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Ground-Based Photographic Monitoring

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Abstract

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Land management professionals (foresters, wildlife biologists, range managers, and land managers such as ranchers and forest land owners) often have need to evaluate their management activities. Photographic monitoring is a fast, simple, and effective way to determine if changes made to an area have been successful. Ground-based photo monitoring means using photographs taken at a specific site to monitor conditions or change. It may be divided into two systems: (1) comparison photos, whereby a photograph is used to compare a known condition with field conditions to estimate some parameter of the field condition; and (2) repeat photographs, whereby several pictures are taken of the same tract of ground over time to detect change. Comparison systems deal with fuel loading, herbage utilization, and public reaction to scenery. Repeat photography is discussed in relation to landscape, remote, and site-specific systems. Critical attributes of repeat photography are (1) maps to find the sampling location and of the photo monitoring layout; (2) documentation of the monitoring system to include purpose, camera and film, weather, season, sampling technique, and equipment; and (3) precise replication of photographs. Five appendices include (A) detailed instructions for photo sampling, (B) blank forms for field use, (C) specifications and photographs of recommended equipment, (D) filing system alternatives, and (E) suggestions for taking photographs and analyzing change over time.

Keywords: Monitoring, photographs, landscapes, transects, animal sampling, riparian, succession, forests, rangeland.

Preface

This document started as an update of my 1976 publication on photo monitoring to appraise rangeland trends. The update was stimulated by a desire to document 40 years of experience in rephotography. This included about 150 ecology sample plots rephotographed at 5- to 10-year intervals, 25 years of herbage production, 25 years of riparian change photographed three times per season, and up to 40 years of rephotography of about 80 other situations, including wildfires, prescribed fires, tussock moth and spruce budworm damage, mountain pine beetle effects on lodgepole and ponderosa pine, fenceline contrasts between good and poor range condition, logging, revegetation, research studies and various landscape views. There is a great breadth of ground-based photographic monitoring in the literature. One aspect I found was use of photographs to estimate various existing conditions of vegetation and soil, such as comparison photo monitoring following Maxwell and Ward's (1976a) guides to estimate fuel loading, fire intensity, rate of spread, and resistance to control. Another was use of remotely controlled cameras to monitor presence of animals as illustrated by Kristan and others' (1996) video monitoring of osprey nest activities. And finally, repeat landscape photography of pictures taken at the dawn of cameras and exploration of the west, as exemplified by Progulske and Sowel's (1974) rephotography of Colonel Custer's exploration of the Black Hills in 1874—100 years of change. It is hoped that the information gained by personal experience and literature review will provide some guidelines for successful ground-based photo monitoring.

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Contents

Introduction

Ground-based photographic monitoring is designed for use by land managers, such as foresters, wildlife biologists, range managers, ranchers, and forest land owners. It is a way to document management activities and evaluate changes. For many people, photographs are faster and easier to interpret than measurements, and measurements, if needed, can be made from the photographs.

The system uses cameras at ground level rather than aerial photography or other aboveground sensing. It includes several applications using either still picture or video media. For example, fuel loading conditions found in the field can be compared with photographs of known fuel characteristics to estimate tonnage per acre, flame length, rate of spread, and control problems; this is known as *comparison photo-graphy*. Or, cameras can be remotely controlled to document animal activities, which is *remote photography*. Camera locations also may be established and the same scene rephotographed periodically for *repeat photography*. Photographs produce a unique kind of monitoring not duplicated by measurement or inventory systems, although photography is subject to requirements that limit its application and use.

I begin with definitions and concepts, then discuss items common to all photography, followed by comparison photo monitoring, remote photography, repeat photography, and end with relocation of photo monitoring sites.

Definitions

Discussion of ground-based photo monitoring should start with a few definitions:

Monitoring is detecting change or condition of various topics. In this paper, it includes detecting change in riparian shrub cover, healing of disturbed soil, identifying presence of animals, documenting air quality, or estimating condition of some item such as fuel loading or percentage of utilization of herbage.

Photography refers to photographs or video or digital images, color or black and white, taken or used at the site, as opposed to aerial photograph interpretation and Landsat image analysis. The concept of ground-based photo monitoring therefore means using photographs taken on the ground to evaluate change or condition of various items.

Camera format specifies a focal length of the lens and ultimate image size. Some common formats are 50-mm lens on a 35-mm camera, 70-mm lens on a 2- by 2-in camera, or a 128-mm lens on a 4- by 5-in camera. All are comparable insofar as what part of the landscape is included in the final image. Formats may differ for the same camera. A zoom lens on a 35-mm camera can change from 35-mm focal length wide angle to 110-mm telephoto. Most photographs in this publication were taken with a 35-mm camera and a 50-mm lens.

Three terms are used to identify types of photography:

Landscape photographs are of distant scenes or of a broad, general area often more than 10 ha.

General photographs document a topic being monitored and commonly cover 0.25 to 10 ha. They may be used alone or in conjunction with closeup photographs.

Closeup photographs are made of a specific topic on a small tract of ground often from a few decimeters to 10 by 10 m. They have no horizon reference, and the locations from where the photographs are taken therefore must be marked with stakes or fenceposts.

Finally, three terms are important in photographic sampling systems:

Witness site is an easily identified reference used to locate the monitoring area. It provides compass direction and distance to the camera locations.

Camera location is a permanently marked location for the camera.

Photo point is the direction of the photograph from the camera location. It is marked permanently by a steel stake or fencepost and commonly involves a size control board located in the center of the photograph. More than one photo point may be taken from a single camera location, and more than one camera location may photograph a single photo point.

Comparison and Repeat Photography

Comparison—In comparison photo monitoring, existing conditions are compared with conditions shown in a set of photographs. For example, Maxwell and Ward (1976a) produced a color photograph field guide for estimating logging fuel loading in tons per acre by size class with estimates of fire intensity, rate of spread, flame length, and resistance to control. Kinney and Clary (1994) developed a guide for estimating the percentage of utilization of riparian grasses and sedges by using photographs of various stubble heights. And Magill (1990) evaluated public concern over logging by having people rate a set of color landscape photographs taken at different camera focal lengths to simulate various distances from the scene.

Repeat—Repeat photography is characterized by taking multiple photographs of the same landscape, tract of ground, or activity, such as animal presence. It's particularly useful in three situations:

1. Landscape photography, where change is documented for landscape-sized areas over time. Some classic examples are Progulske and Sowel's (1974) documentation of Colonel Custer's exploration of the Black Hills wherein they rephotographed pictures taken in 1874. Another is panoramic photography using special camera equipment to take 360-degree views of landscapes, as Arnst (1985) shows for the Cascade Range of the Pacific Northwest.

2. Remotely operated cameras used to monitor animal behavior such as that of nesting ospreys (Kristan and others 1996), evaluate air quality (Fox and others 1987), or document animal distribution (Kinney and Clary 1998).

3. Site-specific repeat photography identifies specific topics on selected tracts of ground to document change or lack of change in vegetation and soil. Gary and Currie (1977) show a 40-year record of plant and soil recovery on an abused watershed in Colorado, and Smith and Arno (1999) document 88 years of change in managed ponderosa pine forests through 14 camera locations.

Clearly, photo monitoring is not a simple, routine procedure, but rather a multifaceted concept covering various purposes or objectives. To discuss this topic, the paper is organized into seven main parts: items common to all photo monitoring, comparison photos where current conditions are compared to a series of photographs and their condition rated, repeat photography of landscapes, photo monitoring by remotely operated cameras, site-specific repeat photography, and lessons in relocation of repeat photography.

The appendices cover many items in detail: Appendix A gives the methodology for monitoring change in vegetation and soil, appendix B contains blank forms for both office and field ready to copy, appendix C has plans for construction of meter boards and plot frames, appendix D discusses filing systems for photo monitoring, and appendix E illustrates photographic tips.

Common Items

Common to all photographic monitoring are (1) determining specific objectives, (2) using a repeatable technique, (3) choosing appropriate camera and film, and (4) developing a filing system.

Select Specific Monitoring Objectives

The first and most important item in any monitoring project is to have specific objectives. Questions answerable by photography must be asked before any kind of monitoring can be developed and installed. Consider a five-part query to develop these objectives: why to monitor, where to locate the sampling, what specific topic to evaluate, when to do the photography, and how to accomplish the photography (Borman 1995; Nader and others 1995; U.S. Department of the Interior, Bureau of Land Management 1996).

Why—Why to monitor asks for definition of the question needing an answer. Implementation monitoring asks if what was done was what was indicated, effectiveness asks whether the treatment did what was wanted, and validation asks if the treatment met the objectives. *Why* sets the stage for all other questions.

Where—Where to monitor depends upon the *why*. Where will the selected representative tracts, animal activity areas, treatment sites, or particular kinds of treatments be located? Will number, size, and location of activities such as fire, logging, revegetation, livestock grazing or flood affect the selected site(s)? Ask where the best location is that will answer the questions. Critical documents are a map to locate the site and a site map to document all camera locations and photo points.

What—Which items on the selected tract—vegetation, soil, streambanks, animals, air quality—will be monitored to support the *why*? Ask what the critical few items are that must be documented. What is expected to change? What will the picture demonstrate? Why should I take this picture (Johnson 1991)? The *what* dictates sampling layout.

When—When to monitor supports the *why* and *what* questions. Does monitoring encompass one year or multiple years? One season or more? Specific dates and time(s) of day? All are important in both animal and site monitoring. Scheduling includes time before treatment as well as after and frequency after initial treatment. Unplanned disturbances, such as fire or flood, pose special problems. A monitoring protocol may have to be developed on the spot to determine when and where during the event to establish photo points and to define a followup schedule.

How—How to monitor is determined by *what*, *why*, and *when*. It encompasses detailed protocols for photographic procedures used to obtain qualitative data (estimates) or quantitative data (measured in the field or measured on photographs). (Appendix B contains detailed instructions for both systems.) An example might be dealing with effects of livestock grazing on a riparian area: (1) Are streambanks being broken down? (2) Are riparian shrubs able to grow in both height and crown spread? (3) Is there enough herbage remaining after grazing to trap sediments from flooding? (4) Is herbaceous vegetation stable, improving, or deteriorating? Answering these questions will require selection of a sampling location and establishment of photo points and camera locations sufficent to gather adequate data. Try to select camera locations that will photograph more than one photo point. The time or times of year to take photos then must be specified, such as just prior to animal use of the area, just after they leave, or fall vegetation conditions. Will this riparian site be monitored for high spring runoff, late season low flows, or during floods? Monitoring of stream flows probably requires different scheduling from monitoring of animal use.

Repeatable Photo Technique

A second common item in photo monitoring is a repeatable technique that can be used by various people to attain similar results. For a technique to be repeatable, it must be simple, thoroughly documented, and illustrated. The following items are key elements in a well-documented and -illustrated technique:

1. A map locating the photo monitoring site and one or more maps of the photo monitoring layout for the site.

2. Camera locations and photo points permanently marked with steel fenceposts or iron stakes. Iron stakes should be flush with the ground to prevent tire and foot (hoof) damage. They are difficult to relocate but can be found with a metal detector. Positions of camera location and photo points are critical (Rogers and others 1983). The need for a constant distance between camera and photo point for all repeat photography is demonstrated under “Camera Format,” below.

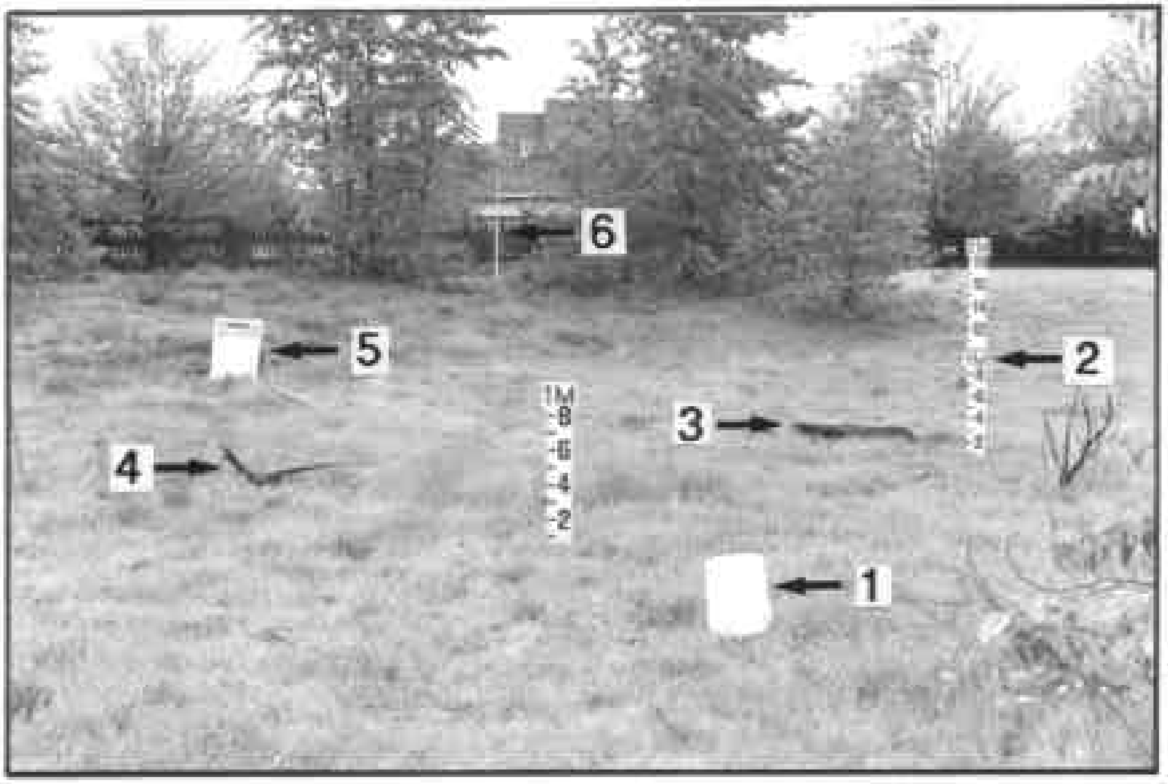

Figure 1—Landscape used to test effects of camera format (focal length), distance from camera to photo point (meter board), and camera position on size and location of items. Camera format is 35-mm using three focal lengths (lenses): 35-mm wide angle, 50-mm standard, and 70-mm telephoto. Distances are 7, 10, and 14 m. Camera positions are eye level (1.8 m), breast height (1.4 m), and offset right by 4 dm. Numbered items are outlined and compared: (1) bucket between camera and meter board, (2) double meter boards, (3) log on the ground, (4) root wad, (5) cart 15 m from the meter board, and (6) lamp pole 50 m from the meter board. Four situations will be evaluated: (**A**) varying the distance from camera to meter board but using the same focal length camera (figs. 2 and 3); (**B**) varying both distance and focal length such that the meter board is the same size in all pictures (figs. 4 and 5); (**C**) varying the camera focal length at a given distance (figs. 6 and 7), and (**D**) varying camera position over the camera location fencepost (figs. 8, 9, and 10).

3. Precise description, by time of day, weather, and season, of when landscape or general and closeup scenes are to be photographed—all are directly related to the objectives for monitoring; for example, before 10 a.m. and after 3 p.m. if back-lighted vegetation is needed (app. E), visibility of 25 or more miles for repeat landscape photography, high overcast to avoid shadows in forest photography (app. E), bird monitoring in spring, livestock grazing at mid or late season, or documenting high and low stream flows in spring and late summer. Special instructions, such as key landscape items to identify in landscape photography, also are needed.

4. A description of how to photograph and show camera locations and photo points on the site map. A size control board (fig. 1; app. C), such as a meter board, is needed for general photos and appropriate plot frames for closeup photos (app. C).

