rection factor for each zone, the measurements of areas with considerable differences in elevation are given approximately the same degree of accuracy as those for level ground.

Ordinarily only every other photograph in line of flight is enlarged since, with a 65% endlap, there is an endlap between photographs of approximately 15%. In the county office the area which should be used to planimeter fields is determined for each photograph and indicated by lines dividing the overlapping areas of adjoining photographs. The photograph which is needed for any individual farm is determined by consulting the photo index. These photo indexes are made up on a county basis to a scale of approximately either 1 inch to the mile or 2 inches to the mile. In areas which are sectionized, the township and section lines are often placed on the photo index to aid in determining the photograph needed to cover any particular area. Section lines are also often indicated on the individual photographs as an aid to locating any parcel of land according to its legal description. The records for each farm in the county office also refer to the number of the individual photograph or photographs on which such a farm appears so that if it is necessary to consult the photograph it can readily be removed from the files.

Only a few of the uses made of aerial photographs in connection with P.M.A. farm programs have been covered. Many of the other uses are of such a non-technical nature, concerned with the planning of programs, their local administration and assisting farmers in planning the efficient utilization of the natural resources of their farms, it appeared they would not be of sufficient general interest to merit inclusion.

PRACTICAL APPLICATION OF PHOTOGRAMMETRY IN LAND CLASSIFICATION AS USED BY THE BUREAU OF LAND MANAGEMENT*

Douglas E. Henriques, Field Examiner, Colorado-Utah Region, Bureau of Land Management, Salt Lake City, Utah

I AM deeply appreciative of the invitation extended to me to speak on the practical application of photogrammetry in land classification, as used by the Bureau of Land Management. I feel that I am somewhat of an interloper in this group because I am only a tyro amongst this large number of professional photogrammetrists. Also, my agency is not equipped to do original work in the field of photogrammetry as such, but merely adapts the work of others in this field, to fit the peculiar needs of the Bureau of Land Management.

The Bureau of Land Management was established July 16, 1946, by the consolidation of the former General Land Office and the former Grazing Service under the President's Reorganization Plan No. 3 of 1946. The new Bureau is charged with the management, leasing, and disposal of the public lands and the resources therein; the execution of all laws relating to the surveying, prospecting, locating, appropriating, entering, reconveying, and patenting of all public lands within the public domain, the national forests, and other reservations; the administration of mining and mineral leasing on lands under the public domain and under the jurisdiction of the Department of Agriculture; and supervision of

* A talk given at Regional Meeting, Rocky Mountain Section, Denver, Colo., Oct. 4, 1949.

grazing on 153 million acres of the Federal range in order to protect lands, permit the highest use of the forage and other resources, and retard soil erosion.

The Taylor Grazing Act of June 28, 1934, directs that all the public domain must be classified as suitable for the purpose intended, before any disposal is permitted under the agricultural public land laws.

It is the use of aerial photographs in connection with the administration of grazing and with classification studies of the public land, that I shall attempt to discuss.

In the administration of grazing districts, certain regulations have to be met to qualify individuals for a grazing permit, but before any permit can issue, information concerning the vegetative cover, density, and terrain features must be secured so that proper numbers of livestock may be permitted on the Federal range.

This information usually is obtained by a range survey. The principal objects of such a range survey are to delineate the vegetative type lines, to appraise the forage value of the plant cover, and to ascertain how the terrain features help or hinder livestock operation. There are several methods of determining plant density and content, all based on local observations of selected plots throughout the area under study. What is perhaps the classical method of range survey is based on a series of plots observed at regular distances along traverses of known direction, usually along a section line or through the middle of a section. Ten plots per mile is the standard sampling and gives fairly satisfactory results. However, it is almost impossible to ascertain exactly the limits of a type line from a line traverse. Aerial photographs with known control and mosaics can be used to assist in determining the irregular boundaries between the various vegetative types. Intensity of necessary sampling also can be determined by studying the aerial photographs in advance of the field work. If it appears in the photos that the type is wide-spread, and shows a homogeneous character with consistent density throughout the type area, fewer samples are needed for a true picture of the carrying capacity and the forage potential.

