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Feasibility of using remote sensors for measuring recreation use

Joe H. Taft

To the Graduate Council:

I am submitting herewith a thesis written by Joe H. Taft entitled "Feasibility of using remote sensors for measuring recreation use." I have examined the final electronic copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Forestry.

Kerry T. Schell, Major Professor

We have read this thesis and recommend its acceptance:

John C. Rennie, Barret

Accepted for the Council:
Carolyn R. Hodges

Vice Provost and Dean of the Graduate School

(Original signatures are on file with official student records.)

May 10, 1972

To the Graduate Council:

I am submitting herewith a thesis written by Joe H. Taft entitled "Feasibility of Using Remote Sensors for Measuring Recreation Use." I recommend that it be accepted for nine quarter hours of credit in partial fulfillment of the requirements for the degree of Master of Science, with a major in Forestry.

Gerry T. Schell
Major Professor

We have read this thesis
and recommend its acceptance:

John C. Rennie

J W Barrett

Accepted for the Council:

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Vice Chancellor for
Graduate Studies and Research

FEASIBILITY OF USING REMOTE SENSORS FOR MEASURING RECREATION USE

A Thesis

Presented to

the Graduate Council of

The University of Tennessee

In Partial Fulfillment

of the Requirements for the Degree

Master of Science

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by

Joe H. Taft

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The study could never have been completed without the understanding of his children and the understanding and help of his wife, who proofread the manuscript.

ABSTRACT

The objective of this study was to determine the technical and economic feasibility of using remote sensing systems for measuring or estimating outdoor recreation use. This involved determining the methods currently being used for estimating recreation use and their cost, determining the technical capabilities of remote sensing systems, and estimating the cost of using these systems to produce recreation use estimates.

To accomplish this, literature was reviewed in the fields of recreation use estimation and remote sensing. Personal visits were made with specialists in both areas to determine capabilities and costs.

The two remote sensing systems selected for cost comparisons were black-and-white aerial photography and infrared scanners. Several recreation locations were selected in the East Tennessee area which had a variety of site characteristics. A sampling plan was designed for each area using the two remote sensing systems and using conventional sampling techniques. Costs were computed for each area and for each system using the cost estimates judged to be the most reliable.

It was found that black-and-white aerial photography can be used in open areas and should be considered for use over large bodies of water where an estimate of only water surface use is desired. (In this study, however, black-and-white aerial photography was more expensive than conventional sampling for obtaining use estimates on a TVA reservoir.) Infrared (IR) scanners might produce useable data in open areas, however,

the cost is 100 times as great as the cost of conventional sampling and seven times as great as aerial photography. Conventional double-sampling methods will probably continue to provide the bulk of use estimates for several years into the future.

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CHAPTER I

INTRODUCTION

The Importance of Use Data

One of the most important inputs for planning and managing recreation resources is use data. The kinds, amounts, and locations of use in the area are needed in order to properly allocate land, labor, management, and capital to the various types and areas of recreational use. Information on the use of recreation areas is necessary to plan for the management of present facilities, for expansion of existing sites, or for the development of new sites. In addition to utilizing use data in management decisions, the use a recreation area receives determines, to a great extent, the amount of finances returned to that area through the Land and Water Conservation Fund.

Advances in Remote Sensors

Good use data is available for some areas, but for many other areas, data must still be obtained from estimates of low accuracy. Lack of accurate estimates or actual counts is not due to poor management but rather to the high cost of manpower and equipment required to get good use data on a continuing basis. Since the advent of satellites and the U-2 reconnaissance plane, there have been reports, in rather vague and general terms of the ability to identify very small objects from high altitude photographs. As a result of these reports extolling the attributes of airborne and spaceborne remote sensors, recreation resource managers began to wonder if some type of remote sensor could be used to accurately and economically measure recreational use. This study attempts to compare the accuracy and cost of conventional methods of determining use data with remote sensing.

Requirements of a Use Data System

In discussing and comparing various systems for measuring, recording, and analyzing data, the requirements of a technically ideal system will be helpful. An ideal system would provide detailed information on each individual recreationist in a given area. The system should be able to measure use and such attributes as sex, age class, and geographic origin. It should identify the type, time, and location of recreation activity. From this specific data, the recreation resource planners and managers can determine three essential statistics: man-hours of use, number of visits, and peak loads. James and Ripley have summarized the need for these statistics as follows:

> Man-hours of use are a good gauge of site wear and tear and service requirements. Visits reflect the number of impressions gained by people and hence provide an index to public approval or dissatisfaction, depending upon site condition. Peak load data are the basis of plans for capacity or overload crowds (James and Ripley, 1963, p. 1).

Ideally, the system would work 24 hours a day every day regardless of weather and would be just as effective in heavily forested areas and trails as in open areas such as lakes. Reasonable acquisition and operting cost would also be a characteristic of an ideal system. Such an ideal system could serve as a standard by which other systems may be evaluated.

CHAPTER II

OBJECTIVE AND SCOPE OF THE STUDY

Objective of the Study

The major objective of this study is to determine the technical and economic feasibility of using remote sensing systems for measuring or estimating recreation use. This objective is to be pursued by:

a. Determining current methods of measuring or estimating recreation use and costs of generating these estimates and their accuracy.

b. Reviewing literature to determine what, if any, work has been done in using remote sensing to gather recreation use data.

c. Evaluating the technical feasibility of employing remote sensors to gather use data.

d. Estimating the cost of acquiring and/or operating remote sensing systems which can now be used or which may be used in the future to gather use data.

e. Comparing the costs of producing use data by aerial remote sensing systems and coventional methods.

Scope of the Study

This study included a literature review, and written, telephone, and personal communication with people involved in obtaining recreation use data and specialists in remote sensing. No experimental recreation data from aerial remote sensing was available since at this time no systems have been judged as economically feasible.

For the purposes of this study, the term "remote sensors" will be defined as any system from which a person may obtain data concerning a given activity without being near enough to the activity to obtain the same data with one or more of the five human senses. This definition includes some of the methods currently being used for estimating use such as traffic counters, electronic eye counters, and water meters. The division of methods into categories of "Present Methods of Measuring and Estimating Use" and "Remote Sensors" was made rather arbitrarily on the basis of the increased complexity of the devices discussed under "Technical Feasibility of Using Remote Sensors."

CHAPTER III

PRESENT METHODS OF MEASURING AND ESTIMATING USE

Entrance Fees

In many recreation areas entrance fees are charged. The method of assessing fees varies, with some basing the charge on the vehicle in which the participants enter the area, while others charge per person. Where a fee is charged to each person, it is a simple matter to determine the total participation for any desired time period. In the case of a fee per car, an acceptable estimate can also be made by periodically determining the average number of participants per vehicle and multiplying this by the total number of vehicles represented by the gate receipts.

With either of the above methods, only total use of the entire area is obtained. Areas which provide for multiple activities require further estimates to determine use by activity. These estimates, too, can sometimes be made with acceptable accuracy and little additional effort. For example, in many areas, concessionaires may charge for additional activities in various parts of the recreation complex. These other charges may be for boat rental, locker rental for swimmers, or fishing bait sales. The use in these activities then is measurable.

Thus, accurately estimating use in recreation areas which charge fees does not represent a great problem. Recreation areas where no entrance fees are charged present the greatest problem in determining use. The non-fee areas may be subdivided into mass-use areas and dispersed-use areas. James and Taylor define these two types of use as follows:

> Use which occurs on developed sites, such as campgrounds and picnic grounds, is referred to as mass use because of its concentrated nature. Use which occurs in the general forest environment with little or no facility development (other than roads and trails) is designated as dispersed. Dispersed use is thinly scattered over areas which may be several hundreds or thousands of square miles in extent, is highly mobile, and is constantly in flux. Examples include fishing, hiking, climbing, ski touring, and driving for pleasure (James and Taylor, 1967, p. 16).

While many of the techniques to be discussed later may be used on either of these types of areas, the ranger estimate and the periodic attendant count are suitable only in mass-use areas.

Ranger Estimate and Periodic Attendant Counts

Both of these methods of use estimation can only be practiced in recreation areas in which there is enough use to warrant having a ranger or some other attendant (life guard, refuse collector, etc.) to at least pass through on a regular and frequent basis.

The ranger estimate is simply a guess of the number of people using a given recreation area or activity for a particular day. Its advantages are that it is easy, uncomplicated by statistics, and inexpensive. However, it is also unreliable and can at best provide only a relative measure of use for one time period with that of another (Douglass, 1969, p. 308-309).

Periodic counts of users by some attendant at the recreation area can produce estimates of greater reliability than the ranger estimate but less reliable than methods to be described later. Such counts have been shown to be most accurate when made at twelve o'clock each day (Douglass, 1969, p. 309).

Double Sampling

Double sampling is a means of estimating use from traffic counters or other measuring devices. George A. James of the USDA Forest Service Southeastern Forest Experiment Station at Asheville, North Carolina, in cooperation with several other researchers, has done several studies using variations of this technique. The basic technique involved the development "of a ratio between the desired statistic (visits, total recreation use, etc.) and traffic counts by simultaneously measuring both" (James and Ripley, 1963, p. 1). Traffic counters were placed across site entrances to tally total vehicle crossings and were read daily. On ten randomly selected sample days during the recreation season, the number of people were counted hourly and tallied for each different type of recreation activity on the site. Using these data, a simple linear regression equation was developed to estimate use from the traffic counter readings (James and Ripley, 1963, p.1). Once a site had been calibrated in the above manner, the relationship between traffic counts and use could be expected to remain fairly constant for the next five years, assuming no major change is made in the recreational facilities on the site (James and Ripley, 1963, p. 7). Errors of estimates using this method are expected to be no greater than "25 percent of the estimated variability at the 67-percent level of probability" when ten 12-hour sampling days are used (James and Ripley, 1963, p. 7).

James and Tyre also used the same procedure in 1967 to correlate recreation use with water meter readings on developed sites. ". . . Estimates of use based on water-use records were consistently better than those based on traffic counts" (James and Tyre, 1967, p. 1).

Both of the above procedures are adaptable for mass-use areas that are unattended.

Variations of these procedures have been used in estimating recreation use on a complex of developed sites (James and Rich, 1966), various use activities on winter sports sites (James, 1968), use at visitor information centers (Cordell, James, and Griffith, 1970), and use of a unique trout stream (James, Taylor, and Hopkins, 1971). Costs for methods such as these have varied from $150 to $340 per year over a five year period. However, a cost of $150 to $200 per year was reported more frequently than higher costs (James, 1971).

Cordon Sampling

On dispersed-use areas, a different procedure has been developed by James and Henley involving a stratified random-sampling technique. The method was tested on the Pacific District, Eldorado National Forest in California, an area of 195,000 acres. Included in the district were several streams, lakes, and reservoirs as well as several important trails. All exit roads were stratified by expected frequency of use (high, moderate, and low). Twenty sample days of 12 hours duration were selected at random from the 101-day recreation season (10 weekdays and 10 weekend days or holidays), and on each sample day one exit from each use class was randomly selected on which to conduct interviews. The driver of vehicles exiting the district on one of the interview roads on a sample day was requested to stop for an interview. A variety of information concerning the type of recreation in which the passengers in the vehicle had participated during their stay in the district was obtained by a trained interviewer.

Prior to the beginning of the study, several roads were selected for location of traffic counters. Roads were selected in hopes that traffic counts on one or more of them could be used as an indicator of use throughout the entire district.

