graphs is the lack of new flights at a scale suitable for the measurement of forest stands. Some of the National and State Forests have been photographed for land classification purposes at 1:20,000 or even 1:15,000 scale. More often the flight was made for mapping purposes at 1:26,000 to 1:50,000 scale. Suitable though such photographs are for topographic mapping, the scale is not large enough for accurate measurements of forest trees and stands. Foresters should learn to use small-scale photographs for maps, medium-scale photographs for general and reconnaissance-type surveys, and either strip or pin-point photographs at much larger scale for detailed stand measurements of selected sample plots. A system closely paralleling this has been successfully employed for years on highway, airport, and other engineering projects.

CONCLUSION

Aerial photographs are being used more and more in forestry work, both administrative and research. At least a working knowledge of techniques of interpreting them will be desired by most foresters to help achieve greater effectiveness on the job.

AERIAL PHOTOGRAPHS AND THE SOIL CONSERVATION SERVICE

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WHEN Dr. H. H. Bennett, the world's greatest living exponent of soil conservation, finally succeeded in his crusade for the passage of some sort of government conservation measure and the Soil Conservation Act of 1935 was enacted by Congress, it is probable that aerial photography was the furthest from his mind. It is very doubtful that he realized the enormity of the boost he was about to give to the pigmy which was to grow into the giant that aerial photography has become. In 1934–35, a few of the present day companies were in existence together with a number of smaller aerial photographers, and together they were putting out photographs and making small uncontrolled mosaics, but there was no incentive to put any great amount of investment, either in time or money into the development of better equipment.

Plotting machines were available but were not being used to any great extent. Considerable mosaic work had been done, but no large scale mapping, using single lens photography, had been attempted until in 1935, after the passage of the above mentioned act. In that year the Soil Conservation Service of the Department of Agriculture advertised for and awarded contracts for aerial photography of 79 small demonstration areas, as they were then called, totaling 5,273 square miles. The largest of these areas was 129 square miles and the smallest 27 square miles. The photographs were to be flown at a scale of 1:15,840, the negatives were to be 7″×9″, and the camera was to be single lens. This photography cost the Soil Conservation Service approximately $14.00 per square mile.

The quality of the photographs was not too good, but the contractors, realizing that here was the beginning of a better era for them, began striving to improve their product, and have thus achieved today's excellent results.

Actually, the use of aerial photographs by the Soil Conservation Service was born of necessity. There was an urgent need for a special type map of each of the areas mentioned above, at a scale of four inches equals one mile which was larger than those in general use. In most cases, no reliable maps were available, and the use of the aerial photographs for maps proved inadequate due to the inaccuracies of the photographs themselves, but when used with the proper photogrammetric methods, they did provide a good working tool through which the construction of adequate maps was possible.

Some time after these first Soil Conservation Service contracts at 1:15,840 were awarded, the Agricultural Adjustment Administration began using aerial photographs but of a different scale. The Department of Agriculture was far-sighted enough to see that aerial photography would soon become a valuable source of information, and would be in demand by many of the Agencies within the Department. In order to avoid duplication of effort, a procedure was set up with the agreement of all agencies within the Department whereby the procurement of aerial surveys by the Department would be coordinated. This agreement resulted in uniform specifications for aerial photography, uniform scale and a uniform method of awarding contracts. In addition duplication of aerial surveys has been avoided, and photographs are produced that can be used by any agency, with a few scattered exceptions. In the Soil Conservation Service, one of those exceptions has been the Rocky Mountain Range area where a smaller scale is satisfactory and economical. In this area the need for detail is not as great as in areas of more intensive agriculture.

These first aerial surveys by the Soil Conservation Service were for the express purpose of compiling large-scale accurate maps of the demonstration areas. These maps were required by the soils scientists at a scale of four inches to the mile, upon which to record the results of their field surveys. The field surveys themselves had been made on plane table sheets, and were to be superimposed on the planimetric bases. The information, obtained by field survey and to be recorded on the planimetric bases, was the type of soil, degree of erosion, per cent of slope, and the land use.