Aerial mosaics have been used by the Bureau of Land Management for overall control of field studies, with contact prints being taken by the range examiners in the actual survey. Data concerning the vegetation, its density and type, the carrying capacity, and the terrain features: including drainage, as well as cadastral survey control, are marked on the contact prints from actual observations on the ground. The information from the contact prints is transferred to the control mosiac on which the land net has previously been constructed. In the range surveys of BLM, each section usually is handled as a separate unit in the computations and in the compilation of the final data. This method of compilation, of course, requires that the sectional grid be the control. The information placed on the mosaic is then used as the basis for preparing the base quadrange maps, and to facilitate the issuance of grazing permits. The base maps for the Bureau of Land Management grazing districts are quadrangles, four by eight townships, on which the salient information is transferred from the photographs. The vegetative type lines are traced on separate sheets as overlays to the base quadrangle. This permits us to print the base map showing only the section lines and the principal terrain features on all of these, plus the vegetative type when necessary.

Without aerial photographs, more intense sampling is necessary to determine the carrying capacity, and more traverses with cross-traverses are necessary to delineate correctly the type lines. Plane table mapping often is used to augment the traverse data obtained from range surveys, but our experience has shown that much time and effort are spared when the aerial photographs and mosaics are available.

Range surveys by the Bureau of Land Management have been made by specially trained personnel learned in the field of agronomy and ecology, but without formal education in photo-interpretation or photogrammetry. Prior to their commencement of range surveying operations, the examiners usually are given short indoctrination training in the practical interpretation of aerial photographs.

The grazing district managers of the Bureau of Land Management have a general knowledge of the physical nature of their districts. By combining their knowledge with a study of the aerial photographs, the range managers are enabled to make usable estimates of carrying capacity, if no range survey has been made of the area in question. They also can point out terrain features in disputes between permittees over their allotment boundaries, without going onto the land. It is sometimes difficult, of course, to explain the beauties of an aerial mosaic to the uninitiated livestock operator, but generally he can be made to "see the light." After the parties in dispute understand the picture, it is easy to show them exactly how much area each has in his allotment, and how the terrain, ridges, and valleys have been used in the division of the Federal range. The range managers also use the aerial photographs to assist them in locating suitable sites for such range improvements as water development, stock water reservoirs, range fences, and access roads.

It must be realized, of course, that the range managers of the Bureau of Land Management are not trained in the science of photogrammetry. Most of them have had college training in range management, which includes a smattering of botany, ecology, forestry, and animal husbandry, but nothing, usually, on photo-interpretation or photogrammetric engineering. Perhaps they have gained some information on photo-interpretation from the study of geomorphology in connection with classes in geology, but I am certain that such a subject is not required in the curriculum of range management.

Interpretation of the information contained in the aerial pictures is usually obtained by BLM range managers, etc., the hard way at first; that is, a controlled picture is taken onto the area depicted, and a comparison of the terrain is made with the picture. By a "controlled picture," I refer to one with easily identifiable objects clearly marked. From such a comparative study of the aerial photos on the ground, the BLM range managers have been able to expand their interpretation to include uncontrolled pictures of known areas, and often even uncontrolled pictures of unfamiliar areas. I believe that this process should properly come under the heading of "photo-interpretation" rather than photogrammetry, but, by whatever name it should be called, we do achieve a more complete knowledge of the areas under our jurisdiction, of which we have aerial pictures.

The range managers are not averse to using planimetric maps, when available, or United States Geological Survey topographic sheets, when available, to assist them in the administration of the grazing districts. In fact, the unanimous opinion of the range managers indicates that a combination of the aerial photograph, the planimetric map, and the topographic map is an almost unbeatable trio of information.