A linear regression equation was developed for estimating 37 activities occurring on Forest Service land and for 33 activities occurring on "other" land within the district boundaries. At the 67-percent level of probability, confidence intervals for activities on Forest Service land varied from 15.5 percent ot 85.0 percent. Confidence intervals for total recreation use at four developed sites were 14.8 percent, 32.2 percent, 32.8 percent, and 15.4 percent (James and Henley, 1968, p. 8-9).

After the initial calibration period the regression equation was used in conjunction with traffic count records from a "key" road in or near the area to estimate use during the next three to five years. However, the researchers suggest that a smaller sample be run every third year to "act as a 'sensor' to detect changes in the character of traffic flow-visitor use relationships" (James and Henley, 1968, p. 13).

This study cost $13,700, however, expected costs for future samples of a similar nature should be about $7,500. The $13,700 was high due to an increased amount of time being devoted to training, administration, and traffic-counter servicing to insure the success of this pilot study. Also, six traffic counters were used when two would have provided similar results. Several hundred dollars of cost were added due to difficulties in installing one of the traffic counters (James and Henley, 1968, p. 12).

In this study by James and Henley, current recreation use of large, dispersed-use recreation areas was obtained by interviewing a sample of recreationists. Also included was the privision for updating the use estimates for a three to five-year period by correlating current use with traffic counter readings. Other researchers had made studies which provided current use but had no provision for updating the estimates. Such studies include those by Lucas in 1964; Cushwa, McGinnes, and Ripley in 1965; and James and Narper in 1965. Costs of these types of study varied from $4,500 for a large, roadless camping area to $15,000 for a National Forest size area, and $18,000 for two Canadian National Parks (James, 1971, p. 21-29).

Self-Registration

In 1967, Wagar tested a method similar to double sampling except it was statistically keyed to visotor self-registration rather than traffic counts. Self-registration records and visitor-use counts were made at three sites: Panquitch Lake Campground on the Dixie National Forest, Utah; Devil's Canyon Campground on the Manti-Lasal National Forest, Utah; and Green River Lakes Campground on the Bridger National Foresty, Wyoming. Self-registration cards available at the entrance to the campgrounds requested information which included name, number of people in the group, vehicle license and state, time and date of arrival, and expected departure time and data. Actual visitor counts were made on a ramdon schedule on 12 days during the summer-use season (Wagar, 1969, p. 3-4).

Regression equations were computed from the registrations and actual visitor counts which could then be used to predict (a) use at the sites where sample counts were made, (b) use for additional years when no sample counts were made, and (c) use of other similar sites where no samples were taken (Wagar, 1969, p. 1).

At the 67-percent level of confidence, errors ranged from 9.0 percent to 83.6 percent for seven different recreation activities on three campgrounds. Errors for total use of each campground were 11.1 percent, 11.2 percent, and 17.7 percent. Traffic counts were also used to predict use. Errors for total-use estimates based on traffic counts were 12.9 percent, 5.2 percent, and 18.2 percent, respectively (Wagar, 1969, p. 11). "Estimates of total visitor use from regression relationships based on self-registration data were as precise as estimates based on pneumatic traffic counter data" (Wagar, 1969, p. 10). The cost of Wagar's study averaged $25 to $30 per year per site (James, 1971, p. 17).

In a study to develop an economical sampling model for estimating use on wilderness areas, James and Schreuder found that 77 percent of trail users completed self-registration cards. Estimates of use were obtained by linear regression and the ratio between interview information and self-registration forms. This model may be used for up to four years on the same area (James and Schreuder, 1971, p. 490-493).

Electronic Eye Counters

A trail counter using an electronic eye has been developed. The system has three components; a transmitter-receiver-counter unit, a reflector, and a battery case. The transmitter-receiver-counter unit is concealed on one side of a trail and the reflector is placed up to 75 feet away on the other side of the trail. A person (or animal) passing along the trail interrupts the infrared light beam causing the counter to be advanced by one digit. Built in delays prevent the counter from being advanced by such things as falling leaves, flying birds, swinging arms of hikers, etc. The system operates on two 12-volt and one 6-volt lantern batteries which, with average use, will last two months. "Twenty-five of the new counters were field tested during the summer of 1970. While the data are still being processed, preliminary analysis indicates high levels of accuracy and reliability" (Deland, 1971, p. 2-4). By varying the height of the infrared beam, such a counter could be used either on foot or bridle trails.

Summary

The methods of estimating use discussed above have ranged from guesses to fairly accurate methods of prediction. However, the most reliable of these systems is still, at best, an estimate and is based on some statistic other than actual use. None of these methods comes close to meeting the criterion established for an ideal system.

CHAPTER IV

TECHNICAL FEASIBILITY OF USING REMOTE SENSORS

The present methods of measuring recreation use are, in most cases, based upon statistical estimates rather than upon absolute counts. There have been expectations that newer devices in remote sensing could provide direct measures of total use or at least provide more accurate estimates than are now available.

Research on the application of remote sensing techniques for making use estimates has been limited. Most of this research has been on a small scale and not tested enough to determine the real value of remote sensing techniques. Researchers in other areas have made more use of remote sensors. Remote sensors are being used in geological explorations, thermal pollution studies of waterways, disease detection in crops and forests, forest fire detection, wildlife censuses, cultural density studies, and numerous other applications in many disciplines. It would seem that some of the work in these other areas might be useful for measuring recreation use. For example, some success has been experienced in inventorying livestock and large wild animals using remote sensors. If these animals can be inventoried using remote sensors, why could not the same equipment and techniques be used to count people in recreation areas?

This chapter will discuss the work which has previously been done in this area as well as the feasibility of using remote sensors now in use in other areas for determining or estimating recreation use.

System Characteristics which Affect their Usefulness

One of the most important characteristics of either spaceborne or airborne sensor systems affecting their ability to 'see' objects on the ground is their ground resolution.

> Ground resolution is a measure of the smallest object on the ground which can be detected in the photograph at a given brightness ratio between the object and its surroundings. Examples are: . . . If ground resolution is twenty feet one can detect most objects with one dimension of ten feet or more, such as buildings, vehicles, and ponds; at five feet, shrubs and larger animals are detectable. Many factors, such as presence of surrounding related objects are helpful. Generally speaking, it appears that ground objects may be detected if their dimensions are approximately equal to the smallest distance resolvable on the ground scene (Shahrokhi and Rhudy, 1971, p. 21).

When viewed from above, a person's cross section is somewhere near 1-1/2 feet by 1-2 feet. Thus, very great resolving power is needed in any system being used to count people. According to Mr. Leo Vroombout, a reconnaissance engineer and physist at Wright-Patterson Air Force Base, Ohio, 1/2-foot resolution would be required to detect and identify a person.[1] The resolution of a system thus becomes one of the critical factors which determines its usefulness in recreation use determination.

A second desirable characteristic of a system used to measure recreation use is its ability to "see" through vegetation. The main recreation season corresponds closely to the season when deciduous trees are in foliage. Several forms of recreation (hiking, picnicking, camping, fishing) occur principally in the shade under this canopy. Thus, an

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[1]Information obtained during personal communication with Mr. Vroombout on February 14, 1972.

ideal system to measure recreation use would have the ability to "see" through, around, or under canopies. Without this characteristic, a system would be limited to use in open areas such as deserts or large bodies of water.

Satellite Systems

Satellites have carried and will continue to carry a wide array of remote sensing devices. These range from black-and-white photography to vidicon, a television type scanner (Sattinger, 1971, p. 11). However, their usefulness for recreation use measurements seems improbable. Less resolution is needed to census livestock than to count people, yet, Frye points out that even data for census of livestock appears "to be unattainable from space." He further points out that cameras have been developed to the highest state of perfection and that non-photographic sensors can best be used to supplement photographic data (Frye, 1967, p. v).

The minimum ground resolution for NASA's Apollo 9 multiband photography was found to be 300 feet (Aldrich, 1971, p. 389). The ERTS A satellite which is to be launched about June, 1972, is to have systems which have 200 feet ground resolution.[2] Obviously, such immagery will be of no value where ground resolution of one half to one foot is needed.

Perhaps as technology improves, greater resolution may be achieved.

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[2]Data from a speech by John Rehder, U.T. Geography Department, presented at the THEMIS Project Annual Meeting on January 11, 1972.

This can be done by "increasing the focal length of the camera and increasing the sensitivity of the film as to the number of discernible lines that can be crowded into one millimeter" (Szarvas, 1970, p. 80). The human eye can see only about seven lines per millimeter. Today's best film delivers 50 to 75 lines per millimeter for color film and over 100 for black-and-white film (Szarvas, 1970, p. 80).

According to Szarvas, NASA already has used a camera having a 240 inch focal length which will give resolution of five feet from satellite altitudes. He further states that a 960-inch focal-length camera is being developed that would have resolution of one foot.[3] The potential, he says, is for lenses of more than 100-feet focal length using a technique of "folded optics" (Szarvas, 1970, p. 80).

Even if lenses and films can be improved to give the needed resolution to detect, identify, and count people, the problem of canopy penetration still remains. No photographic sensor has the capability to see through objects. Thus, photographic sensors still could not measure all recreation use. Perhaps if resolution does improve in the future, space photographs might serve as another index to recreation use in the same manner as traffic counts, water use records, and self registration have been used.

At this time, it seems that all satellite systems lack both the resolution and/or the penetration necessary to provide even the data which could be used as an index to recreation use.

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[3]See also Dew, R. E., Application of Earth Sensing Sattelites, p. 63; and Carneggie, David M., Analysis of Remote Sensing Data for Range Resource Management, p. 12.

Aerial Photography

Aerial photography has been used for more than 100 years. In 1857 a French ballonist used a simple box camera with which to capture an image of a part of Paris on a film emulsion (Lauer, 1969, p. 8).

> . . . today cameras--especially aerial cameras--provide one of our most powerful tools for remote sensing. Aerial photography in the visible region gives the most accurate information on the size, shape and relative position of objects of any sensor (Parker and Wolff, 1966, p. viii).

In a sensor detection capabilities study conducted cooperatively by NASA and the U.S. Geological Survey, ten sensors were tested on 98 different targets. The sensors included black-and-white photography, color photography, infrared (IR) color photography, and black-and-white IR photography. "Of the 98 targets considered in this evaluation, 89 indicated that a photographic system had the greatest promise of object detection" (Wilson, 1969, p. 2). Furthermore, it seems that for most purposes conventional black-and-white photography is most useful.[4]

Black-and-White Photography

Recreation Use Studies. In a paper discussing specifications for special purpose photograhy, Colwell and Marcus use as an example the

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[4]According to notes on a conversation by Dr. Kerry Schell with Dr. Robert Peplies, a geographer at East Tennessee State University, about 85 percent of our information from aerial photography is from conventional black-and-white photography. Also personal conversation with the personnel in the office of Mr. Fred Cole, Chief, Photogrammetric and Remote Sensing Section, Tennessee Valley Authority, Chattanooga, Tennessee, indicated that there is probably no advantage of color imagery over black-and-white when trying to detect and identify people.

photographic specifications necessary to "permit a photo interpreter to measure the intensity of recreation use in wildland[5] areas " (Colwell and Marcus, 1961, p. 619). A series of test photographs were made in order to derive the required specifications. The photographs were made with a hand held aerial camera with a 15-inch focal-length lens from a three place helicopter. The film used was Super XX Aerial. Exposures were made from nearly every side of the campground from altitudes ranging from 30 to 600 feet. In one photograph taken from approximately 30 feet over the lake, all persons and vehicles[6] in the campground were detectable. A further series of pictures was taken to test various film-filter combinations. Based upon these two sets of photographs the following specifications were recommended for photography of campgrounds to measure their use: (a) an altitude of 500 feet or less, (b) a camera station selected to avoid obstructions to vision, (c) a film of low contrast, (d) a film with high sensitivity to short wavelengths, and (e) a filter to transmit short wavelengths and absorb long wavelengths (Colwell and Marcus, 1961, p. 621-625).