5. Suitable forms and field instructions for accomplishing the monitoring (apps. A and B).

6. An equipment list including a specified camera and film, field forms to be used in each photograph, any needed measuring or calculating equipment, and fenceposts and equipment to permanently mark photo locations. Specify whether a tripod is required and why.

7. Specific, detailed diagrams and instructions for installing and maintaining photographic equipment. This is particularly important with remotely operated camera systems to assure their proper functioning.

8. A comprehensive filing system (app. D; Johnson 1991, Nader and others 1995) with a container for each study to hold all information: monitoring objectives, site descriptions, maps, color slides, and black-and-white pictures with their negatives or digital memory cards with a copy of the images. All color slides, black-and-white pictures plus their negatives, and digital images and their memory cards need to be labeled immediately after processing. A note on the outside of the file of the last monitoring date is helpful.

Cameras and Film

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.

Two kinds of cameras are available: film and digital. Each has specified formats, such as a film camera with 35-mm film with a 50-mm lens, which is similar to a digital camera with a 13-mm lens. Some photographers suggest that changing from one kind of camera format to another poses serious problems in matching photographs. This is not insurmountable, however, as discussed under “Camera Format,” below. Another concern is quality of image. Switching from one brand of color film to another tends to change tones, particularly green and blue. And changing from film to digital usually influences image resolution and color.

Film and digital camera characteristics—Both types of cameras come in two configurations: (1) viewfinder and (2) view-through-the-lens or single lens reflex (SLR). Many digital cameras use SLR principles with a liquid crystal display (LCD). An LCD is a miniature (about 25 by 37 mm) computer monitor screen that displays the image as seen through the lens (Kodak 1999b). Viewfinders show an image that is parallel with the lens and have an outlined box in the viewer to show what the image will cover when a picture is taken at close range (parallax correction). The image will always appear sharp. With SLR systems, the image is viewed exactly as it will appear: there is no parallax correction and the image will appear fuzzy when out of focus, but SLR cameras are more expensive.

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 within 2 m for direct light and within 6 m for fill-in. More expensive cameras provide a “hot shoe” for attaching a more powerful and adjustable flash system. Additional flash systems add cost to the camera. Some cameras provide both an internal flash and a hot shoe.

Zoom lenses have become popular, particularly with the point-and-shoot automatic 35-mm cameras. They also seem to be common on many digital cameras. These lenses have two main attributes: they add flexibility to the camera and they tend to be less sharp than a fixed lens. Zoom lenses may pose problems in photo monitoring because of the need to set a precise focal length to reproduce the original image coverage. For an SLR lens, this isn't too difficult because the lens will have focal lengths marked. But a point-and-shoot 35-mm camera will zoom from 35-mm focal length to 100 mm or greater, a threefold difference in photo coverage, with no indication of the precise focal length used. The equivalent in digital cameras would be 9.2 mm to 28 mm. See "Camera Format" for details.

Lens quality and speed vary. Lens speed 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, at f-3.5, two times more light is admitted than at f-5.6, and f-5.6 admits twice the light of f-8. Depth of field also increases with an increase in f-stop. A slow lens of moderate sharpness is often characterized by f-stops of 3.5 to 4.8 and fast lenses of good sharpness by f-stops of 1.2 to 2.4. A film camera with an f-3.5 lens that's wide open and shooting at 1/60 of a second will create an underexposed image if the light meter says f-2.4 is needed, but a camera with an f-1.2 lens can easily capture the image. Faster lenses are more expensive. The processing unit in the camera computer usually provides digital camera speed; faster speed costs more.

Resolution (sharpness of the image) in film cameras is a function first of lens quality and second of film speed, which translates to graininess in the final picture. The difference in cost for films between ISO 100 and 400 is minimal, but good lenses do cost more. In digital cameras, resolution is determined by maximum dpi (dots per inch) of the camera. As of January 2000, most digital cameras started at about 0.7 megapixels, suitable for 4- by 6-in snapshots, and go up to 3.6, appropriate for 11- by 14-in pictures. Do not use less than a 2-megapixel camera. Good quality optical lenses also enhance resolution. Most digital cameras offer a choice of three to five resolution levels. For example a 1.3-megapixel camera might offer its best resolution at 1280 by 1020, midresolution at 900 by 700, and lowest at 600 by 400. Finer resolution results in fewer images on a digital storage card and slower processing. Quality also is influenced by the kind of compression, if any, used to store the image, and compression influences how many images may be placed in a memory card.

Film and digital concepts—One might consider the digital camera a special purpose computer designed to take photographs (Kodak 1999b). Digital images are captured on an electronic storage, or memory, card that must be processed to produce an image. The camera can alter an image with 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 shortly.

A camera using slide film exposes an image on film—*period*. Once the exposure is made, there is no recourse with correction. There is some recourse with black-and-white and color negative film by 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) CPU (the computer) that processes the image with its ability to make major changes in the pixels and thus the image; (3) 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 that either prints the image (printer) or projects it (projector). The camera, CPU, and output device affect the resolution (dpi), color quality, and contrast. Matching the camera resolution with that of the CPU and output device attains best image quality. They are **not** all the same.

Film speed, the amount of light required to expose the film, is characterized by an ISO rating. Film resolution (graininess of an image) also is a product of film speed: faster film has more grain. Common ISO ratings are 100 for slow speed and fine-grain film (for example 1/60th second at f-5.6); ISO 200, which can be shot at twice the shutter speed (1/120th second at f-5.6) and has medium graininess; and ISO 400, which can be shot at four times the shutter speed (1/250th second at f-5.6) but is rather coarse grained.

Digital camera equivalents are approximately 1640 by 1400 dpi for ISO 400 (2.4-megapixel camera), 1960 by 1600 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: 1280*1020 = 1.3 megapixels.

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

Slides made from film and digital images share few common traits, however. A film image is determined at exposure and can be shown in presentations through a slide projector. A digital image cannot. Generally, the digital image first must be downloaded from the camera and placed into memory of a laptop computer. Then the laptop must be connected to a digital projector for presentation. Recently, cameras have been programmed for download directly to a projector; however, this projects only slides in the camera. It does not provide for a presentation using title, data, and instructional slides. Here are some things to consider when projecting digital images for a presentation (Kodak 1999a):

1. Know the native resolution (dpi) of the laptop and the camera. Select the resolution that will support "high color" (16 bit) color depth (1280 by 1024 dpi; a 1.3-megapixel camera) or higher. Settings of the laptop computer above or below the camera settings will result in reduced image quality.

2. Match the resolution of the laptop with the resolution of the digital projector. If the laptop uses 1280 by 1020 dpi and the projector only 800 by 600, image quality will be at the projector resolution.

3. Understand that colors on the computer monitor used to modify image characteristics are not the same as those projected. The projector gives the more accurate color.

Film—Film is another consideration in photo monitoring, particularly the use of color slide film compared to negative films when prints are the desired outcome. Prints can be modified many ways by using different kinds of printing paper, exposure timing, dodging, burning, and different filters to make good comparison pictures. An advantage of black and white film is its long life. Most color films or prints tend to fade over the years, even if they are kept in dark, cool, dry locations.

Tones in color film differ according to the chemicals used in manufacturing and processing the film: Kodachrome has warmer, more vivid colors then Elite Chrome (Ektachrome), yet Elite Chrome (Ektachrome) tends to produce a truer reproduction of the greens and browns in a natural landscape.[1] Repeat photography done with different brands of film therefore produce some significant differences in appearance of vegetation conditions in the scene, whether real or not (Magill 1989). The photo monitoring protocol should prescribe the brand of film, speed of film, and light (weather) conditions for the project.

Film processing will influence how well photos can be compared. Most film is sent to a commercial processor where either slides are produced or pictures are printed at a standard size, such as 3½ by 5 or 4 by 6 in. Quality of processing differs. Do not cheapen your product by cutting costs and quality at the final step (Johnson 1991).

Weather should be related to film. How does current weather compare to conditions of previous photographs (Magill 1989, Maxwell and Ward 1980a)? 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 that causes deep shadows. Maxwell and Ward (1980a) suggest overcast skies to reduce shadows and taking at least three different exposures to bracket light conditions for comparable colors between photos. Weather conditions of original photographs should be duplicated.

Digital storage cards—Digital cameras do not use film, but rather electronic storage cards (Kodak 1999a). Storage cards are not developed but are processed by computer. Any or all images can be erased and the card reused. The color quality, contrast, and depth can be manipulated. Either all images or selected ones can be copied from one card to another, greatly facilitating storage and retrieval of images. Different brands of cameras use different storage cards. Storage cards also come in several sizes and makes.

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[1] The use of trade or firm names in this publication is for reader information and does not imply endorsement by the U.S. Department of Agriculture of any product or services.

Storage cards vary in their megabyte (MB) capacity, which 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-to-1.2 ratio: a 1-megapixel photo requires about 1.2-MB of storage card capacity. For example, an image at 1280 by 1024 pixels (1.3-megapixels) would require an entire 2-MB card, or 24 photos could be placed on a 32-MB card. The same 32 MB card would hold 66 photos at 800 by 600 pixels (0.48-megapixel).

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

Processing of storage cards is quite different from film, with two alternatives: commercial or home processing. Commercial means the storage 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 computer should be compatible, and the dpi of the computer and printer also should be compatible. Image quality is sacrificed if either the computer or printer cannot process the dpi of the camera, or image quality may be sacrificed by color rendition of the printer.

Digital images may be stored in three ways: (1) in the memory card used with the camera, (2) transferred to a compact disk (CD) and the memory card reused, or (3) transferred to a computer hard drive with essential information in its file and the memory card reused. If stored in a computer, assure that instructions for locating the folder or file are placed in the photo monitoring filing system.

Color prints are similar in cost between film and digital systems; however, slides made from digital memory cards tend to cost more. The use of two steps, from card to negative and from negative to slide, tends to reduce quality of the image.

Camera Format

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.

When using slide film, however, 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.

Some examples of common film camera formats that cover about the same area of a landscape are (1) 1- by 1.5-in image size (35-mm camera) using a 50-mm focal length lens, (2) 2- by 2-in (50- by 50-mm) image size using a 70-mm lens, or (3) a 4- by 5-in (100- by 125-mm) image using 128-mm lens. All are equivalent to a digital camera at 13-mm focal length. The advent of good quality zoom lenses permits a great variety of camera formats having both desirable and undesirable features.

A desirable feature is increased flexibility in choosing photograph formats without the need to change lenses. Undesirable features include higher f-stops and no constant focal length when rephotographing monitoring sequences.

The effects of camera format and distance from camera to subject are shown and discussed in figures 1 through 7. Camera position concerns are illustrated in figures 8 through 10. Change in emphasis on a topic by distance is discussed in “Camera Techniques,” below.

Figure 1 shows a testing landscape where six objects are positioned, photographed, and outlined to compare size and location of the objects with change in distance, focal length, and camera position. Three lenses were used with a 35-mm camera body: (1) 35-mm wide angle, (2) 50-mm as a standard for comparison, and (3) 70-mm telephoto; these are equivalent to digital cameras of 9, 13, and 18 mm. They were used in conjunction with three distances from camera to meter board: (1) 7 m, (2) 10 m as a standard for comparison, and (3) 14 m. The effect of camera position was evaluated at 10 m with a 50-mm lens. The standard for comparison was 1.4 m above the ground (breast height) centered over the camera location fencepost. Camera position was moved upward 4 dm to 1.8 m (eye level) and sideways 4 dm.

The first evaluation (fig. 2) is a standard camera format of 50-mm lens on a 35-mm camera positioned 7, 10, and 14 m from a meter board. All photographs in figure 2 are clearly different. Outlines of objects, adjusted in size to the meter board at 10 m are shown in figure 3. All objects are different in both size and location.

Next, both camera format and distance to meter board were adjusted. The objective was to photograph the meter board at a constant size where the 35-mm lens at 7 m gave the same size meter board as 50-mm at 10 m and 70-mm at 14 m (fig. 4). Notice the difference in backgrounds. Comparison of object outlines in figure 5 shows that all objects are different in both size and location, almost identical with figure 3.

Finally, focal lengths (35, 50, and 70-mm) were changed at a fixed distance, 10 m (figs. 6 and 7). Figure 6 appears to show very different scenes insofar as what is included within each photo. But when the images are adjusted to size of the meter board at 50 mm shown in figure 7, each object is almost exactly the same size and location. This effect is what Rogers and others (1983) discuss. Figures 2 through 7 clearly indicate that distance from camera to meter board is critical; whereas focal length is not.

Text continues on page 20.

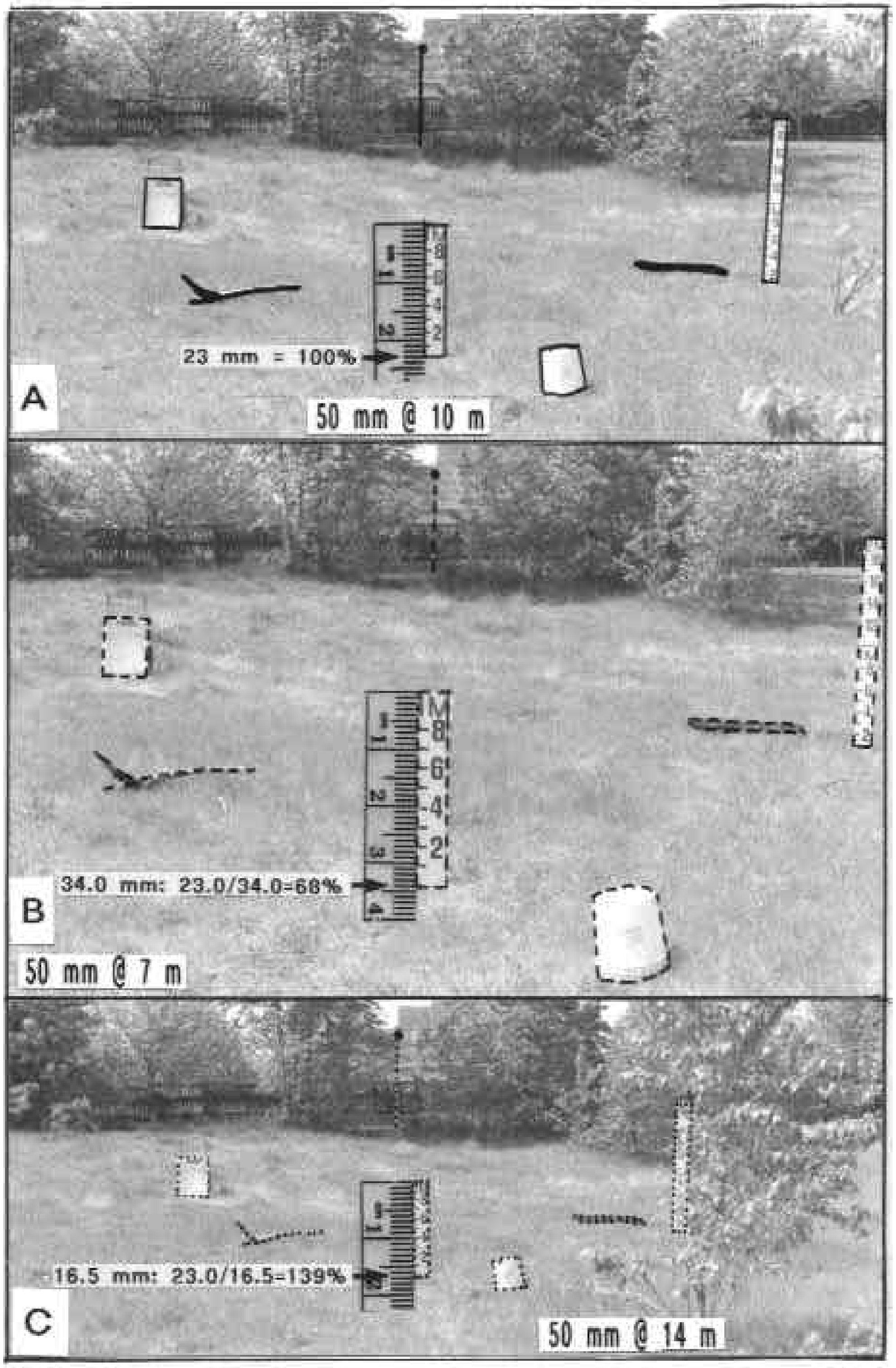

Figure 2—Effect of distance from camera to meter board on location and size of outlined objects when using the same camera format. Camera format is a 50-mm length lens on a 35-mm camera at 7, 10, and 14 m from the meter board. Objects were outlined on clear plastic overlay sheets as follows: 10 m in a solid line, 7 m in dashes, and 14 m in dots. Each outline was adjusted in size to match the meter board at 10 m as follows: measure in millimeters from the top of the board to bottom; this measurement is divided into the measure for 10 m for a percentage of change; then enlarge or reduce the overlay by that percentage. (**A**) The 10-m board was 23.0 mm and 100 percent; (**B**) the 7-m board was 34.0 mm reduced to 68 percent, and (**C**) the 14-m board was 16.5 mm enlarged to 139 percent. Figure 3 compares the adjusted outlines.