CARTOGRAPHY

The work of the Service, as stated above, requires large-scale (usually 1:15,840) planimetric maps of country where the amount of existing control is generally sparse. Reasonable accuracy on this large scale at a reasonable cost is desirable. To accomplish this we have adopted the "slotted-templet method" of extending radial control. It was invented by Charles W. Collier, while with the Soil Conservation Service, and since then has been perfected through improvements made in the Cartographic Division and elsewhere. Through the use of this method a minimum of ground control is required to obtain the necessary accuracy. In 1942 and 1943, the Service further cut down the required ground control by having high-altitude photographs flown at a scale of 1:63,360, to be used only as a means of providing additional control for the lower flown 1:20,000 photographs. Ground control for the 1:63,360 photographs was obtained the same as for the 1:20,000 photographs, but to a lesser degree of density. Slotted templets of the inch to the mile photographs were made and assembled at a scale of 1:12,000. The radial control points thus obtained were used as fixed control points for the assembly of the 1:20,000 photographs. Nine-lens photographs also were used for the same purpose on several projects, with considerable success.

After the radial-control assembly has been made at a scale of 1:12,000 and transferred to metal-mounted manuscript boards, the detail is compiled through the use of the multiplex projectors at the same scale. Color separation boards are drafted and photographed and the maps are printed on an offset press.

Copies of these maps are available at no charge, by request addressed to the Division of Cartography, Soil Conservation Service, Washington 25, D. C.

The use of the photographs was not limited, however, to the compilation of the bases. After the receipt of the photographs, it was found that they would serve as a plane table sheet on which to make the field surveys mentioned above. More and more uses have been found for aerial photographs, until at the present time practically all technical divisions of the Soil Conservation Service use them for planning, education, presentation, and execution of their respective programs. Some of these activities are described in the following pages.

SOIL CONSERVATION SURVEYS

One of the larger users of aerial photography within the Soil Conservation Service is the Soil Conservation Surveys Division. This division began functioning with the Demonstration Areas mentioned above and with the aid of aerial photographs made a careful study of the physical soil conditions of the areas on the ground. They then presented this picture of the soils conditions, together with a study of their recommended conservation practices, to the owners or operators of the farms within the areas. Most of the farmers put the practices into effect with remarkable results. The farmers outside these areas, seeing the progress being made within, decided that they too would like to become a part of this scientific farming and, in most cases, increased production, and appealed to the Soil Conservation Service for assistance. Accordingly, a plan was evolved whereby farmers living within a given area, usually one or more counties, are encouraged to form a Soil Conservation District. The farmers within the area of the proposed district are asked to vote on whether or not they want the district formed. In most cases they have voted overwhelmingly for its establishment. After they thus vote a District into being, a District Governing Body is set up consisting of farmers in the District and known as District supervisors or District Directors. The Governing Body sets up priorities for planning of farms or areas within the District. Generally an attempt is made to group farms so that more efficient use of the technician's time is possible. When the Governing Body asks the Soil Conservation Service for assistance, the first thing that is requested within the Service is the aerial photographs covering the District. The use of the aerial photographs in Soil Conservation Surveys is indispensable for making over-all plans, conservation surveys, range surveys, water surveys, farm plans, etc.

A representative district is the York County Soil Conservation District in Pennsylvania. Figure 1 is an aerial photograph taken in May 1938 and shows how the area appeared before any conservation work was attempted. It is not too difficult to imagine the heavy rain water or water from melting snows rushing down the hillsides, causing deep gullies and carrying away the precious top soil, in the straight line, square field farming practiced when this photograph was taken. Figure 2 shows the same area in October 1947, less than ten years later. A careful study of the two photographs will show that about 80 per cent of the 584,960 acres of land in the district is suitable for agricultural purposes; of this percentage, over 900 farms covering approximately 90,000 acres have been subjected to soil conservation practices.