The researchers recommended designing the campground to accommodate the use of aerial photography from helicopters. They conclude:

> The larger the number of recreational sites to be inventoried in a given area, the more economical it will be to fly aerial photography for this purpose. For example, in an area of heavy recreational use,[7] 30 campgrounds might be inventoried in a

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[5]Emphasis added by writer of this paper.

[6]Only one family was in the campground at the time the imagery was made. These people were supplemented by forestry students and additional vehicles. A total of 17 people and five vehicles were present.

[7]Emphasis added by writer of this paper.

> single two-hour period, using only one helicopter manned by a pilot and aerial photographer. To do the same job on the ground in the same time might require 15 to 30 enumerators, depending on travel time between sites (Colwell and Marcus, 1961, p. 625).

This technique of flying at 500 feet or lower and finding a point of observation from which the whole campground is visible seems highly questionable, especially in "wildland areas" where one might expect to find foliage the heaviest. The costs of good campground design may be too great in making all areas of the campground visible from some particular location. Also, the researchers terms "wildland areas" and "an area of heavy recreational use" seem rather contradictory. It would seem that use in areas of heavy use could be determined by means even more economical than helicopter photography, for example, camping permits.

A later study using black-and-white aerial photography to determine recreation use is reported by Kreig. The study was conducted by the Center for Aerial Photographic Studies at Cornell University and the New York State Conservation Department, Division of Parks, Bureau of Planning. Its objective was to gather recreation use data from both public and private recreation areas in a 20-county area of central and eastern New York (Kreig, 1969, p. 41).

Existing aerial photographs and maps were used to locate the 257 recreation sites that were inventoried. These included parks, beaches, amusement parks, outdoor museums, golf courses, hunting areas, country clubs, and swimming pools. Flights over the areas were made only on Sundays throughout the summer. The information desired from the aerial flights included numbers of automobiles in parking areas, numbers and kinds of boats on lakes and rivers, counts of camping units in use, and number of people swimming and sunbathing (Kreig, 1969, p. 41-43).

A four-seated Tri-pacer aircraft was rented with pilot for $20 per hour. A photographer using a 35mm single lens reflex camera with black-and-white film took pictures of areas from the rear seat, while another person in the front seat acted as navigator-notekeeper. The first photograph of an area was usually taken vertically from 700 to 1000 feet above the area. Then several oblique shots were made to see cars under trees. Photographs were then made from about 500 feet in order to record the number of swimmers and sunbathers. In sparcely used areas and for boats, visual counts alone were usually sufficient. Analysis of the imagery showed that accuracy was quite good except for occupancy of camp sites, where heavy tree cover hid the sites (Kreig, 1969, p. 41-43).

In 1971, James, Wingle, and Griggs used a combination of black-and-white aerial photography, aerial counts, and ground based interviews to develop a procedure for yielding estimates of recreation use on large bodies of water. Their study was done in 1968 on East Lake and Paulina Lake on the Fort Rock Ranger District, Deschutes National Forest, Oregon. The lakes are 1,000 acres and 1,300 acres, respectively. The primary type of recreation on both lakes is fishing.

During the 101-day recreation season, recreation use was sampled on 10 randomly selected days evenly divided between weekdays and weekend-holiday days. Five flights were made on each sample day over each lake. On each flight, an observer made a visual count of all boats on the lake from an altitude of 1,000 feet. On a second pass over the area at 500 feet, photographs of the boats were made with a hand-held camera at a 45 degree angle to the water surface. At approximately the mid-time of each flight, shore-based personnel used binoculars to count the number of boats on the lake. Also returning boaters were interviewed at the principal landing area for each lake. Information obtained from these interviews included number of persons per type of boat and hours of boating time per person. Twenty-four hour traffic counts were obtained from roads leading to the principal boat launching area for each lake. A regression equation was computed using number of boats counted on the aerial photographs and twenty-four hour traffic counts as variables. This equation was then used to produce estimates of boating use based upon traffic counts.

Another equation was also computed using shore based observer counts and twenty-four hour traffic counts as the variables. This equation, too, was used to estimate boating use based upon traffic counts alone. The researchers compared the precision of estimates from these two equations and stated that "a careful count made on the ground at boat-landing areas is more precise than aerial photography for determining number of persons per boat" (James, Wingle, and Griggs, 1971, p. 3). At the 95-percent level of probability, the confidence intervals (expressed as a percentage of the estimate) for number of persons per boat and the means were:

	East Lake		Paulina Lake	
	Mean	Confidence Interval	Mean	Confidence Interval
Ground observation	2.53	± 7.1	2.61	± 11.2
Aerial photographs	2.40	± 18.2	2.27	± 9.4

(James, Wingle, and Griggs, 1971, p. 4)

"The means determined by the two methods were not significantly different for East Lake, but were significantly different at the 95-percent level of probability for Paulina Lake" (James, Wingle, and Griggs, 1971, p. 3). Confidence intervals at the 67-percent level of probability, expressed as percentages of the estimates, for total boating use were 9.3 percent for East Lake and 19.0 for Paulina Lake (James, Wingle, and Griggs, 1971, p. 5).

Even though the precision of aerial counts is less than that for ground observation, this study seems to show that in open areas where overhead vegetation is not present, it is technically feasible to use black-and-white aerial photography for determining recreation use.

Livestock and Animal Inventories. Considerable study has been done in the use of aerial photography for livestock inventories. In an experiment in the Sacremento Valley of California by Huddleston and Roberts, comparisons were made of the accuracy of livestock inventories gained by ground enumeration and by interpretation of aerial photography. "Preliminary analysis of the results indicate that comparable inventory numbers are obtained" by these methods "except for those 'domains' where buildings, man-made shading devices, or trees obscure part of the animals from aerial view" (Huddleston and Roberts, 1968, p. 307). Correlation coefficients between enumerated data and image counts were as follows:

	Cattle	Sheep	Other	Total
Cultivated stratum	.997	.944	.105	.933
Range stratum	.920	.818	.394	.810

A scale of not less than 1:5,000 was necessary for consistent results (Huddleston and Roberts, 1968, p. 308-312). Carneggie and Colwell point out that "even at an optimum photographic scale, terrain features including hay bales, rocks, shrubs, etc., are occasionally misinterpreted as livestock" (Carneggie and Colwell, 1966, p. 25). It would seem that an even greater problem would be encountered when attempting to count people since they present a smaller target.

Color Photography

There is no evidence that data on color photography would be easier to interpret than data on otherwise comparable black-and-white photographs for recreation. In comparing films for use in inventorying livestock, Huttleston and Roberts concluded:

> Panchromatic films proved to be the most acceptable when considering both cost and effectiveness. Although interpretation from color transparency film was shown to give greater accuracy, particularly for identification of animal type and breed, its use is considered too costly for complete sample coverage unless part of the cost can be borne by other potential users of the photography (Huddleston and Roberts, 1968, p. 308).

Color could possibly be an advantage in providing more contrast between a recreationist and his surroundings. On the other hand, resolution of black-and-white photography should be slightly greater than for color film. This results from more discernible lines per millimeter on black-and-white film. Economy is certainly an advantage for black-and-white photography. However, color photography is also technically feasible in the same types of areas as is black-and-white photography.

Infrared Color Photography

Use of infrared (IR) color photography may also be technically feasible for providing data on recreation use. However, with it, all vegetation shows up as shades of red. This great amount of red color in and around recreation areas could possibly decrease the amount of contrast between a recreationist and his surroundings. In their livestock inventory study, Huddleston and Roberts reported:

> Tests with infrared film and a Wratten 89B filter show that contrast between sheep and a green grass background is inadequate for consistent identification; however, cattle can be identified under these conditions. Against a brown grass background neither sheep nor cattle can be consistently identified on infrared photography (Huddleston and Roberts, 1968, p. 308).

On the other hand, inventorying of sea otters on Amchitka Island, Alaska, was best accomplished using Ektachrome Infrared Aereo Film Type 8443. This resulted in the greatest contrast between the sea otters and their background (Stephan, 1969, abstract). Since recreationists would be dressed in an assortment of colors and kinds of fabric, it is difficult to predict the consistency of data from IR-color film from one area or time to another.

Multi-spectral Photography

Multi-spectral photography is obtained by using several cameras, each mounted so as to view a common point of terrain (Shahrokhi and Rhudy, 1971, p. 29), or a single multi-lens camera which exposes a separate portion of the film through each lens, simultaneously (Parker and Wolff, 1966, p. vii-ix).

> Each camera [or lens] is equipped with a filter that will pass a particular narrow band of wavelengths and, perhaps, a film suited to that particular band. . . . The multiband camera is used when one is seeking to differentiate areas of, in this case, the earth surface, that have slightly different spectral reflectance characteristics. The differences are too subtle to show on the broad-band color film used in metric cameras, but they can be detected by comparing (through color manipulation or enhancement) a number of photographs each taken in a narrow band (Shahrokhi and Rhudy, 1971, p. 30).

Specific spectral "signatures" have been determined for many natural features of the earth and for different species of crops, making this type of imagery useful in agronomy, geology, and geography. Unfortunately, no such "signatures" are likely to be found for people because of the variety of their outer coverings. Tschantz summarizes the usefulness of multi-spectral photography. He says, "Little value can come from volumes of multispectral photography generated by such systems unless desirable features are first 'fingerprinted' and appropriate spectral bands used" (Tschantz, 1971a, p. 1).

Infrared Scanners

Some disciplines have been interested in the use of infrared systems as remote sensors. While the factors that affect emission and reflection of infrared energy are quite complex, the following is presented as a brief introduction to the principles and operation of infrared scanner systems.

> Objects are discernible to the human eye because of reflected energy from a visible light source such as the sun. However, any object or material at any temperature above absolute zero emits electromagnetic radiation independent of visible light. The wavelength of this energy emission is outside the response of the human eye and therefore is not visible, but it can be detected

> by infrared systems which in turn produce a visible output for human observation. These infrared systems do not require visible light to operate and can detect objects through varying degrees of fog, smoke, and camouflage.[8]
>
> A common method of obtaining aerial infrared imagery is with an optical-mechanical device in which a rotating mirror scans the terrain in continuous strips transverse to the line of flight. Radiation from each element of the scene is reflected off the face of the mirror and focused on a photoelectric detector such as indium antimonide or impurity doped germanium. The detector output is amplified electronically and may be recorded on magnetic tape or used to intensity-modulate a cathode ray tube trace or a light source for recording directly on film. The resulting image is a strip map that superfically resembles an aerial photograph. The vital difference is that the tone in the conventional aerial photograph is a function of light reflectance whereas the tone in the infrared image represents variations in the intensity of the emitted radiation resulting from variations in the product of emissivity and surface temperature (Parker and Wolff, 1966, p. x).

Several studies have been done using IR scanners to census or inventory animals, and IR scanners are now in use by the U.S. Forest Service for the detection of forest fires. The techniques used in each of these applications can possibly be used in measuring or estimating recreation use.