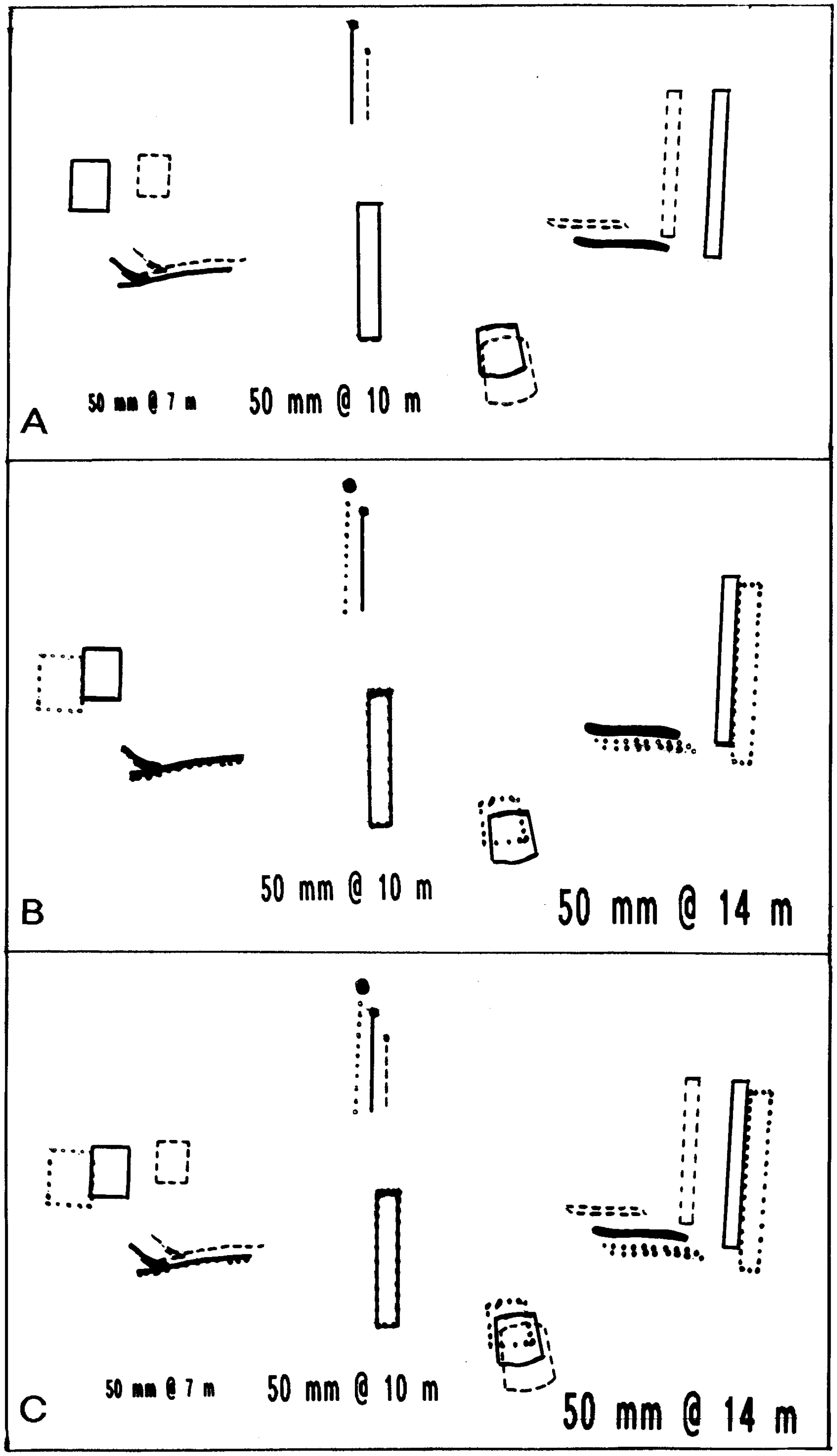

Figure 3—Overlays of object outlines from figure 2 adjusted in size to 10 m. The 10-m outline is solid, 7 m is dashes, and 14 m is dots. (**A**) Overlays of 7 m and 10 m shows objects of different size and location. (**B**) The 10-m and 14-m overlays also show different sizes and locations. (**C**) All three overlaid show that all objects are different in both size and location. Distance from camera to meter board is critical if objects in photographs are to be compared.

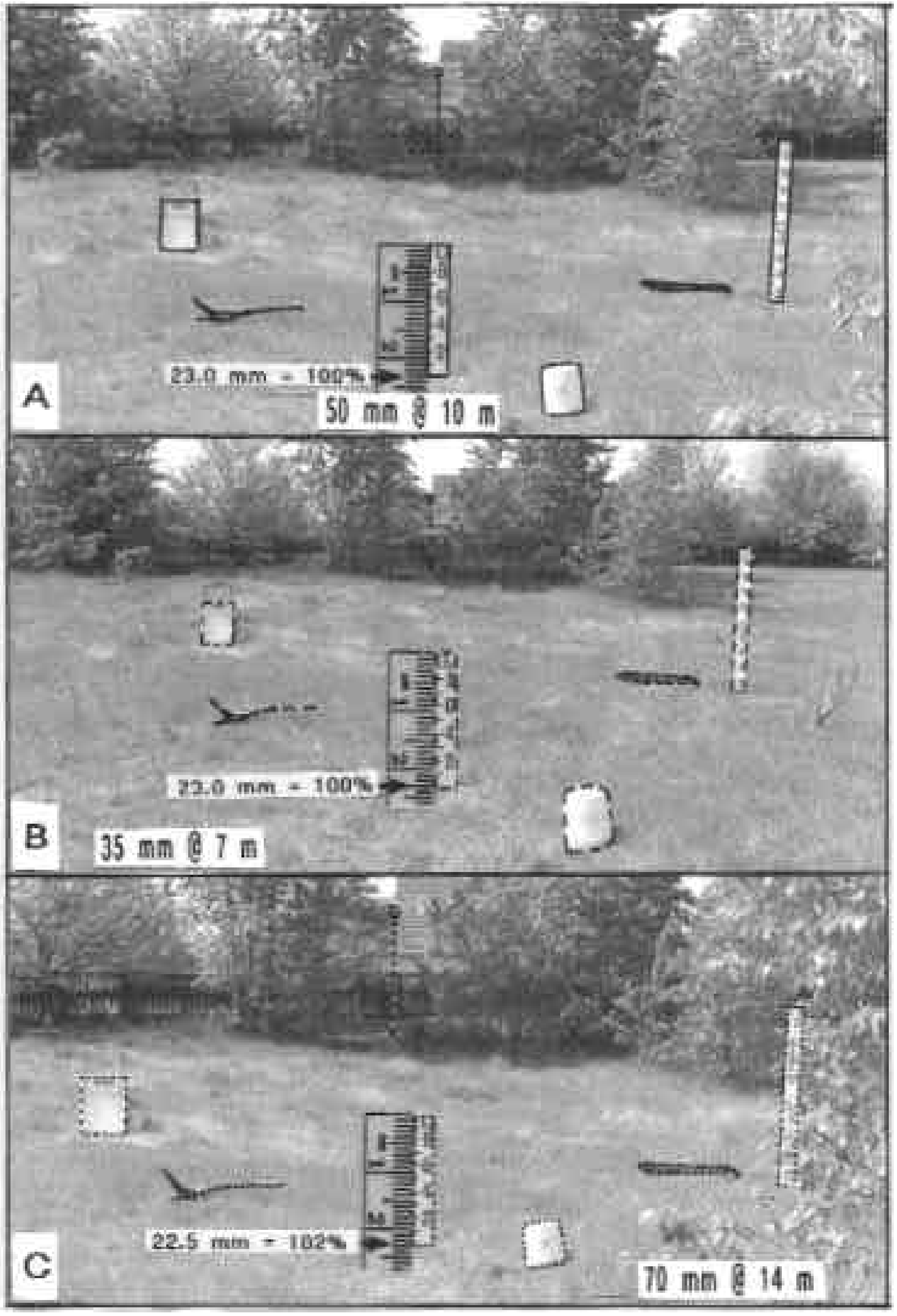

Figure 4—Both focal length and distance to meter board are adjusted to make the meter board the same size in each photograph: (**A**) 50-mm at 10 m, (**B**) 35-mm at 7 m, and (**C**) 70-mm at 14 m. Meter boards are measured to show similarity, and outlines were adjusted by the percentages shown. Objects are outlined on clear plastic overlays as follows: 50-mm with a solid line, 35-mm in dashes, and 70-mm in dots. Notice how the backgrounds change with a constant size meter board. Figure 5 compares the object outlines.

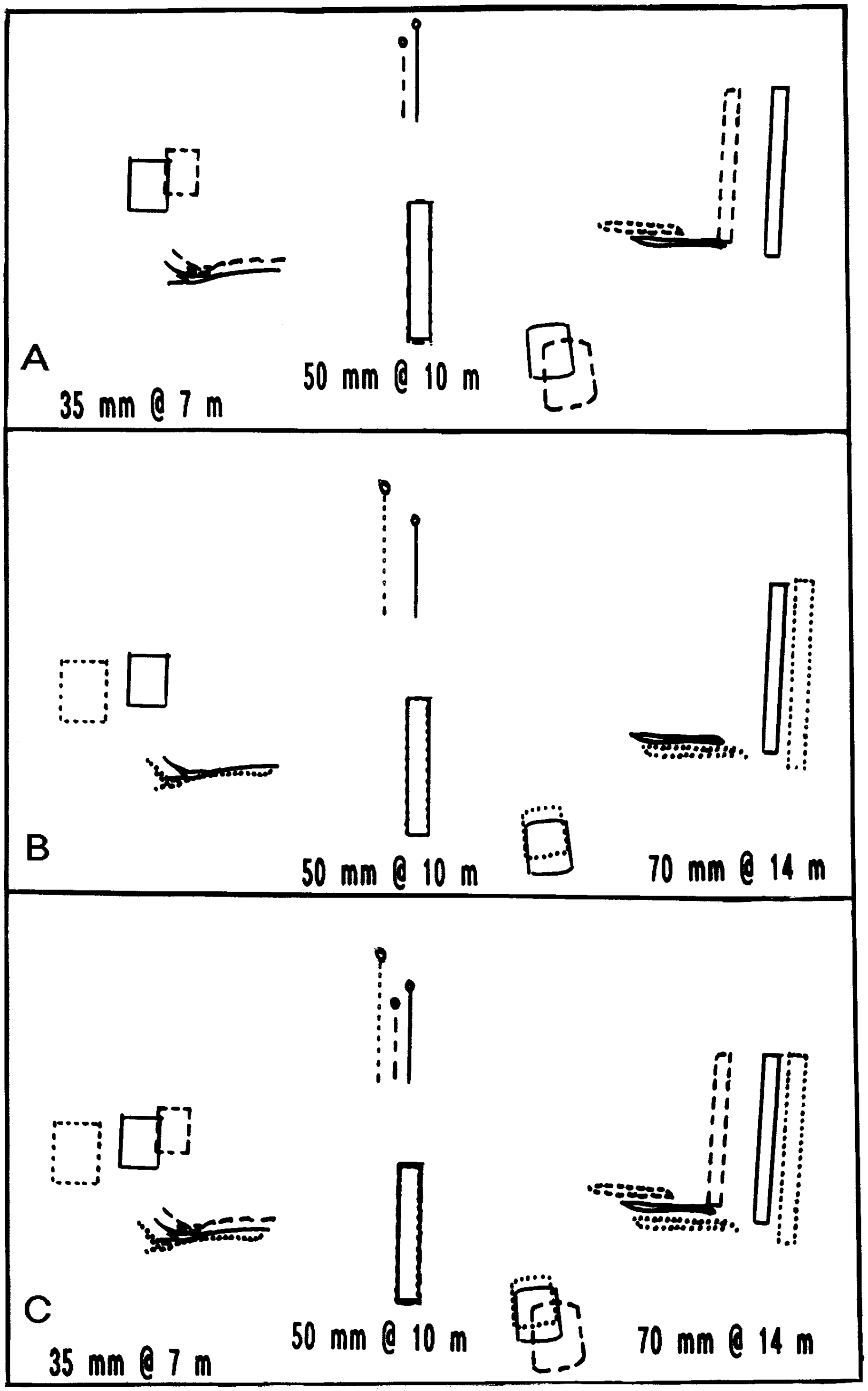

Figure 5—Object outlines from figure 4 overlaid to evaluate effects of camera focal length and distance from camera to meter board on size and location of objects. Photos were taken to keep the meter board at the same size. (**A**) The overlays for 35-mm at 7 m and for 50-mm at 10 m show different sizes and locations of items. A similar situation occurs with **B**. (**C**) All three overlaid shows a striking similarity to figure 3 because distance from camera to meter board is critical and focal length is not, as will be shown in figures 6 and 7.

