E**) trend interpretation using "Range Trend Rereadings"; and (**F**) clear plastic holders for slides. Not shown are black-and-white negatives in their envelopes identified by date, cluster, and transect.

Filing System

Photo monitoring requires a way to file maps, data, slides, prints, negatives, or digital memory cards. My system places each study in an expandable file containing everything (fig. 50): local map to find the study site (fig. 5, part A), the "Photographic Site Description and Location" with map of the photo monitoring layout (fig. 6, part A), photo mounting forms for color or black-and-white prints (figs. 2 and 11, part A), analysis grids if used, and clear plastic slide holders. Negatives are filed in their envelopes from processing. Two prints are made of each negative, one for mounting and one to be kept in the envelope for future use. Digital images may be filed as memory cards or as compact disks (CDs), which are recommended. The disk should have an index card where identification of each image is stored. If images are stored on a computer (not recommended), identify the location and name of the computer, and the file where stored.

The expandable files are in a file cabinet dedicated to sampling and organized first by geographic location and then by date for next photography. Filing of studies by geography greatly facilitates travel planning. Noting the next photography date on each file helps in seasonal planning (fig. 50).

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