Censusing Animals

Several studies, both theoretical (Marble, 1967, Harker, 1970, Bartholomew, 1966) and practical (Croon *et al.*, 1968, Colwell *et al.*, 1966), have been conducted to determine if animals could be counted from IR scanner imagery. While the results of these studies have been reasonably successful, there are limitations as to what can be done.

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[8]Taken from Texas Instrument, Inc. brochure titled "Infrared Systems, Highlighting IR Mappers and Real-time IR Sensors"; not dated, p. 1.

Resolution is not as good as that of conventional photography. IR scanners that are commercially available have resolution of from 1 to 1-1/2 feet when flown at 1,000 feet above ground level (AGL).[9] Thus, it is necessary to fly at 1,000 feet AGL or lower in order to obtain the desired 1/2-foot resolution required to identify people. As has been pointed out previously, the variations in the tone of IR imagery result from a combination of the product of emmissivity and surface temperature of objects. Changes in surface temperature of different objects do not occur at the same rate. Surface temperature of animals and people change very little even with great variations in air temperature. During the day the earth's surface and surroundings are warmed by the sun and their surface temperature increases while that of people and animals remains fairly constant. This phenomena makes detection of animals more difficult during the day than the night and more difficult during the summer than the winter. Unfortunately, the main recreation season is during the summer and most activity is during the day, the times when detection would be most difficult. There is some recreation activity at night such as camping. This might be detectable using IR scanners, but flying at altitudes of 1,000 feet AGL and lower at night is dangerous.[10] Also campers would likely be under some type of shelter at night, blocking their radiation.

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[9] Letter and accompanying brochures from Charles F. Whistler, Texas Instruments, Inc., February 15, 1972.

[10] Personal communication with Charles Lockwood, University of Tennessee Research Pilot, indicated that he would not fly over the Smoky Mountains at 1,000 feet AGL at night.

Another problem of using IR scanners to count people is that the radiation emitted by people (or animals) will not pass through canopies of trees or any other obstruction (Carneggie, n.d., p. 95). Therefore, the probability of seeing images of people at night would be very small since most would be under some type of shelter. There is also the possibility of confusing people with animals or other "relatively warm objects, such as dead logs, stumps, warm rocks, etc." (Carneggie, n.d., p. 95). The only advantage then, that IR scanners have over conventional photography is their ability to be used at night, and this has limited value for a use-measurement system.

Forest Fire Detection

The U.S. Forest Service has successfully used two different infrared scanners to detect forest fires. One of these is called a bispectral detection system and produces imagery from two IR wavelengths. The system is designed to operate in a twin turboprop, light executive, pressurized aircraft. In a test in 1970, signals were generated in the system by a bucket of glowing charcoal with a surface area of 1/2-square foot. This was done at 15,000 feet AGL (Hirsch, 1971, p. 5). Fire targets of this size, or even somewhat larger, would be comparable to the size of campfires. It is therefore possible that remote and wilderness camping areas could be overflown with such an IR scanner and the number of campfires counted from the imagery. By obtaining ground truth on a few sample days a relationship between the number of campfires and the number of campers could be established. Estimates of use could then be made from the number of campfires in an area.

Another IR scanner used by the Forst Service is called the "Fire Spotter." It is produced commercially by the Barnes Equipment Company. The system is small and can be mounted on a single engine aircraft such as a Cessna 182. The output of this system is an audible signal and the illumination of one of five sector lights to indicate which 24-degree segment of the total 120-degree scan contains the target. The system can detect targets of one square foot and 600 degrees centigrade at altitudes up to 2,000 feet AGL (Kruckenberg, 1971, p. 9-10). It is possible that this system can be used as an index to camping use in the same manner as the bispectral system above.

No tests have been conducted to determine the success of using these scanners for the specific purpose of detecting campfires. While in theory they will work for this application, only comparison of ground truth data and imagery data from actual test flights flown for this purpose can establish this technique as a feasible one for estimation of camping use.

Multispectral Infrared Scanners

The infrared bands of the electromagnetic spectrum occur between .72 and 1,000 micrometers(μm).[11] "The atmosphere reduces the amount of energy received by any infrared system from a distant object through refraction, reflection, and absorption."[12] This reduction of energy is

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[11]"A μm is a unit of measure for wavelength and represents 1×10^{-6} meter, or 0.000,001 meter."[12]

[12]Taken from Texas Instruments, Inc. brochure titled "Infrared Systems Highlighting IR Mappers and Real-time IR Sensors, n.d., Presented at Remote Sensing for Forest Fire Control Workshop, May, 1971, Forest Fire Laboratory, Macon, Georgia, p. 2-4.

not as pronounced in the bands between 3 and 5 μm and between 8 and 14 μm. Very sophisticated IR scanners are available which can "measure emittance or reflectance or a combination of each" across the entire IR spectrum (Rouse, 1969, p. 29). However, "peak radiation from animals and people occurs between 8 and 14 μm . . ." (Croon et al., 1968, p. 755). This band, therefore appears to be the optimum wavelength region for detection of people since it is not attenuated greatly by the atmosphere and is the band of peak radiation for people. Use of a multispectral IR scanner would not be justified, since only the band between 8 and 14 μm is needed.

Radar

"Radar is not promising for ordinary civil photo/interpretation" (Hempenius et al., 1968, p. 360). While resolution of radar has been greatly improved, especially in the newer side-looking-radars, its primary non-military use is for mapping (Shahrokhi and Rhudy, 1971, p. 13). Even the synthetic-aperture systems, the avilability of which is quite limited for non-military applications, only have resolution in the 30 to 150-foot range (Taschantz, 1971, p. 13). A picture of low-altitude side-looking-radar imagery appears in the U.S. Geological Survey's Sensor Detection Capabilities Study and "displays the system's inability to provide information on any but very large objects" (Wilson, 1969, p. 10).

Based on the above information one may conclude that using radar to determine or estimate recreation use is not technically feasible.

Ground Based Systems

Various types of information may be obtained from devices located in or adjacent to recreational areas. These devices include photographic devices, seismic detectors, and other monitoring devices.

Photographic Devices

In a study completed in 1970 by Haugen and Lenning, Super-8 movie cameras were modified so as to take one frame of film at five minute intervals. These were placed near bridges in the study area (Saylorville Reservoir on the Des Moines River in Iowa). The cameras recorded boating activity on the river, fishing activity from the bridges, and traffic over the bridges. Exposed film was studied using a movie editor. Total boat sightings and total number of sightings of people on the bridges served respectively as indexes to total boating use and total recreation use of the bridges (fishing). Some problems were encountered with operation of the cameras (battery failure, mechanical problems, and vandalism). Naturally film exposed at night was of no value (Haugen and Lenning, 1970, p. 26-27). An improved camera is now available commercially which is activated by movement, thus conserving both film and batteries.[13]

The military has developed and tested a similar system using a camera focused on a section of jungle trail. This system is triggered by the signal output from a seismic detector which is discussed below. The results of the test mission were "considered successful from a technical

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[13]Telephone conversation with Dr. Haugen, Iowa State Water Resources Research Institute, on May 7, 1972.

viewpoint inasmuch as the camera system performed well" (Arney, 1969, p. 1-2).

It would seem that cameras such as these could be used along trails, at dispersed camping areas, dispersed boat launching sites, and other dispersed-use recreation areas to either provide a measure of actual use or an index to use.

Seismic Detectors

In another military experiment, it was found that humans have a rate of walking that is fairly consistent and that is different from animals (Arney and Custer, 1968, p. x). Based on this feature, a device has been developed which can transmit a signal to a distant receiver when triggered by the human footstep signature (Arney et al., 1968, p. 2). The basic concept of the system is the deployment of geophone sensors near trails.

> ... When the sensor is disturbed by a succession of seismic events (either footsteps or noise), a nearby, concealed HF transmitter sends in real time a tone-coded . . . signal of about ten seconds duration to a distant radio receiver located at a central headquarters. All received signals are automatically displayed and stored on magnetic tape at the central headquarters (Arney et al., 1968, p. 5).

The tone-coded signal not only indicates the presence of a person, but also the specific transmitter sending the signal. To be triggered, the system requires a series of seismic events at a frequency of the human footstep. This helps eliminate transmissions caused by seismic events other than human footsteps (Arney et al., 1968, p. 2-13).

Since the signals from this system are transmitted, displayed, and recorded, it would seem that a system such as this could have several applications for determining recreation use, especially of trails. It has been pointed out previously that the signal from the system can be used to trigger a camera. Another application would be to operate a counter. Since the signals are location-coded and are recorded, periodic analysis could be made at a central location (such as park headquarters) of recreational use over a fairly large recreational area.

Other Systems

Another military system is the Multipurpose Concealed Intrusion Detection (MCID) System.

> The MCID system consists of buried sensor wires, attached to small buried self-contained pickups which report intrusions back to an annunciator by buried telephone line, without the knowledge of the intruder. Detection is accomplished when an intruder crosses the sensor wires, actuating the electronics and causing an audible "beep" signal and a lock-up light at the annunciator. A system test button at the annunciator permits remote testing of the entire system of simulation of the intruder effects, thus assuring high reliability. All parts of the system are completely tamper proof (Multipurpose concealed intrusion detection (MCID) system, 1966, p. 1).

While it is possible that the system could be applied in determining recreation use, its use requires that two wires completely encircle an area. This would seem impractical for large geographic areas where dispersed use is to be measured and even on large mass-use areas.

The Army has also studied the possibility of detecting people by measuring the amount of carbon dioxide in the air. Morris states that "an ambush can be detected when it is windward and the detection instrument can measure enrichments of a few tenths of a part per million (ppm) within a few tenths of a second" (Morris, 1965, p. 1). No indication was given if instruments are available with this precision. This system would seem most impractical for recreation use measurement.

Summary

Of all the remote sensing systems described in this chapter, none offers the possibility of measuring recreation use under all conditions. In open areas such as lakes and beaches, conventional aerial photography at low levels seems to be the best method of determining use. For areas that are obscured by foliage, some other means would have to be used. Trails in remote areas can probably best be monitored with an electronic eye counter or a seismic detection system. An alternate system would be photographs from cameras triggered by either motion or a seismic detector. Use of remote campsites could be indexed by night flights with an IR scanner and counting campfires or possibly by seismic detectors.

Use of dispersed boat-launching sites and fishing along narrow streams presents the greatest problem for use determination or indexing. Probably the best method for boat launching areas would be one of the photographic systems or seismic detectors. It would seem that fishing on narrow streams would have to be indexed to some more measurable use of other nearby areas.

The best system for a given type of recreation area will also be affected by its cost of acquisition and operation.

CHAPTER V

ECONOMIC COMPARISON OF METHODS OF MEASURING USE

Previous discussion has shown that under certain conditions, various remote sensing systems are technically feasible for application as use data gathering systems. However, a system may be technically feasible and yet not be economically feasible, thus making it impractical to put the system into general use. This chapter makes an economic comparison of some of these systems with the methods of measuring use now being employed. This will be done by a hypothetical case study of a given geographic area comparing the costs of ground sampling techniques, black-and-white aerial photography, and infrared scanner imagery. The procedure used to make these estimates and the sampling plans are presented in Appendix A. A discussion of the economic aspects of several use measuring systems will be presented in the latter part of this chapter.

Cost Comparisons

The assumptions of this cost comparison study are that use data is needed for three areas in East Tennessee. The areas are the southern portion of the Cherokee National Forest, administered by the U.S. Forest Service; the Great Smoky Mountains National Park, administered by the National Park Service; and Norris Reservoir, administered by the Tennessee Valley Authority.