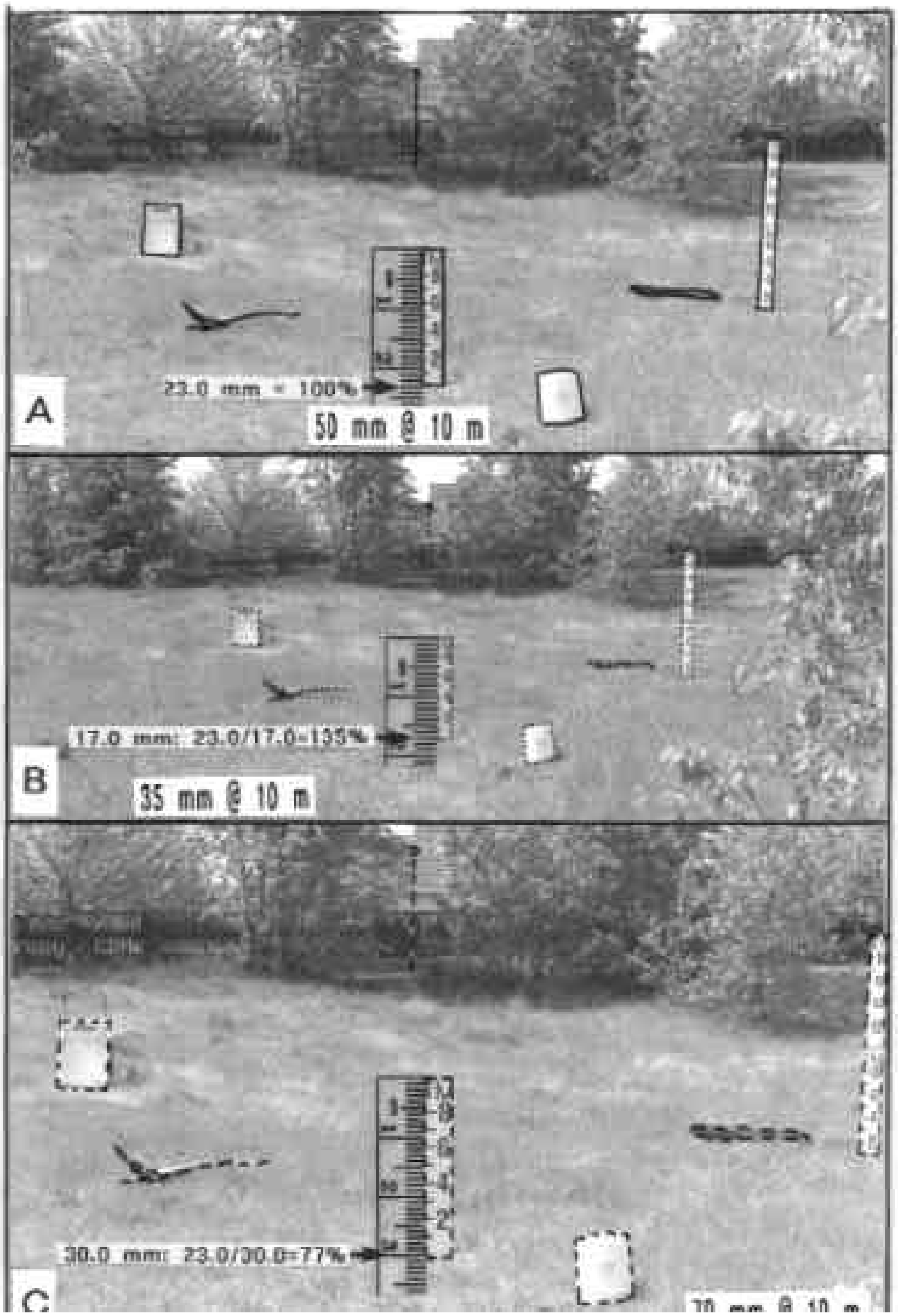

Figure 6—Effects of change in camera focal length of 35-mm, 50-mm, and 70-mm, at 10-m distance from camera to meter board using 50-mm at 10 m for comparison. Objects in each photograph were outlined on clear plastic overlays and were adjusted in size to the 50-mm at 10 m from the meter board as follows: (**A**) 50-mm was measured at 23.0 mm for 100 percent, solid outline; (**B**) 35-mm focal length was 17.0 mm, enlarged to 135 percent, outlined in dots; and (**C**) 70-mm was 30.0 mm, reduced to 77 percent, outlined in dashes. They are compared in figure 7.

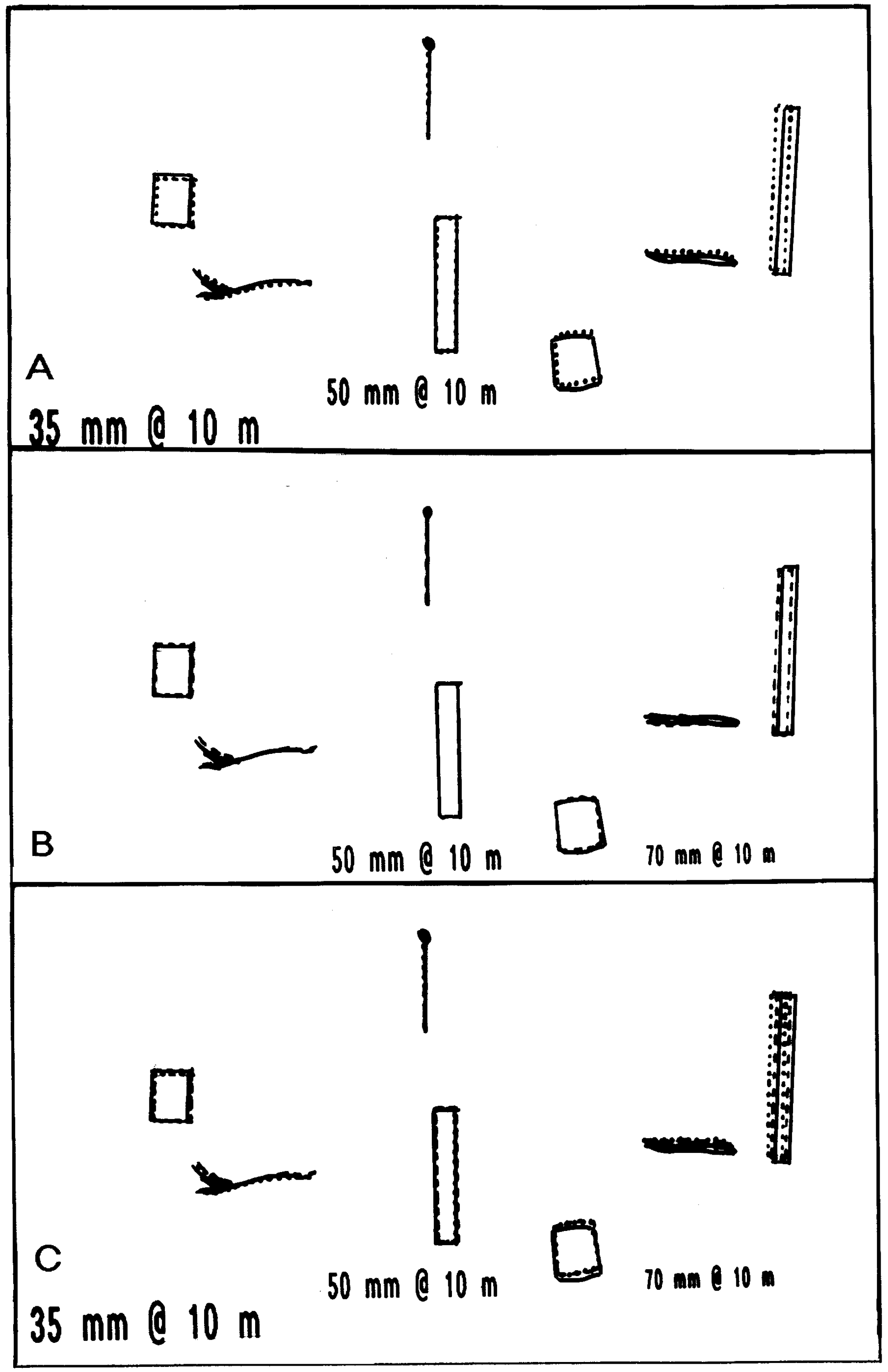

Figure 7—Object outlines for three camera focal lengths taken at 10 m from the meter board shown in figure 6. (**A**) Overlaying 35-mm and 50-mm shows almost no difference in object size or location. (**B**) Similarly, overlaying 50-mm and 70-mm shows little difference. (**C**) When all three are overlaid, there is almost no 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. A major disadvantage of using various focal lengths is the loss of background coverage in each photograph (shown in fig. 6, B and C). Comparison with figures 3 and 5 clearly demonstrates that distance from camera to meter board must remain the same.

Open to view page 18.

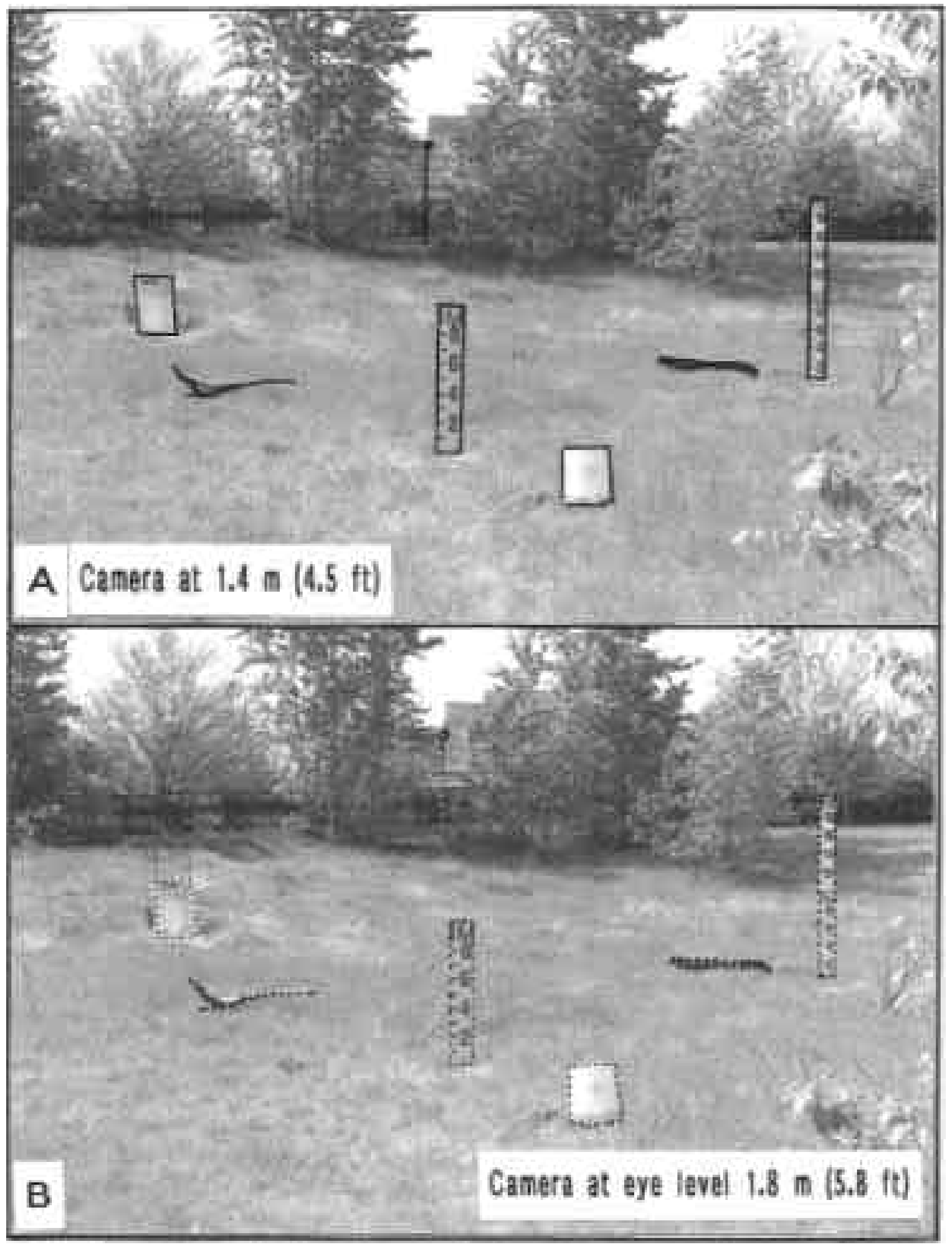

Figure 8—Effects of camera height aboveground on size and location of outlined objects. (**A**) Height of 1.4 m (4.5 ft, breast height) outlined in solid lines, is compared with (**B**) eye level of 1.8 m (5.8 ft) outlined in dots. The difference of 4 dm (16 in) is shown in figure 10A.

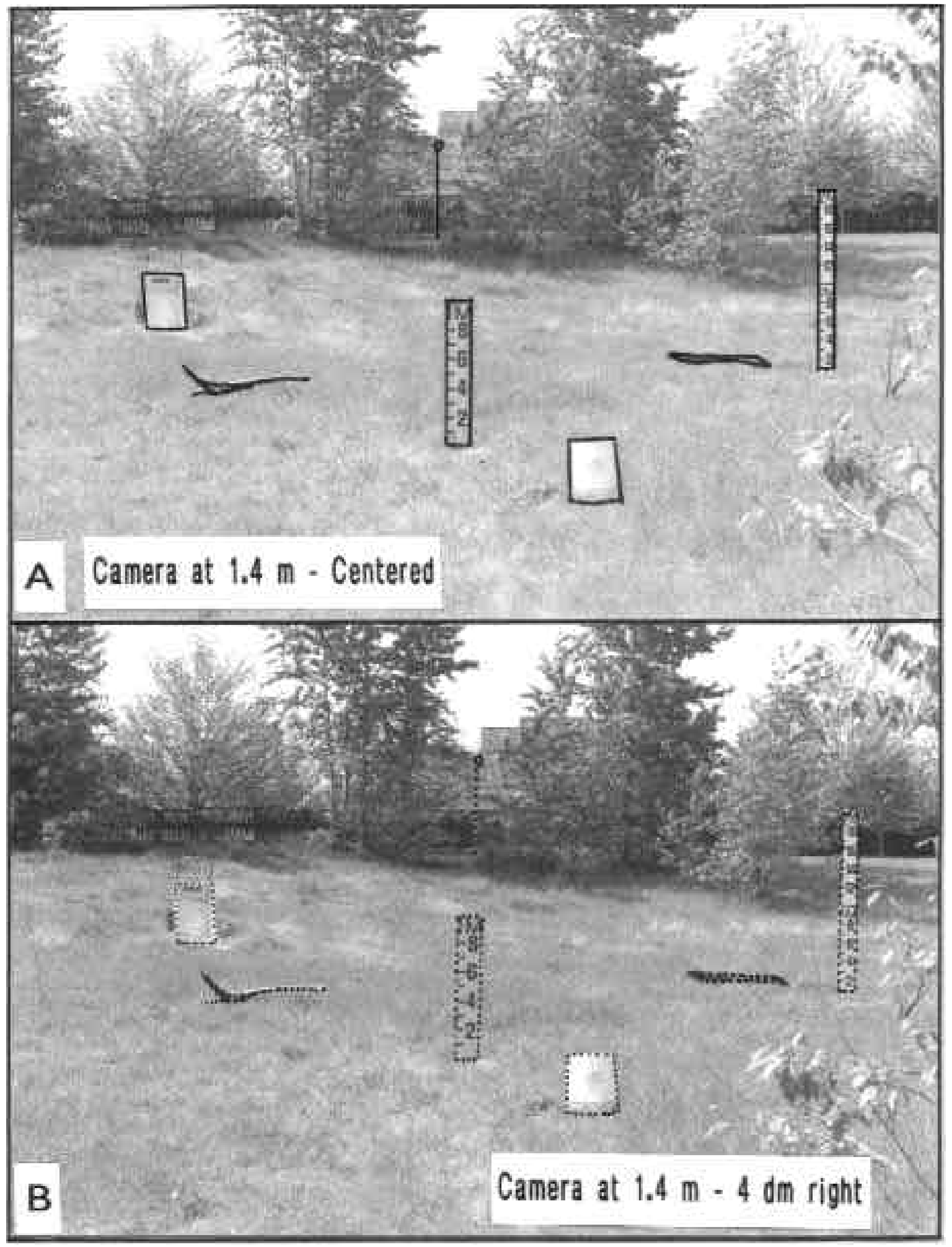

Figure 9—Effects of horizontal offset of the camera 4 dm (16 in) from center. (**A**) Center position is outlined in solid lines and (**B**) camera position to the right is outlined in dots. Difference in object size and location is shown in figure 10B.