Contour farming is generally the practice most associated with soil conservation work. It revolutionizes the old time method of straight-line-up-hill-and-down farming. The seemingly wild patterns shown in Figure 2 are a method of

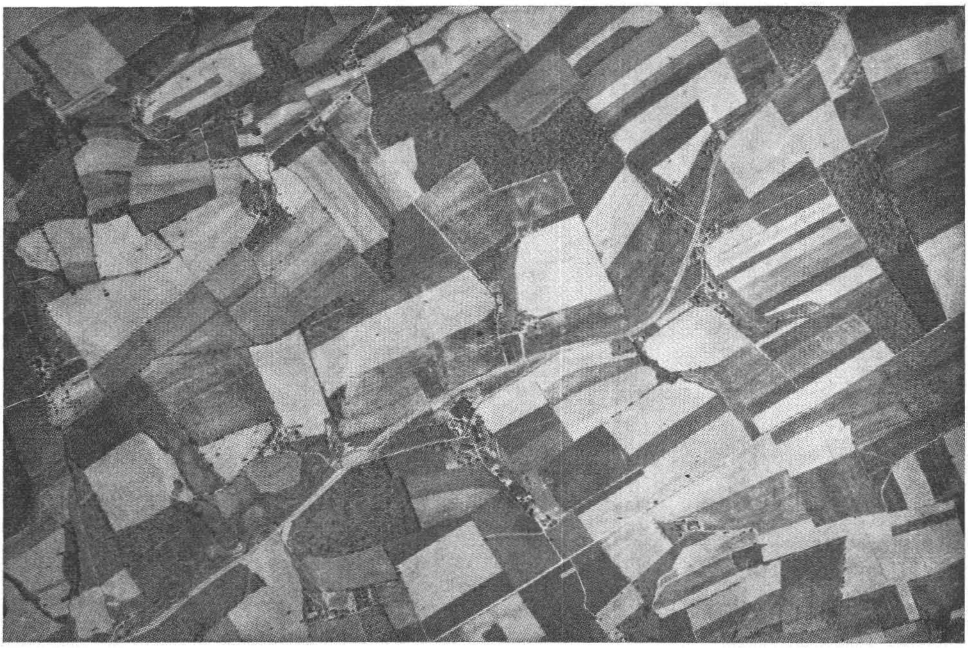


FIG. 1. York County SCD before any conservation work was attempted.

FIG. 2. The same area ten years later showing the results of conservation work.

EXAMPLE OF A FARM PLAN

LAND USE IN 1938

CROPS (1938)

CORN SILAGE	7.0 ACRES
CORN GRAIN	14.9 "
SMALL GRAIN	21.0 "
MIXED HAY	34.2 "
OTHER CROPS	4.5 "
PASTURE	39.0 "
WOODLAND	74.0 "
FARMSTEAD	5.4 "
TOTAL FARM	200.0 "

LIVESTOCK (1938)