The specific locations within each of these areas for which use data is desired and the percentage of the area represented by the location are presented in Table 1.

Table 1. Locations Where Use Data are Desired and Percentage of the Areas Represented by the Locations

Location	Percentage of area based on flight-line miles
Cherokee National Forest	
Parksville Lake	36
Hiwassee River and Trail	36
Warrior's Passage Trail	24
Four camping sites and one recreation site	4
Great Smoky Mountains National Park	
Appalachain Trail	49
Andrews Bald-Clingmans Dome area and Trails	3
Chimneys-Mount LeConte area and Indian Trail	36
Trails around Mount LeConte	12
Norris Reservoir	
Total area of main reservoir and shoreline	100

Table 2 presents the costs for obtaining three different use estimates by conventional sampling, black-and-white aerial photography, and IR scanner imagery, for each recreation site, for each of the three major areas, and for the total study. The conventional sampling methods upon which these estimates are based included various techniques such as pneumatic and magnetic loop traffic counters, electronic eye trail traffic counters, and basing estimates on use of other areas. Complete sampling plans for each use estimate are presented in Appendix A. Certain costs such as for photo interpretation, data analysis, and flying between airport and work area and between work areas (ferry flying) were not computed for each individual site. In such cases, the site cost was obtained by taking a percentage of the area cost based on the percentage of the total area represented by each site as presented in Table 1.

All of the costs presented in Table 2 are based on estimates for labor, equipment, and services. Cost data was obtained from known reliable sources. Various cost estimates are presented in Appendix B, and the ones used in this study are identified.

Costs of labor, equipment, and services required in conventional sampling have been fairly well established over a period of several years. Thus, these estimates are probably the most accurate ones in this study. On the other hand, only a limited amount of aerial survey work has been done for the prupose of recreation use estimation. Nevertheless, confidence in the cost estimates provided for aerial photography

Table 2. Costs to Obtain Use Data by Different Methods

Location	Cost of obtaining use data		
	Conventional sampling	Aerial photography[a]	IR scanner imagery
Parksville Lake	$ 1,818.00	$ 9,826.80	$ 66,174.00
Hiwassee River and Trail	1,770.00	9,668.40	64,674.00
Warrior's Passage Trail	1,267.00	6,571.20	54,136.00
Four camping locations and one recreation location	1,038.00	1,152.00[a]	7,860.00[a]
Cherokee National Forest Total	$ 5,893.00	$ 27,218.40	$ 182,844.00
Appalachian Trail	$ 1,435.70	$ 25,927.50	$ 180,211.50
Andrews Bald-Clingman's Dome location and Trail	87.90	1,740.60	12,473.40
Chimneys-Mount LeConte location and Indian Trail	1,054.80	19,262.40	134,640.00
Trails around Mount LeConte	351.60	6,330.30	43,895.10
Great Smoky Mountains National Park Total	$ 2,930.00	$ 53,260.80	$ 371,220.00

Table 2 (Cont'd)

Location	Cost of obtaining use data		
	Conventional sampling	Aerial photography[d]	IR scanner imagery
Norris Reservoir	$ 7,174.00	$ 155,272.20[b]	$1,078,293.00
Total for three areas	$15,997.00[c]	$ 235,751.40	$1,632,357.00

[a]Cost per flight mile in this study is based on the assumption that 520 work-miles will be flown on each flight. These five locations require only 2-1/2 work miles for complete coverage. Therefore these costs are only realistic as part of the total study. Comparison of costs for these locations alone would be in error.

[b]For photographs at a scale of 1:60,000 the cost would only be $5,311.20.

[c]All conventional sampling was designed so that estimates could be updated for a five year period, thus reducing this to approximately $3,199 per year for the total study. All other costs in this column would also be reduced by 80 percent.

[d]Aerial photography, 1:3,000 scale.

seemed justifiable after due consideration.[1] Only one estimate was obtained for the cost of IR scanner imagery, therefore cost estimates for this type of data may be questionable. However, if the actual cost is as much as 90 percent lower than the estimated cost of obtaining IR imagery data, the actual cost would still be greater than that of conventional sampling.

The estimates in this study for aerial photography and IR scanner imagery are based on ideal situations. Under real conditions, such factors as cloud coverage over an area or flying incorrect flight lines, could cause the costs to be higher than those presented in this paper. Thus, if the estimates for aerial photography and IR scanner imagery are biased, it is most likely that they are too low. Such inaccuracies would make the case for conventional sampling even stronger.

In situations where use data is desired for large bodies of water, and there is little or no concern for estimating activity around the shore, black-and-white aerial photography may compete favorably with ground based sampling techniques. Boats can be counted and categorized by type accurately on photography of a 1:60,000 scale.[2] A limited amount of shore-based interviewing can then produce a correlation between boat type and number of people per boat.

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[1]Mr. Chess Lyon, Environmental Systems Incorporated, Knoxville, Tennessee, provided a "ball park" estimate for the aerial photography mission specified in this study (1:3,000 scale). His estimate for one flight over the entire study area was only $500 (10 percent) lower than the one computed in Appendix A.

[2]Personal communication with George James, U.S. Forest Service Experiment Station, Asheville, North Carolina, on April 18, 1972.

In this study, the annual cost of sampling Norris Reservoir by conventional methods would have been approximately $1,435, assuming that the statistical model produced could have been used for another four years. Data from aerial photograhy at a scale of 1:60,000 for the same area would cost $5,851.20 per year, assuming no updating procedure. In this particular case conventional sampling techniques are cheaper. However, as the size of the body of water increases, the travel distance to access points will also increase, thus increasing the cost. Therefore, anyone considering estimating use on a large body of water should consider aerial photography as a possible sampling method and make estimates of cost based upon the particular situation.

Discussion of Economics of Other Devices

No studies have been conducted using seismic detectors in recreation areas. Therefore, no total costs for their use are available. Their function is the same as the electronic eye counter, that being to detect persons passing along a given point. For each point where information is desired, a sensor unit ($300 each) and a transmitter unit ($500 each) is required for a total cost of $800 per unit (Arney *et al.*, 1968, p. 44). In addition, one receiver unit ($4,000) and a power supply, antennas, and other ancillary equipment ($50,000) would be required (Arney *et al.*, 1968, p. 44).

In the case of the Great Smoky Mountains National Park, 18 self-registration stations ($50 each) were used for a total cost of $900. Eighteen electronic eye counters could have been used instead, for a cost of $3600. The seismic detector system would cost $14,400 for the 18 sample sites plus $54,000 for the other equipment for a total of $68,000.

The electronic eye counter may compete with self-registration on the basis of greater accuracy and may possibly reduce required sampling intensity. The seismic detection system costs 18 times more than the electronic eye counter and would therefore be quite difficult to justify on a cost basis.

The use of a movie camera for recording use at remote sites would require the initial purchase of a camera for each site ($600 each[3]). A 50-foot roll of movie film costs about $5.00 including processing. Each roll will produce about 4,000 single frame pictures. Assuming that one frame is exposed each five minute period[4] during a 14-hour period of daylight, one roll would be used every four and three-fourth days. Thus, each site would have to be attended this frequently.

Although the cost is three times as great as the electronic eye counter, it would seem that no calibration would be needed to determine non-response or animal counts (as must be done for self-registration stations and electronic eye counters, respectively). The only cost of a survey using this method would be for the camera, film, personnel and travel for changing film and batteries occasionally, the additional cost

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[3]Personal communication with Dr. Arnold O. Haugen, Iowa State Water Resources Research Institute, Ames, Iowa, on March 7, 1972.

[4]Dr. Haugen used a five minute interval in his study of river traffic, however, this interval could be adjusted to meet the needs of specific situations.

of film interpretation, and an additional 20-percent of the total cost to cover replacement of equipment damaged by vandalism. Since little experience has been acquired with this system, no further evaluation will be made.

Summary

Conventional methods of sampling to estimate recreational use are considerably more economical than aerial photography except where estimates of only surface use of large bodies of water are desired. Economically, infrared scanner imagery is not feasible for use in estimating recreational use.

Self registration points, electronic eye counters, and seismic detectors perform a similar function. Initial purchase cost of the electronic eye counters is more expensive than construction of self-registration boxes, but may be economically justified because of other aspects, such as greater accuracy and requiring less time for data analysis. The seismic detection system cannot be justified economically.

Automatic cameras have not been used sufficiently to make a valid evaluation of their application; and thus, they cannot be evaluated economically.

CHAPTER VI

SUMMARY AND CONCLUSIONS

Recreation use information is needed for proper planning, management, and financing. In many situations, depending upon the economic value of the resource and available financing, the cost of completely accurate recreation-use data cannot be justified. In such cases, the recreation resource manager must settle for estimates of use based upon the relationship between samples of recreation use and some continuously measurable parameter such as traffic counts. Even samples of desired accuracy are expensive, involving personnel, equipment, and travel costs. Less expensive methods such as ranger estimates and periodic attendant counts are commonly used but lack the needed accuracy. In areas where fees are charged, total use can be directly measured or at least closely approximated.

Typically, conventional methods of sampling involve some form of double sampling. In this technique or method, some device is used to measure a parameter related to recreation use; and on randomly selected sample days, usually 10 to 20, an enumerator gets direct measurements or counts of use. Correlation-regression methods are then used to make estimates for the total period. Various parameters have been measured as indicators of use. Some of these have been vehicle counts by pneumatic, magnetic loop, or electric traffic counters, water used at a recreation site, people passing a point measured by self-registration cards or electronic eye counters, number of campers registered at a nearby camping site, restaurant sales, ski lift tickets purchased, and numerous others. Estimates based on samples such as these usually have a confidence interval of approximately 25-percent at the 67-percent level of probability (James and Ripley, 1963, p. 7).

While photographic and electronic remote sensing devices have advanced in recent years, they cannot compete with the conventional methods of use estimation either economically or statistically. Remote sensing systems carried on satellites do not have the ground resolution required to identify recreationists or their surrogates.

On aerial photography at a scale of 1:3,000 or larger, recreationists can be identified when they are in open areas and contrast sufficiently with their background, however they cannot be seen under canopies of trees. In general, standard black-and-white photography having sufficient overlap for stereo viewing and at a scale of 1:3,000 will cost at least five times as much as conventional techniques. Color or infrared color coverage will cost even more and will, at best, be only slightly easier to interpret.

Surrogates of recreationists, such as boats, cars, recreation vehicles, tents, etc. may be counted on smaller scale photography when they are in open areas. In some cases where estimates of surface use of large bodies of water are desired, aerial photography at a scale of 1:60,000 may be as accurate and economical as conventional sampling methods. The larger the body of water the more likely photography is to be economical. Some ground surveying is needed, however, to establish the number of people per boat type and other ground control or indices.

It is questionable that infrared scanners could produce an identifiable image of a recreationist that could be distinguished from the images of animals, warm rocks, or logs, even when the scanner is flown at 1,000 feet above ground level. Furthermore, IR scanners cannot "see" through canopies or other obstacles. They can, however, produce images of cars, boats, recreation vehicles, and campfires from altitudes higher than 1,000 feet. Ground surveys would be required to determine the significance of each of these surrogates in relation to recreation use. Even if technology improves these devices so that they can produce images of people and see through canopies, their high cost of operation will prevent competition with conventional sampling methods. An IR scanner survey at 2,000 feet would cost about 100 times the cost of a conventional use sample and about seven times the cost of black-and-white aerial photography from 1,500 feet.

