REMOTE SENSING APPLICATIONS IN FORESTRY

THE USE OF HIGH ALTITUDE, COLOR AND SPECTROZONAL IMAGERY FOR THE INVENTORY OF WILDLAND RESOURCES

R-09-038-002

Volume II of III: The Range Resource

By
David M. Carneggie
Edwin H. Roberts
Robert N. Colwell

School of Forestry
University of California

Annual Progress Report 30 September, 1966

A report of research performed under the auspices of the

FORESTRY REMOTE SENSING LABORATORY,
BERKELEY, CALIFORNIA—

A Coordination Facility Administered Jointly By

The Pacific Southwest Forest and Range Experiment Station of the Forest Service, U.S. Department of Agriculture and by the School of Forestry, University of California

For

NATURAL RESOURCES PROGRAM
OFFICE OF SPACE SCIENCES AND APPLICATIONS
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

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PREFACE

Mountain meadows and open grass and brush ranges commonly associated with "wildland" areas are the source of a most important wildland resource, the Forage resource. So important is this resource for livestock production that the inclusion of all subject matter which discusses the inventory of this resource within a single volume, THE RANGE RESOURCE, is justified. THE RANGE RESOURCE, Volume II, is one of three volumes prepared for this research study entitled, "The Use of High Altitude, Color, and Spectrozonal Imagery for the Inventory of Wildland Resources".

The timber resource and all materials related to forest inventory, planting, harvesting, and protection are included in Volume I, THE TIMBER RESOURCE. The water, soil, wildlife, and recreation resources associated with wildlands might justifiably be discussed separately. However, for convenience, they have been combined into Volume III, THE SOIL, WATER, WILDLIFE AND RECREATION RESOURCE.

It should be recognized at the outset that the three principal wildland resources, vegetation, soil and water are so completely interrelated that it is difficult to discuss a single resource without also recognizing the influence and presence of the others. Thus, for each wildland resource it has been necessary to limit the discussion to the characteristics or terrain features which permit the interpreter to recognize, identify and evaluate the particular resource, present or potential, which may be found associated within wildland areas.

A B S T R A C T

High altitude multispectral imagery of annual and perennial rangeland in the Sierra Nevada, Cascade Mountains and foothills of the Coast Range of California was studied to determine the ease and accuracy of identifying and mapping important range characteristics. Specifications and recommendations for making more accurate inventories are discussed. In so doing, the season for obtaining useful imagery, the optimum scale of imagery and the usefulness of each film or image type are illustrated and discussed. This preliminary analysis indicates that no one film-filter combination or image type is best for identifying or mapping all of the significant range features. However, considerably more information can be obtained from interpretation of two or more spectral bands in concert. Ekta Aero infrared film appears to be the most useful single film-filter combination for inventorying the greatest variety of range characteristics. False color photographs can also be made by image enhancement techniques which combines the unique spectral signatures of objects from more than one spectral band. The interpretability of range features is thereby increased. Further studies are needed to compare the gains from interpretation of many spectral bands in concert and/or image enhanced photographs, with imagery from any one spectral band (e.g. Panchromatic) or with imagery which combines three separate spectral bands (e.g. Ektachrome, Anscochrome or Ekta Aero Infrared).

ACKNOWLEDGMENTS

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Presentation of the material contained in this report has been made possible through the cooperative effort of several individuals and organizations. Among the students and staff of the School of Forestry at the University of California who rendered vital services in the collection of ground truth, compilation and interpretation of the imagery used in this report were Eric Janes, James Fleming, Larry Pettinger, Thomas Tracy, Jerry Lent, Gene Thorley and Ruth Ormondroyd.

Grateful acknowledgment also is given to Cartwright Aerial Surveys, Incorporated, Fred Warren (USDA, Washington, D.C.) and Robert Heller (Pacific Southwest Forest & Range Experiment Station) for procurement of some of the imagery used in this report.

Special thanks is also given to Dr. Charles Poulton, Oregon State University, Corvalis, Oregon for his helpful comments and ideas.

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THE USE OF HIGH ALTITUDE COLOR AND SPECTROZONAL PHOTOGRAPHY FOR THE INVENTORY OF THE RANGE RESOURCE

by

David M. Carneggie, Edwin H. Roberts and Robert N. Colwell

INTRODUCTION

In the United States there are over a billion acres of range and pasture land suitable for livestock or wildlife grazing, but which are not primarily adapted for crop production or other intensive land use (Thomas and Ronningen, 1965). Present productivity on these rangelands, measured either in herbage production or pounds of livestock and wildlife, is normally very low as a result of deficient water, rough topography, remoteness, soil adversities and severe temperatures. In spite of these environmental limitations, productivity on rangeland often may be increased two or three fold by more intensive management. Brush removal and planting, fertilization, and irrigation are among the present techniques for increasing forage production. In order to effectively plan the development and management of rangeland, an accurate inventory of the plant communities must be made.

The research effort discussed in this feasibility study is directed toward determining the extent to which accurate inventories of the forage resource can be made using imagery obtained in different portions of the electromagnetic spectrum. Further consideration is given to the time or season for obtaining imagery that would yield the greatest quantity of useful information. The principal film-filter combinations studied were: Panchromatic film (minus blue filter); Aerographic infrared film (89B filter); Aerial Ektachrome (E-3) film with appropriate haze-cutting filter, and Ekta Aero infrared film (Wratten 12 filter). In addition, thermal infrared and K-band radar imagery were obtained and their usefulness in making forage inventories is discussed. The specific objective of this research is to determine the ease and accuracy with which the forage resource, in the Sierra Nevada Mountains (Bucks Lake test site), Cascade Mountains (Harvey Valley test site), and Coast Range (Pinole, California), can be identified and mapped through the use of imagery eventually to be obtained from manned earth-orbiting vehicles.

JUSTIFICATION FOR RESEARCH

The first step in the preparation of an accurate inventory is the procurement of suitable photography at a scale which permits the interpreter to identify and delineate the terrain features or vegetative boundaries of importance. Since 1948, instructions on all national forests of the United States have specified that aerial photos will be used as a base for all range resource inventories (MANUAL OF PHOTOGRAMMETRY, 1952). Until recently, panchromatic (minus-blue) photography flown to a scale of 1/15,840 or 1/20,000 has served as the standard for mapping in wildland areas. Unfortunately, very limited use has been made of available photography for range inventories except as a base map for indicating broad vegetative boundaries or positions of established sample plots in the field. Within the past year, Dr. Charles Poulton, Range Ecologist at Oregon State University, has demonstrated that the interpretation of conventional panchromatic photography, together with ground checking, is an invaluable aid for mapping distinct soil-plant communities. However, the limited number of distinct tone signatures which can be discerned on this imagery restricts its usefulness when more intensive mapping is required.

The need for more intensive mapping and data collection in wildland areas has stimulated further research to determine the feasibility of using other types of aerial imagery for identifying, mapping, and evaluating wildland resources. Jensen and Colwell (1949) demonstrated that a greater number of wildland features could be identified when panchromatic and Aerographic infrared aerial photographs were interpreted in unison than when the identification of the same wildland features was attempted on either the panchromatic or infrared aerial photograph alone. This technique of procuring imagery using two or more film types, or sensors, which records reflected or emitted radiation from two or more bands of the electromagnetic spectrum, is termed, "multiband spectral reconnaissance". (Colwell, 1961). By exploiting the differences in tone signatures which certain terrain features exhibit in the various bands, it is possible to discriminate between two features which appear similarly in one band, due to similar reflectance or emittance characteristics, if and when the two features have different tone signatures in another band of the spectrum.

A systematic investigation of imagery from all spectral bands is necessary to determine which band is most useful for providing information relevant to the <u>forage</u> resource. The results of this research will permit a determination of the feasibility of using specified spectral bands for identifying and mapping important rangeland resources. Such information will be useful for deciding the type of imagery eventually to be obtained from manned earth-orbital vehicles. In addition, this study seeks to develop improved means for making more accurate range inventories; a prerequisite to the intelligent management of meadows, grassland or brushland areas.

METHODS AND PROCEDURE

1. The Bucks Lake Test Site in the Plumas National Forest, located in the Sierra Nevada Mountains of California, was selected as a NASA Fundamental Test Site for Forestry to study wildland resources. This selection was based on the diversity of typical wildland resources found within the area, and the large extent to which "ground truth" for these resources already is known.

2. Flight lines were drawn on a U.S.G.S. topographic quadrangle map so that complete areal coverage could be obtained on small scale imagery.

3. On June 4 and 5, 1965, NASA's Houston-based Photographic Unit obtained complete high altitude and some low altitude aerial photography of the Bucks Lake Test Site. The approximate scale of the imagery was 1/30,000 and 1/10,000, respectively.

4. Utilizing the spectrozonal photography taken June 4 and 5, a general ground reconnaissance of the 120 square mile Test Site was made early in the summer of 1965.

5. Smaller study areas (including three range study areas) containing representative samples of wildland features were established. "Ground truth" photography was taken periodically of various terrain features to document their appearance on the ground and to show any seasonal changes.

6. Samples of a few important forage species which grow in pure stands were transported to Richmond, California, where light reflectance curves were made on a General Electric Spectrophotometer.

7. Surface soil moisture measurements were made to determine the effect of this variable on the data imaged by the various sensors.

8. Throughout the summer, image analysts in the field studied the

tone, color, texture, shape and other identifying characteristics of the range and meadowland on panchromatic, Aerographic Infrared, Ektachrome and Ekta Aero Infrared imagery (photographic scales were approximately 1/10,000 and 1/30,000). These studies served as the basis for determining the ease and accuracy of identifying the variety of different range and meadow conditions which existed.

9. On September 26, 1965, imagery was again obtained of the Bucks Lake Test Site by the NASA Photographic Unit. This imagery provided an opportunity to observe and study the changes in the range and meadow conditions that had occurred during the summer season.

10. K-band radar imagery obtained in late October provided an opportunity to study the feasibility of using radar imagery in evaluating range and meadow land. Interpretation of the radar imagery was facilitated by the previous compilation of knowledge about specific meadows, and by comparisons with the existing multiband imagery.

11. Thermal infrared imagery and other classified line-scan imagery was obtained of the Bucks Lake Test Site and the Harvey Valley study area on May 18, 19 and 20, 1966. Interpretation and study of the usefulness of this imagery for identifying and evaluating wildland resources is still being carried out.

12. On April 14, 1966, and at two-week intervals thereafter, ground photographs were taken of annual grassland range near Pinole, California. Aerographic infrared, Ektacolor and Ekta Aero infrared aerial photography of the annual range was obtained on April 27, 1966. The seasonal development and drying of the annual vegetation was observed in order to determine the optimum time for obtaining imagery which would provide useful information about the annual forage resource.

13. Supplementary high altitude Aerial Ektachrome and Ekta Aero Infrared imagery of the Bucks Lake Test Site was procured on June 11, 1966 (1/30,000) to study similarities and differences of the range vegetation with their appearance on the June 5, 1964 photography. In addition, two low altitude and two high altitude passes were made over the Harvey Valley study area. Approximate photographic scales obtained were 1/8,500 and 1/27,500.

14. The Harvey Valley Experimental Range Allotment was selected as a study area because of the diversity of range-vegetation communities and the accumulation of "ground truth" already available for this experimental range. Studies of the species composition, density, vigor, and trend have been conducted for more than 16 years by personnel of the Pacific Southwest Forest & Range Experiment Station, U.S.F.S. Continued investigation of the June 11, 1966 imagery, together with the imagery obtained on September 1, 1966 by the NASA Photographic Unit, will permit the preparation of keys for the identification of the forage resource (to be published in a later report).

DISCUSSION

The objective of any inventory is to compile a descriptive list or report of the quantity and value of each article being inventoried. A range resource inventory has as its objective the mapping of plant communities with reference to their present or potential productivity, and their relative suitability for intensive management. In preparing such a range inventory, it is first necessary to develop an accurate map of all plant communities, and second, to assign a capability or productivity rating to each, based upon sound ecological evaluation of the vegetation and soils. Fulfillment of both these inventory objectives is most expediently accomplished by employing the use of aerial photography. Panchromatic aerial photographs of most range lands in the United States are already available through many government agencies (e.g. U.S. Forest Service, U.S. Geological Survey, Bureau of Land Management, Army Map Service). However, the date, scale and type of photography are fixed. In order to make a more accurate inventory of range resources, the time, scale and type of imagery should not depend upon the photography which is available, but should be determined by the characteristics and diversity of the range vegetation being mapped, and by the specified level of accuracy desired. Hence, the photo specifications for an inventory of one area will not necessarily be the same as those for another area, for in each case the optimum time for obtaining imagery, the optimum scale, and the most useful film type or sensor used will be governed by the characteristic(s) and variability of the range vegetation and the specified degree of detail required of the inventory.

SEASON OR DATE OF IMAGERY

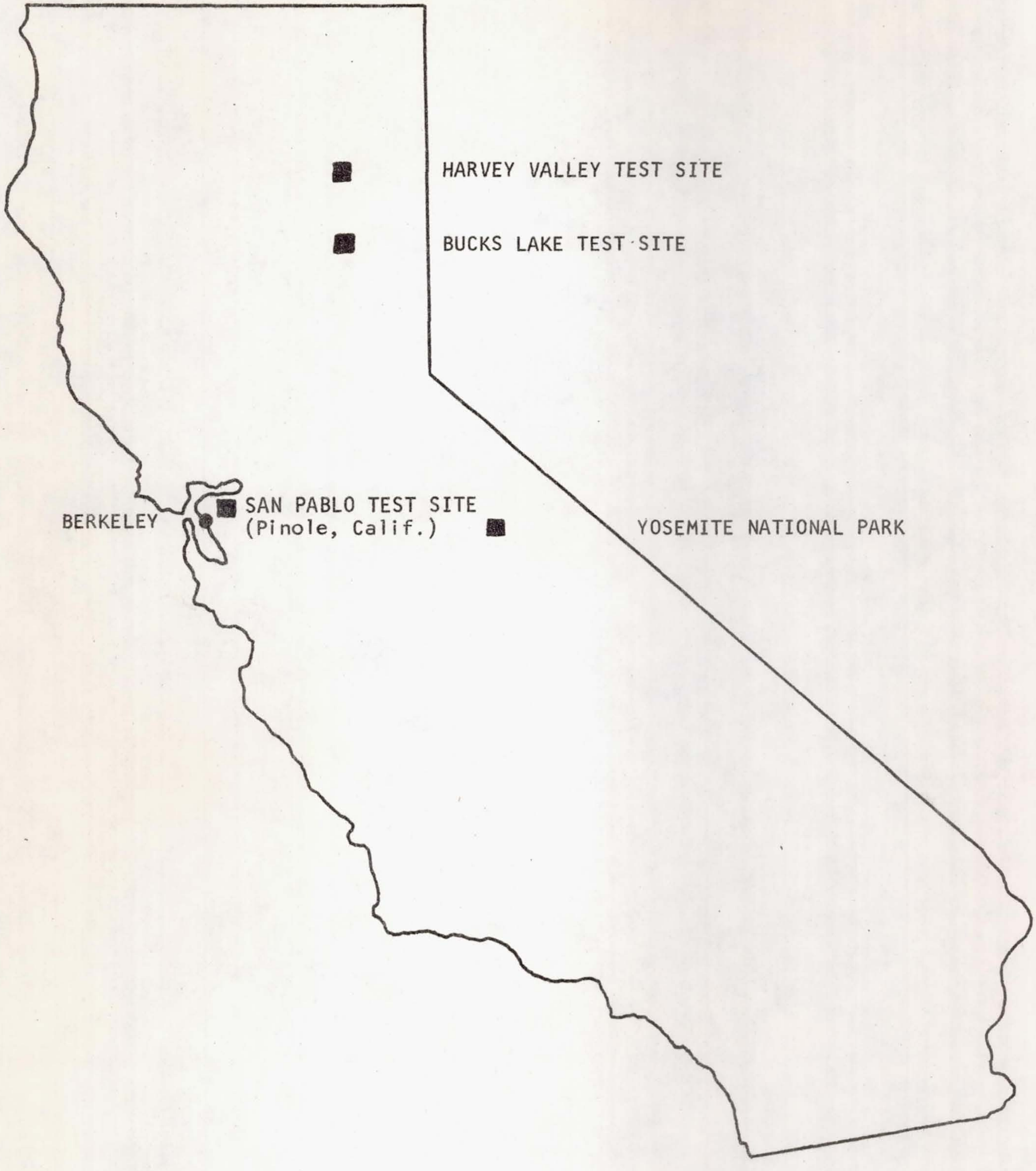
The importance of selecting the optimum time for obtaining imagery is illustrated by the annual grassland characteristics in California. Annual grassland vegetation germinates in late fall or early winter, after the first appreciable rainfall of the season, covering the foothills and plains with a homogeneous green carpet. Growth until mid-March is slow or suppressed by low winter temperatures. As temperatures begin to rise with the approach of spring, growth increases, reaching a maximum rate in April. The development of mature seed heads usually occurs in late April or May, after which the grasses begin to dry from insufficient moisture.