COWS	18.5
OTHER CATTLE	8.0
HOGS PRODUCED, CWT.	45.0
POULTRY	107.0
HORSES	4.0
COLTS	1.0

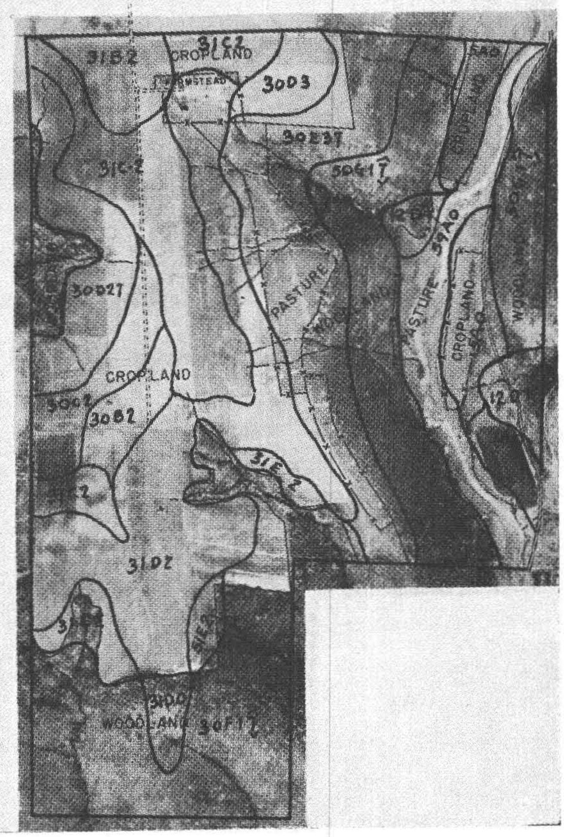


FIG. 3. Land use survey.

contour farming known as contour strip cropping. The curved ridges following the contours of the land form little barriers which tend to hold the rain water and water from melting snows in check and prevent the washing away of valuable top soil. In the contour strip-cropping process, a close growing crop such as wheat or hay is planted in one strip and a cultivated crop such as corn or potatoes in the next and the process is repeated until the entire field is scientifically planted.

Soil conservation also includes other practices not easily discernable on the photographs such as crop rotation, pasture management, woodland improve-