Seismic sensor systems in use by the military would work well as trail monitors or counters but are much more expensive than electronic eye counters. Self-registration along trails has produced data that is accurate enough for most needs. Self-registration boxes and signs are less expensive to construct and install than the cost of an electronic eye counter. Automatic cameras along trails and other dispersed-use sites show promise of being useful but have not yet been thoroughly evaluated.

At this time, the only remote sensing systems that may be considered technically feasible for estimating recreation use are aerial photography, IR scanner, and seismic detectors. The potential applications of aerial photography and IR scanners, however, are limited to open areas, thus greatly reducing their usefulness. None of the remote sensors discussed here can compete on a cost basis with conventional sampling methods. Therefore, conventional double-sampling methods will probably continue to provide the bulk of use estimates for several years into the future.

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APPENDIXES

APPENDIX A

SAMPLING PLANS AND COST ESTIMATION

In all of the following sampling plans, sample days will be randomly selected and will be evenly divided between weekdays and week-end-holiday days. The assumption is made that acceptable accuracy will be obtained for the given sample intensities. All times refer to Eastern Daylight Saving Time. Costs are based on estimates presented in Appendix B.

Specific recreation sites where use data is desired were suggested by Russ Griffith, Staff Recreation Specialist, Cherokee National Forest, for that area; and a special study group from the Great Smoky Mountains National Park which included the park superintendent, the chief ranger, and the park naturalist suggested those for the Park.

Sites for the study were located on the 1969 map of the Cherokee National Forest published by the U.S. Department of Agriculture, Forest Service, Southern Region; the 1971 map of the Great Smoky Mountains National Park-North Carolina and Tennessee, published by the U.S. Department of Interior, National Park Service; and the 1970 Norris Lake Recreation Map, prepared by TVA, Maps and Surveys Branch. Reference was also made on the Clinch-Powell Rivers Watershed, Tennessee map, scale 1:250,000 and Little Tennessee River Watershed map, scale 1:250,000, published by the Tennessee Valley Authority, Division of Water control Planning; and to both sections of Topographic Map, Great Smoky Mountains National Park, scale 1:62,500, published by U.S. Department of Interior, Geological Survey.

Conventional Use Estimation

Cherokee National Forest

Recreation sites on the southern portion of Cherokee National Forest for which use estimates are desired are Parksville Lake, Hiwassee River and trail, Warriors Passage Trail, Holly Flats, Big Oak Cove, State Line, Double Camp and Jake Best. Sampling procedures for each site will be described below.

Parksville Lake. This site will be sampled using one observer to count and record recreational activity on and around the lake from three observation points. Twenty sample days will be used. Seven counts will be made each day beginning at odd hours. A sample day will begin at 7:00 A.M. and end at 8:00 P.M. (Eastern Daylight Saving Time). Observation points are a 1,646-foot hill, one mile north of Camp Ocoee, Parksville Beach, and Mac Point. The observer, using binoculars, will count and record the number of people boating, fishing, swimming, or picnicking, that can be seen from the observation point and then proceed systematically to the other points. At each point he will record the number of people observed participating in each activity. The next count and all subsequent counts for that day will begin at the ending point of the previous count. Travel time from the beginning point to the end point should not exceed 50 minutes (including 30 minutes for climbing and descending the hill). At the end of each sample day the observer will obtain the number of campers registered at Parksville Lake camping site, located one mile north of the lake. This statistic will be correlated with the sample observations to produce a regression equation. This equation can then be used to estimate total use of Parksville Lake from daily registrations at Parksville Lake Campground. Costs for sampling this location are presented in Table 3.

Table 3. Costs of Sampling Parksville Lake

Item	Cost
Personnel (observer) 20 days of 13 hours each at $5.00 per hour	$1,300
Personnel (supervisor) pro rata share (38 percent)[a] of cost for entire National Forest area	228
Travel 2,400 miles at 10¢ per mile	240
Data analysis	50
Total	$1,818

[a]Based on percentage of total observation time for entire National Forest area presented by this location.

Hiwassee River and Trail. This site will be sampled as two sites since the river portion of Lost Corral Camp to Appalachia Power House is used quite heavily for fishing. The trail begins at Appalachia Power House and follows the river upstream on the north shore of the river. The trail is not heavily used.[1]

A pneumatic traffic counter will be installed on Highway 30 near

[1]Personal communication with Russ Griffith, Cherokee National Forest on April 19, 1972.

Quinn Springs and one will be installed on Highway 14 just north of the river bridge. Electronic eye trail counters will be installed on the trail, one near its beginning at Appalachia Power House and one near the trail intersection with Highway 68. The fishing portion of the river and the trail at Appalachia Power House will be sampled by one observer on 10 days. On four other days he will observe and interview persons on the trail at a point near the trail intersection with Highway 68.

Sample days will begin at 7:00 A.M. at which time the observer will read the traffic counter at Quinn Springs and then proceed by vehicle from Quinn Springs along Highway 30. He will stop as often as is necessary to make visual counts of all fishing activity on the river. He will cross the river at Reliance, read the traffic counter on Highway 14, then proceed along Road 108 to Appalachia Power House, observing and recording fishing activity as he goes. He will then read and record the data from the trail counter near the power house and then record the number of persons passing along the trail for a three hour period. Persons will be interviewed to obtain more detailed information concerning their use of the trail. The reading from the trail counter will be recorded at the end of the period.

Between 11:00 and 12:00 A.M. and again between 1:00 and 2:00 P.M., the observer will observe and record fishing activity along the river. From 2:00 until 5:00 P.M. he will observe, record, and interview people on the trail at the power house. The trail counter will be read at the beginning and end of the observation period. Between 5:00 and 6:00 P.M. and again between 7:00 and 8:00 P.M. the observer will observe and record fishing activity on the river. Traffic counters will be read and the reading recorded at approximately 7:30 A.M. on the following day.

On four of the days following this procedure the observer will hike the trail to Highway 68. At that point he will record the reading from the trail counter and then count, record, and interview people using the trail. He will remain at this point from approximately 10:00 A.M. until 5:00 P.M. He will again read and record the trail counter reading before departing. Fishing use data will be correlated with the traffic counter readings. One or both traffic counters should provide an acceptable index to fishing use. Trail use will be correlated with the readings from the electronic eye counters to estimate trail use from the counter readings. Costs for these two sites are presented in Table 4.

Table 4. Costs of Sampling Hiwassee River and Trail

Item	Cost
Personnel (observer) 14 days of 13 hours each at $5.00 per hour	$ 910.00
Personnel (supervisor) 27 percent pro rata share	162.00
Traffic counters	150.00
Electronic eye trail counters	400.00
Travel 980 miles at 10¢ per mile	98.00
Data analysis	50.00
Total	$1,770.00

Warriors Passage Trail. This site will be calibrated from user counts by an observer and readings from electronic eye counters and self-registration stations. Four sampling points will be located along the trail. Sampling points at the trail terminals will be equipped with self-registration stations. The two intermediate points will have electronic eye counters installed. Ten sample days will be used. The interviewer will spend approximately two and one half hours at each point and then move to the next point up the trail. The beginning point will be selected randomly each day. After making observations at the highest point the observer will then observe at the lowest point and then proceed upward again. The trail counters and self-registration points will be checked before and after each observation period. Costs for this site are presented in Table 5.

Table 5. Costs of Sampling Warriors Passage Trail

Item	Cost
Personnel (interviewer) 10 days of 12 hours each at $5.00 per hour	$ 600.00
Personnel (supervisor) 17 percent pro rata share	102.00
Self-registration stations (construction, erection, and forms)	100.00
Electronic eye trail counters	400.00
Travel 400 miles at 10¢ per mile	40.00
Data analysis	25.00
Total	$1,267.00

Four Camping Locations and One Recreation Location. These locations will have their use indexed to the number of camper registrations at Indian Boundary Campground, a large developed campground. Use data for each of these locations will be determined three times per day on 10 sample days. Because of the long travel distance between Jake Best and Double Camp locations and the othre three locations, Jake Best and Double Camp will be considered one unit, and the other three locations (Big Oak Cove, State Line, and Holly Flats) will be considered as another unit for determining the beginning point on each sample day. The beginning location will be selected randomly, however all locations in one unit will be observed before proceeding to the next unit. Big Oak Cove and State Line will always be completed in sequence regardless of the starting point.

At each location the observer will record the number of occupied camp sites as well as all recreation activity taking place in the area. After observing at all five locations he will have a one-hour break. Then, starting where he ended on the previous circuit, he will make observations at each location again. This procedure will be followed three times each day.

It will be the observer's responsibility to determine by phone, radio, or on location, the number of registered campers at Indian Boundary Campground on each sample day. Costs for sampling these locations are presented in Table 6.

Table 6. Costs of Sampling Four Camping Locations and One Recreation Location

Item	Cost
Personnel (observer) 10 days of 13 hours at $5.00 per hour	$ 650.00
Personnel (supervisor) 18 percent pro rata share	108.00
Travel 1,550 miles at 10¢ per mile	155.00
Data analysis	125.00
Total	$1,038.00

Great Smoky Mountains National Park

Use estimates will be obtained for the Appalachain Trail; the trail between Andrews Bald and Clingman's Dome and the surrounding area; the heavy day use area in the vicinity of Mount LeConte, The Chimney Tops, Indian Trail, and Alum Bluff Cave; and the trails surrounding Mount LeCounte. Estimates for these trails will be derived from self-registration cards and actual observed counts. Eighteen observation points have been established. Twelve of these are along the Appalachian Trail and have been selected so that regardless of where a hiker joins the trail he must pass one of the points before he leaves the trail unless he reverses his course. If this happens, his use of the Appalachain Trail will be considered insignificant.

Fourteen sample days will be selected for the Appalachain Trail, three for the Clingman's Dome-Andrews Bald area, and three for the remaining points. The starting point for each sample day will be selected at random. The observer will check the self-registration box before and after each three hour observation-interview period. At the end of each three hour period he will proceed north or east to the next point. If he has no more points to the north or east within the same unit he will move south or west for the remainder of that day. Two and sometimes three points may be observed per day depending upon the hiking distance to and between points. Costs for the entire Smokey Mountain area are presented in Table 7. Costs for the different locations are shown in Table 8. These costs have been computed on a pro rata basis from the percentage of the total area represented by each location.

Table 7. Total Costs of Sampling Smoky Mountain Area

Item	Cost
Personnel (observer) 20 days averaging 13 hours per day at $5.00 per hour	$1,300.00
Personnel (supervisor) 40 hours at $7.50 per hour	300.00
Self-registration stations (construction, erection, and forms) at $50.00 each	900.00
Travel 1,000 miles at 10¢ per mile	100.00
Overtime (when overnight camping is required) three nights at $10 per night	30.00
Data analysis	300.00
Total	$2,930.00

Table 8. Pro Rata Cost of Sampling Individual Smoky Mountain Locations

Location	Pro Rata Percentage	Cost
Appalachain Trail	49	$1,435.70
Andrews Bald-Clingman's Dome area and Trails	3	87.90
Chimneys-Mount LeConte area and Indian Trail	36	1,054.80
Trails around Mount LeConte	12	351.60
Total	100	$2,930.00

Norris Reservoir

Recreational use on Norris Reservoir and the adjoining shore areas will be estimated based upon data obtained from a cordon sample (described by James and Henley (1968)). All roads leading away from the reservoir have been examined and stratified by the amount of expected use they will receive. Three strata were used: low, medium, and high. On this basis the area included 55 roads in the low stratum, 17 in the medium stratum, and eight in the high use stratum. One road from each stratum will be selected for sampling on each of the 20 twelve hour sampling days. Sampling will consist of interviewing a person in each vehicle leaving the area to determine the kind and amount of recreational activity that the occupants of the vehicle participated in while in the Norris Reservoir area. Three magnetic loop traffic counters will be placed on roads which should have traffic flow that is closely correlated with recreational activity in the area. These locations are near Demory on the road leaving Rainbow Marina, the Byrams Ferry Road near the exit from the Big Ridge State Park, and near Highway 33 on Sharps Chapel Road. After the sampling is complete only the counter at the location giving the highest correlation will be left in place to produce use estimates. Since the other two traffic counters as well as the signs and warning devices can be used again in other study areas, their value after one year of use is credited to the cost of sampling this area. Cost estimates for sampling this area appear in Table 9.