The entire life cycle of this annual vegetation is subject to regulation by temperature, and the distribution and quantity of rainfall. When winter temperatures and rainfall are below average, herbage production is below average and the vegetation dries much earlier in the year. When temperatures and rainfall are above normal, and the rain is distributed evenly throughout the growing season, herbage production is above average and the annual vegetation remains green much longer.

When all aspects of the life cycle of annual vegetation are considered, it is apparent that the optimum time to obtain imagery that provides useful information about the variation of herbage production on different sites is during the period of maximum growth rate and maturation of the annual vegetation growing on the more productive sites (late April or early May - see Figure 2). During this period the annual vegetation growing on the poorer sites has begun to dry, due to inadequate moisture, and change color. Prior to this period, ample moisture is available to support green herbage on all sites, making it difficult to evaluate from the aerial viewpoint the relative differences in herbage production. Following the period of maximum growth and maturation, the vegetation on the more productive sites begins to dry and change color until it appears the same or similar in tone as the dry vegetation on the poorer sites. Distinguishing between the two sites at this time is very difficult (see Figure 9). A series of ground photos (Figures 3, 4, 5, 6, 7 and 8) illustrates the appearance of annual vegetation prior to, during, and after the period in the annual life cycle (late April and early May) when the greatest differences between range sites occur. The reader is encouraged to note the relative ease of differentiating range sites on the four film-filter combinations illustrated.

The changing aspect of range vegetation is not restricted to annual vegetation. Rangelands consisting primarily of perennial vegetation also undergo marked seasonal changes, but the timing of development and drying is not as regular as with the annual vegetation, due to the different growth habits of the many kinds of perennial species which occur on these ranges. Figure 10 illustrates the change in appearance of one important bunch grass when imaged early in the season before grazing, and later in the season after drying and/or grazing. The optimum time for obtaining imagery of this particular range species depends upon the inventory objectives. If it is more important to determine the available herbage cover, imagery taken early in the season (before grazing - usually before June 1) would be necessary. If the objective is to distinguish the grazed and non-grazed areas, imagery taken later in the season would be more useful. This latter example is illustrated in Figures 29 and 30. The similarity of tones for vegetation inside and outside of an exclosure (Figure 30) suggests that heavy grazing has taken place during the interim period. Since range vegetation undergoes marked seasonal changes, this suggests that <u>sequential</u> imagery will permit the interpreter to extract considerably more information about the herbage cover by species, plant vigor and degree of utilization than is possible from imagery taken at any fixed date.

Another transient feature associated with rangelands consists of areas of accumulated or ponded moisture. This moisture may temporarily cover the forage or render a particular site unsuitable for grazing as a result of the trampling damage which occurs from grazing too early in the season. Detection of these moisture conditions also gives clues to


HARVEY VALLEY TEST SITE
BUCKS LAKE TEST SITE
BERKELEY
SAN PABLO TEST SITE
(Pinole, Calif.)
YOSEMITE NATIONAL PARK

SCALE OF IMAGERY

An observer who is close to an object is more apt to discern distinct characteristics about the object than an observer who is positioned farther away. Similarly, greater detail can be seen on large scale photography than on smaller scale photography when the resolving power of the "collecting optics" (camera), like that of the observer's eye, is fixed. As the interpreter employs a smaller and smaller photographic scale to identify and map objects, he must rely more heavily upon tone characteristics, for often the objects in which he is most interested can not be clearly discerned. This is especially true, for example, if the interpreter is interested in seeing objects as small as individual clumps of bunch grass on aerial photographs.

Figures 19, 20 and 21 furnish an opportunity to observe the loss of detail encountered by interpreting imagery flown at different photographic scales. The ground photos in Figure 19 show individual clumps of bunch grasses; they also reveal the soil texture, rocks and different brush species. Note how many of these features are no longer discernible on the Aerographic infrared photo in Figure 19d. Texture and rockiness of the soil are no longer discerned, but the largest clumps of bunch grass and individual plants of two different brush species are still seen, due to the contrast in tone between the vegetation and its background. On panchromatic imagery at the same scale, large clumps of bunch grass are not visible and differences in brush species are not readily seen because tone signatures of the objects in question are similar. Thus the contrast between objects is an important factor which must be considered, along with the scale of photography, when determining the ease of identifying objects at any given scale.

The two different brush species may still be distinguished on the smaller scale photo (b) in Figure 20, but notice how much easier this distinction is made on Ekta-Aero infrared film due to the color contrast between each brush species and the soil background. In all probability the brush species would not be detectable on Aerographic imagery at a scale as small as 1/30,000. Note, however, in Figure 21 that while it is still possible to detect the brush and distinguish it from the soil background, it is not possible to consistently differentiate between these two brush species. Thus, when the scale is reduced, the amount of discernible detail is also reduced. On some film-filter combinations, deterioration of detail is apparent sooner than on others; this is, in part, a result of the different levels of contrast which exist between the objects of interest and their background. Hence, the optimum scale will always be a variable depending upon (1) the extent to which detail is needed to identify an object, and (2) the level of contrast between the object and its background.

THE USEFULNESS OF MULTISPECTRAL IMAGERY

The steps involved in determining the ease and accuracy of identifying range characteristics have been discussed, giving consideration to the date, season, time and scale of imagery. It is therefore appropriate at this point to discuss the ease and accuracy of identifying objects in terms of the film-filter combinations or other image forming media used in recording them.

Whenever possible in this report, the four principal film-filter combinations studied (panchromatic, Aerographic infrared, Ektachrome and Ekta Aero infrared) have been illustrated together in the same figure.

For each of these illustrations, the ease of detecting or identifying many of the important range characteristics has been pointed out to the reader, but because of space limitations it has not been feasible to call attention to all important range characteristics. The reader therefore is encouraged to study each series of four film-filter combinations and compare the relative ease of detecting or identifying a particular feature on each.

As a guide to such a comparative study, many of the relative merits or limitations of each film type are given. Panchromatic film with a minus-blue (Wratten 12) filter is nearly equally sensitive to all wavelengths between 0.5 and 0.7 microns. Hence, the resulting gray tones seen are indicative of the differing degree of total reflectance from each object in the 0.5 to 0.7 micron band. Objects which appear dark in tone on the panchromative positive print reflect less light in this band than objects which appear lighter in tone. It is reported that 200 different tones of gray are potentially discernible by the human eye but much fewer than this number are discernible on an opaque panchromatic print. This fact reduces the interpreter's ability to distinguish between many features, e.g., vegetation and soil, which may have different color characteristics but which appear similar in tone on panchromatic prints. Aerographic infrared film with a Wratten 89B filter is sensitive to wavelengths of reflected radiation in the 0.7 to 0.9 micron band of the electromagnetic spectrum. Objects which are high reflecters of near-infrared radiation, e.g., most healthy vegetation and snow, appear light in tone, whereas objects which are low reflecters in this band (e.g. rock, soil and water) appear dark in tone. The light reflectance curves for specific species of range vegetation indicate high reflectance in the 0.7 to 0.9 micron band, whereas most soils show low reflectance in the same band. The curves therefore suggest that the infrared portion of the spectrum is best for distinguishing between soil and vegetation, but it does not follow from analysis of the curves that this distinction is possible when sparse vegetation is not resolvable, as on small scale imagery.

Aerial Ektachrome (E-3) film contains three dyes of different colors which have peak sensitivities to blue, green and red light, respectively, permitting this film to record hundreds of different colors, hues and chromas. Even under ideal conditions, however, it is difficult to obtain true color balance for the objects seen on the ground. Improper exposure or improper selection of a haze-cutting filter will contribute to the difficulty of achieving true color balance. In spite of these limitation, suitable Ektachrome imagery has been obtained; when studied, this imagery permits the interpreter to discriminate between many more objects than is possible on panchromatic film alone.

Ekta Aero infrared film also contains three dyes of different colors. These dyes are responsive, collectively, throughout the visible and near infrared bands, but a Wratten 12 filter cuts out the blue wavelengths. The net effect is a 3-dye color film having peak sensitivities to green, red and near infrared radiation. Since this film type is sensitive to longer wavelengths than Ektachrome film, a sharper image is obtained. Healthy vegetation, which has peak reflectance in the infrared portion of the spectrum, activates the infrared-sensitive dye which, when processed, gives a red coloration. The greater contrast between the red image of the vegetation and the blue-green image of the soil permits the interpreter to distinguish between these features more readily on this imagery than is possible on Ektachrome imagery. In addition, this distinction may be made from much higher altitudes on Ekta Aero infrared imagery since, in conformity with Rayleigh's Law, the long wavelengths to which it is sensitized are scattered less than the short wavelengths to which most other films (including Aerial Ektachrome, E-3) are sensitized.

The <u>thermal infrared</u> imagery used in this report was made by transforming emitted energy (8-14 microns) into electrical impulses which activated a light source that was, in turn, recorded on a photographic emulsion. Dark tones on this imagery correspond to low emittance, attributable primarily to low absolute temperatures of objects. Light tones correspond to high emittance and higher absolute temperatures of objects (according to the Stefan-Boltzman Law). Therefore, objects or features which differ in temperature generally can be distinguished from each other by their tone signatures on this imagery. The usefulness of such imagery is demonstrated in Figure 17(e) where vegetation types are readily seen and mapped, and in Figure 33 where livestock may be counted on imagery obtained at night.

<u>K-band radar</u> imagery is made by transmitting longer wavelengths (for example, 1 to 3 centimeters) to the earth's surface and recording the strength of the reflected energy. Light tones on this imagery result from high reflectance of these wavelengths, due either to the high reflective properties of the object or to its position with respect to the sensor (high energy returns are obtained from features or slopes which are aligned normal to the angle of incident radiation). Dark tones are indicative of signal attenuation caused by the absorbing characteristics of many wildland features, including meadows, lakes, moist areas, etc.

The usefulness of radar imagery for mapping gross meadow boundaries is illustrated in Figure 17(f). Since the sensor system transmits its own energy, it may be employed either night or day, and during either clear or adverse weather.

Each type of imagery discussed thus far is useful for identifying or evaluating certain range characteristics. No one image type alone, however, equips the interpreter with a panacea for identifying or evaluating all important range features. The interpretation of two or more image types in unison yields considerably more information than can be obtained from any one image type alone. This is in keeping with the concept of "multiband spectral reconnaissance". Consequently, the selection of the most useful image type depends upon the extent to which information is desired about (a) species composition, cover density, vigor and degree of utilization of the vegetation, (b) the soil condition, (c) the moisture conditions, and (d) the numbers of livestock or wildlife.

RESULTS

The interpretation of multispectral imagery, i.e., imagery obtained which is sensitive to radiation from more than one band of the spectrum, is a useful aid for making inventories of the forage resource. In this study imagery was obtained in the 0.5 to 0.7 micron band (using panchromtic film and a Wratten 12 filter); in the 0.7 to 0.9 micron band (using Aerographic Infrared film and a Wratten 89B filter); in three separate bands of the 0.4 to 0.7 micron region (using Aerial Ektachrome E-3 film with the appropriate haze-cutting filter); in three separate bands of the 0.5 to 0.9 micron region (using Ekta Aero Infrared film with a Wratten 12 filter); in the 8 to 14 micron band (using a thermal infrared sensing device); and in the 1 to 3 centimeter band (using K-band radar equipment). Imagery was obtained in all of these bands of selected range areas within the Bucks Lake Forestry Test Site and the Harvey Valley Experimental Range Allotment, to determine the ease and accuracy of identifying various range characteristics.

Panchromatic photography (.5 to .7 microns) is useful for delineating many important vegetation and soil boundaries by close analysis of tones and texture. Frequently, however, important plant communities or soil types are overlooked or misinterpreted because they cannot be distinguished from other soil or plant communities having similar tone signatures. The similarity of tones between moist areas, certain kinds of dry vegetation and heavily vegetated areas (Figure 26) often does not permit consistent differentiation between these important range characteristics on panchromatic photography. In analyzing species differences between Bitterbrush (*Purshia tridentata*), an important browse species, and Big Sagebrush (*Artemisia tridentata*), a less important browse species, panchromatic photography was least useful, even though a fairly accurate determination of total brush density could be made (Figure 20). An evaluation of herbage cover, except in dense meadow vegetation, is difficult if not impossible to make at scales exceeding 1/2000. Cultural features associated with livestock production, including watering facilities, salt licks, fences, trails, corrals and roads are normally readily seen on panchromatic imagery. Inventory of livestock numbers at photo scales up to 1/8000 is possible when sufficient contrast exists between the animal and its background.

Aerographic infrared (.7 to .9 microns) imagery is useful for detecting and mapping dense healthy vegetation and distinguishing this range condition from other vegetative communities which are less vigorous or which have greater amounts of soil exposed. Moist areas, streams and standing water (Figures 11, 26) are also easily identified, due to the characteristic tone signatures which these features exhibit on infrared imagery. Only limited use could be made of this imagery for mapping community boundaries, since the vegetative cover often is too sparse to be resolved; hence, distinct boundaries between types are not detectable. One valuable feature of this film-filter type was its distinct usefulness in differentiating between two important browse species, Bitterbrush and Big Sagebrush, at a scale of 1/1500 (Figure 19d). This same distinction was also possible, although not as readily, at a scale of 1/8500 (Figure 20b).

Aerial Ektachrome proved to be considerably more useful than panchromatic for mapping a large number of vegetation and soil types. This is explained by the large number of colors, hues and chromas that permit the interpreter to more readily discriminate between objects. The value of Ektachrome far exceeds that of other films when the true color of an object is an aid to its identification. Soil color as a correlative factor for determining site potential is one example. At a scale of 1/8500 differentiation between Bitterbrush and Big Sagebrush could not be made consistently even though the foliage colors of these two species are quite different (Figure 20). At higher altitudes, (scale 1/27,500), the relatively low contrast in color between certain soil types and other vegetated sites did not permit the interpreter to accurately map these range features (Figure 28). The vigor and vegetative cover were also difficult to determine at small scales.

Ekta Aero infrared imagery combines the advantages of the visible and near-infrared bands into one color film. Consequently, this imagery has proved more useful than panchromatic, near-infrared or Ektachrome for identifying and mapping a great variety of plant communities and soil types (Figure 14, 17). This distinction is significant because the plant community and/or soil type will serve as the basic unit on which land capability or potential productivity is determined. The ease with which these range characteristics are discriminated is attributed to the increased contrast between the various forage species and their soil background, and to a greater number of distinct spectral signatures. Soil and rockiness conditions could also be mapped more readily (Figure 26) and sites which were low in productivity due to adverse soil characteristics were consistently identifiable (Figures 23, 27). Furthermore, a more reliable estimation of relative forage cover could be made for many important plant communities (Figure 28). Moist areas, streams and standing water were also more reliably identified and mapped (Figures 12, 27). The spectral signatures of Bitterbrush and Big Sagebrush (Figure 20), permitted the interpreter to discriminate consistently between the two species. Less consistency was encountered at small scales (Figure 21) in making a bush to bush distinction, but the presence or absence of either species was readily determined. Finally, plant vigor, and in certain instances pure stands of individual species, are recognizable on this imagery.

Investigation and interpretation of unclassified thermal infrared imagery (8-14 microns) indicates that moisture conditions such as standing water and saturated or moist soil (Figure 17) are readily determined. Recognition of these areas is important in order to avoid trampling damage which results from grazing too early in the season. Furthermore, distinct plant communities may be differentiated, especially if the vegetative cover of each differs enough to cause one community to be warmer or colder than another (Figure 31). Thermal infrared imagery obtained at night when the thermal differences between the animal and its background are the greatest, provides a potential means for inventorying livestock or wildlife (Figure 33).

A single example of K-band radar imagery (Figure 17e) illustrates the usefulness of this imagery for mapping the gross boundary of meadow vegetation. Although this at first may not seem significant, one should recognize that this radar system is operable either day or night and in either clear or adverse weather. Large areal coverage, showing the distribution of major grazing sites in vast wildland areas, may be obtained rapidly with this sensor system.