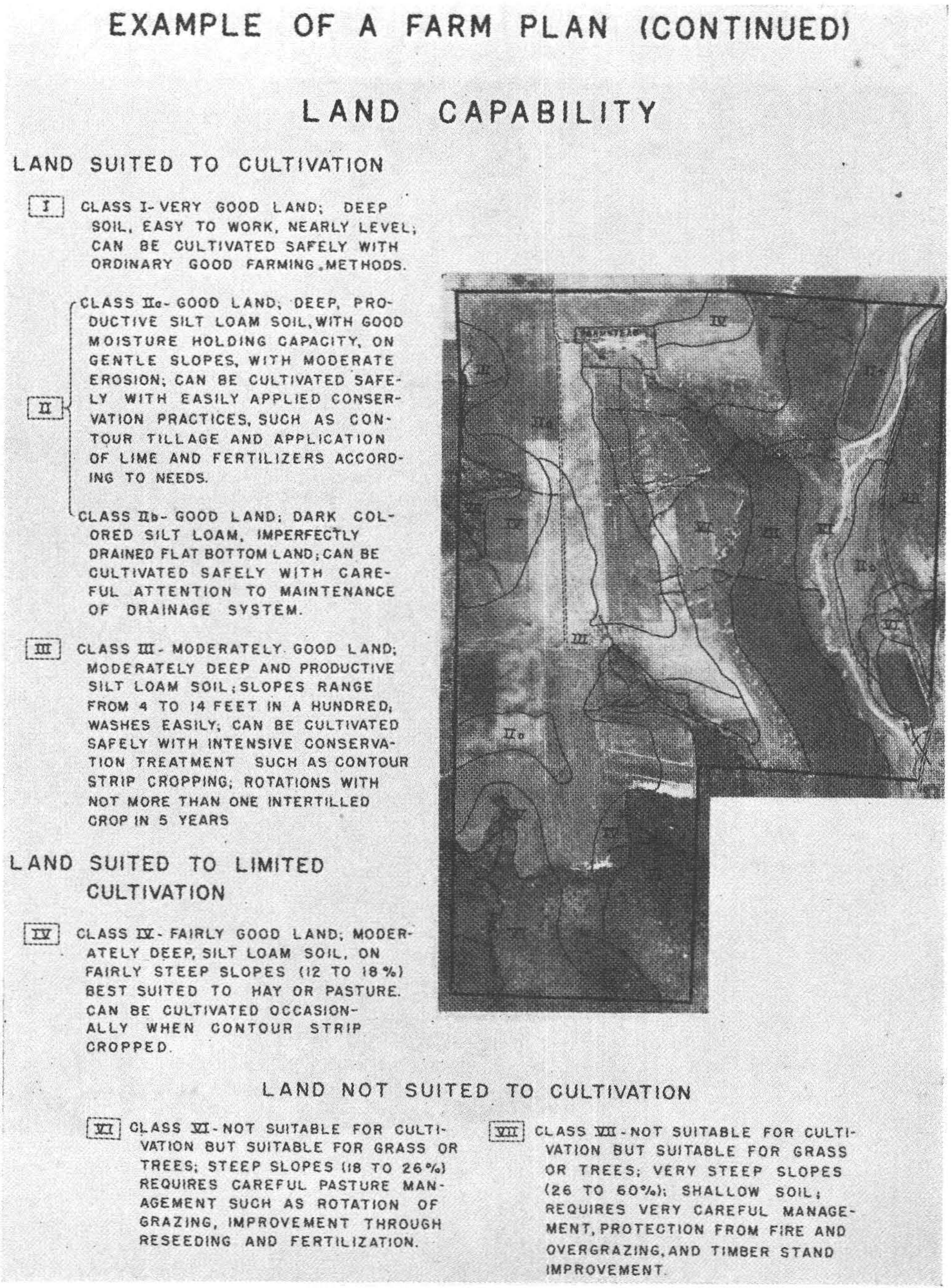


FIG. 4. Land capability.

ment, windbreak planting, stream channel improvement, stream erosion control, field and gully planting and others.

In order properly to plan the conservation practices necessary to arrive at the variety of patterns shown in Figure 2, the following procedure was followed: First, the owner had to submit a request to his District Committee, for assistance; this request was turned over to a Soil Conservation Service technician;