Table 9. Costs of Sampling Norris Reservoir Area

Item	Cost
Personnel (interviewers) 3 for 20 days of approximately 13 hours each at $5.00 per day.	$3,900.00
Personnel (supervisor) 80 hours at $7.50 per hour	600.00
Three magnetic loop traffic counters	2,100.00
Signs and warning devices	470.00
Travel 6,000 miles at 10¢ per mile	600.00
Data analysis	1,000.00
Sub-total	$8.670.00
Less credit for reusable equipment	
Two traffic counters	1,120.00
Signs and warning devices	376.00
Sub-total	-$1,496.00
Total charged to study	$7,174.00

Sampling Using Aerial Photography

Based on personal study of films and black-and-white photographic prints, as well as discussions with several people familiar with aerial photography, it was determined that the minimum scale for detection and identification of people in recreation areas is 1:3,000. Using a camera with a six inch focal length lens, a flight altitude of 1,500 feet above ground level (AGL) would be required to achieve this scale.[2] Because of a variety of factors, great difficulty was experienced in arriving at a reasonable cost figure for use in this study. (Some survey companies charge based on a rate per hour, others quote a rate per flight line mile, while some contract for a complete job. Also, some include in the price only the cost of flying the aircraft while others may quote a contract cost which includes interpretation and delivery of the desired data to the user.)

Since Chapter V is a hypothetical cost study for given geographic areas, some reasonable cost had to be derived. For non-photographic flying (flying from airport to and from study area and between areas where use data is desired, hereafter referred to as ferry flying) a cost of $80 per hour[3] and a speed of 165 statute miles per hour[4] will

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[2]The formula $\frac{1}{\frac{A}{FL} \times 12} = S$, where A is altitude AGL, FL is the focal length of the lens in the camera being used, and S is the scale of the photograph, may be used in altitude-scale computations.

[3]Personal communication with Dr. Goodwin, Dean of Research, The University of Tennessee, Knoxville, on April 11, 1972.

[4]Personal communication with University of Tennessee Research Pilot, Charles Lockwood, concerning flights with U.T.'s Aero Commander aircraft, about February 4, 1972.

be used. The most detailed data on the cost of photographic aerial surveys was in a paper by Craib. In order to include the total cost of the aircraft, photography, and prints a cost of $10.56 per flight line mile will be used while actually performing photography. An aircraft speed of 120 statute miles per hour will be used while performing aerial photography and while working within an area.[4] The cost of $10.56 is based on Craib's data and derived as follows.

According to Craib, the cost of making an aerial regional mineral exploration survey over an area of 50 by 100 miles would be $18,000. This price includes "data collection, including film, processing and delivery of one set of black-and-white 9-inch prints . . ." (Craib, 1972, p. 9). This estimate is based on the use of a T-11 or equivalent mapping camera with a six inch focal length lens mounted in a single engine aircraft, and flying at 10,000 feet above mean sea level (MSL) over terrain having an elevation averaging 2,000 feet. This will result in photographs having a scale of 1:16,000. "Assuming a normal 60-percent forward overlap and 30-percent side-lap, 32 flight lines with 110 photos per line will be required to cover the area once" (Craib, 1972, p. 9). Converting this data to a cost per flight-line-mile results in a total of 3,200 flight-line-miles at a cost of about $5.62 per mile.

A scale of 1:3,000 is desired for recreation use surveys. At this scale ground distance covered by a 9-inch by 9-inch print is 2,250 feet by 2,250 feet. Allowing for 60-percent forward overlap and 30-percent side-lap, forward gain with each photograph is 900 feet and lateral gain is 1,575 feet with each succeeding flight line. This scale, then, increases the number of photographs required per flight-line-mile from 1.1 in the above example to 5.9. Based on a cost per picture of $0.24 for film, $0.04 for processing, and $0.75 for printing,[5] the cost of 4.8 additional pictures per mile would increase the cost per flight-line-mile to approximately $10.56.

Where more than one flight line is required, adjoining flight lines should be 1,575 feet apart.

An estimate of costs for aerial photography at a scale of 1:60,000 was also computed. One 9 inch by 9 inch photograph would cover a ground area of approximately 8-1/2 by 8-1/2 miles. Assuming 60 percent forward overlap, forward gain with each photograph would be 3.4 miles. Lateral gain with each succeding flight line would be approximately 6 miles which should be the distance between lines.

Flight lines were plotted on the maps having scales of 1:250,000 and 1:62,500 (previously discussed on page 59). Straight line air routes were plotted between airports and study areas, between study sites, and between study areas. These distances were measured in statute miles and considered as ferry miles. Turns between succeeding flight lines were also computed as ferry miles. All flight lines where photographs were to be made were measured in statute miles and totaled for each site, area, and the complete study.

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[5]Cost of film, processing, and printing computed from data provided by Victor P. Sparks, Aerial Photographic Unit, Maps, and Surveys Branch, Tennessee Valley Authority, Chattanooga in personal communication on March 24, 1972.

Costs were computed for work miles for each site. Ferry miles within an area were computed for the entire area. Ferry miles to, from, and between areas were totaled and a pro rata share computed for each area based on the percentage of total work miles for the study that were flown in each area. Ferry cost for each site was pro rated on a similar basis.

Flight costs represent only the cost of obtaining the prints. Counts of people must be made on each print. Cost of this interpretation is computed at a cost of $7.00 per hour and assumes that 10 prints can be interpreted each hour. This cost is prorated to each site as was done for ferry flying costs.

Costs determined in the above manner represent the cost of one instantaneous observation at each site on one day. To have a meaningful sample, a minimum of three observations should be made each sample day and at least 10 sample days should be used. Fewer samples than this would not give a valid representation of use throughout the day and over the entire recreation season, respectively. Thus all costs for a single flight must be multiplied by 30 to determine cost of the sample. Costs for an aerial photography survey are presented in Table 10. Costs for 1:60,000 scale photography for Norris Reservoir are shown in Table 11.

Sampling Using Infrared Scanners

Very little use has been made of infrared scanners for detecting people except for military applications. Cost data for their use for such applications is even more difficult to obtain than for the cost of black and white aerial photography.

Table 10. Costs of Sampling Using Black and White Aerial Photography

Location	Percent of Area	Work Miles	Cost	Area Ferry Miles	Area Ferry Time	Pro rata cost	Total Flying Cost	Number of Prints	Inter-pretation Time	Inter-pretation Cost	Total Cost per Flight	Cost of Complete Study (30 flights)
Parksville Lake	36	21	$ 221.76			$ 19.70	$ 241.46	123	12.3	$ 86.10	$ 327.56	$ 9,826.80
Hiwassee River and Trail	36	20-1/2	216.48			19.70	236.18	123	12.3	86.10	322.28	9,668.40
Warriors Passage Trail	24	14	147.84			13.10	160.94	83	8.3	58.10	219.04	6,571.20
Four Campsites and one Recreation area	4	2-1/2	26.40			2.20	28.60	14	1.4	9.80	38.40	1,152.00
Cherokee National Forest Area Total	100	58	$ 612.48	86	:41	$ 54.70	$ 667.18	343	34.3	$ 240.10	$ 907.28	$ 27,218.40
Appalachain Trail	49	57-1/2	$ 607.20			$ 17.65	$ 624.85	342	34.2	$ 239.40	$ 864.25	$ 25,927.50
Andrews Bald-Clingman's Dome area and Trails	3	4	42.24			1.08	43.32	21	2.1	14.70	58.02	1,740.60
Chimneys-Mount LeConte area and Indian Trail	36	43	454.08			13.00	467.08	250	25.0	175.00	642.08	19,262.40
Trails around Mount LeConte	12	14	147.84			4.37	152.21	84	8.4	58.80	211.01	6,330.30
Great Smoky Mountains National Park Area Total	100	118-1/2	$1,251.36	65	:27	$ 36.10	$1,287.46	697	69.7	$ 487.90	$1,775.36	$ 53,260.80
Norris Reservoir Area Total	100	344	$3,632.64	210.5	1:30	$120.00	$3,752.64	2030	203.3	$1,423.10	$5,175.74	$155,272.20
Totals for Complete Study	---	520-1/2	$5,496.48	361.5	2:38	$210.80	$5,707.28	3070	307.0	$2,151.10	$7,858.38	$235,751.40

Table 11. Costs for 1:60,000 Scale Photography of Norris Reservoir

Flight Lines Required 2		
Work Miles	60 miles at 120 mph = :30 minutes	
Ferry Miles	66 miles at 165 mph = :24 minutes	
Work Time at $150.00 per hour[a]	:30 minutes =	$ 75.00
Ferry Time at $80.00 per hour[a]	:24 minutes =	32.00
Photographic Prints[a] (one each 3.4 miles) 18 at $1.03 each	=	18.54
Interpretation 15 minutes per photo = 4:30		
4-1/2 hours at $7.00 per hour	=	31.50
Camera operater at $10.00 per hour for 2 hours	=	20.00
Total Cost per Flight		$777.04
Total Cost for 30 Flights for Entire Study of Area		$5,311.20

[a]The assumption is made that the University of Tennessee research aircraft and camera will be used for these flights.

A cost of $100 per flight mile will be used in this paper.[6] This cost includes all costs associated with obtaining useable IR imagery. Since there is no basis for interpreting IR scanner imagery to determine number of persons, there is no basis for cost of interpretation. Since this would be just as difficult as interpreting black-and-white photographic prints, the same total interpretation cost will be used that was derived for aerial photography.

It is questionable that IR scanners can now be used to detect images of humans even when used at 1,000 feet AGL or lower. However it is quite possible that IR scanning devices now in use by the military, but still classified, may have the capability of detecting people from even higher altitudes and possibly through canopies. For the purposes of making cost comparisons in this paper, the assumption is made that IR scanning devices will become available which can detect people through a canopy when flown at 2,000 feet AGL. It is further assumed that such a device could be used for the costs stated above.

At an altitude of 2,000 feet AGL an IR scanner would cover a path on the ground only slightly wider than photography from 1,500 feet AGL with a camera having a six inch focal length lens.[7] Therefore

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[6]In a telephone conversation on April 14, 1972, Dr. Alan Stephens, Remote Sensing Unit, Maps and Surveys Branch, Tennessee Valley Authority, Chattanooga, Tennessee, provided an estimated cost of procuring IR imagery of $100 to $150 per flight mile. He qualified the estimate by saying that it was a "gross utopian estimate" assuming a large amount of flying and that no special processing of the output would be required.