When the limitations and merits of each image studies are taken into consideration collectively, it appears that Ekta Aero infrared film is most useful for detecting, identifying and mapping the greatest number of significant range features. Ekta Aero infrared film, however, cannot detect thermal radiation and hence cannot be used to distinguish between objects by their thermal characteristics. Nor can Ekta Aero infrared be flown in adverse weather conditions or at night, as is possible with K-band radar.

Thus it is apparent from this study that no one spectral band alone can provide all of the advantages to be gained by remote sensing. Ekta Aero infrared film, to some extent, exploits the basic multispectral principle, since its many unique tone and color signatures are attributed to the sensitivities of dyes in the visible (.4 to .7) and near-infrared

(.7 to .9) bands of the electromagnetic spectrum. Similarly, "image enhancement" by color projection exploits this basic multiband technique, as seen in Figure 22. (Compare Figure 22 with Figure 20). Here, three spectral bands, two in the visible, and one in the near-infrared portion of the spectrum, were projected through colored filters and superimposed upon a screen, giving a color enhanced image which in most respects is as interpretable, if not more interpretable, than Ekta Aero infrared imagery. Within the context of this report, the advantage gained by "image enhancement" is that a particular range feature may theoretically be enhanced to the degree that it is much more easily identified than is possible on any other kind of imagery. The color enhanced imagery in Figure 13 also demonstrates that by simply superimposing existing panchromatic and near-infrared imagery together on a screen, using various colored filter, a more interpretable image is made.

CONCLUSIONS AND RECOMMENDATIONS

High altitude, color and spectrozonal imagery of wildland areas within the Bucks Lake and Harvey Valley Test Site was procured at various times during the summer and fall of 1965 and 1966. Interpretation and evaluation of this imagery, both in the field and in the office, was performed with the specific objective of determining the ease and accuracy of using this imagery for making inventories of the forage and range resource. The extent to which this objective was satisfied is discussed in this report in terms of the best time to obtain imagery, the scale of imagery desired and the properties of each film-filter combination necessary to distinguish specific objects.

In this preliminary analysis, it appears that the greatest number of significant range features could be identified on Ekta Aero infrared imagery. However, additional studies which include procurement of sequential spectrozonal imagery at several specified altitudes, are necessary to compile a more complete list of the advantages or disadvantages of each type of imagery. From this analysis, identification keys and feasibility tables can be prepared to aid in the training of persons involved with making range inventories. Furthermore, the indicated success of image enhancement by color projection techniques suggests the need for additional studies. Specifically, further comparison should be made of visible and near-infrared multispectral imagery(as obtained with a multi-lens camera and color enhanced by projection) with imagery obtained from all bands of the electromagnetic spectrum, including various thermal infrared and radar bands.

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Colwell, Robert N., Some practical applications of multiband spectral reconnaissance, American Scientist, Vol 49, No. 1 March 1961.

Jensen, Herbert A., and Colwell, R.N., Panchromatic vs. infrared minus-blue aerial photography for forestry purposes in California, Photogrammetric Engineering, 201-223 pp. June 1949.

Thomas, Gerald W., and Ronningen, Thomas S., Rangelands -- our billion acre resource. Agricultural Sci. Review, 4th Quarter, Vol. 3 No.4 1965

a) Meadow Valley, Plumas National Forest, California.
Elevation: 3720 feet. Spanish Peak (in background).
Elevation: 7017 feet.

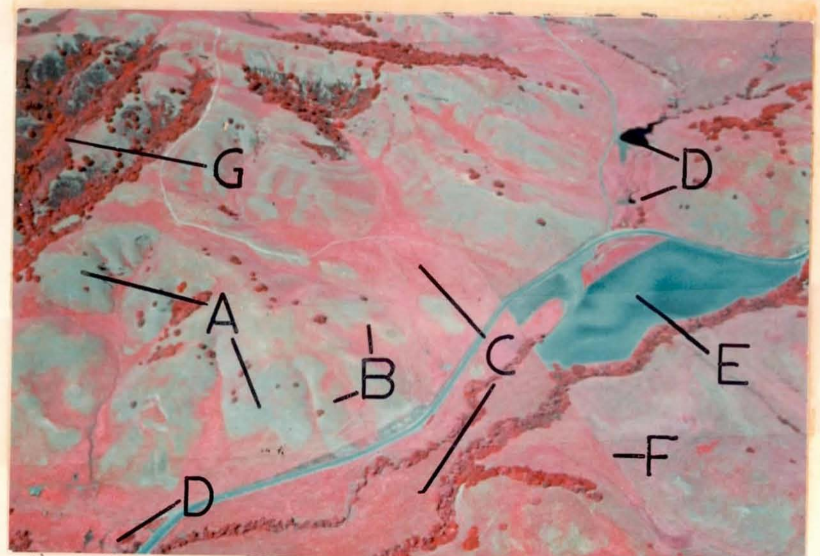
b) Harvey Valley, Lassen National Forest, California.
Elevation: 5600 feet. Harvey Mountain (in background).
Elevation: 7354 feet.

Figure 1. Kodachrome II ground photographs of primary range land within the Bucks Lake, Forestry Test Site in the Sierra Nevadas (a), and the Harvey Valley, Forestry Test Site located in the southern Cascade Mountains of California (b). These uncultivated, perennial mountain ranges are utilized by cattle and sheep during a four to six month period beginning in May or June.

a) Panchromatic no filter

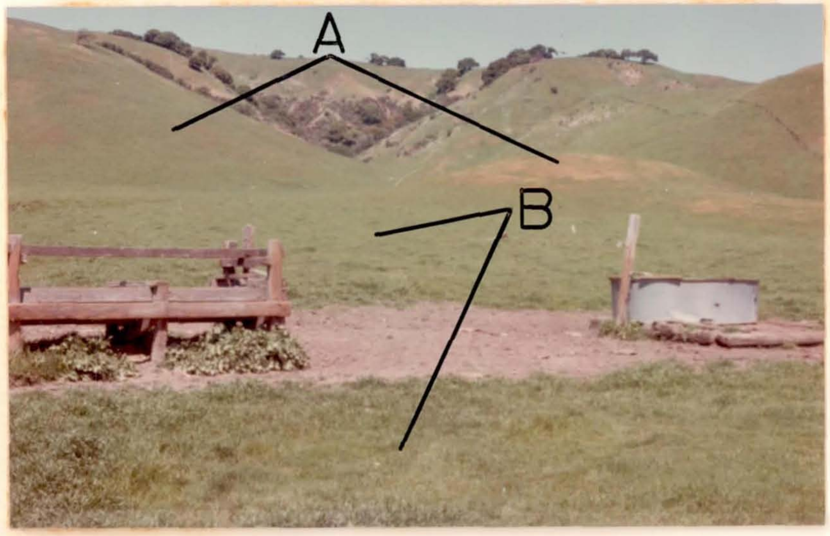
b) Aerographic Infrared Wratten 89B filter

c) Ektacolor no filter



d) Ekta-Aero Infrared Wratten 12 filter

Figure 2. Aerial photographs of typical annual grassland range (approximate scale 1/16,000), taken near Pinole, California on April 27, 1966. Imagery obtained at this season of the year permits the interpreter to differentiate between (A) dry grass and forbs growing on shallow, upland soils, (B) partially dried grasses and forbs growing on slightly deeper soils along gentle slopes, and (C) green, vigorous grasses and forbs growing on deep, bottomland soil. Note the ease of detecting available water for livestock at (D) on photos (b) and (d), and of using tone signature to differentiate these water bodies from the freshly-cultivated field at (E). Differences in intensity of utilization are seen at (F). Brush and low-growing trees compete with annual grasses and forbs along canyon slopes and bottoms at (G). The ground photos seen in Figures 3,4,5,6,7, and 8 were taken of the 2 areas indicated on photo (c).



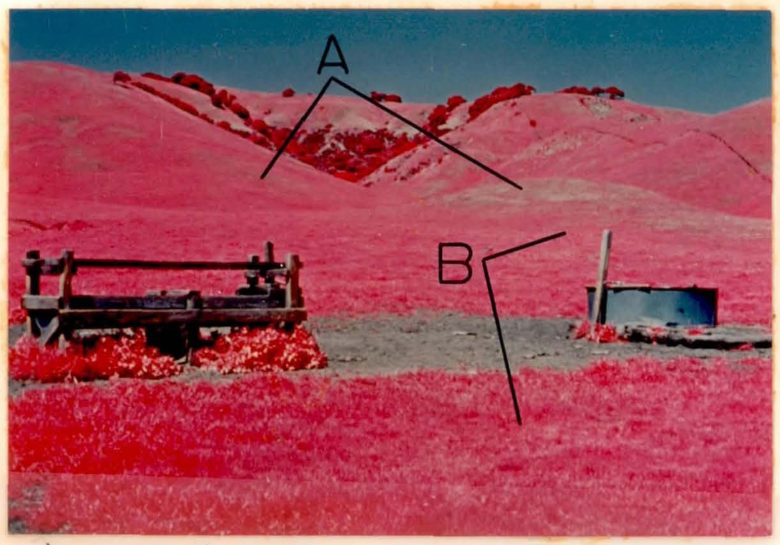
a) April 14, 1966

b) April 27, 1966

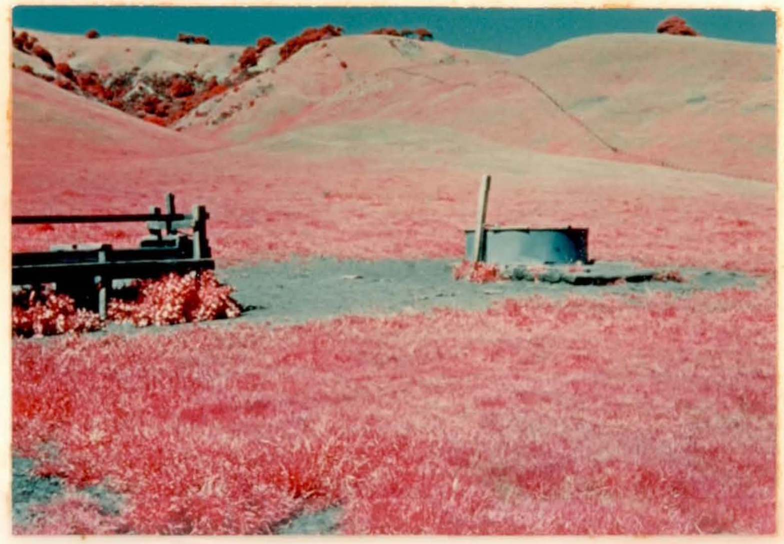
c) May 23, 1966

d) August 17, 1966

Figure 3. Sequential Kodacolor ground photographs of annual grassland range near Pinole, California (see area no. 1, Figure 2c) which illustrates the development and drying of annual vegetation on various sites. Note the sparse vegetation on shallow, upland sites (A) dries much earlier in the season than the dense vegetation on deep, bottomland soils (B). Note also the thistles (C), Silybum marianum which invade and occupy the better sites and compete with the annual grasses for moisture and space.



a) April 14, 1966



b) April 27, 1966

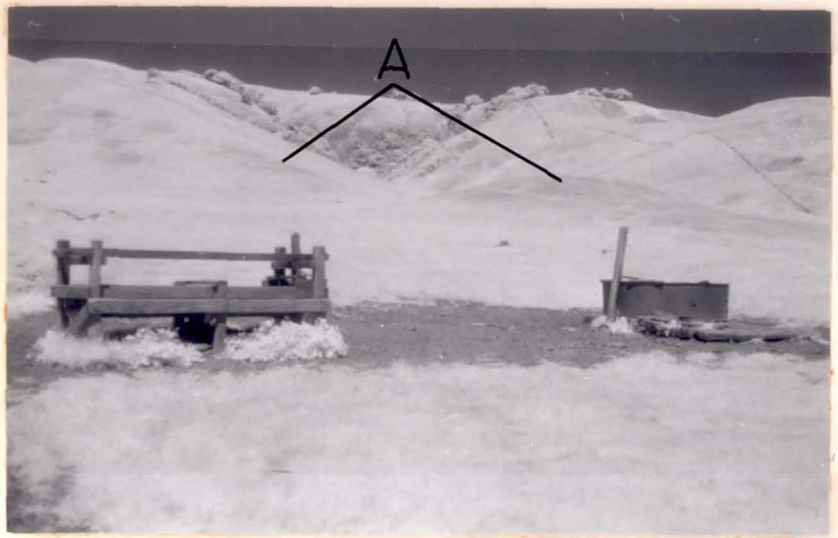
c) May 23, 1966

d) August 17, 1966

Figure 4. Sequential Ekta-Aero Infrared photographs of annual rangeland near Pinole, California (see area no. 1, Figure 2c). Note the change of tone over time and compare the tones and color differences between (A) shallow upland site, (B) dense vegetation on bottomland soils, and (C) milk thistles on bottomland sites.

a) Panchromatic April 14, 1966

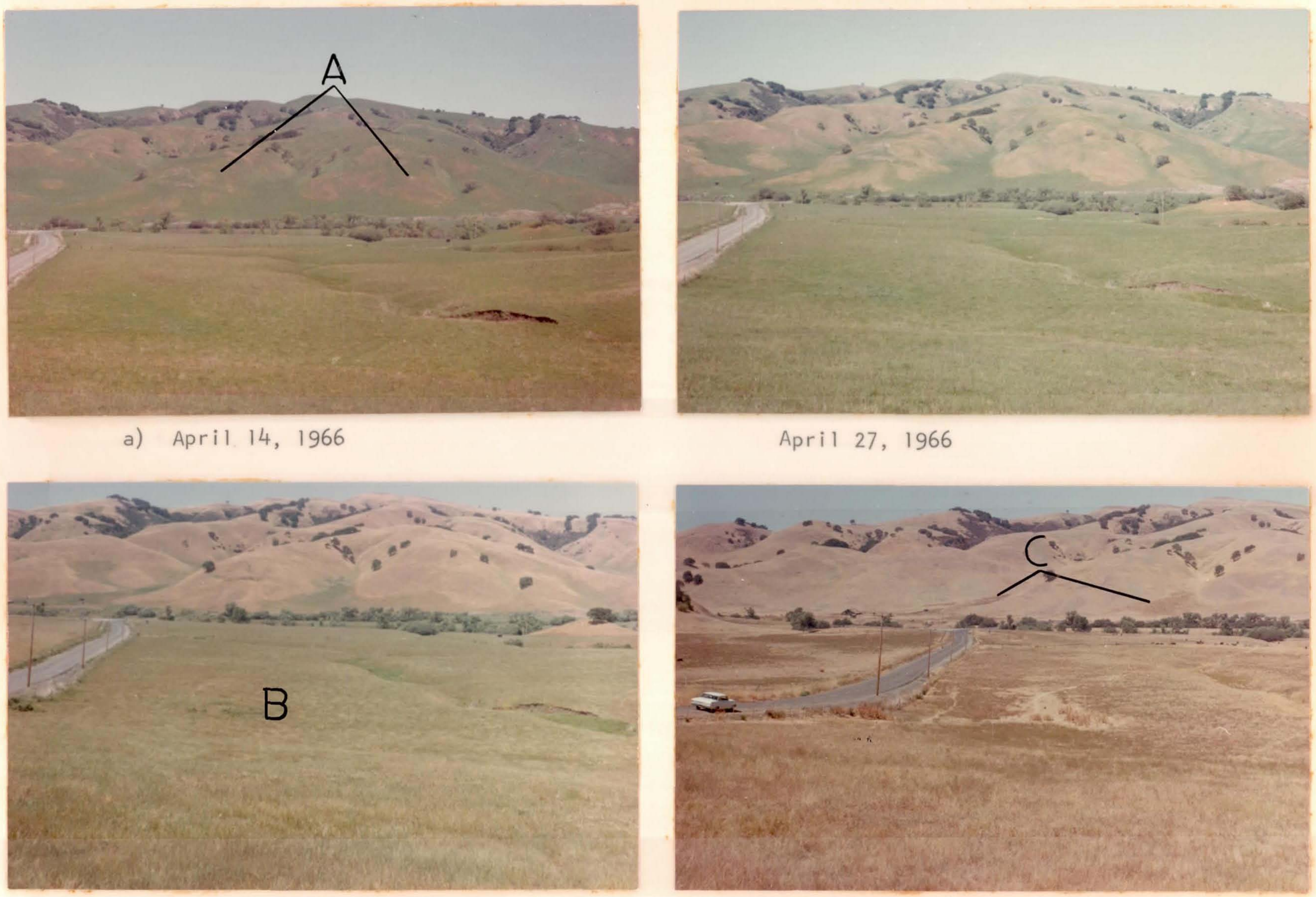
b) Panchromatic August 17, 1966



c) Infrared April 14, 1966

d) Infrared August 17, 1966

Figure 5. Panchromatic and near infrared photographs of annual grassland range near Pinole, California (see area no. 1, Figure 2c). Note the ease of detecting less vigorous vegetation on shallow upland sites (A) early in the season on near infrared imagery (photo c). Dark toned thistles (Silybum marianum) (C) are more readily detected on panchromatic imagery (photo b).