I have here a series of mosaics of the scale, two inches to the mile, representing an area in southeastern Utah. These mosaics demonstrate the different degrees of intensity of recording information in the field. Some of the plats have nothing added to them; some have the tentative land net without surface control; others have the land net built from identified section corners; some have the drainage traced in white (we use white because it is more readily seen); some have the type lines indicated in black; and some have all of the enumerated information traced thereon. I am sure that you will realize from looking at these pictures

just how difficult it is to perform a ground examination. Much of the area BLM administers in this Region—Utah and Colorado— is of a similar, rough, deeply incised plateau type. From a study of these pictures, you will easily discern that the terrain is much too rough to permit a straight-line traverse for range survey purposes.

In the type of country depicted in these pictures, the trained observer, by making random traverses through the various vegetative types identified in the picture, can approximate very closely the actual carrying capacity and range use potential of the land, by expanding his observations over limited areas to cover the entire area of each type shown in the picture. Areas of types are measured by planimeter. In fact, the expansion method was the manner in which this very area was typed and the carrying capacity determined.

From these mosaics, the basic quadrangle maps used by BLM have been built. We realize that they are not as accurate as the planimetric maps created by the Soil Conservation Service technicians using their photogrammetric skill and scientific artifacts, but our maps do represent what is on the land, so far as it appears necessary for our grazing administration.

I have here a planimetric map and one of the BLM quadrangle maps depicting the same area as shown in this series of aerial mosaics. The mosaic and the planimetric map are on the scale of two inches to the mile, while the BLM quadrangle map is on the scale of one inch to the mile. You will notice that the planimetric map shows hundreds of tiny, intermittent drainage courses, whereas the BLM map merely shows a few long drainage courses. A study of the mosaic shows the tiny fingerling arroyos leading into the larger ones, but they are merely precipitation run-off channels down the semi-barren slopes. Our interpretation of these is that they are an erosion problem, and should not be included in the water-course map. They are shallow and create no problem in the management of livestock on this land. The other prominent terrain features, such as the cliffs and the mesa tops and the deep arroyos, are depicted on the BLM map in almost the same shape as on the planimetric map. These, of course, are important to the management of livestock in this area, and so we add them to our base map.

In the field of timber management, the Bureau of Land Management, especially in Utah and Colorado, does not have timbered resources of the type usually associated with forests. Instead, what we have are large areas of the "pygmy forest," a woodland type characterized by juniper and piñon. While these trees are not valuable for saw-timber, they do have a very prominent place in the economic life of the area, as most of the fences which have been built in the West over the years have been strung on "cedar posts," which, in reality, are nothing more than the trunks of the juniper trees.

By running a random course through the "timbered" area, and then by making a study of the aerial photographs of the same area, it is possible for the experienced BLM forester to determine very closely the stand of post-sized trees which should be harvested early on a sound timber management plan.

Summarizing the place of aerial photographs in the administration of a grazing district, we in BLM find them valuable in making range surveys; as an aid in determining the carrying capacity of the range; in making range allotments where they are of value in depicting the area in the individual allotment and the natural boundaries of the allotment; in the locating of sites for range improvements; in the demonstration of the over-all terrain conditions; in giving assistance to establishing ground control—that is, locating section corners; in the study of erosion conditions and possible alleviation thereof by check-dams and reseeding; and in the phases of woodland management.

In the field of land classification, there are two types practiced by BLM—area and specific.

In area classification, we examine intensively large blocks of the public land, in order to determine what use or uses of the land would be most advantageous to the public interests. An example of this type of classification is that which the BLM is doing in the Missouri Basin studies in the State of Wyoming, where the public domain is very extensive in area, with patented lands as but small tracts interspersed therein.

Specific classification is that made on individual parcels of the public domain land involved in a land disposal application, such as a homestead, or in an area study where most of the land is patented. An example of this latter type is the classification of the Missouri Basin studies involving the South Platte River Basin in the State of Colorado.