[7]To compute ground coverage of an IR scanner, the maximum useable field of view is assumed to be 60 degrees. For this field of view, a formula of 2/1.7 x Altitude AGL = Ground width covered may be used. This data is based on personal communication with Mr. Leo Vroombout, Reconnaissance Engineer, at Wright-Patterson Air Force Base, Ohio, on March 13, 1972.

the same flight lines, flight line distances, ferry distances, and flying times are used in the computations for the sample using IR scanner imagery. Cost of ferry time is computed at $80 per hour.

Costs were computed for each area and the total study. Costs for each site may be prorated on a percentage basis.

As with aerial photography, imagery from one flight is only one observation. For a representative sample at least 30 observations should be made, therefore cost of one flight must be multiplied by 30 to arrive at total study cost. Costs for using IR scanner imagery for sampling recreation use are presented in Table 12.

Table 12. Costs of Using IR Scanner Imagery for Sampling Recreation Use

Location	Percentage of Area	Work Miles	Cost	Ferry Cost	Interpretation Cost	Total Cost per Flight	Total Cost for Study (30 flights)
Parksville Lake	36	21	$ 2,100.00	$ 19.70	$ 86.10	$ 2,205.80	$ 66.174.00
Hiwassee River and Trail	36	20-1/2	2,050.00	19.70	86.10	2,155.80	64,674.00
Warriors Passage Trail	24	14	1,400.00	13.10	58.10	1,471.20	54.136.00
Four Camping sites and one Recreation site	4	2-1/2	250.00	2.20	9.80	262.00	7,860.00
Total for Cherokee Forest Area	100	58	$ 5,800.00	$ 54.70	$ 240.10	$ 6,094.80	$ 182,844.00
Appalachain Trail	49	57-1/2	$ 5,750.00	$ 17.65	$ 239.40	$ 6,007.05	$ 180,211.50
Andrews Bald-Clingman's Dome area and trails	3	4	400.00	1.08	14.70	415.78	12,473.40
Chimneys-Mount LeConte area and Indian Trail	36	43	4,300.00	13.00	175.00	4,488.00	134,640.00
Trails around Mount LeConte	12	14	1,400.00	4.37	58.80	1,463.17	43,895.10
Total for Great Smoky Mountain Park area	100	118-1/2	$11,850.00	$ 36.10	$ 487.90	$12,374.00	$ 371,220.00
Norris Reservoir	100	344	$34,400.00	$120.00	$1,423.10	$35,943.10	$1,078,293.00
Total for Study	---	520-1/2	$52,050.00	$210.80	$2,151.10	$54,411.90	$1,632,357.00

APPENDIX B

COST ESTIMATES OF LABOR, EQUIPMENT, AND SERVICES

Cost estimates are presented in Table 13 to provide the reader with a general idea of the range of costs associated with certain items and services and/or to provide the source of cost estimates used in Chapter V, "Economic Comparisons of Methods of Measuring Use." An asterisk (*) following a cost estimate indicates that this cost was used in the study.

Table 13. Cost Estimates and Their Source

Item	Cost		Source of Estimate
Traffic Counters			
Pneumatic type	$75.00 each*		James, Wingle, and Griggs, 1971
Magnetic loop type	$700.00 each*		James, 1968
Electronic type	$200 - $500 each		Wagar and Thalheimer, 1969
Water Meters	$150.00 each		James and Tyre, 1967
Electronic Eye Trail Counters	$200 - $250 each		Deland 1971
	$200 each*		Personal communication with George James on April 18, 1972
Self-registration Sign and Box	Material	$30.00	Personal communication with George James on April 18, 1972
	Labor to erect 4 hrs at $3.00 per hr.	12.00	
	Supply of forms, pencils, etc.	8.00	
	Total	$50.00*	

Table 13. (Cont'd)

Item	Cost	Source of Estimate
Camera, 35 mm (type used in Army RAM experiment)	Less than $100 in the U.S.	Arney, 1969, p. 8-9
Movie Camera, Super 8 mm (type used by Haugen). Available from Detection Systems, Inc., Box 6033, Salt Lake City, Utah 84106	$600.00*	Dr. Arnold O. Haugen Personal communication on March 7, 1972
Film, Super 8mm, including processing	$5.00 per 50 foot roll*	Personal experience
RAM seismic Detector System		Arney et al., 1968, p. 44
Sensor Unit	$300 per unit, based on 100 units*	
Transmitter Unit	$500 per unit, based on 100 units*	
Receiver Unit	$4,000 per unit, based on 4 units*	
Ancillaries; power supplies, antennas, and instrumentation	$50,000*	
Army MCID System	$800 per set in quanties of 1,000	"Multipurpose concealed intrusion detection (MCID) system," 1966
Infrared Line Scanner	Rental - $1,200 per day	Notes from interview of Professor Joseph Ppochaskra, University of Tennessee, School of Planning, by Dr. Kerry F. Schell on June 15, 1971

Table 13. (Cont'd)

Item	Cost	Source of Estimate
Type unknown	$1,000 - $3,000 per job	Personal communication with Mr. Chess Lyon, Environmental Systems Corp. on March 7, 1972
Type unknown	"Less than $50,000"	Personal communication Mr. Leo Vroombout, Reconnissance engineer, Wright-Patterson AFB, Ohio, on Feb. 14, 1972
Bendix	"in the neighborhood of $50,000"	McCullough, Olson, and Queal, 1969, p. 145
Type unknown	"above $50,000"	Croon, 1967, p. 19
Small	"more than $50,000"	Parker and Wolff, 1966, p. xi
Infrared Line Scanner	$100* - $150 per flight line mile. Includes flying cost and useable imagery.	Dr. Alan Stephens, Remote Sensing Unit, Maps and Surveys Branch, Tennessee Valley Authoritory, Chattanooga, Tennessee; Personal Communication
Cameras		
K-37 9 x 9 Fairchild	$2,331	Third Annual Report (Part II-Fiscal, Publication, and Equipment Summaries) Project THEMIS, The University of Tennessee, Knoxville, 1971
RC-8 9 x 9	$25,000 - $30,000	Personal communication with Fred Cole, Supervisor, Photogrammetric and Remote Sensing Section, Maps and Surveys Branch, TVA, Chattanooga, Tennessee, on March 24, 1972

Table 13. (Cont'd)

Item	Cost	Source of Estimate
Flying, Aircraft, not camera equipped		
Small	$20 per hour	Notes on phone conversation between Dr. K. F. Schell and Robert Jenkins, Bureau of Sport Fisheries and Wildlife, Fayetteville, Arkansas, on July 8, 1971
Single engine	$20 per hour	Kreig, 1969, p. 41
Tri-Pacer	$30 per hour	James, Wingle, and Griggs, 1971, p. 6
Flying, Aircraft, camera equipped		
Type unknown	$160 per hour	Notes on phone conversation between Dr. K. F. Schell and Robert F. Kruckeberg, U.S. Forest Service, Missoula, Montana, on January 20, 1972
Twin Beechcraft	$85 per hour	Notes on phone conversation between Dr. K. F. Schell and Rober Hoffer, Department of Forestry, Purdue University, on March 14, 1972
Twin engine Beech	$70 per hour plus $245 per day standby	Personal communication with Fred Cole, TVA, Chattanooga, on March 24, 1972

Table 13. (Cont'd)

Item	Cost	Source of Estimate
Type unknown	Approximately $7.42 per mile with total black-and-white coverage and 14% color coverage. Approximately $31.50 per mile with total black-and-white coverage and 40% color coverage.	Huddleston and Roberts, 1968, p. 320
Aero Commander	$150 per hour for actual research flying and $80 per hour for ferry flying*	Personal communication with Dr. Goodwin, Dean of Research, University of Tennessee, Knoxville, on April 11, 1972
Single engine	$18,000 for 5,000 square mile area, including 9 x 9 prints at 1:16,000 scale	Craib, 1972, p. 8-9
Type unknown	$15,000 - $20,000 for 400 square miles including day photographs and night IR imagery	Personal communication with Chess Lyon, Environmental Systems, Corp., Knoxville, Tn., on March 9, 1972
Type unknown	$4,000 - $5,000 per one day's flying (4-5 hrs. typically) including imagery. Might vary from low of $1,500 to high of $7,000.	Personal communication with Chess Lyon on March 9, 1972
Type unknown	$100 - $200 per hour for plane and pilot only	Personal communication with Chess Lyon on March 9, 1972
Type unknown	$10 - $20 per flight-line mile plus mobilization cost	Personal communication with Keith Sherman, Remote Sensing, Inc., Houston, Texas, on March 7, 1972.

Table 13. (Cont'd)

Item	Cost	Source of Estimate
Type unknown	Mobilization may cost $1,500 - $2,000	Personal communication with Ken Craib, Aero Service Corp., Philadelphia, Pa., on March 7, 1972
Film, Black-and-White Pancromatic	$65.00 per 250 foot roll which yields 275 to 280 9 x 9 inch pictures, or about 24¢ per picture*	Personal communication with Victor P. Sparks, Aerial Photo Unit, Maps and Surveys Branch, TVA, Chattanooga, Tenn., on March 24, 1972
Developing B and W Film	$5.00 - $10.00 per 250 foot roll for chemicals or about 4¢ per picture*	Personal communication with Victor Sparks, TVA, on March 24, 1972
Printing	About $ .75 per print*	Personal communication with Victor Sparks, TVA, on March 24, 1972
Photo Interpretation	15* - 20 minutes per stereo pair of prints	Personal communication with Victor Sparks, TVA, on March 24, 1972
	6* - 8 minutes per photo	Huddleston and Roberts, 1968, p. 320
	$3.25 per hour	Huddleston and Roberts, 1968, p. 320
	$7.00 per hour*	James, Wingle, and Griggs, 1971, p. 6
Transportation	10¢ per mile*	James, Wingle, and Griggs, 1971, p. 6
Personnel		
Interviewers	$5.00 per hour*	James, Wingle, and Griggs, 1971, p. 6
Supervisor	$7.50 per hour*	

Table 13. (Cont'd)

Item	Cost	Source of Estimate
Observer	$2.95 per hour	Personal communication with John Needy, Supervisor, Research Section, Recreation Resources Branch, Tennessee Valley Authority, Knoxville, on September 17, 1971
Supervisor	$3.80 per hour	
Personnel		
Observer	$50.00 per 12 hour sampling day including overtime	Personal communication with Dr. K. F. Schell concerning his discussions with supervisory personnel in Great Smoky Mountains National Park

VITA

Joe H. Taft was born in Taft, Tennessee, on February 1, 1937. He attended elementary school there and was graduated from Blanche High School, Blanche, Tennessee, in 1954. The following September, he entered the University of Tennessee and in June, 1958, he received a Bachelor of Science degree in Agriculture and was commissioned as a Second Lieutenant in the United States Air Force.

After serving on active duty in the U.S. Air Force as a navigator for five years, he taught Vocational Agriculture in Gate City High School in Virginia for one year, and Everett High School in Maryville, Tennessee, for five years. During this period he became an active member of the 151st Air Refueling Squadron, Tennessee Air National Guard, where he now has the grade of Major.

In 1969, he left teaching to attend the U.S. Air Force Air Command and Staff College. Upon his graduation in 1970, he entered the Graduate School at The University of Tennessee where he received the Master of Science Degree in Forestry in June, 1972. He is a member of Gamma Sigma Delta, Xi Sigma Pi, and Alpha Gamma Rho.

He is an active member of the First Christian Church, Maryville, Tennessee, and has served as a member of the Board of Directors for the past four years.

He is married to the former Barbara Lee Giles of Wytheville, Virginia. They have two sons, Marshall and Timothy.