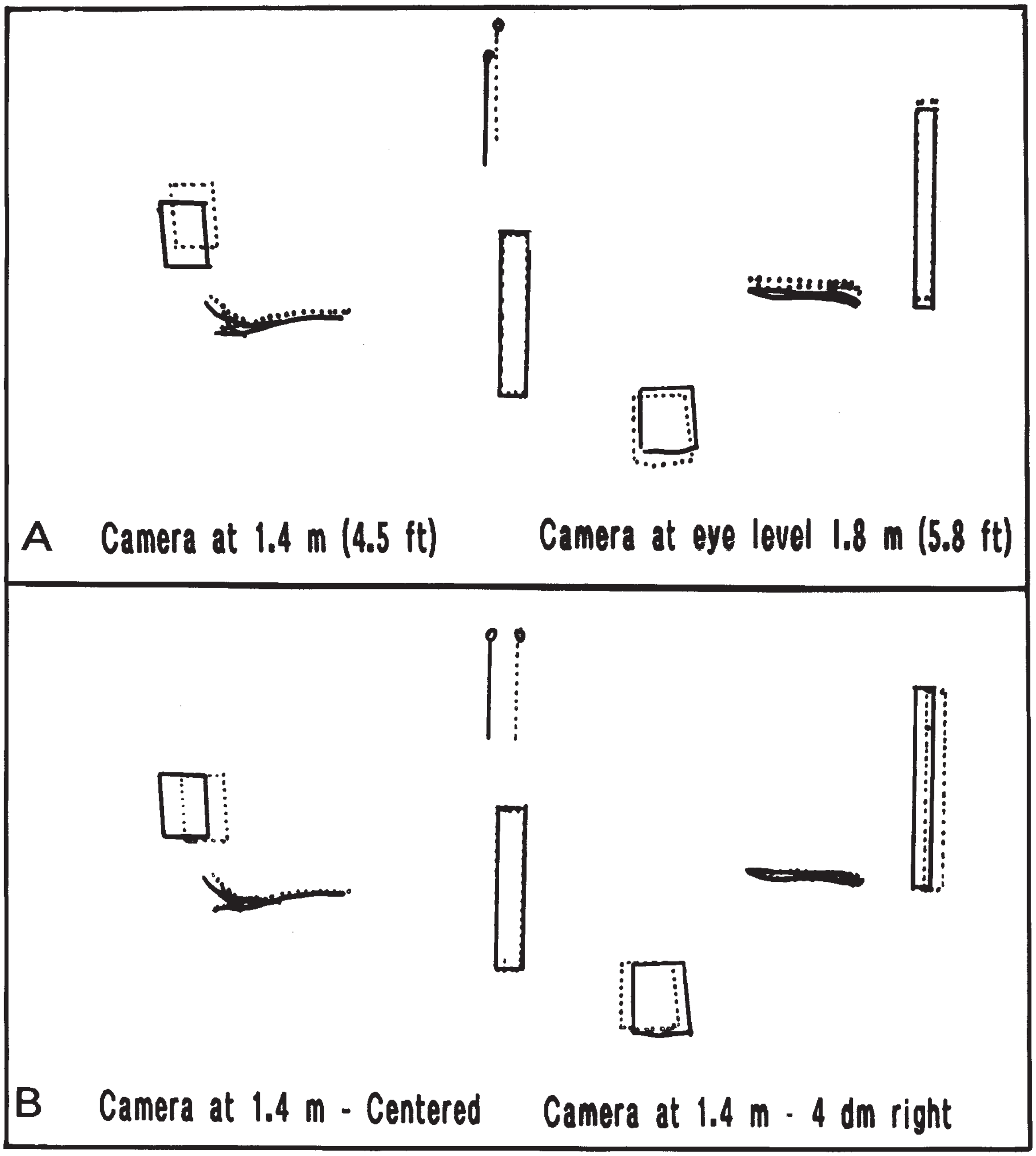

Figure 10—Effects of altering camera position by 4 dm (16 in) vertically and horizontally on size and location of outlined objects in figures 8 and 9. The reference position is 1.4 m (4.5 ft) centered over the camera location fencepost and outlined in solid lines. (**A**) Vertical movement of camera position, outlined in dots, to 1.8 m results in no change in object size but significant change in location on the photograph. (**B**) Horizontal movement of 4 dm (16 in) to the right, outlined in dots, results in no change in object size but significant change in position with the shift in a different direction from A. Position of the camera over the camera location fencepost affects location of objects but not size of objects.

Effects of camera position on object size and location are illustrated in figures 8 through 10. The photographs in figures 8 and 9 do not look different because 4-dm movement of the camera is difficult to detect. Figure 10, however, illustrates how much movement of objects occurs with only 4 dm (16 in) of change in camera position up or sideways. Although there is substantial change in object position, there is no change in size because the distance from camera to meter board was the same. Camera position is critical if location of objects is an objective of photographic monitoring; it is not critical if change in size of object is the objective.

Few restrictions and many opportunities exist in camera selection. The objective of photo monitoring suggests the appropriate style of camera and economics dictate the sophistication.

Filing System

A filing system must be developed for repeat photography. Place each photo study in a folder complete with purposes for the monitoring, site descriptions, notes, maps, color slides, and black-and-white prints with negatives or digital memory cards with prints (Johnson 1991, Nader and others 1995). The purpose of the file is to contain everything that other people will need for rephotography. Appendix D covers filing systems in detail.

Special note—It cannot be overemphasized to label and date all slides, black-and-white and color photographs, and the negatives as they are processed. Date and study location should be recorded on slides and negatives or digital memory cards by use of photo identification forms placed in the picture view at time of photography. Too often, negatives cannot be positively identified with their prints or date of photograph. I have found this a particular problem with negatives over 5 years old that document gradual change in conditions.

With these common characteristics in mind, two kinds of photo monitoring will be discussed: comparison photos and repeat photos.

Comparison Photo Montoring

Comparison photo monitoring means comparing on-the-ground circumstances to a set of photographs depicting various known conditions and assigning a value or rating to the field situation. This deals primarily with effectiveness monitoring and asking the question, “Did we do what we said we would?” Three examples are illustrated: (1) appraisal of fuel loading, (2) estimation of herbage utilization, and (3) monitoring of public concern.

Forest Residue Estimation

An example of comparison photo monitoring is appraisal of fuel loading (fig. 11). Maxwell and Ward produced photo series for quantifying forest residues in the coastal Douglas-fir—hemlock type (*Pseudotsuga menziesii* (Mirb.) Franco-*Tsuga heterophylla* (Raf. Sarg.) (1976a), ponderosa pine type (*Pinus ponderosa* P. & C. Lawson) (1976b), Sierra mixed conifer type (*Abies* spp.) (1979), and natural forest residues in several Pacific Northwest forest types (1980b). Other examples are Koski and Fischer (1979) using photo series for appraising thinning slash in northern Idaho, Wade and others’ (1993) photo series for estimating posthurricane residue in southern pine, and Ottmar and others’ (1990) sophisticated stereophoto series for quantifying forest residues in the Willamette National Forest in Oregon.

Maxwell and Ward (1980a) and Fischer (1981) present detailed instructions for developing photo series for forest residues. Their procedures were very similar except that Fischer placed the size control marker 20 ft (6 m) from the camera and Maxwell and Ward placed it 30 ft (9 m). Color was preferred by both to enhance recognition of dry and green fuel. The procedure of Maxwell and Ward follows:

1. Find very high and very low fuel loadings in the proposed forest type and size class, and then intermediate loadings. A forest type is the dominant tree species, and size class is the diameter at breast height (dbh) of the stand; for example, Douglas-fir pole size 5 to 9 in (12 to 22 cm) dbh. Their publications showed three to five different fuel loadings per forest type and size class.

2. Select slightly concave topography so that residue within 180 ft (54.5 m), a desired sampling distance, is visible.

3. Take photographs on overcast days because bright sunlight streaming through canopies creates sharp contrasts (see app. E).

4. Use a quality 35-mm camera with 50-mm lens.

5. Take the photograph in landscape format (long dimension of the photo will be horizontal.)

6. Use a reasonably fast, fine-grained color film (for example, Kodachrome 64).

1-DF-4-PC

DATA SHEET   Residue descriptive code 1-DF-4-PC

LOADING

Size class (inches)	Weight (tons/acre)	Volume (ft^3/acre)
0.25-1.0	1.1	61
1.1-3.0	2.3	143
3.1-9.0	2.3	174
9.1-20.0	1.0	65
20.1+	0	0
Total	6.7	443

OTHER MEASUREMENTS

Average residue depth (feet) 0.1
Ground area covered by residue 1/4-inch diameter and larger (percent) 40
Average duff and litter depth (inches) 0.7
Sound residue 3.1-inch diameter and larger Douglas-fir (percent) 79
(percent)
(percent)
Rotted residue 3.1-inch diameter and larger (percent) 21

HARVEST INFORMATION

Gross volume cruised (M fbm/acre) 51
Net volume cruised (M fbm/acre) 39
Average stems/acre cut 52
Average d.b.h. of stems cut (inches) 27
Stand age (years) 300
Cutting prescription Shelterwood
Yarding method Tractor
Slash treatment Machine piled & burned
Period since cut or treatment (months) 12

PRECOMMERCIAL THINNING INFORMATION

Stems cut/acre
Stems remaining/acre
Basal area/acre before
Basal area/acre after
Average d.b.h. before (inches)
Average d.b.h. after (inches)
Thinning method
Slash treatment

FUEL RATING

U.S. Forest Service Region 6 fuel type identification LL

REMARKS

Figure 11—Fuel loading comparison photograph from Maxwell and Ward (1976a, p. 32), originally produced in color. Conditions in the field are compared to a series of photographs to estimate fuel loading. This is one of a nine-report series showing residue after commercial thinning in Douglas-fir—western hemlock, size class 9 to 20 in dbh. The data table lists fuel loading weight and volume by size class, residue depth, percentage of ground cover by residue, average duff and litter depth, sound residue larger than 3.1 in by species, rotted residue larger than 3.1 in, harvest and precommercial thinning data, and the USDAForest Service fuel rating.

7. Shoot between f-8 and f-16 for a long depth of field.

8. Always use a tripod because low light under tree canopies may require exposures below 1/30th of a second.

9. Use the standard national field system marker placed 30 ft (9 m) from the camera; it is a pole 6 ft (1.8 m) tall with a 1-ft^2 (3 by 3 dm) marker at the top and alternate foot distances painted black and white (fig. 11).

10. Take a minimum of three exposures so that all fuel loadings from different locations can be presented in the same color mode.

11. To sample fuel loading, establish five base lines radiating from the camera and equidistant apart, with five sample points on each line in view of the camera. Sample the down material from each of the 25 sample points.

12. Sample standing live and dead material from six sample points distributed over the 25 fuel loading points.

13. Compute down fuels, standing fuel (live and dead trees, shrubs, grasses, and forbs) by size class, anticipated rate of spread, and flame length under selected moisture content and wind speed.

Maxwell and Ward's format shows a color picture of fuel loading with all data contained in that picture as computed by their instructions (fig. 11). The product is a pocket-sized booklet, about 5 by 9 in (12 by 22 cm), listing the forest type, such as west-side Douglas-fir or east-side pine associated, size class of the forest type, and within each forest type and size class, three to five fuel loadings.

To use their system, a person goes to the field, identifies the forest type and size class, then turns to appropriate photographs in the booklet and compares the fuel loading at the site with pictures in the booklet. The fuel loading is then estimated by comparing the existing conditions to those described for the photograph most nearly approximating field conditions. Jensen and others (1999) applied the concept for estimating fuel loading to a fire hazard to do a watershed analysis for the parks department of British Columbia.

Herbage Utilization

Another comparison photo monitoring system deals with utilization of grasses and forbs by livestock. Schmutz (1971) and Schmutz and others (1963) pioneered a series of photographs for grasses in the Southwest. Kinney and Clary (1994) developed a series depicting various kinds of utilization on riparian graminoids (fig. 12). On a single page, the latter depict six degrees of utilization: 0, 10, 30, 50, 70, and 90 percent. To use their guide, the species in question must be identified, its stubble height determined, and the height compared to photographs in the guide to estimate the percentage of utilization.

Kinney and Clary's procedure for developing a guide is rather simple and straightforward, as follows:

1. A height-weight curve was developed for each species to be photographed. A height-weight curve is the relation of the percentage of total height of the plant with seed heads to percentage of utilization. For example, a plant 5 dm tall might have 10 percent of its weight in the top 20 percent of its height (fig. 12). Thus, a plant 80 percent as tall as an ungrazed plant would represent 10-percent utilization.

2. A plant with seed heads of the desired species is selected, vegetation removed from around that individual, and a black backdrop placed behind the plant (fig. 12).

3. The plant is photographed in its full stature. Then it is clipped at heights that represent 10, 30, 50, 70, and 90 percent utilization. At each clipping, the plant is rephotographed.

4. These six photographs are then assembled onto a single page and accompanied with a height-weight graph showing the relation between plant height and percentage of utilization (fig. 12).

Guenther (1998), working in annual grass rangeland in California, developed a photo-monitoring guide dealing with residual dry matter. He used a Robel pole[2] (Robel and others 1970) photographed from 10 and 20 ft. Eight photographs depict increments of annual grass biomass from over 1,000 lb/acre to less than 125 lb/acre. The Robel pole is supplemented with a 0.96-ft^2 hoop placed at its base with four golf balls to help appraise grass density.

His procedure is to place the pole and take a photograph. Then the vegetation is clipped within the 0.96-ft^2 hoop to document the herbage production.

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[2] The Robel pole is discussed in appendix A.

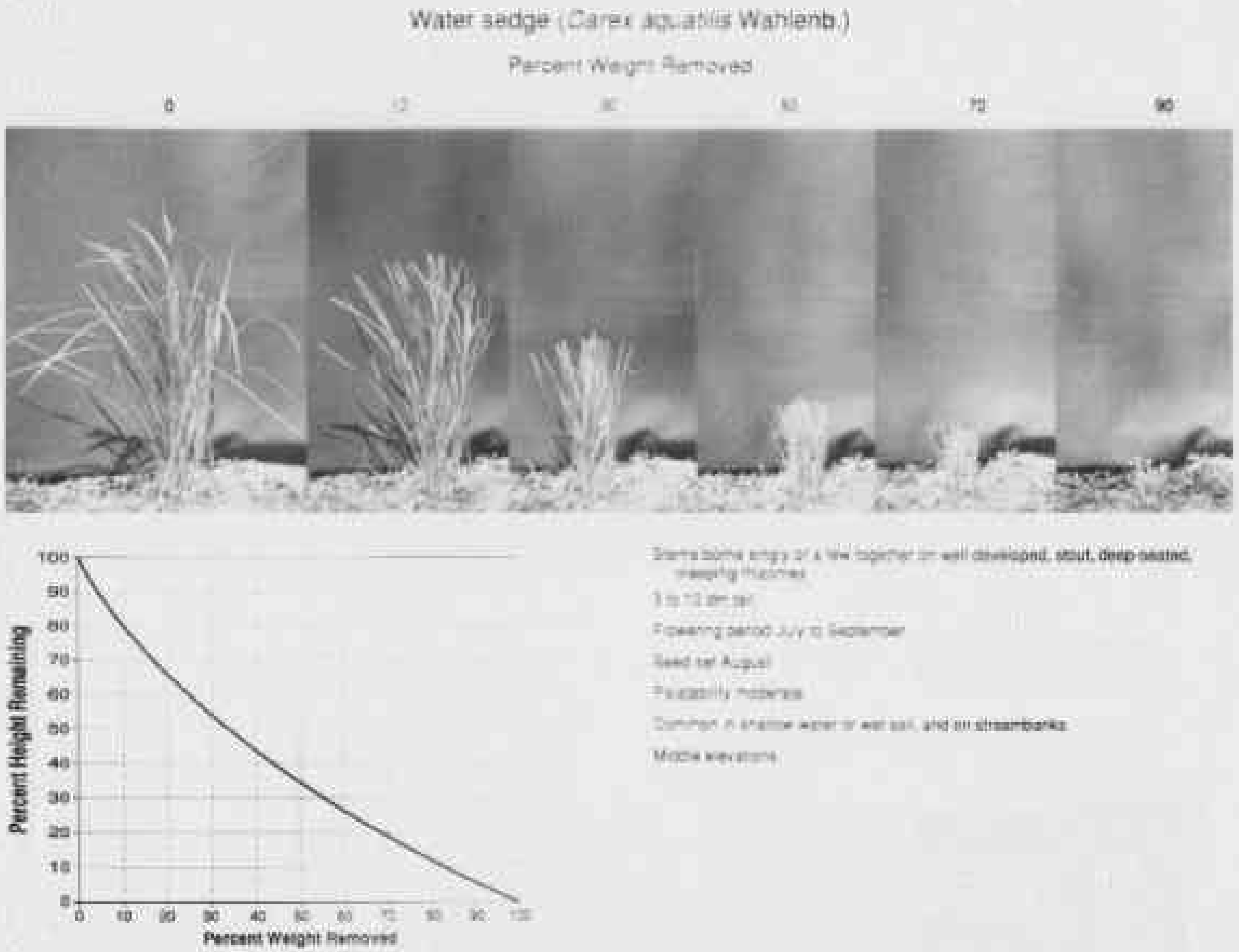

Figure 12—Sedge utilization comparison from Kinney and Cleary (1994, p. 7) for water sedge. Stubble height is shown for six levels of utilization. The photograph is compared to sedge utilization found in the field to appraise the amount of use.