Fundamentally, the procedures are similar in each type, the differences being merely in the magnitude of the area studied at one time. The land examiner making a classification study gathers information concerning the soil type, the vegetative type and density, the slopes, the water resources, and the relationship of the land examined to the adjacent lands. Aerial photographs, especially contact prints, have been used whenever available by the examiner in the classification studies of individual tracts of public domain. In the area classification studies now under way in the Missouri Basin, aerial mosaics on a scale of two inches to the mile are being used for base control, much in the manner of the range surveys I discussed before. Mosaics on a scale of four inches to the mile are better than the two-inch prints, but their very large size reduces their practical use, and mosaics on a scale of one inch to the mile are too small to permit complete identification of the terrain features. In practice, the field study is made with contact prints on which the cadastral survey control net is noted when identified on the ground. The vegetative type lines, erosion class lines, and land-use capability zones, as well as drainage and ridge lines, are indicated on the contact prints. The prints then are returned to be used in the construction of a field map on an acetate overlay to the mosaic. The cadastral land net is drawn on the acetate, as well as the informational legend from the contact prints. When the overlay has been completed and corrected, all of the information then is transferred to linen tracings, and reproduced in quadrangles of four townships, that is, two townships square. This transfer process is a modification of the acetate template method based on radial plotting.

In areas of extremely rough terrain, if surveyed, such as are depicted on these mosaics, survey lines are protracted tentatively from the closest known control. With this protraction as a guide, field observers attempt to locate at least six section corners including the four township corners for each township. From these found corners, the land net is built. On some of the areas only two or three corners have been identified on the ground. We can expand the sectional net for a township from two found corners, but if we can find more, it makes our job a little more accurate. I won't dwell on the methods of trying to find elusive corners in the rough terrain, as I believe Mr. Brown of the Bureau of Land Management already has explained this in great detail.

At the present time there is a project of land classification by the Bureau of Land Management in northern Utah, where many small parcels of public land are interspersed among patented holdings. It is within the area of a railroad grant where the Central Pacific was given the alternate sections for a distance of 20 miles on either side of the right-of-way. It is the intention of the BLM to construct a map suitable for land classification, as well as administration of the grazing district, with alternate contact prints having about a 15 per cent overlap.

If we can obtain sufficient funds to permit us to acquire the remaining alternate coverage, we hope to do so, and then construct our field map more easily with complete coverage. We will transfer the information from the contact prints to our base map by radial plotting from acetate templates. The base map will have the survey grid established from the township plats of the cadastral engineers. The contact prints that we shall use on this study are scaled one thousand feet to one inch and have been prepared by PMA. I believe that all of you are familiar with the type of picture put out by this agency. I have a single strip of the alternate prints, and I shall be glad to discuss our problems in relation to these prints with any one who cares to ask questions later. We believe that from the alternate coverage we can build a complete base map showing all pertinent data, even though we won't be able to build a mosaic. The scale of these plats is sufficiently large, and known ground control can be established on many points in each print, so that the distorted area in the overlap easily can be scaled onto our base map.

Looking toward the future, it is the hope of BLM to make a complete land classification study of the Colorado River Basin. The area, in large part, that will be covered by such a study, has not yet been surveyed by the cadastral engineers. If our dream of making a land classification study becomes an actuality, aerial photographs will be the only method of maintaining accurate control for the classification. I assure you that we would not attempt to run a precise land classification study without complete aerial coverage, so that we could build our own control mosaic and perhaps even be of assistance to the cadastral engineers in their surveying.

Perhaps you have wondered why I have talked at length concerning both range surveys and land classification when the context for each seemed to be related. Prior to their union as the Bureau of Land Management, neither the General Land Office nor the Grazing Service gave much attention to the peculiar work of the other. My personal experiences in both of the antecedent organizations of the present Bureau of Land Management have formed the basis for this paper. To my knowledge and experience, I have added the comments, in essence, from the range managers in Utah and Colorado.

I thank you very much for your kind attention, and I hope that at a future meeting of the American Society of Photogrammetry, we of the BLM will be able to report further on our use of aerial photographs in connection with land classification.