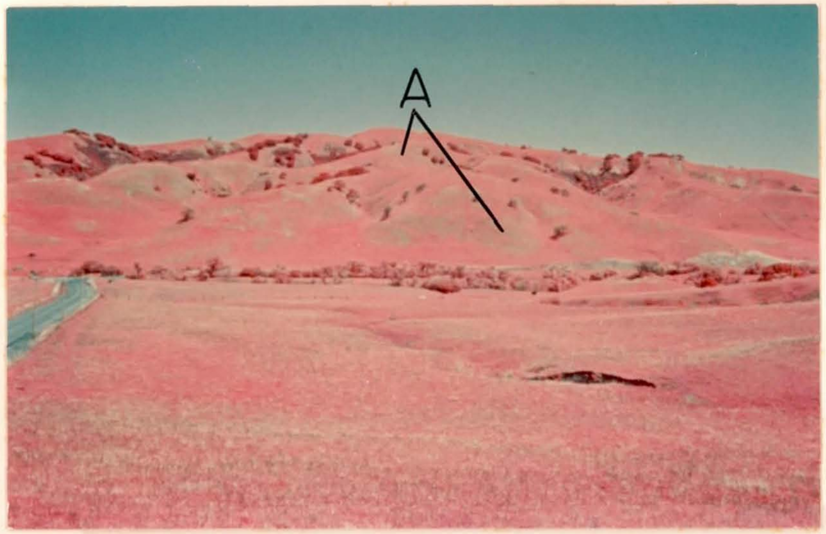
a) April 14, 1966

April 27, 1966

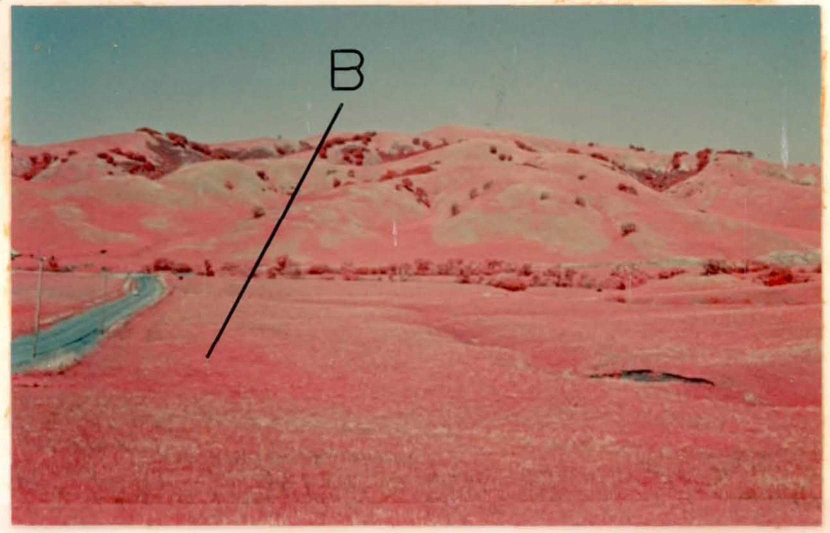
c) May 23, 1966

d) August 17, 1966

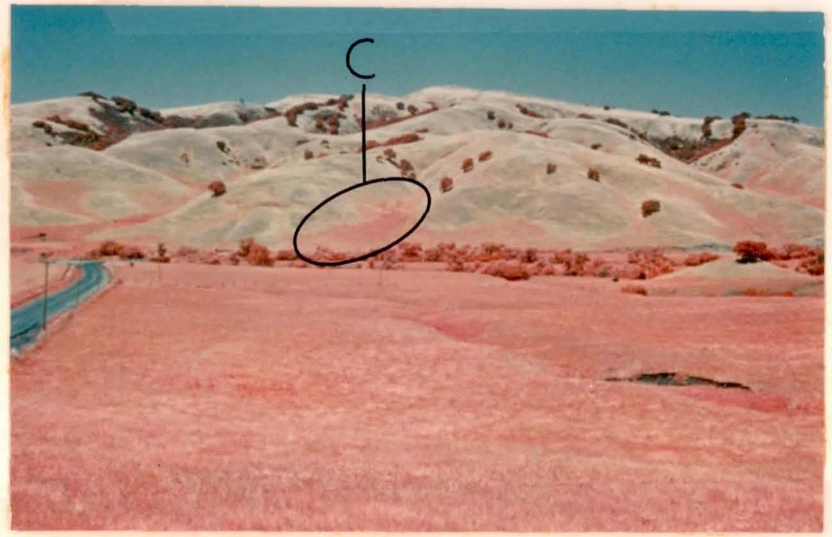
Figure 6. Sequential Kodacolor photographs of typical annual grassland range near Pinole, California (see area no. 2, Figure 2c). Note the change in tone of upland sites (A) as the sparse vegetation dries during the season. Note how much longer the dense vegetation on bottomland sites (B) remains green. Note the ease of detecting milk thistles (C) which invade and occupy the better sites and compete with grasses for moisture and space.



a) April 14, 1966



b) April 27, 1966



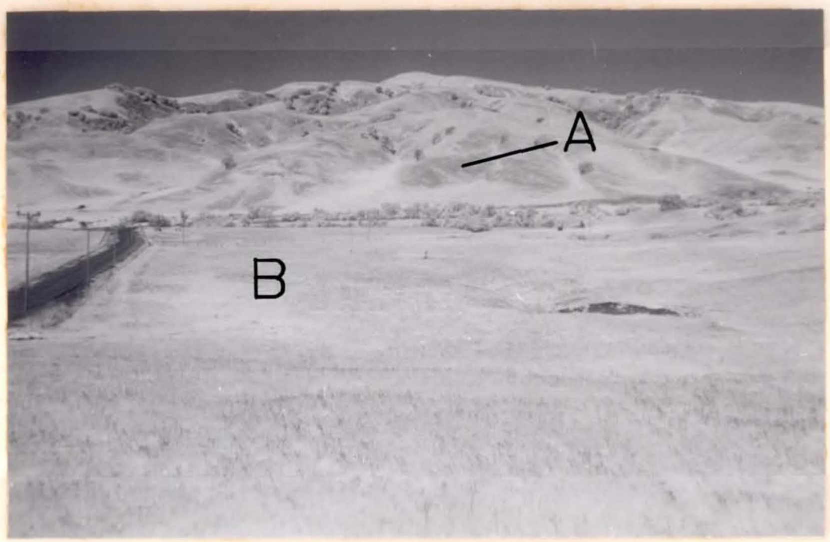
c) May 23, 1966

d) August 17, 1961

Figure 7. Sequential Ekta-Aero Infrared photographs of annual rangeland near Pinole, California (see area no. 2, Figure 2c). Note the changing tones of upland sites (A) having sparse vegetation which dries earlier in the season. Vegetation on bottomland sites (B) remains green for a longer period. Contrast the ease of detecting milk thistle (C) on photos (c) and (d).

a) Panchromatic April 14, 1966

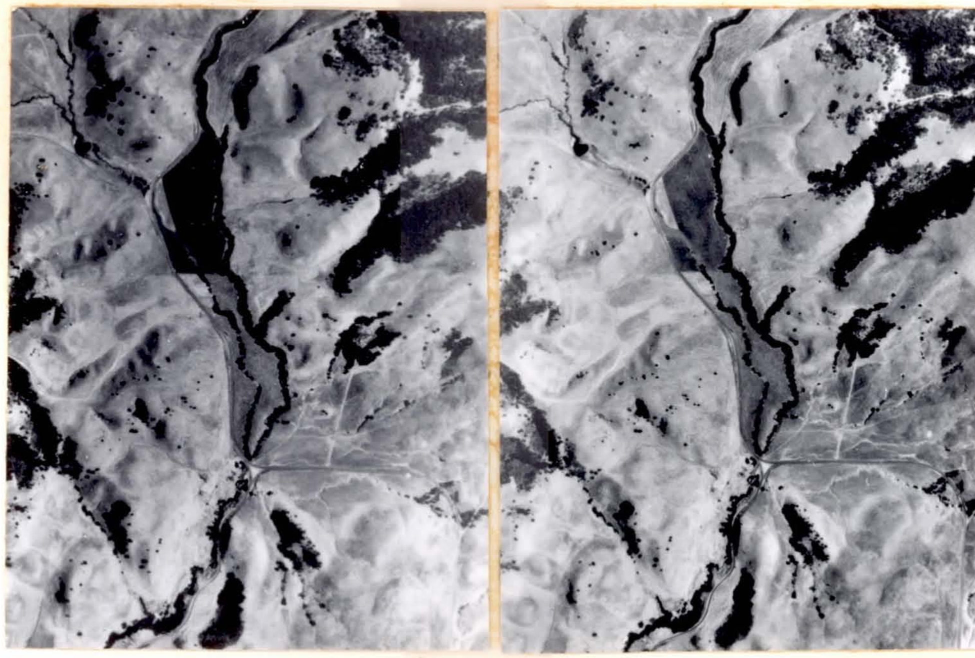
b) Panchromatic August 17, 1966



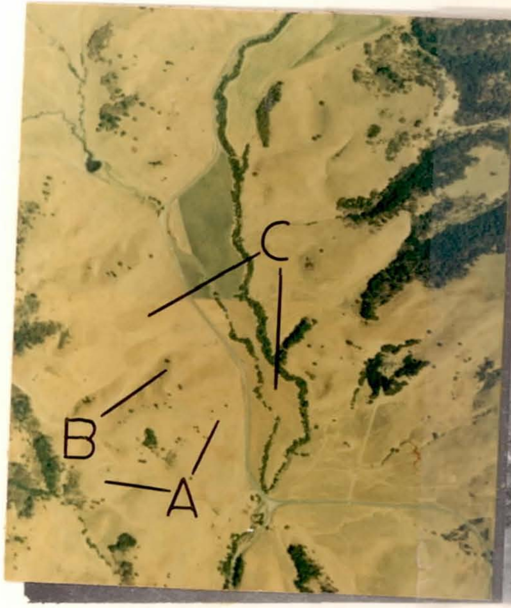
c) Infrared April 14, 1966

d) Infrared August 17, 1966

Figure 8. Panchromatic and near infrared photographs (see area no. 2, Figure 2c) of annual rangeland near Pinole, California. Compare the ease of differentiating between shallow upland sites (A) and deeper bottomland sites (B) on near infrared imagery (photo c). Note the ease of detecting milk thistle (C) on panchromatic imagery (photo b) late in the season.

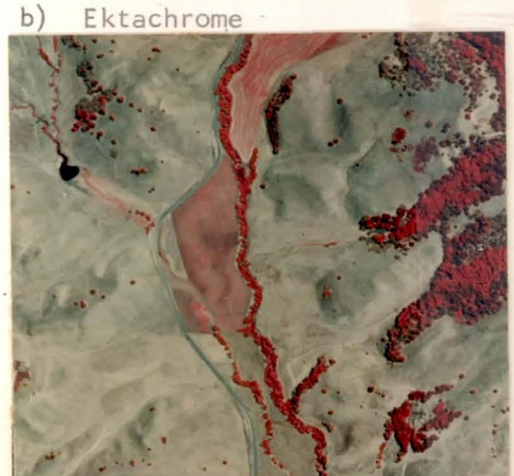


a) Panchromatic stereo pair



b) Ektachrome

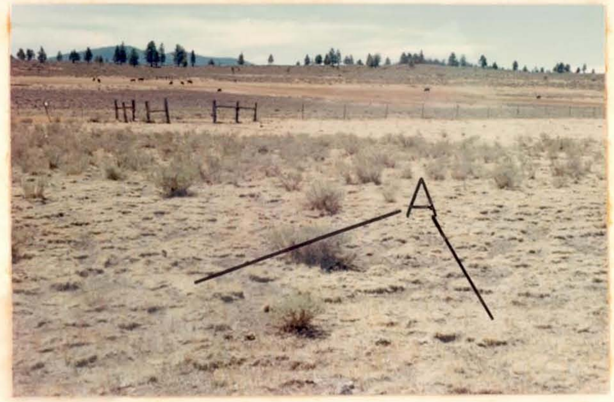
c) Aerographic Infrared



d) Ekta-Aero Infrared

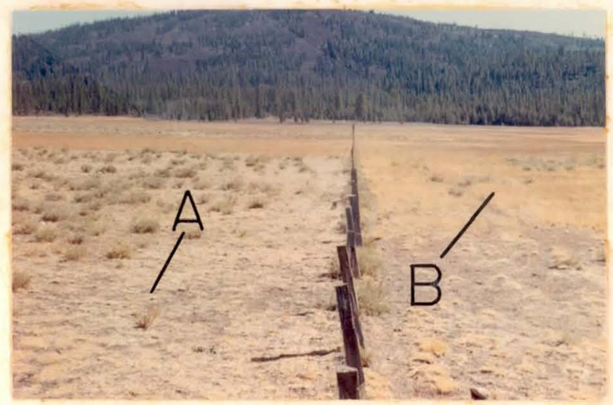
Figure 9. High altitude aerial photographs (scale about 1/35,000) of annual rangeland near Pinole, California, taken August 28, 1966. Note the dryness of vegetation on all sites at this time of year, making it difficult to accurately differentiate between important site conditions. Compare the tones or colors of (A) upland sites, (B) gentle slope sites and (C) bottomland sites, on this August imagery with imagery obtained in April (Figure 2). Also note the ease of differentiating between rangeland conditions on the April imagery.

a) Kodacolor May 18, 1966



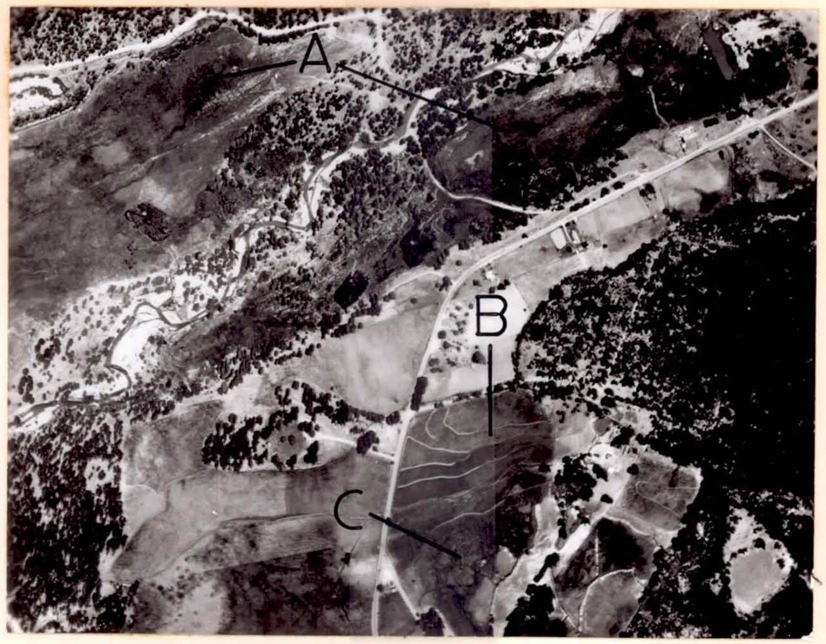
b) Kodachrome II July 20, 1966

c) Kodacolor May 18, 1966

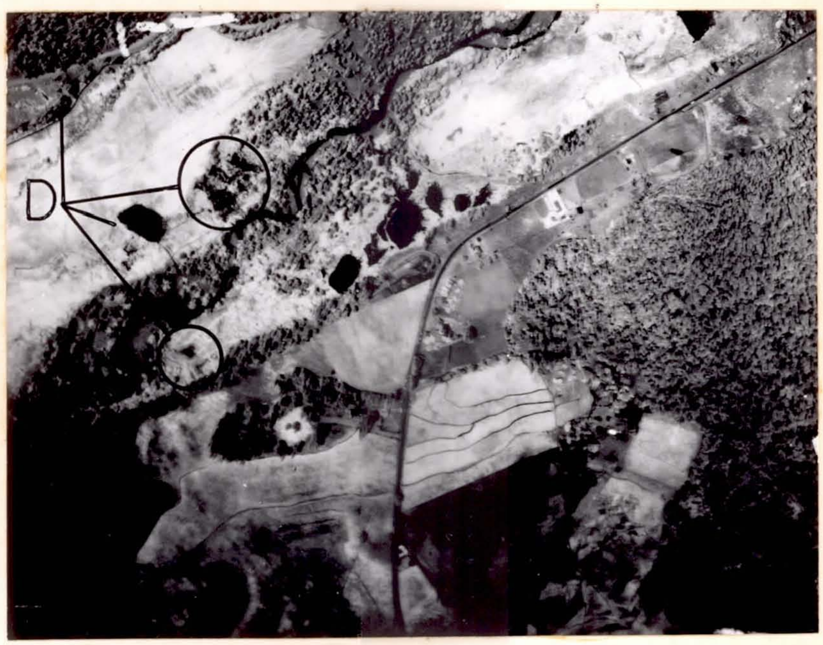


d) Kodachrome II July 20, 1966

Figure 10. Color ground photographs of perennial rangeland in Harvey Valley. Photos (a) and (c) were taken in May before cattle grazing and while the vegetation was yet green and vigorous. Photos (b) and (d) were taken in late July when the vegetation was considerably drier. Note the heavy utilization of the bunch grass, Poa nevadensis (A) and the unutilized forage in an adjacent ungrazed holding pen (B).