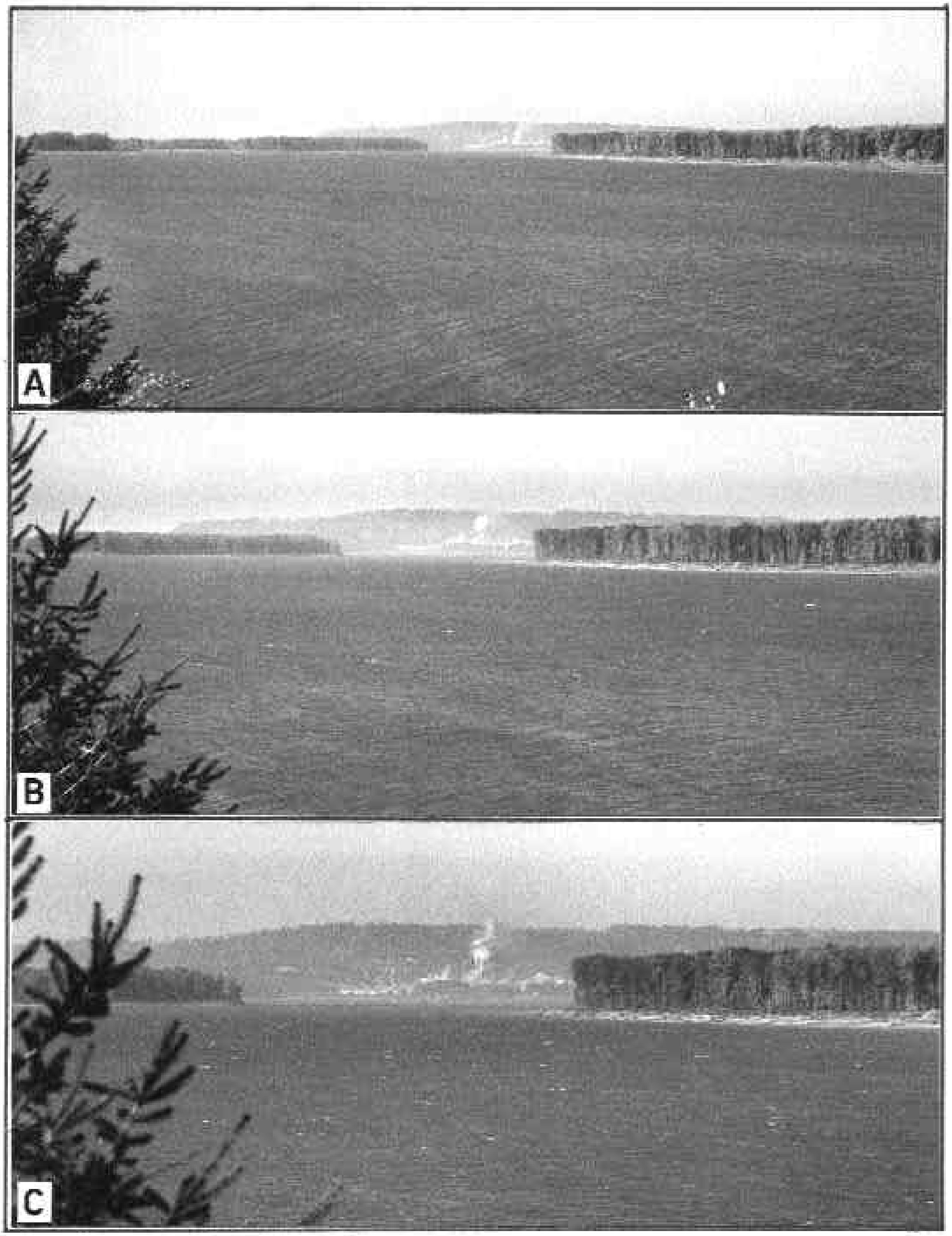

Figure 13—Comparison photographs of smoke from a pulpwood mill along the Columbia River taken from a turnout on Interstate 84: (**A**) 35-mm focal length simulating 20 mi distant, (**B**) 70-mm simulating 10 mi distant, and (**C**) 140-mm simulating 5 mi distant. Similar sets of photographs were used by Magill (1990), Benson (1983), and Ribe (1999) to appraise viewer's reactions to landscape scenes.

Monitoring Public Concern

Monitoring of public concern for landscape quality also uses a comparison photographic technique as discussed by Benson (1983), Magill (1990), and Ribe (1999). Their objectives were to test public awareness and concern for various landscape items, particularly effects of logging. Magill (1990) used a set of three to five photographs of the same landscape viewed at different distances (fig. 13). These were shown to people and their reaction or concern about the view documented. He tried to develop a threshold definition of various landscape features. The technique was as follows:

1. A landscape feature was selected as viewed from a suitable vantage point, such as a road or viewpoint.

2. This landscape was photographed with a 35-mm camera using color film and a zoom lens. Pictures were taken at 50, 70, 100, and 150 mm (fig. 13). This was done to simulate different distances from the landscape object, for example, 4.8, 3.2, 2.1, and 1.6 mi for each focal length, respectively.

3. No effort was made to select good visibility or particular weather conditions (fig. 13).

Benson (1983) discusses scenic beauty estimation and visual quality objective analysis through methods similar to those of Magill (1990). He also uses comparison photos to rate elk habitat characteristics and recreational impacts as part of forest planning. Ribe (1999) used photographs to test public response to 15-percent retention of green trees in clearcuts as a research method for appraising acceptance of alternatives in the Northwest Forest Plan.

Repeat Photography

As the name implies, repeat photography means retaking photographs from the same spot and of the same subject several times. To be effective, most repeat photography requires precise replacement of the camera and composition of the subject, be it a sample plot, view of a particular subject such as a streambank, or rephotographing a distant landscape.

Repeat photography is used for many purposes and, thus, can take on many different forms. It may be landscape rephotography covering 50 to more than 100 years of change (Skovlin and Thomas 1995); documenting animal activity at a specific site, such as ospreys (*Pandion baliaetus*) rearing young (Kristen and others 1996) or livestock distribution in a meadow (Kinney and Clary 1998); assessing air quality (Fox and others 1987); sampling change in vegetation using both general and closeup views (Hall 1976, Nader and others 1995); and appraising effects of management such as livestock utilization or logging (Gary and Currie 1977, Kay 1999, Kay and others 1999, Smith and Arno 1999). Hart and Laycock (1996) and Rogers and others (1984) present bibliographies on repeat photography. In this paper, a riparian setting, Pole Camp in eastern Oregon, will be used to illustrate various aspects of repeat photography.

Three things must be done for repeat photography to be successful: (1) map the site and the system layout, (2) document the system, and (3) permanently mark camera locations and photo points.

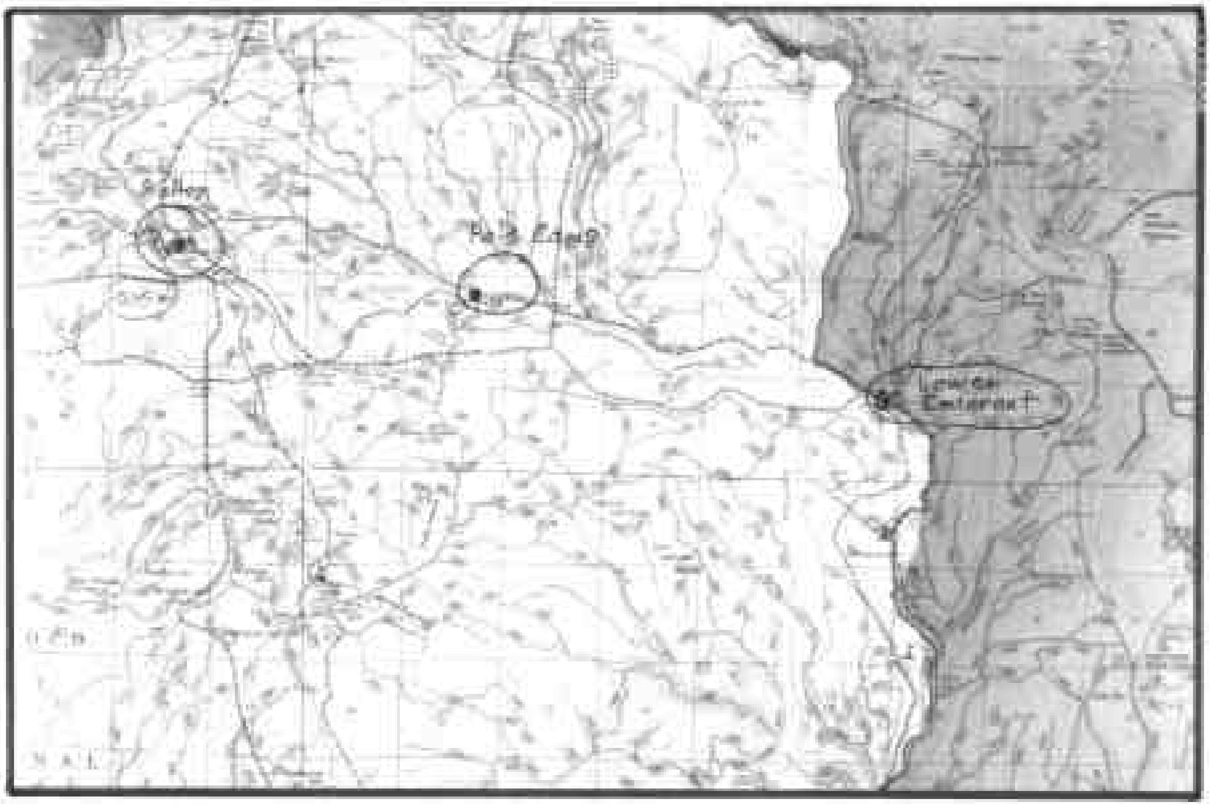

Figure 14—USDAForest Service Ranger District map showing locations of the Button Meadow, Pole Camp, and Lower Emigrant riparian study sites in northeastern Oregon. Road numbers, mileage from road junctions, and directions to the witness sites (a tree or fencepost with an orange tag identifying the monitoring area) are given in the study writeup.

Maps of Location and Monitoring Layout

Maps are essential for relocating and rephotographing topics as discussed by Bauer and Burton (1993), Borman (1995), Governor's Watershed Enhancement Board (1993), Hall (1976), Nader and others (1995), National Park Service (1992), USDA Forest Service (1982), and USDI Bureau of Land Management (1996). Two maps are important:

1. Map of the monitoring site location so that those other than the installers can find it. Figure 14, a USDA Forest Service ranger district map, identifies the road on which the site is located. Establish a witness marker along the road by placing an orange tag on a tree or fencepost. Inscribe on the tag the identity of the monitoring site.

2. A map of the photo monitoring system layout so that others can duplicate the original photography (fig. 15). From the witness marker identified on the general map, record directions and measured distances to each camera location and photo point (fig. 15). Measure on the ground; do not attempt conversion to horizontal distance.

The emphasis on *others* (other people) refers to a problem discovered by many (Borman 1995; Gruel 1980, 1983; Johnson 1984; Magill 1989; Nader and others 1995; Parker and Harris 1959; Phillips and Shantz 1963; Progulske and Sowel 1974; Puchbauer and Carrol 1993; Reppert and Francis 1973; Strickler and Hall 1980; USDA Forest Service 1982; USDI Bureau of Land Management 1996).

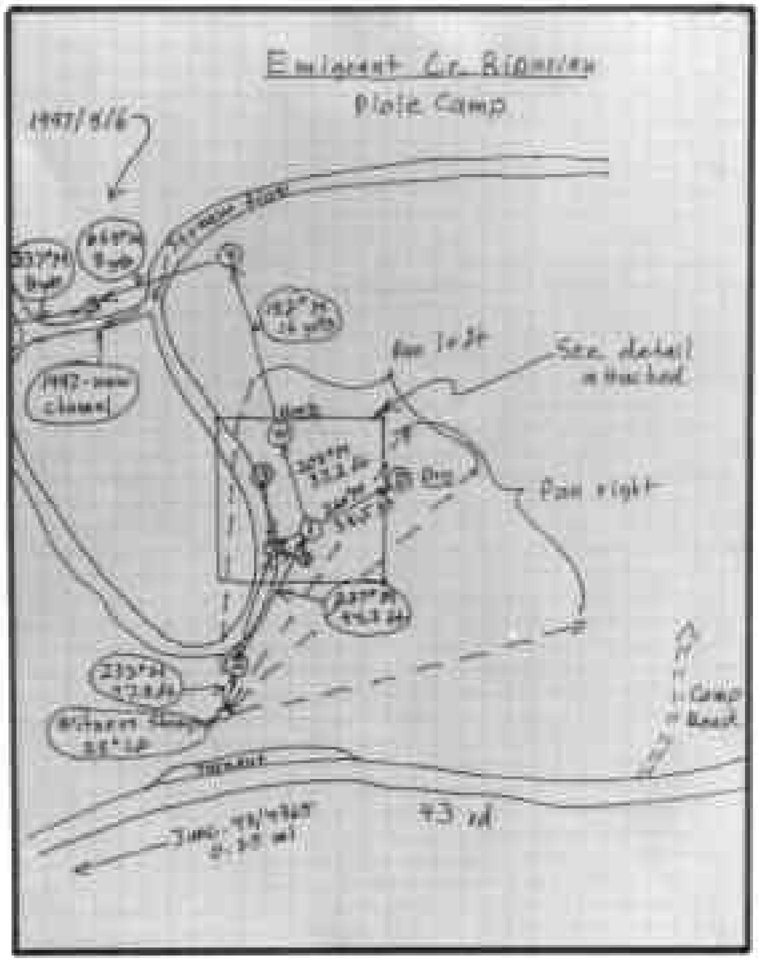

Figure 15—Study layout of the Pole Camp riparian site. Notice that all compass headings are shown as magnetic (M) to reduce confusion with the 21-degree deviation from true north in the Pacific Northwest. When distance is shown with a decimal point, it indicates a measured rather than a paced distance. Notice the two photo points from camera location 1—dry and wet. The boxed map is shown later in figure 27, which details location of the instream photo point.

Compass deviation is one item of particular importance in laying out the site map and relocating sites for repeat photography. In the Pacific Northwest, deviation is about 21 degrees east. The problem is, What does this mean? Does one add or subtract 21 degrees from the magnetic compass heading? Most people traveling by water, air, or land use magnetic headings for their direction; land survey, on the other hand, uses true direction. When providing direction on any map, specify true or magnetic. Notice in figure 15 that direction is listed first and distance second to provide easily followed instructions: You have to know what direction you are going before you can start moving.

Documentation of the Photo System

Each repeat-photography monitoring system must be documented in writing (in other words, a protocol for operation is created). It should include the following items:

1. The original size and focal length of camera such as a 35-mm camera with 50-mm lens or a 2- by 2-in (50- by 50-mm) square format camera with 70-mm lens.