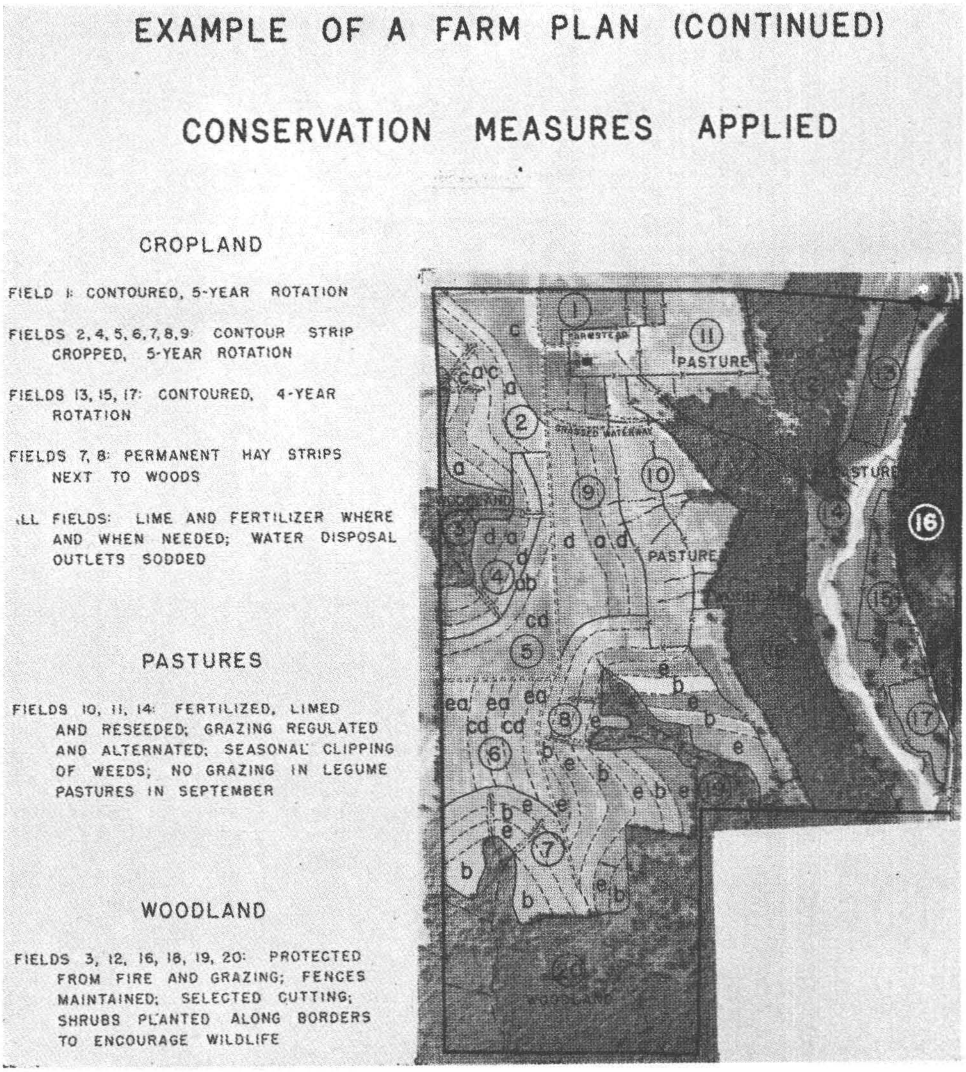


FIG. 5. Conservation measures to be applied.

next the technician obtained an aerial photograph of the farm at a scale of 4 inches equals 1 mile, upon which he made a thorough land use survey (see Figure 3) showing (a) land use such as cropland, pasture, forest, and idle land; (b) soils type; (c) slope and (d) erosion. Next a land capability map was made on an aerial photograph at the same scale (see Figure 4). This land capability map shows the land capability with a minimum of soil conservation practices and when studied in conjunction with Figure 3 helps to determine the conservation measures to be applied.

Armed with these two photographs, the information shown thereon and a plain 8-inch to the mile photograph, the technician visits the farm and discusses the economic necessities of the farm with the farmer. Together they visit and discuss the problems of each field. The farm planner, or technician, makes a tentative plan for each individual field on the plain 8-inch to the mile photograph, and returns to his office for additional study. Upon the completion of his

EXAMPLE OF A FARM PLAN (CONTINUED)