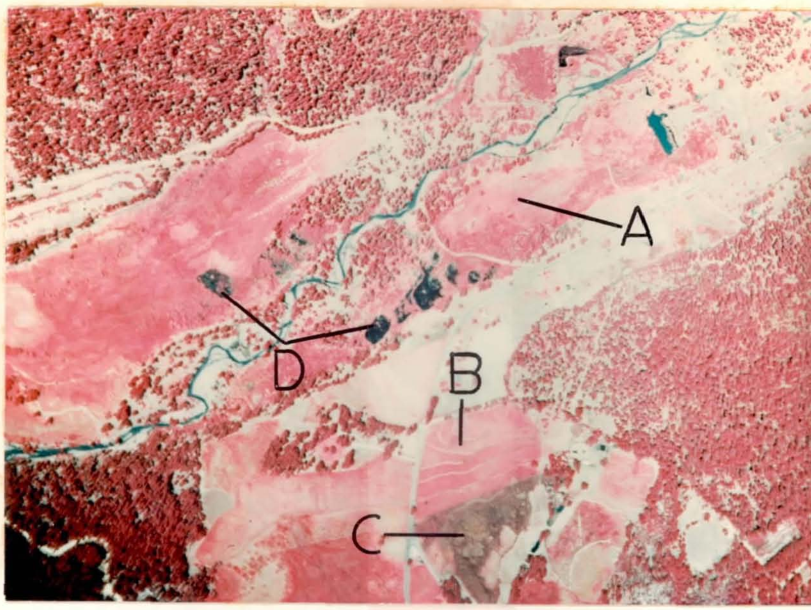


a) Panchromatic Scale 1/10,000 June 5, 1966



b) Aerographic Infrared Scale 1/10,000 June 4, 1966

Figure 11. Panchromatic and Aerographic Infrared (89B filter) aerial photographs of primary perennial range at Meadow Valley, California. Note the ease of detecting dense, lush wet meadow vegetation (A) on the infrared photo. A forage crop of alfalfa, clover and grasses (B), presently being irrigated, can readily be differentiated from the adjacent pasture (C) which remains saturated throughout the grazing season due to irrigation run-off and a high water table. Note the ease of detecting water holes, ponds, or streams (D) which may provide a potential source of irrigation water or drinking water for livestock.

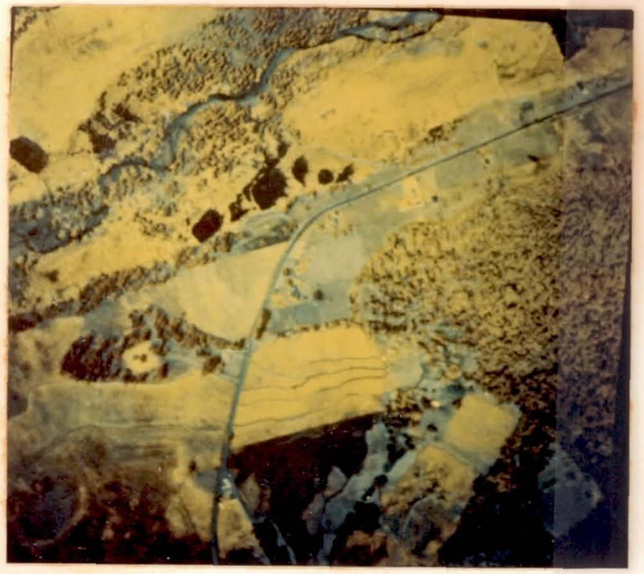


a) Ekta-Aero Infrared Scale 1/10,000 June 4, 1965

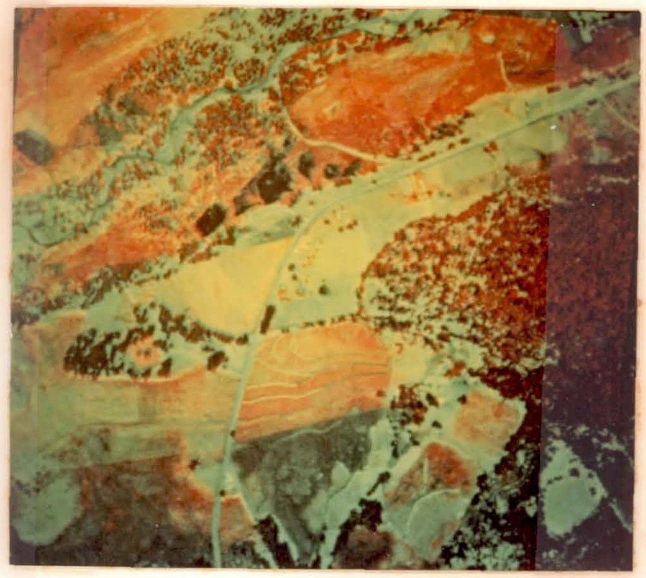
b) Ektachrome Scale 1/30,000

c) Ekta-Aero Infrared Scale 1/39,000

Figure 12. Photo (a) is Ekta-Aero Infrared imagery illustrating the ease of detecting lush, wet meadow vegetation at (A), forage crop of alfalfa, clover and grasses (B), saturated pasture at (C) and ponds and stream at (D). Photos (b) and (c) are small scale Ektachrome and Ekta-Aero Infrared images, respectively, taken June 11, 1966. Note that at this small scale all of the range features listed above are quite detectable in photo(c). Greater difficulty is encountered in distinguishing between saturated meadows (C), ponds or bogs (D), and a dense forage crop (B) in photo (b). Note the light reflectance from standing water in the saturated meadows (C) in photo (c). Across the valley an irrigated pasture can be seen at W, saturated meadow conditions at X, moist, yet drained site at Y, and dry xeric conditions at Z. The range outlined in photo (b) (lower) supports 70-110 head of cattle for a 4 to 6 month period beginning in May, depending upon the condition of the range.



a)



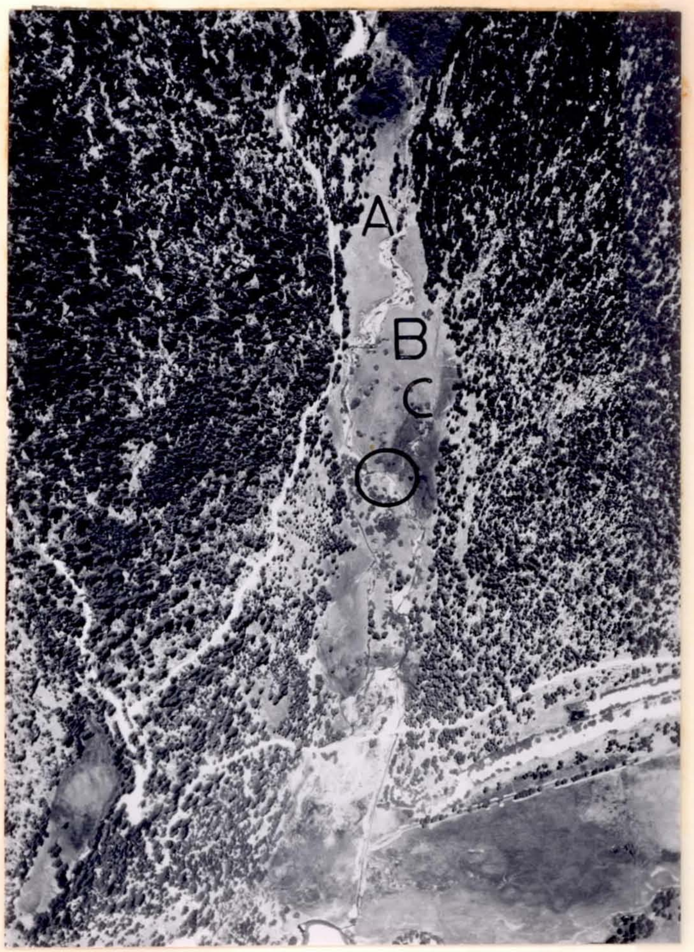
b)

c) May 23, 1965

d) June 4, 1965

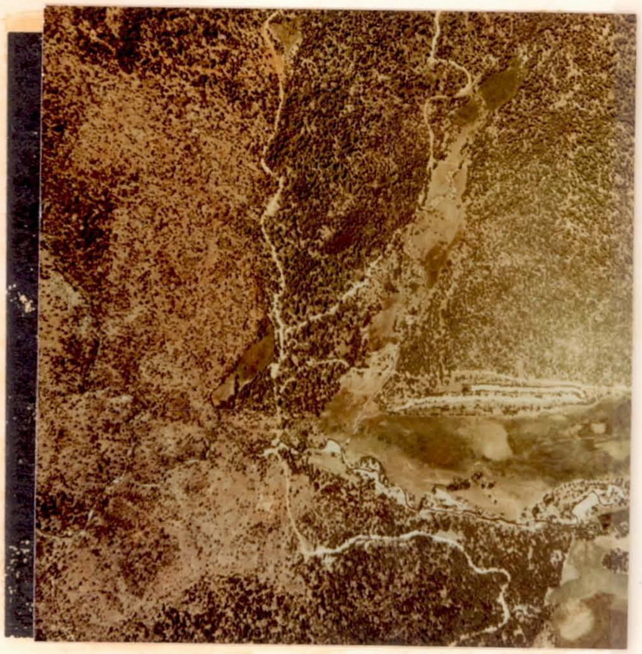
e) July, 1965 First cutting

Figure 13. Photos (a) and (b) are color enhanced photographs of meadow rangeland seen in Figures 11 and 12. They were made by superimposing panchromatic and aerographic infrared positive transparencies with various colored filters upon a screen. Photo (a) was made by placing an ochre filter (Wratten 90) over the infrared transparency and a turquoise filter (Wratten 75) over the panchromatic transparency. Photo (b) is a combination of a dark red filter (Wratten 70) over the infrared and a green (Wratten 74) filter over the panchromatic transparency. Photos (c) and (e) are ground shots of the forage crop (B) seen in Figure 11. Photo (d) is a ground shot showing the rushes which occupy the very moist or saturated sites in field (C), Figure 11.

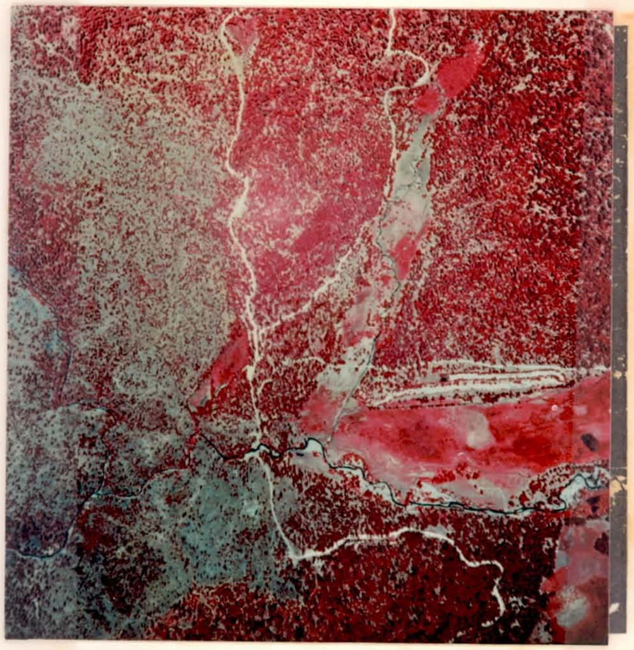


a) Panchromatic Scale 1/10,000

b) Aerographic Infrared Scale 1/10,000



c) Ektachrome Scale 1/30,000



d) Ekta-Aero Infrared Scale 1/30,000

Figure 14. Aerial photographs of various range conditons along Little Schneider Meadow, Bucks Lake Test Site. Note the ease of distinguishing between gravelly soil, supporting only annual grasses and forbs (A), and nearly pure Kentucky blue grass (B) on Infrared photo (b). Dense lush vegetation on moist sites (C) and (F) is readily seen in photos (b) and (d). Corn lily (Veratrum californicum), a poisonous plant for livestock, is found growing on moist sites in and around the willow clump at (D). Area (E) is a community of rushes, sedges, grasses and forbs. Note the channel erosion occurring between areas (A) and (B) and along the bank(circled) below Type C. Early detection and correction of erosion may save valuable range vegetation and soil from complete deterioration.

a) April 24, 1966

b) May 20, 1966

c) September 2, 1966

Figure 15. Sequential Kodacolor ground photographs of bank channel erosion in Little Schneider Meadow, Bucks Lake test site. (See Figure 14 for aerial view.) Note the change in density and vigor of the meadow vegetation, and the change in quantity of water draining from the meadow at the various dates.

a)

b)

c)

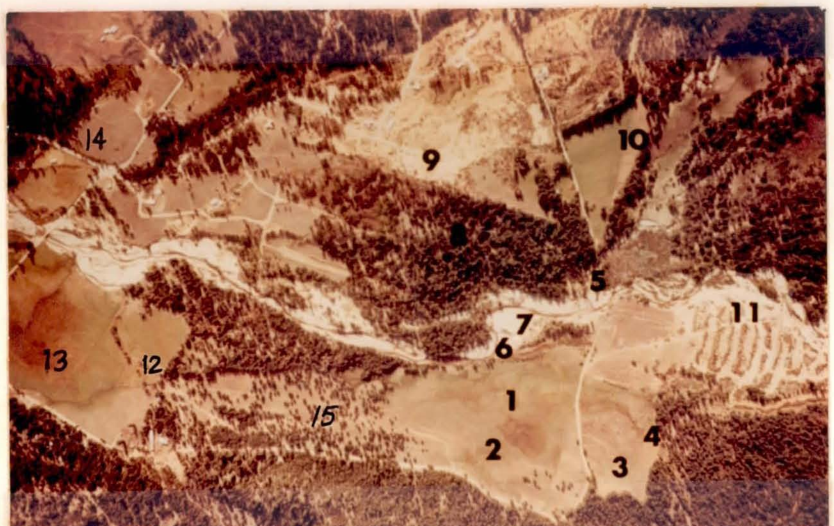
d)

e)