2. The film to be used: speed and type of film such as Kodachrome 64 versus Elite Chrome (Ektachrome) 200, color or black and white negative film. Using both may require two different cameras or one camera with two backs. Digital cameras do not use film.

3. Definition of methods for repeatability of photographs. Specify how to aim the camera to repeat the field of view; for example, “site on the 1M of a meter board.” The field of view must be held constant so changes in the subject matter, such as stream stability, vegetation change, or management activities, can be clearly documented.

4. Time of day, season of year, air quality for landscape rephotography, and lighting conditions, such as overcast sky to reduce shadows or backlighting to highlight vegetation (app. E).

5. A list of all equipment required.

6. Instructions for using mechanical or electronic aids for rephotography.

Permanent Marking

Witness sites, camera locations, and photo points or transects must be permanently marked for efficient photo monitoring. Steel stakes or fenceposts can be used. Each has advantages and disadvantages:

1. Steel stakes are difficult to find if vegetation overtops them.

2. Steel stakes protruding above the ground may be stepped on by animals or people, or run over by vehicles causing foot or tire damage. Stakes can be driven flush with the ground but then will require a metal detector to be relocated (White’s Electronics, Inc. 1996).

3. Fenceposts are clearly visible and thus subject to theft.

4. Cheap fenceposts made of stamped steel are useful and durable (including against theft) when purchased in 5-ft (1.5-m) lengths and pounded 2 ft (0.6 m) into the ground. The 3 ft (0.8 m) above the ground is easily seen, and the flimsy construction deters theft because the stamped steel posts are as difficult to remove as strong T-bar posts.

5. Any fencepost aboveground is subject to destruction by equipment when an area is disturbed. When disturbance monitoring is contemplated, stakes driven flush with the ground are appropriate. Most inexpensive metal detectors will locate a 3/8-in (1-cm) diameter steel stake driven flush with the ground within a radius of 12 in (3 dm) (White’s Electronics, Inc. 1996).

With this background, three kinds of repeat photography will be discussed: (1) landscape photography, (2) remote photo monitoring, and (3) site-specific monitoring.

Landscape Photography

Repeat landscape photography seems to have been devised by Professor S. Finsterwalder, who photographed and mapped glacial changes in the eastern Alps starting in 1888 (Hattersley-Smith 1966). In the United States, after the Civil War, photographers were invited to participate in exploring the Western United States. Some of these historical landscape pictures have been rephotographed 100 or more years later; for example, Progulske and Sowel (1974) rephotographed the area of Colonel Custer’s 1874 exploration of the Black Hills to show changes in 100 years,

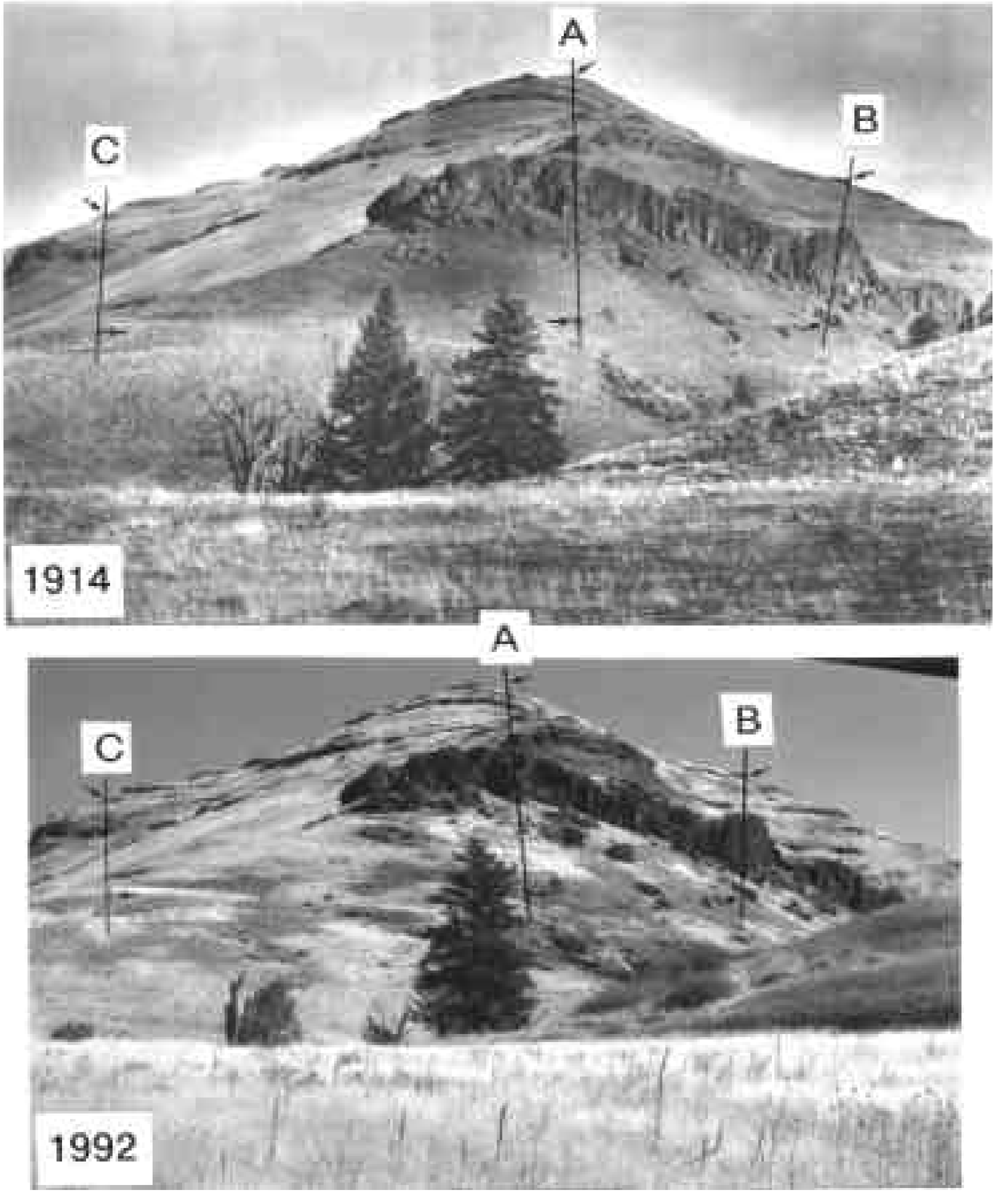

Figure 16—Relocation of historical photographs showing a view (1992) by Skovlin and Thomas (1995, p. 22-23) of Branson Creek, Wallowa County, Oregon, originally photographed in 1914 (top picture). The letter “A” identifies centerline orientation. Once the photographer was centered as on the original photograph, objects on the edges of the picture, such as “B” and “C”, were chosen to refine location of the original camera. The photographer has to move forward or back until the angles of “B” and “C” are similar to the original photograph. Slight differences in orientation lines between 1914 and 1992 suggest the camera in 1992 was a few yards left of the original location. The usefulness of black-and-white photographs is illustrated here by triangulation lines placed directly on the picture.

and Skovlin and Thomas (1995) illustrated changes over 70 to 90 years in eastern Oregon (fig. 16). Landscape photography of small areas (10 to 100 ha) is discussed later and will be shown in figures 26 and 38. Appendix E illustrates some photographic techniques.

Johnson (1984), whose purpose was to evaluate change in sagebrush (*Artemisia* spp.) over 100 years or more, retook pictures taken by William H. Jackson during the 1860s to 1870s as part of the Hayden Expedition in Wyoming. Johnson concluded that sagebrush is highly site-specific, some changes have occurred but they differ among sites, and there has been no major shift in sagebrush distribution, although densities have changed. He felt the landscape today is a fair representation of the 1870s.

Phillips and Shantz (1963), who compared photographs taken by Dr. Shantz 50 to 60 years previously, report on another historical photo series of vegetation changes in the northern Great Plains. Dr. Shantz also photographed in eastern Colorado in 1904. Many of the locations for his pictures were rephotographed in 1986 after 82 years (McGinnies and others 1991).

Branson (1985), Gary and Currie (1977), Gruell (1980, 1983), Johnson (1987), Puchbauer and Carroll (1993), Rogers (1982), and Veblen and Lorenz (1991) discuss additional landscape rephotography.

Purpose

Purposes other than historical documentation have prompted long-term retaking of landscape photographs. Long-term, in this context, refers to retaking photographs taken by another person, usually more than 20 years previously. Some have evaluated effects of livestock grazing and change in western rangelands (Branson 1985; Chaney and others 1991; Johnson 1984, 1987; McGinnies and others 1991; Phillips and Shantz 1963, Skovlin and Thomas 1995).

Changes in rangeland vegetation from 1902 to 1988 were documented by Medina (1996) in his history of the Santa Rita Experimental Range in southern Arizona. Fifty years of secondary succession under sheep grazing in green fescue (*Festuca viridula* Vasey) grasslands were rephotographed in the Wallowa Mountains (Reid and others 1991), and effects of revegetation in green fescue grasslands depleted by sheep grazing in the Wallowa Mountains were shown by Strickler and Hall (1980). They documented Dr. Arthur Samson’s pioneer range work in rehabilitation, which helped to formulate the first textbook on range management.

Other uses for long-term landscape photography have been to appraise the historical effects of fire on wildlife habitat in the Bridger-Teton National Forest, Wyoming (Gruell 1980, 1983); forest health concerns in the Boise National Forest, Idaho (Puchbauer and Carroll 1993), which used photography from as early as 1870; changes in wildlife habitat in north Yellowstone (Houston 1982); causes for mule deer (*Odocoileus hemionus* Zimm) population eruptions in the intermountain West (Gruell 1986); long-term successional changes in Blue Mountain ecosystems (Skovlin and Thomas 1995) as it affects forest health, range condition, and wildlife habitat; and to illustrate change in research natural areas (Herring and Greene 1997).

Considerations in long-term repeat landscape photography include three important factors:

1. Relocating photographs done 50 to 100 years previously.

2. Duplicating photographs taken by cameras that are no longer manufactured or available.

3. Dealing with photographic conditions such as season, weather, light, and air quality.

Relocation

Most authors say that finding the camera location was their most difficult problem. Without precise camera relocation, duplicating the scene photographed by original cameras and duplicating weather conditions were unimportant (Gruell 1980, 1983; Hart and Laycock 1996; Johnson 1984; Phillips and Shantz 1963; Progulske and Sowel 1974; Puchbauer and Carroll 1993; Skovlin and Thomas 1995).

Johnson (1984) notes that each: "...photosite was relocated over a 12 year period through time-consuming search in the field aided by knowledge of the countryside and comparison of expedition maps and reports with modern references." He was referring to the Hayden Expedition. He also says that: "...the exact photo point was relocated by detailed inspection of photo features" (see fig. 16 and app. E).

A summary follows of comments by authors who have had to relocate landscape photography camera locations after 50 or more intervening years:

1. Study the travel log books, trail routes, and other descriptions of travel, not overlooking the slow rate of movement by horses and wagons, to locate a geographical area in which the old photograph might have been taken (Progulske and Sowel 1974).

2. Show the old photographs and descriptions to local residents for their ideas about location. In many cases, original photographers did not know local names of buttes; however, shape of the buttes and landforms are clues current residents can use to suggest camera locations (Progulske and Sowel 1974). If no travel logs are available, study of historic travel routes and railroads can provide clues as to where the photographers traveled and where they might have photographed (Phillips and Shantz 1963).

3. Identify unique landscape features such as hills, drainage ways, and their interrelationships. Phillips (in Phillips and Shantz 1963) comments that Dr. Shantz always seemed to find a prominent landmark to include in his photos, even on the Great Plains, which greatly aided in relocation. Many of Shantz's photos were taken from the first railroads into an area where he would take photographs from a siding, town, or coaling station that could be readily relocated.

4. Orient the camera location by lining up near and distant objects in a triangulation system (fig. 16). For example, Progulske and Sowel (1974) point out that mountain profiles, abundance of rocks, thickness of soil, escarpments, and stream configuration were used. A search then can be made for rocks or dead trees, which lead to the target camera location. As Puchbauer and Carroll (1993) note, objects in the original photo often are overlooked during first examination; they suggest using a hand lens to locate subtle objects, such as old monarch trees (or their remains), on black-and-white photos.[3]

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[3] In my experience, black-and-white prints are superior to color slides in relocation because prints can be easily examined by hand lens, and triangulation lines, shown in fig. 16, may be placed directly on the photograph.

5. Problems with relocation:

   A. Historic travel routes, roads, or railroads may have been obliterated by modern activities, thereby making identification of camera locations difficult.

   B. Intervention by other objects is one of the most common problems encountered. These objects can be trees, buildings, or other obstructions to the view from the original camera location.

   C. No clear, identifiable landscape feature by which to locate even the general area of a photograph.

Considerations

Camera—The original cameras and films cannot be duplicated by equipment available today in nearly all cases of photography before 1930. Duplication of the original scene, therefore, requires matching negative size with focal length to replicate the original photographs as nearly as possible. For example a 4- by 5-in press camera with 128-mm lens is roughly similar to a 35-mm camera with 50-mm lens. Most authors of historic landscape rephotography comment on this situation and recommend solutions. Rogers and others (1983) deal specifically with this problem and demonstrate that camera format is not critical; camera location and distance to featured objects are the critical factors. They discuss adjustment of print size to original prints and some problems with loss of items on the periphery of photographs; for example, some detail is lost when using a 35-mm camera format (a 2-to-3 ratio) to duplicate a 4- by 5-in format (a 2-to-2.5 ratio).

Film—Film, of course, also is different; one would hardly expect to use a wet plate glass negative in today's world. And even if an early camera is still in working condition, compatible films no longer are made.

Season and weather—The season and weather (lighting conditions, time of day, and air quality) are a third important consideration in long-term landscape rephotography. Many authors note that not all the original photographs could be used because of poor quality due to air conditions, deterioration, processing, or inadequate photographic technique. When a photo site was found, Johnson (1984) points out that “subsequently, one or more visits were made to the site to duplicate as closely as possible the light, time of day, and date of originals.”

These problems and conditions lead to rejection of many photographed landscapes as subjects for rephotography (Gruell 1980, 1983; Johnson 1984; Phillips and Shantz 1963; Progulske and Sowel 1974; Puchbauer and Carroll 1993; Skovlin and Thomas 1995).

Panoramic cameras—Panoramic cameras also have been used in landscape photography (Arnst 1985, Hanemann 1989). Hanemann describes the Osborn photo-recording transit, which is a unique camera once built in Portland, Oregon. The lens rotates through an arc of 120 degrees and focuses through a narrow slit onto a negative held in a semicircular position. This camera was used to rephotograph some of the scenes taken by Arnst (1985) in the Cascade Range of Oregon.