FIELD	USE	LAND CAPABILITY CLASS	DETAILS OF CONSERVATION MEASURES
1	CROPLAND	II	CONTOUR CROPPED 5 YEAR CROP ROTATION-1 YEAR CORN, 2 YEARS SMALL GRAIN; 2 YEARS CLOVER AND TIMOTHY
2	CROPLAND	II & III	CONTOUR STRIP CROPPED 5 YEAR CROP ROTATION-1 YEAR CORN; 1 YEAR GRAIN; 3 YEARS ALFALFA AND TIMOTHY
4	CROPLAND	IV III & IV	CONTOUR STRIP CROPPED STRIP a-5 YEAR CROP ROTATION-1 YEAR CORN; 1 YEAR GRAIN; 3 YEARS ALFALFA AND TIMOTHY STRIP d-5 YEAR CROP ROTATION-1 YEAR CORN; 2 YEARS GRAIN; 2 YEARS TIMOTHY AND CLOVER
5	CROPLAND	III	CONTOUR STRIP CROPPED 5 YEAR CROP ROTATION-1 YEAR CORN; 1 YEAR GRAIN; 3 YEARS ALFALFA AND TIMOTHY
6	CROPLAND	II & III II & III	CONTOUR STRIP CROPPED STRIP cd-5 YEAR CROP ROTATION-1 YEAR CORN; 1 YEAR GRAIN; 3 YEARS ALFALFA AND TIMOTHY STRIP ea-5 YEAR CROP ROTATION-1 YEAR CORN; 2 YEARS GRAIN; 2 YEARS TIMOTHY AND CLOVER
7	CROPLAND	III & IV VI	CONTOUR STRIP CROPPED STRIP 7a AND 7b-5 YEAR CROP ROTATION-1 YEAR CORN; 1 YEAR GRAIN; 3 YEARS ALFALFA AND TIMOTHY STRIP 7b NEAR WOODS-PERMANENT HAY-CORN OR GRAIN NOT TO BE GROWN
8	CROPLAND	III & IV VI	CONTOUR STRIP CROPPED STRIP 8b AND 8e-5 YEAR CROP ROTATION-1 YEAR CORN; 1 YEAR GRAIN; 3 YEARS ALFALFA AND TIMOTHY STRIP 8e NEAR WOODS-PERMANENT HAY-CORN OR GRAIN NOT TO BE GROWN
9	CROPLAND	II & III	CONTOUR STRIP CROPPED 5 YEAR CROP ROTATION-1 YEAR CORN; 1 YEAR GRAIN; 3 YEARS ALFALFA AND TIMOTHY
13	CROPLAND	II	CONTOUR CROPPED 4 YEAR CROP ROTATION, 2 YEARS CORN; 1 YEAR GRAIN; 1 YEAR ROTATION PASTURE
15	CROPLAND	II	CONTOUR CROPPED 4 YEAR CROP ROTATION, 2 YEARS CORN; 1 YEAR GRAIN; 1 YEAR ROTATION PASTURE
17	CROPLAND	I & II	CONTOUR CROPPED 4 YEAR CROP ROTATION, 2 YEARS CORN; 1 YEAR GRAIN; 1 YEAR ROTATION PASTURE
			GENERAL CONSERVATION TREATMENTS FOR ALL CROPLAND ALL WATERWAYS WILL BE SEEDED AND MAINTAINED IN SOD ALL TILLAGE OPERATIONS WILL BE PERFORMED ON THE CONTOUR
3	WOODS	VII	PROTECT FROM FIRE AND GRAZING KEEP FENCES IN GOOD REPAIR CUT ONLY MATURE OR UNDESIRABLE TREES LEAVE VINES AND SHRUBS ALONG FENCE ROWS TO ENCOURAGE WILDLIFE AND PROVIDE GAME COVER
12	WOODS	VII	
16	WOODS	VI & VII	
18	WOODS	VII	
19	WOODS	VII	
20	WOODS	III & VI	
10	PASTURE	III & VI	IMPROVE WORN OUT AREAS WITH LIME, FERTILIZERS, AND SEEDING TO A PASTURE MIXTURE. REGULATE GRAZING INTENSITY AND TIME OF GRAZING ROTATE GRAZING ON PASTURE TO PROVIDE ALTERNATE GRAZING AND RESTING PERIODS OF ABOUT 2 WEEKS. CLIP WEEDS AND TALL GRASS AT LEAST ONCE ANNUALLY IF MOWING IS POSSIBLE. PASTURE IMPROVED AREAS CAREFULLY THE FIRST YEAR REGULATE GRAZING SO SWEETCLOVER WILL RESEED ITSELF THE SECOND YEAR AND THEREAFTER KEEP LIVESTOCK OFF PASTURE DURING SEPTEMBER SO THE ROOTS MAY BUILD A GOOD RESERVE. THIS IS ESPECIALLY NECESSARY ON LEGUME PASTURES.
11	PASTURE	IV & VI	
14	PASTURE	VI (VII FOR LANE)	

PASTURE WAS RENOVATED AS FOLLOWS:
1939, 3 ACRES; 1940, 5 ACRES; 1941, 9 ACRES; 1942, 5 ACRES; AND BY 1946 ALL THE OPEN PASTURE HAD BEEN RENOVATED.

FIG. 6. Example of a farm plan.

study, he submits an 8-inch to the mile photograph to the farmer, showing the recommended conservation measures to be applied (see Figure 5). Along with the photograph, he submits a tabulated plan similar to the one shown in Figure 6. If the farmer is satisfied with these, he is asked to sign an agreement similar to Figure 7, in which he agrees to put the changes into effect.