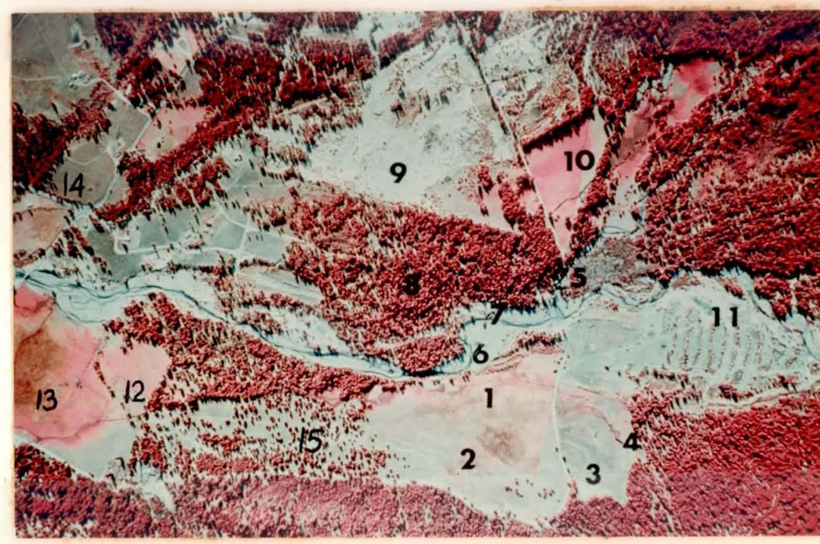
Figure 16. Kodacolor ground photographs of range types found in Little Schneider Meadow, Bucks Lake test site. Photo (a) shows corn lily growing around and within a dense clump of willow. This is area (D), Figure 14. Photo (b) is gravelly soil, supporting only annual grasses and forbs (area (A), Figure 14). Photo (c) shows the rushes, grasses, and forbs corresponding to area (E) in Figure 14. Photo (d) shows a nearly pure community of Kentucky blue grass (area (B) in Figure 14). Photo (e) shows a pure sedge community growing on a moist site (area (F) on Figure 14).

a) Panchromatic minus-blue filter

b) Aerographic Infrared Wratten 89B filter

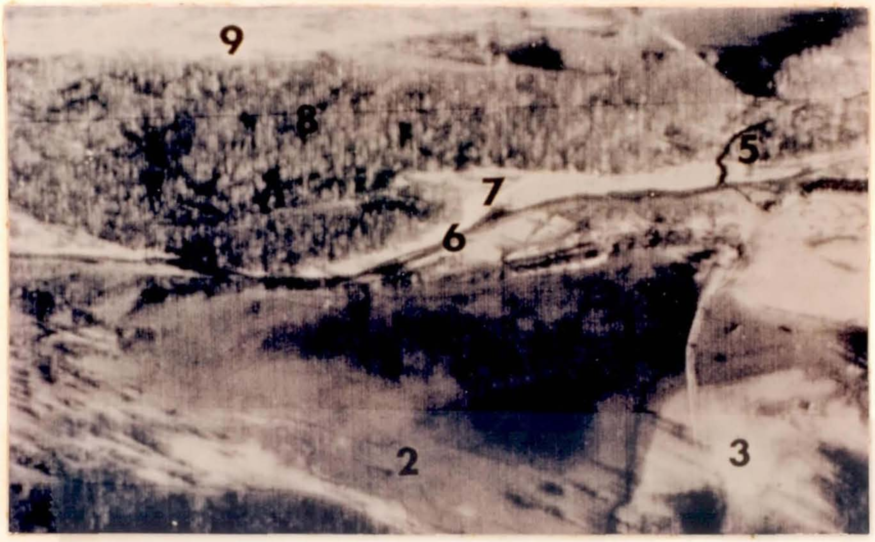


c) Ektachrome

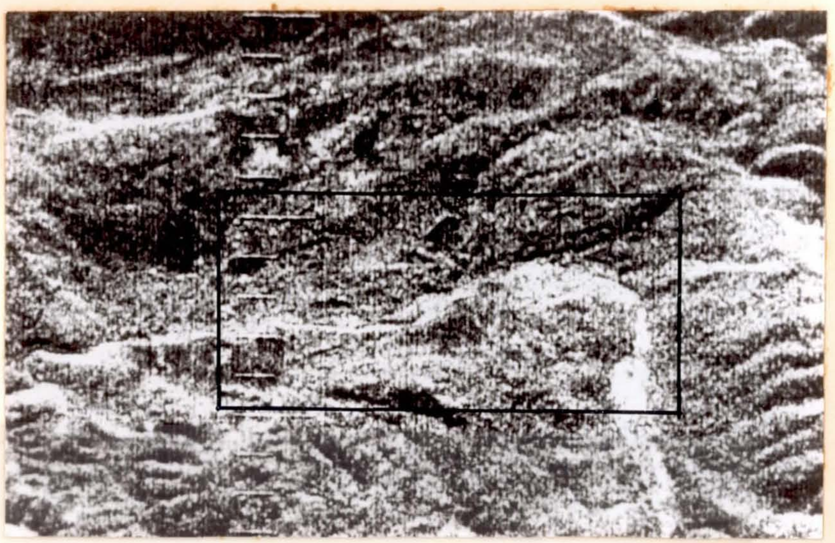


d) Ekta-Aero Infrared Wratten 12 filter

Figure 17. High altitude aerial photographs (scale 1/10,000) of pasture and rangeland in Meadow Valley, California; Bucks Lake test site, taken September 26, 1965. Note the ease of detecting the pastures (10) and other fields (12) on photos (b) and (d), which at this time of year are still green and vigorous due to periodic irrigation or high water table. Poorly drained sites (1 and 14) support a distinct community of rushes and sedges and are best identified by their peculiar color on photos (c) and (d). Well-drained or gravelly soils (3) lack sufficient moisture to maintain the vigor of annual grasses, forbs or perennials which dry early in the season. Note that ponderosa pine (Pinus ponderosa) has invaded on the well-drained sites (15) thereby lowering the water table and reducing the available moisture for forage.

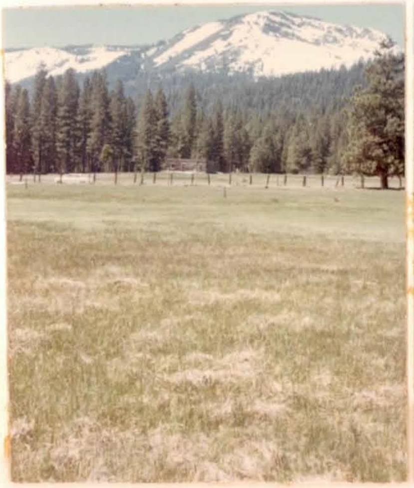


e) Thermal Infrared image (8 to 14 microns) Late summer .



f) Radar image (1 to 3 cms.) Late summer

Figure 17 (cont.) Thermal infrared and micro wave imagery of the area seen in Figure 17 a,b,c, and d. Note the ease of detecting the poorly drained site (1), the moist site (2) and the well-drained or gravelly site (3) on the thermal infrared image. A natural spring, seen at (4) on photos (c) and (d), can also be seen in photo (e). Although the quality of microwave imagery does not permit detailed mapping of various range conditions, the gross boundaries of areas that may provide forage for livestock or wildlife can be drawn. The area within the inked box (photo (f)) corresponds to the area seen in Figure 17a,b,c, and d.



a) April 24, 1966

b) May 20, 1966

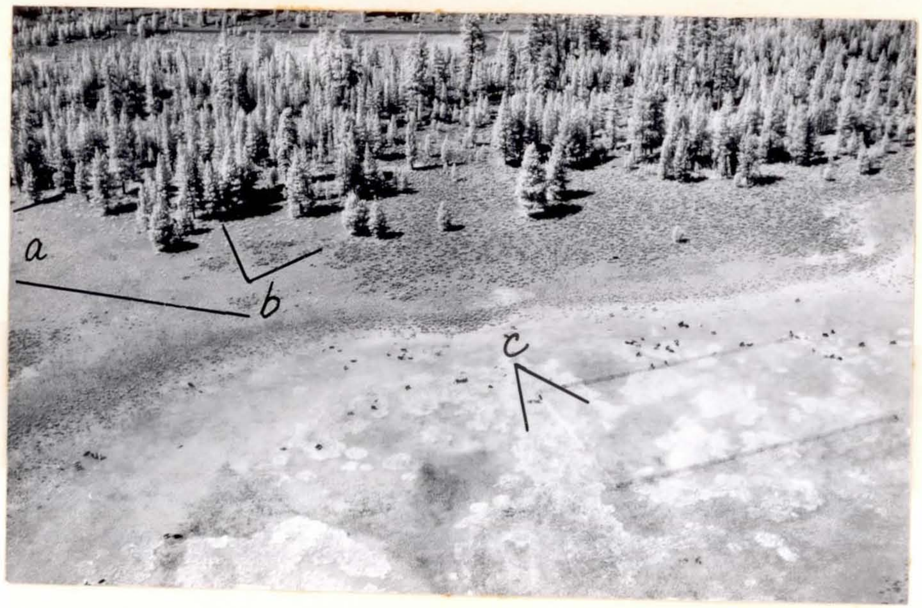
c) September 2, 1966

Figure 18. Kodacolor ground photographs of a sedge-rush-forbs community on a poorly drained site (1), and grasses, clover and forbs growing on a moist site (2). The corresponding aerial view of these plant communities is labelled 1 and 2 in Figure 17.

a)

b)

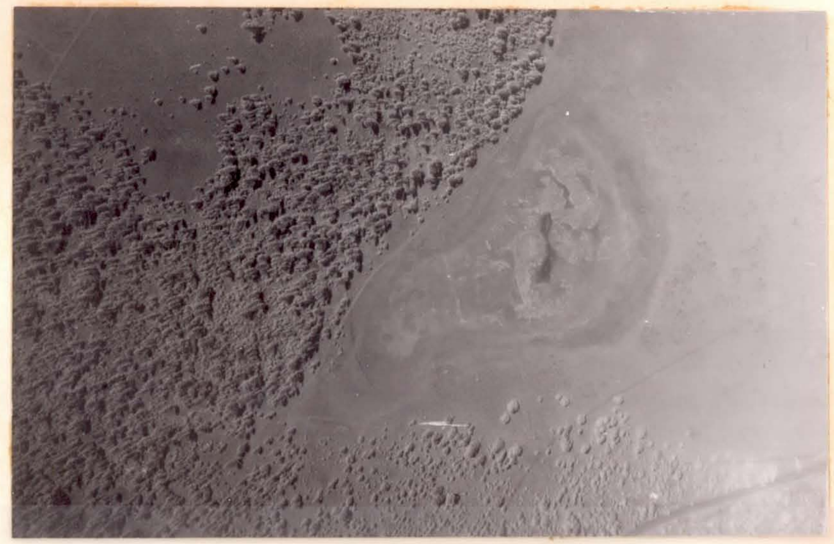
c)



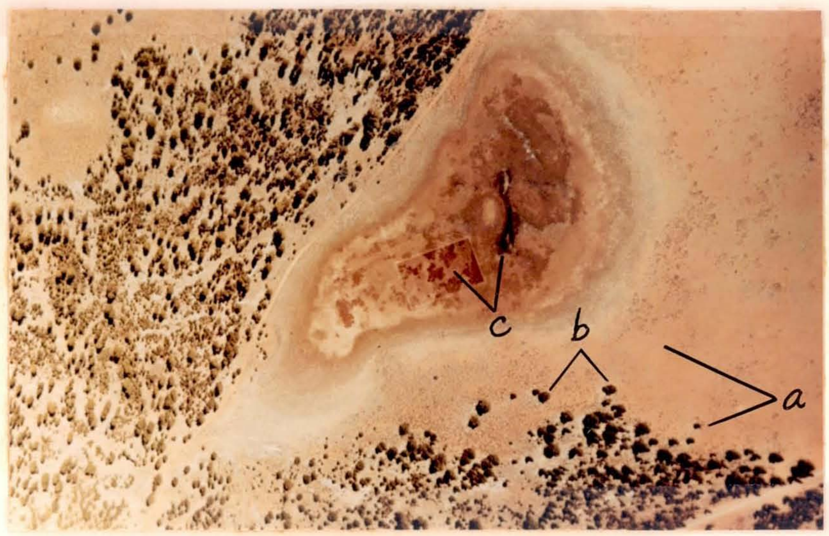
d) Aerographic Infrared 89B filter Scale 1/1500

Figure 19. Photos (a), (b), and (c) are Kodacolor ground shots of three important plant communities found within the Harvey Valley Experimental Range, Lassen National Forest, California. The ground position of each plant community is indicated on the Infrared aerial photograph (photo (d)). Note that many of the larger bunch grasses (Stipa occidentalis) in photo (a) can be seen as very small white blobs on photo (d). Bitter brush (Purshia tridentata, dark green brush), and Big Sagebrush (Artemisia tridentata, gray-green brush) in foreground (photo (b)) are imaged as white and dark gray blobs respectively in photo (d). The exclosure (C) was erected to measure herbage production of the two plant communities contained within, and to observe the degree of utilization which these plant communities receive from intensive grazing during a two month period from June through July.

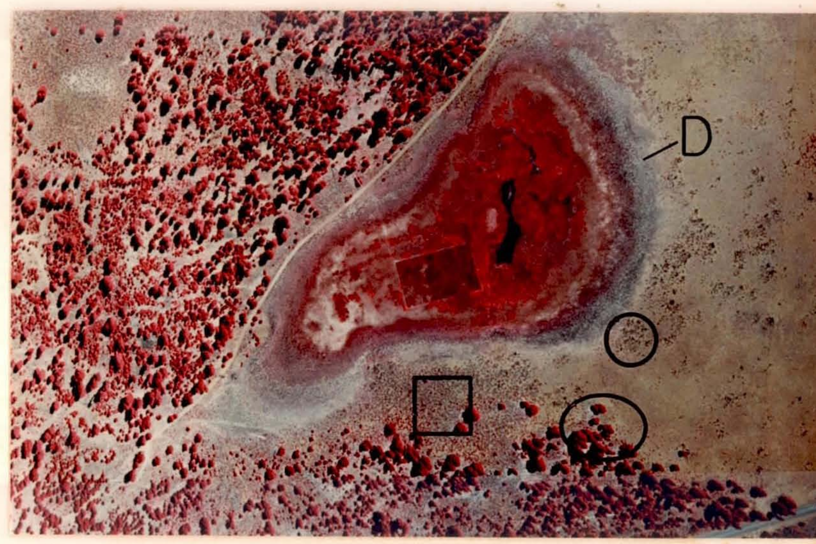
a) Panchromatic



b) Aerographic Infrared



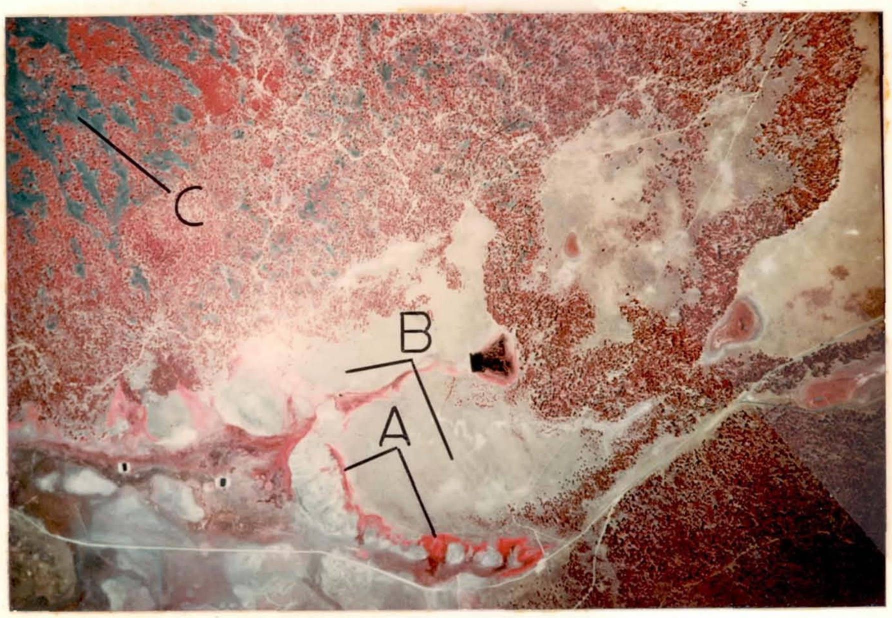
c) Ektachrome



d) Ekta-Aero Infrared

Figure 20. Aerial photographs (scale 1/8500) of a portion of the Harvey Valley Experimental Range. Note that it is still possible to differentiate between Big Sage (circled) and Bitterbrush (small red blobs within oval) and mixed Big Sage and Bitterbrush (square) on color infrared film(photo (d)). Note the difficulty of making a clear-cut distinction between these two brush species on the other film types. The portions of ground shots in Figure 19a, b, and c are indicated by carets in photo (c) above. Several distinct plant communities align themselves in bands around the intermittent lake. Observe the blue-gray band (photo (d)) indicative of a Silver Sage community (D) (<u>Artemisia cana</u>) growing among volcanic rocks which cover 25-40% of the surface.

a) Ektachrome Scale 1/27,500

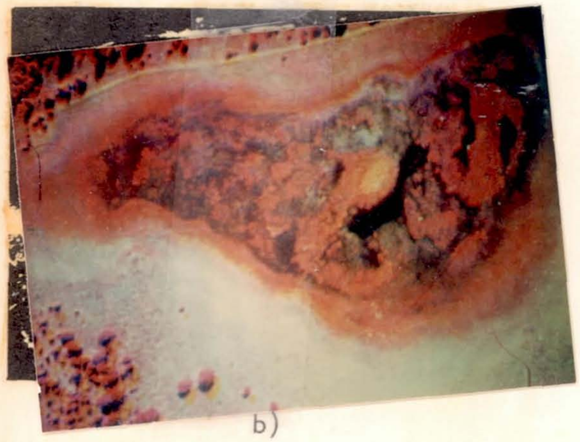


b) Ekta-Aero Infrared Scale 1/27,500

Figure 21. Small scale imagery of typical rangeland in Harvey Valley Experimental Range. Primary (A), secondary (B) and unsuitable (volcanic rock, C), range are readily detected and mapped on either of the photos above. Dense Big Sage communities (D) are barely discernible on photo (a) but are differentiable from open grassland (E) and dense bitter brush communities at F. Compare the resolution of the larger scale examples in Figures 20, 23, 24, and 26 with their corresponding areas above.