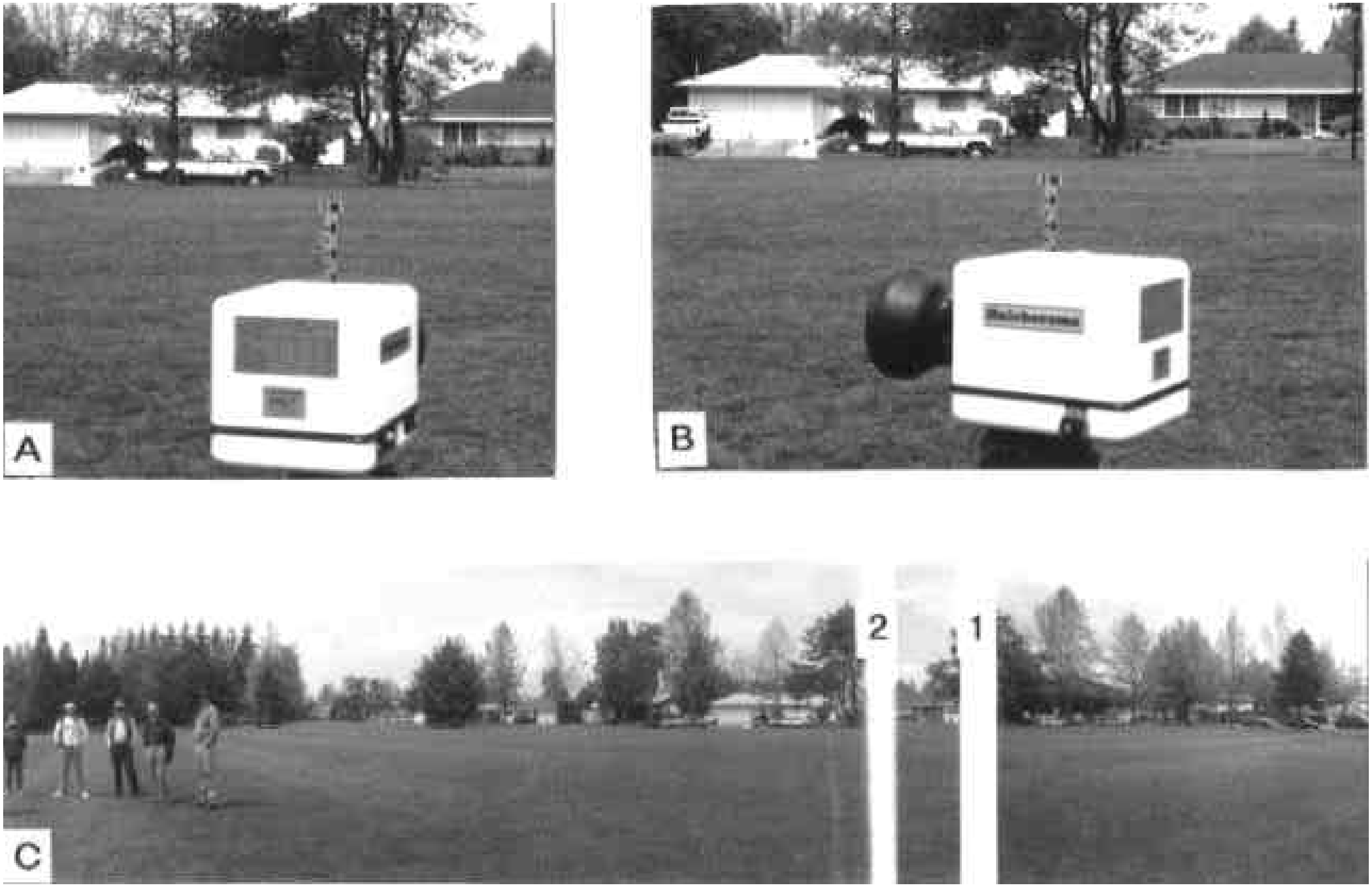

Figure 17—Panoramic photography using the rotating Hulcherama® Model 120 camera. The camera has no shutter. Instead, light is admitted through a vertical slit shown by the solid white bar (1) on the right in C. Amount of light is governed by a lens f-stop and by speed of camera rotation. (**A**) The camera begins its 360-degree rotation with the white line in C, then (**B**) continues past 360 degrees a few degrees to overlap the image. (**C**) Once started, the camera must continue to rotate at a specified speed. Should it be stopped, a fuzzy white strip will occur as shown by the white line (2) left of line (1) in C. A meter board has been used as a reference for the start of the rotation.

Today, panoramic cameras are built such that the camera itself rotates on a 360-degree arc while the film moves at the same rate of speed. The image passes through the lens and is constrained by a thin slit. The film rotates past the thin slit. An example is the Hulcherama® model 120 camera (Hulcher, n.d.; fig. 17).

Panoramic cameras have a singularly important requirement: they must be very accurately leveled so that rotation of the camera will photograph a constant horizon and this photograph can be retaken at a later date. Modern cameras can use both color and black-and-white film, commonly in 120 size, 12-exposure rolls. Exposure is determined by f-stop, slit width, and speed of camera rotation (Hulcher, n.d.).

Figure 18 illustrates problems using the meter board to orient general photographs instead of keeping a panoramic camera level. Camera location 1 at Pole Camp was chosen as the center of a 360-degree panoramic view of the area. Camera format was a 50-mm lens on a 35-mm camera body. The meter board was placed 10 m from the camera. For each successive photo, it was moved 8 m in a 10-m radius around the camera. On a flat flood plain, a meter board could be used to focus and orient the camera. However, camera orientation on the meter board in the stream of figure 18B lowered the view 1.3 m at the board, thereby causing displacement of the photos. Arrows point to a rock at top and a shrub in the center for orientation. An ideal panoramic view would have the camera level in all views to show changes in topography; thus the meter board would be lower in figure 18B and unusable for photo orientation.

Jensen and others (1999) used a camera rotated on a tripod similar to figure 17. In a test of observer variability, they found that 72 percent of the repeat photographs did not attain 20 percent overlap with originals. The causes were swapping cameras during rotation (to change film), thus causing misalignment of the view; inconsistent placement of the photo identification card, which should be placed at the same distance and location in the photo; and significant inconsistencies in exposure, which rendered some photos unacceptable for comparison because sun angle changed during 360 degrees of view.

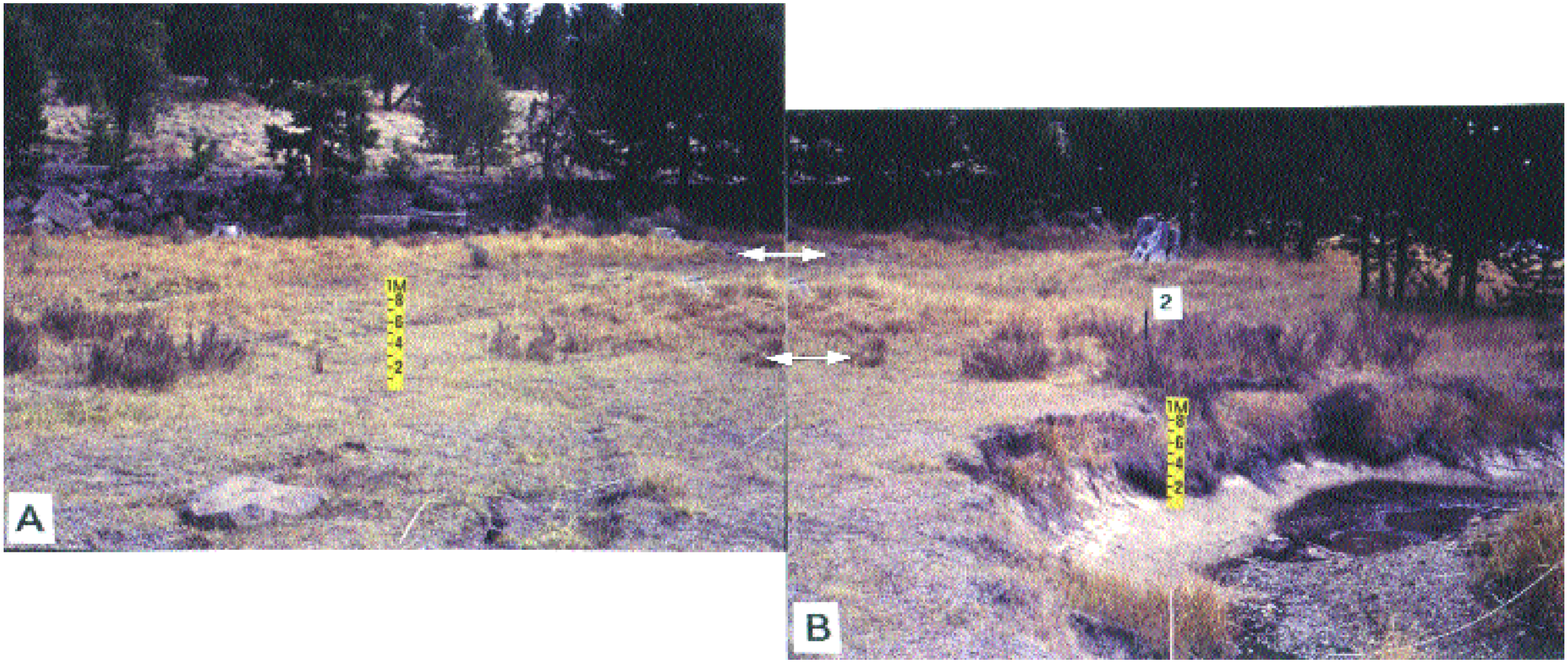

Figure 18—Two photographs of a 360-degree panoramic view of Pole Camp from camera location 1. The camera was focused on the "1M" of the meter board, similar to topic photographs, as a means for exact reorientation of subsequent pictures. As a result, view **B** is significantly displaced because the meter board is about 1.3 m lower than in view **A**. Overlap items are shown at arrows that cross from A to B. The number (2) identifies camera location 2. Above the (2) is the lodgepole pine witness stump. Figure 15 is a map of this site.

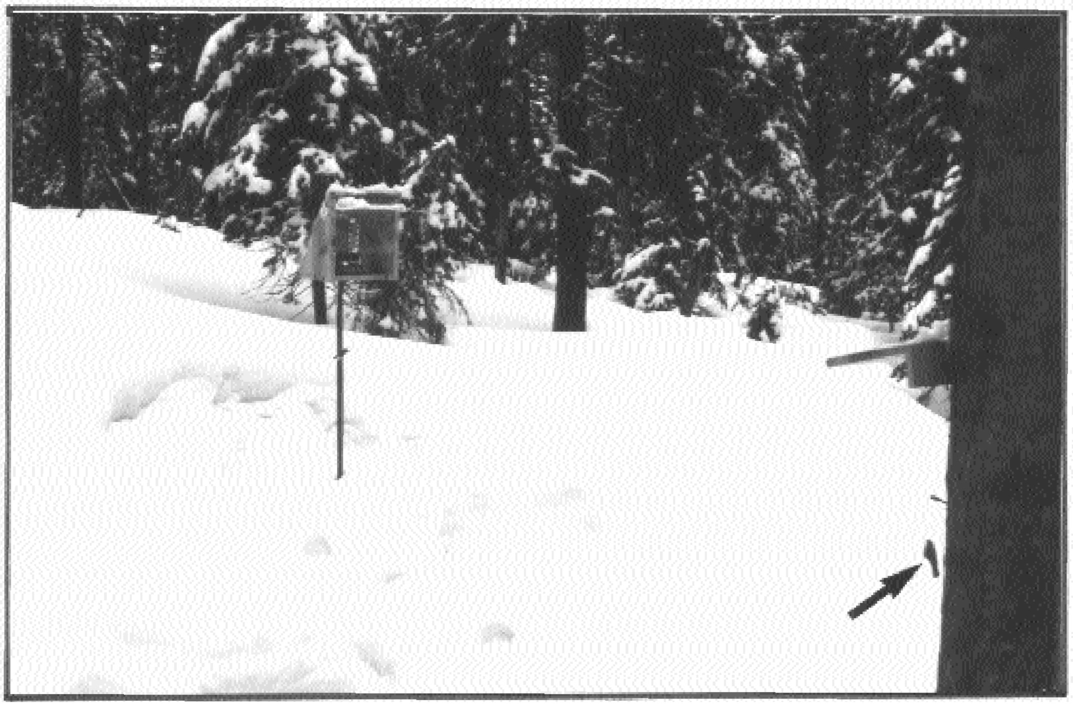

Figure 19—Mechanically triggered camera system used by Bull and others (1992) to monitor presence of marten (*Martes americana* Turton). Bait (arrow, lower right) was suspended on the tree to the right under a cover as one modification for winter operation. Camera was a 110 size with flashcube.

Remote Photo Monitoring

Remote photo monitoring uses unattended camera or video systems. Repeat photos are taken of a specific view, which may be a landscape (Fox and others 1987) or a specific activity such as a nest of ospreys (*Pandion haliaetus* Linn.) (Kristen and others 1996). Zielinski and Kucera (1995) deal with photo detection of animal presence in detail (fig. 19). Because remote photo monitoring is a topic unto itself, only a few examples will be presented.

Time-lapse systems have been described by Bryant,[4] [5] Bull and Meslow (1988), Fox and others (1987), Kinney and Clary (1998), Kristen and others (1996), and Temple (1972). They all used timing systems to trigger the camera at specified intervals ranging from fractions of a second to several hours. Movie cameras, 35-mm cameras, and video cameras were used. Bull and Meslow (1988) monitored pileated woodpecker (*Dryocopus pileatus* Linn.) chick feeding with a super 8-mm camera set to expose a frame every 8 to 12 seconds (Temple 1972).

Bryant (see footnote 4) used a time-lapse super 8-mm movie camera (Temple 1972) to monitor winter ice floods on Meadow Creek in eastern Oregon. The location was a research study site testing various livestock grazing effects on riparian ecosystems. The 45-minute flood lasted about 4 minutes at standard speed in a movie projector. Super 8-mm movie cameras have been replaced by camcorders.

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[4] Personal communication. 1990. Larry D. Bryant,wildlife biologist, on Meadow Creek flood. USDAForest Service, Pacific Northwest Research Station, 1401 Gekeler Lane, La Grande, OR 97850-3368.

[5] Personal communication. 1990. Larry D. Bryant, wildlife biologist, on remote video camera. USDAForest Service, Pacific Northwest Research Station,1401 Gekeler Lane, La Grande, OR 97850-3368.

In another study (see footnote 5), Bryant used time-lapse remote video to document livestock use of riparian areas. He found that video “film” is less expensive than camera film, instant viewing and transmission were advantages, and cost of camcorders and deterioration of video film were disadvantages.

Kinney and Clary (1998) monitored livestock distribution patterns over several grazing seasons in meadows through repeat 35-mm camera photography. The camera took a picture every 20 minutes during daylight hours during a 15- to 20-day grazing period on three meadows over 2 to 4 years. Dry graminoid locations were preferred even though forage production was not the highest. They emphasized several things: The sun must be behind the camera for all exposures. The camera must be set to expose for the desired kind of vegetation; for example, on grass and not on the surrounding evergreen forest. And, animals are curious and often affect the camera location by pushing on it, which modifies the camera aim or destroys the installation.

Fox and others (1987) discussed monitoring of air quality with a 35-mm camera. Their equipment was a 35-mm camera body with a 135-mm lens, automatic winder, automatic exposure designed to be on only during the exposure (not continuously), an ultraviolet filter, a data back capable of imprinting the date and time, and a battery-powered programmable timer capable of triggering the camera at least three times per day in a housing for the complete system capable of standing alone and operating in temperatures from –34 to +54 °C while being unattended for at least 10 days. Their criteria state that the site must contain at least one horizon-visibility target with as many of these characteristics as possible: (1) large, (2) identifiable on a topographic map, (3) dark vegetation (such as conifers), (4) 32 to 80 km in distance, (5) two or three targets at various distances, (6) camera and target at about the same elevation, (7) target centered in the camera viewfinder, (8) site path not affected by local sources of air pollution, (9) target as free of snow in winter as possible for contrast, (10) exceptionally bright or dark foreground objects avoided, and (11) camera oriented to avoid sun on the lens for pictures taken any time during the day. They provide a diagram and a system for evaluating film by using microdensitometric analysis of color slides.

Kristen and others (1996) monitored osprey nest activity over a season by using a video camera set to expose one frame every six-tenths to one second. The images were then transmitted by a directional antenna to a receiving station up to 8 km distant and viewed on a monitor. The lapse in time could be adjusted at the monitor receiving station. A deep cycle battery supplemented by a solar panel supplied the power to the system.

Figure 20—Pole Camp "wet" sample location showing three dates of the same year. June 15 is before scheduled grazing, August 1 is at change in rotation pastures, and October 1 is after grazing. This pasture was rested from June 15 to August 1. October 1 illustrates the degree of livestock use of Kentucky bluegrass at the meter board, aquatic sedge behind the board, and willows in the distance.

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