Spectral band (microns)	Projection Filter
.40 - .42	Wratten 70 (dark red)
.63 - .69	Wratten 50 (dark blue)
.78 - 1.2	Wratten 99 (green)

a)



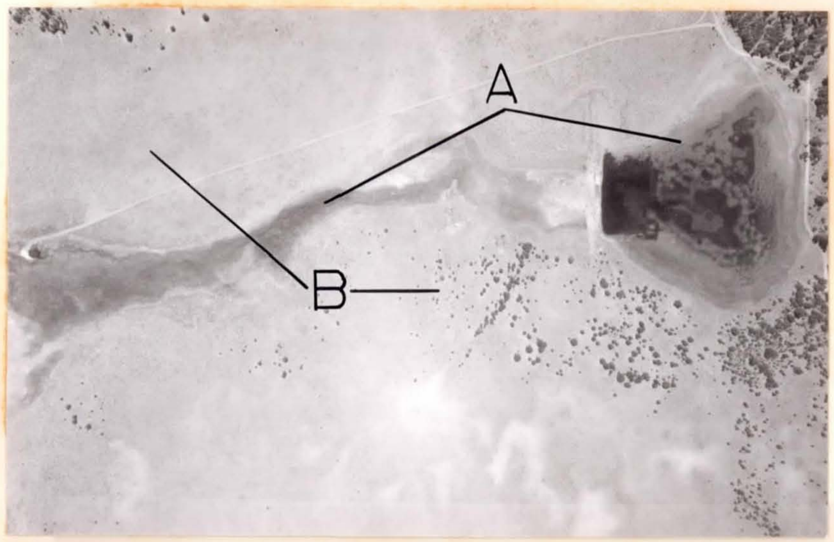
Spectral band (microns)	Projection Filter
.40 - .42	Wratten 99 (green)
.63 - .69	Wratten 50 (dark blue)
.78 - 1.2	Wratten 70 (dark red)

b)

Spectral band (microns)	Projection Filter
.40 - .42	Wratten 72B (burnt orange)
.63 - .69	Wratten 74 (green)
.78 - 1.2	Wratten 50 (dark blue)

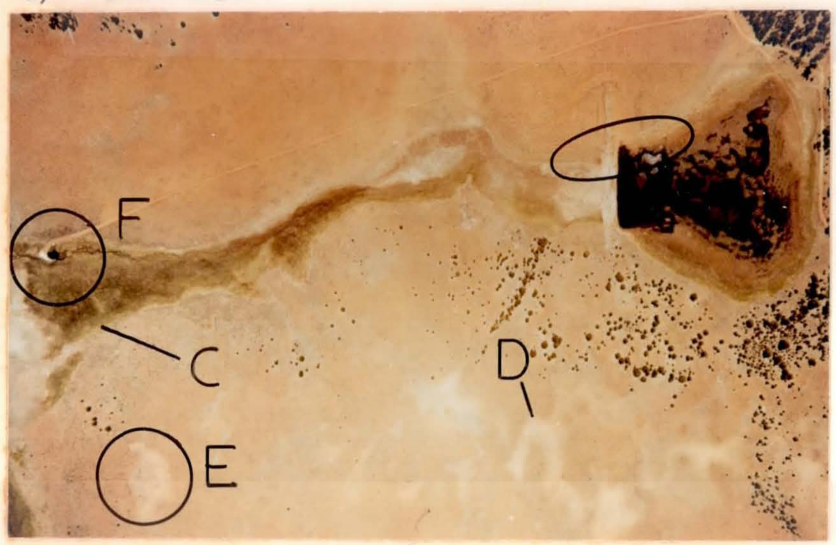
c)

Figure 22. Color enhanced photographs of a dry, intermittent lake in Harvey Valley; see Figure 20. Each of the above photos was made by projecting three positive transparencies through colored filters; see specifications above. The spectral bands projected for color enhancement were three of sixteen channels obtained by a multi-lens camera. Notice that all of the various vegetative, soil, and moisture conditions seen in Figure 20d have been reconstituted above.

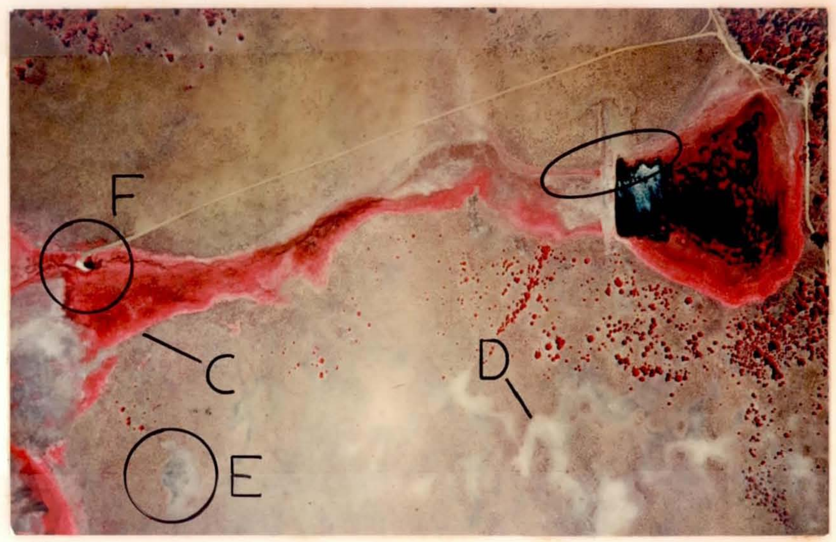


a) Panchromatic

b) Aerographic Infrared



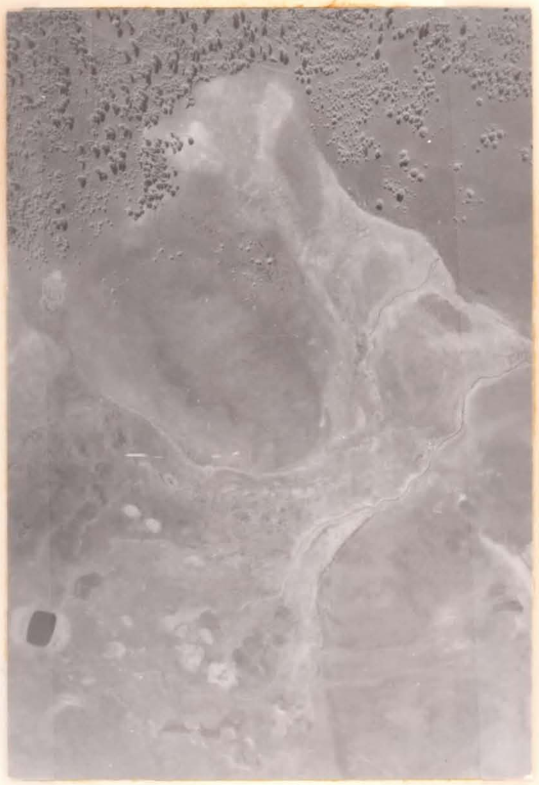
c) Ektachrome



d) Ekta-Aero Infrared

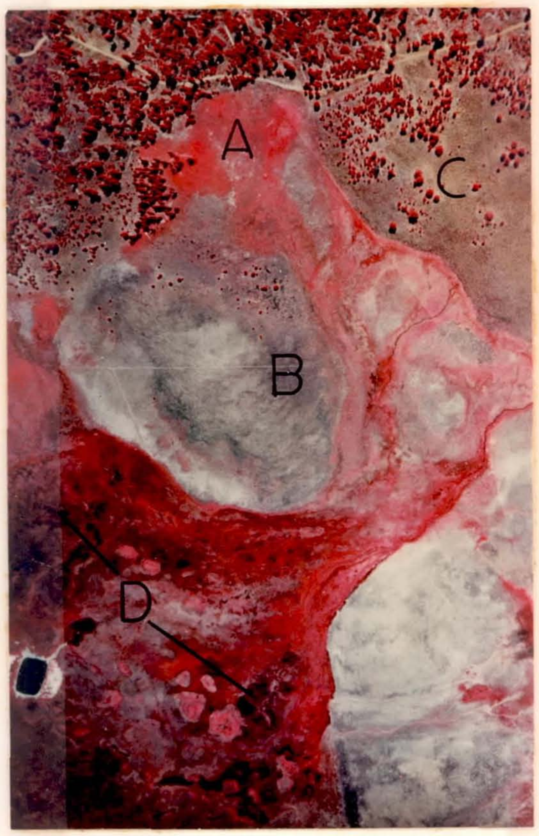
Figure 23. Aerial photographs of primary (A) and secondary (B) range around White Horse Reservoir on Harvey Valley Experimental Range. Note the sharp boundary (ecotone) between the wet meadow and Big Sage community at (C), and the Big Sage (Artemisia tridentata) and Black Sage (Artemisia arbuscula) community at (D). Dark gray areas (E) are volcanic rock covering about 50% of the ground surface. Productivity on these rocky sites is very low. Many livestock (dark specks within oval) may be seen grazing near the reservoir. Natural springs and subsurface moisture (F) provide ample water to keep the meadow vegetation green and vigorous during most of the grazing season.

a) Panchromatic



b) Aerographic Infrared

c) Ektachrome



d) Ekta-Aero Infrared

Figure 24. Aerial photos (scale 1/8500) of various range sites in Harvey Valley. The deep red tones (photo (d)) are indicative of moist sites(A) which support dense, vigorous grasses, forbs, rushes and sedges. The dark gray tones (B) are indicative of a very rocky site, where Black Sage (<u>Artemisia</u> <u>arbuscula</u>) and <u>Poa</u> <u>secunda</u> are the dominant species. Productivity on these sites is very low relative to the wet meadow sites (A). The brownish tones at (C) are resultant from Big Sage and a reddish soil background. Productivity could be increased several fold by removing the overstory of Big Sage. The dark brownish-black mottled pattern ((D) on photo (d)) is characteristic of shallow water among or covering the wet meadow species. Grazing on these areas should be avoided until later in the season.

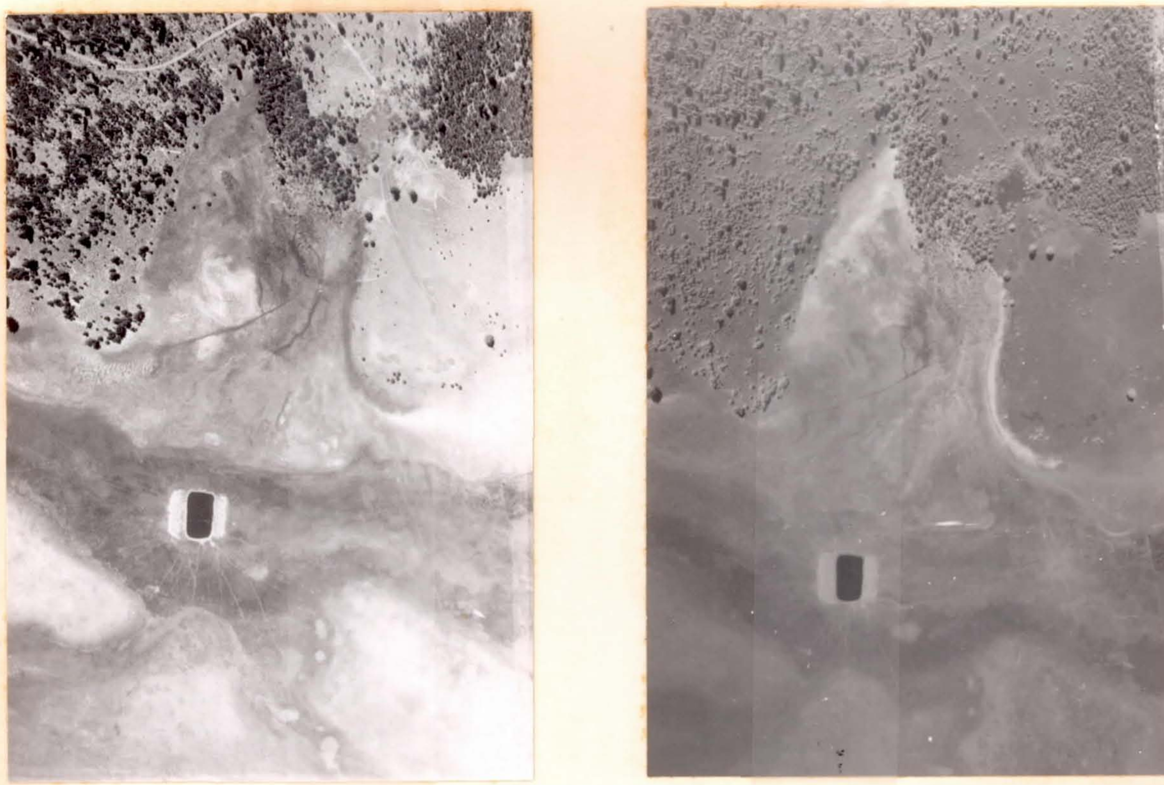
a) Big Sagebrush community

b) Rocky-Black Sagebrush type

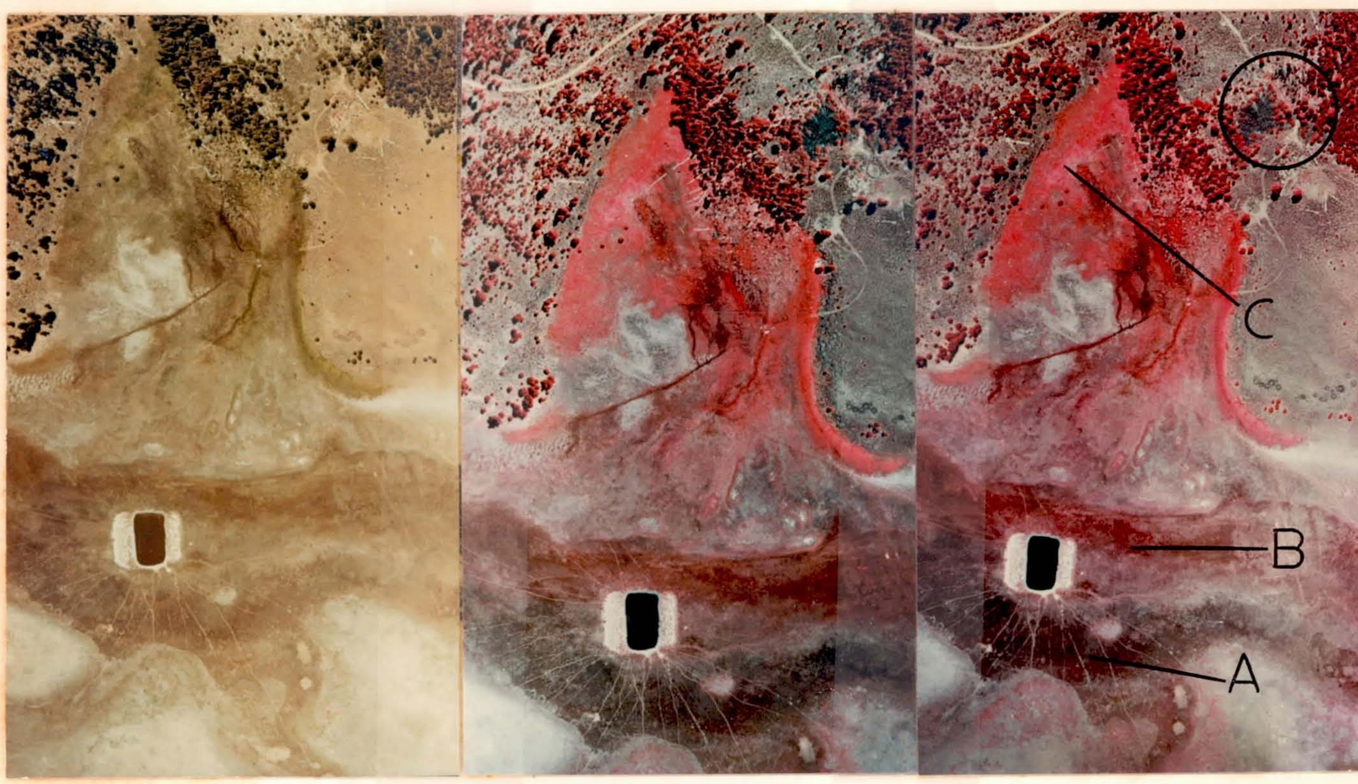
c) Volcanic basalt lava

d) Grazing at Whitehorse Reservoir

Figure 25. Kodacolor ground photographs of various terrain features found within Harvey Valley Experimental Range. Photo (a) shows a typical Big Sagebrush community growing on fairly deep (2-4 ft.) soils. Two of the most important grasses, (Idaho fescue, Festuca idahoensis, and Western needlegrass, Stipa occidentalis), found on this experimental allotment are common associates in this plant community. (For aerial view see type B in Figure 23). Photo (b) shows a very rocky site which gives rise to the dark texture seen in Figure 24d. Black sagebrush (Artemisia arbuscula) and Sandberg bluegrass (Poa secunda) are common associates on this type. Photo (c) shows the volcanic basalt lava which is so conspicuous in Figure 26d. Photo (d) shows a portion of the wet meadow vegetation (primary range) surrounding Whitehorse Reservoir. Note the sharp boundary between the meadow vegetation and the Big Sagebrush type in the foreground. The position of this photograph is indicated by a caret in Figure 23c.



a) Panchromatic b) Aerographic Infrared

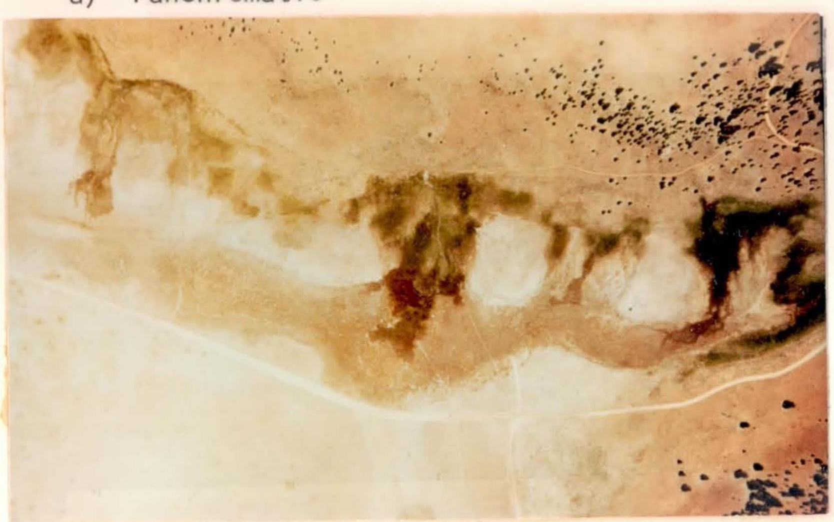


c) Ektachrome d) Ekta-Aero Infrared stereo pair June 11, 1966

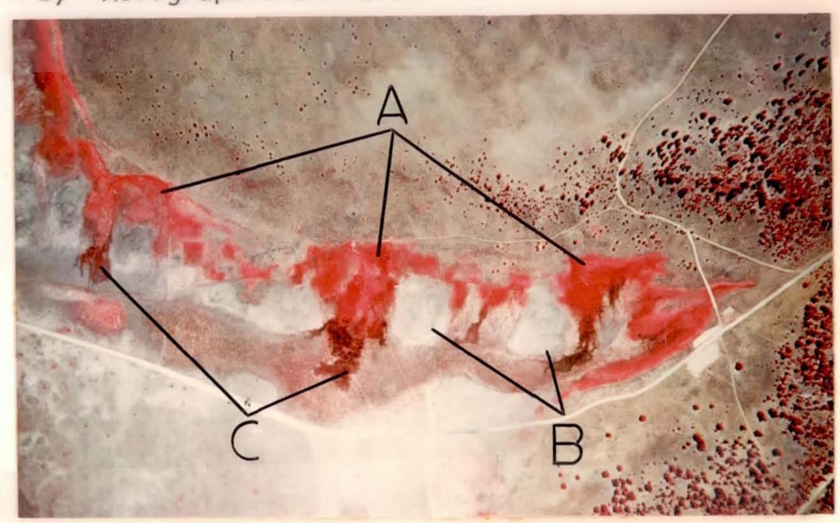
Figure 26. Aerial photos (scale 1/8500) of various range sites within the Harvey Valley Experimental Range. Note the ease of identifying distinct plant communities on photo (d). The dark toned area (A) is nearly pure rushes (Juncus balticus), area (B) is nearly pure sedge (carex sp.) and area (C) is wet meadow grasses, forbs, sedges and rushes. The dark brownish-black tones within the wet meadow are caused by standing water. Notice that the conspicuous lava rock, circled on photo (d), might go unnoticed on photos (a) and (c).

a) Panchromatic

b) Aerographic Infrared



c) Ektachrome



d) Ekta-Aero Infrared

Figure 27. Aerial photos (scale 1/10,000) of wet meadow sites (A) in the Harvey Valley Experimental Range. The natural springs and subsurface drainage, which create the moist sites, result from rainfall and snowmelt which percolate through lava rock on basalt lava cones adjacent to the Range. Interspersed between the moist sites are Black Sage sites (B) (Artemisia arbuscula) which are underlain by a clay hardpan. Productivity on these latter sites is relatively very low. The brown tones are indicative of standing water (C) in or among the meadow vegetation.

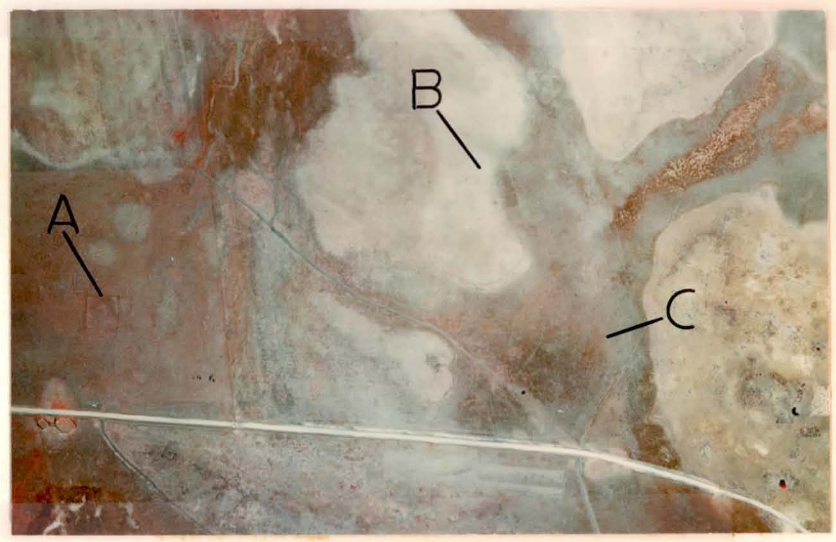
a) Ektachrome Scale 1/27,500 b) Ekta-Aero Infrared

Figure 28. High altitude photos (scale 1/27,500) of perennial range land in Harvey Valley. Although the land pattern may at first seem complex, the tones and textures of the various plant communities enable the interpreter to identify and map similar range sites. Note the ease with which the interpreter may recognize red, pinkish or lavender tones (photo (b)) as being indicative of available forage on any given site.

a) Panchromatic

b) Aerographic Infrared

c) Ektachrome June 11, 1966



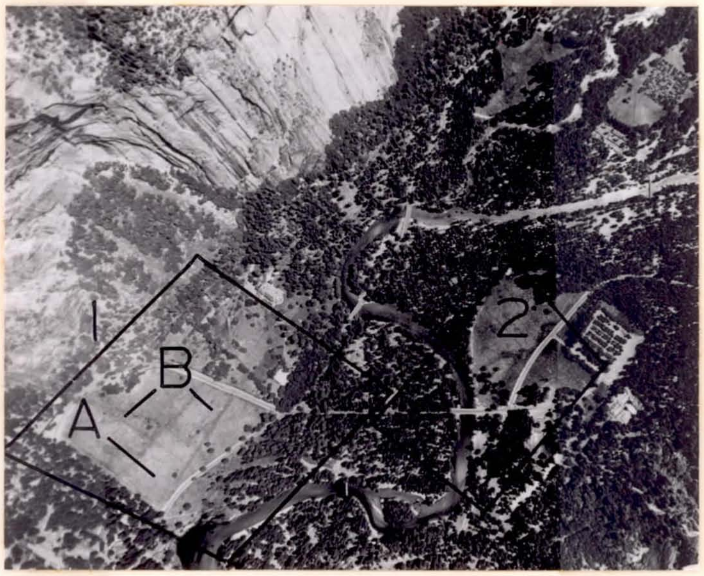
d) Ekta-Aero Infrared June 11, 1966

Figure 29. High altitude aerial photos (scale 1/8500) may be used to locate representative areas for establishing sample plots or erecting exclosures. Note that the exclosure at (A) is quite representative of the planted smooth brome grass (Bromus inermus) stand of which it is a part. The exclosure at (B), however, is located along a boundary condition between two plant communities and may not represent either community. The bluish toned area at (C) is heavy textured soil having poor drainage characteristics.

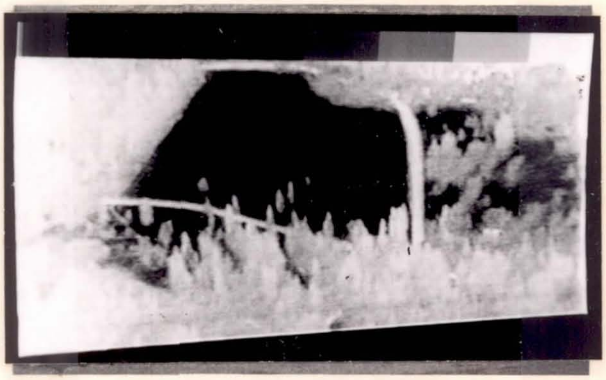
a) Ekta-Aero Infrared, July 22, 1966

b) Kodachrome II, July 22, 1966

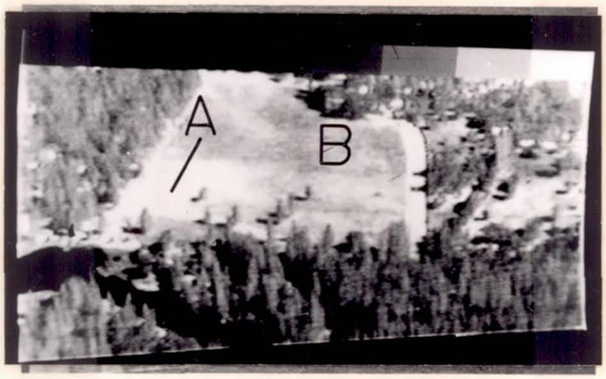
Figure 30. Photo (a) is a color infrared aerial photograph taken July 22, 1966 (scale 1/8000). Note the distinct tone differences between the vegetation inside the exclosure (A) and that outside, indicating heavy utilization. Note that on the June 11, 1966 imagery (Figure 29d), the vegetation within the same exclosure (A) has a similar tone to the vegetation outside indicating no utilization early in the season. The overall change in tones of the vegetation between imagery taken in June and late July reflect the drying of the vegetation during this period. Photo (b) is a ground shot of the vegetation inside and outside the exclosure.



a) Aerial view of Yosemite Valley



b) Thermogram taken at 0100 A.M.

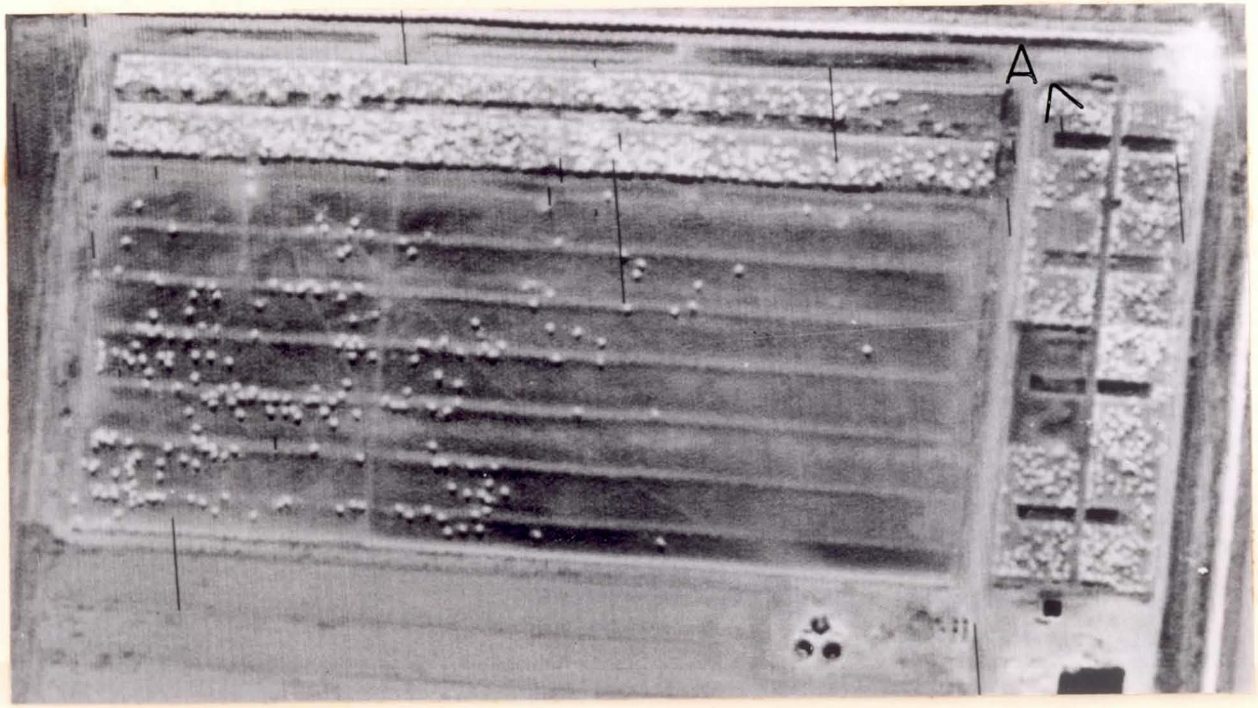


c) Thermogram taken at 1000 A.M.

Figure 31. Photo (a) is an aerial photograph of Yosemite Valley showing the position of two areas which were imaged by a Barnes Thermal Infrared camera positioned on Glacier Point, located 4000 feet above the Valley floor. Photos (b) and (c) are thermograms (of area number 1) taken at two different times. Note that two distinct vegetative types can be seen in photo (c) which are not readily discerned on the aerial panchromatic photo (a). The light-toned area (A) is a sparse stand of perennial and annual grasses and forbs, while the gray-toned area (B) is wet meadow vegetation. Area(A)heats up more quickly and remains warmer throughout the day than area (B), consequently these two types may be distinguished from each other during the daytime hours on thermal infrared imagery.

Figure 32. Color enhanced photograph made by projecting, with colored filters, two thermograms and a near infrared transparency of a meadow in Yosemite Valley; see area #2 in Figure 31a. As many as seven different vegetative communities were identified through interpretation of this color enhanced print, while only four were distinguishable on panchromatic imagery.

Thermal Infrared Imagery of Cattle Feedlot
Imperial Valley, California
(Unclassified imagery taken with a Reconofax-4 sensor, courtesy of HRB-Singer, Inc.)



Panchromatic Ground Shot taken of feedlot from Point A

Ektachrome ground shot taken of feedlot from Point A