All of the above services are provided by the Soil Conservation Service at no

______ SOIL CONSERVATION DISTRICT

FARMER-DISTRICT COOPERATIVE AGREEMENT

AGREEMENT NO. ______

THE ATTACHED FARM CONSERVATION PLAN COVERING THE LAND INDICATED THEREIN WAS DEVELOPED WITH THE ASSISTANCE OF THE TECHNICIANS MADE AVAILABLE TO ME BY THE ______ SOIL CONSERVATION DISTRICT. THE DISTRICT AGREES TO ASSIST ME IN CARRYING OUT THE PLAN BY FURNISHING ME SUCH INFORMATION, TECHNICAL AND OTHER ASSISTANCE AS IT MAY HAVE AVAILABLE AT THE TIME THE WORK IS TO BE DONE AND IS REFERRED TO IN THE FARM CONSERVATION PLAN. THEY HAVE ALSO FURNISHED ME A SUMMARY OF ANTICIPATED EFFECTS OF THE APPLICATION OF THE PLAN ON THE ORGANIZATION OF THE FARM. SINCE I BELIEVE IT WILL BE TO MY ADVANTAGE TO FOLLOW THIS PLAN, I PROPOSE TO DO SO IN ORDER TO PROMOTE SOIL CONSERVATION AND TO BUILD UP THE PRODUCING ABILITY OF MY LAND

SHOULD MATERIALS AND EQUIPMENT BE FURNISHED BY THE DISTRICT, IT IS UNDERSTOOD THAT IT WILL BE USED IN THE MANNER SPECIFIED IN THE PLAN. IN THE EVENT I DO NOT FOLLOW OUT MY FARM PLAN, IT IS AGREED THAT THE DISTRICT SUPERVISORS MAY TERMINATE THIS COOPERATIVE AGREEMENT

IT IS AGREED THAT I WILL MAINTAIN IN AN EFFECTIVE CONDITION ALL MECHNICAL STRUCTURES AND VEGETATIVE MEASURES, WHICH HAVE BEEN ESTABLISHED IN ACCORDANCE WITH THE CONSERVATION PLAN, AND CONTINUE THE USE OF ALL OTHER CONSERVATION PRACTICES PUT INTO EFFECT

I AGREE THAT NEITHER MYSELF NOR THE DISTRICT SHALL BE LIABLE FOR DAMAGE TO THE OTHER'S PROPERTY RESULTING FROM CARRYING OUT THE PLANS UNLESS DAMAGE IS CAUSED BY NEGLIGENCE OR MISCONDUCT

IT IS UNDERSTOOD THAT IN CASE THIS FARM IS SOLD, NEITHER MYSELF NOR THE NEW OWNER WILL BE UNDER ANY OBLIGATION TO CARRY OUT THIS PLAN. IT IS FURTHER UNDERSTOOD THAT THE ASSISTANCE TO BE PROVIDED BY THE DISTRICT WILL BE DEPENDENT UPON APPROPRIATIONS OR SERVICES AVAILABLE TO THE DISTRICT

THE ATTACHED PLAN MAY BE CHANGED BY THE CONSENT OF ALL PARTIES.

THIS AGREEMENT SHALL TAKE EFFECT ON THE DATE OF THE LAST SIGNATURE TO IT AND, UNLESS OTHERWISE TERMINATED, WILL REMAIN IN EFFECT UNTIL ______ IT WILL BE AUTOMATICALLY RENEWED FROM YEAR TO YEAR UNLESS EITHER PARTY GIVES WRITTEN NOTICE TO THE CONTRARY TO THE OTHER AT LEAST SIXTY DAYS BEFORE ANY TERMINATION DATE

CONCURRED IN

______ OWNER'S NAME DATE ______ OPERATOR'S NAME DATE

______ ADDRESS ______ ADDRESS

DISTRICT OBLIGATIONS ACCEPTED BY ______ SUPERVISOR ______ DATE

(EACH SOIL CONSERVATION DISTRICT PREPARES ITS OWN FORM OF COOPERATIVE AGREEMENT — THIS IS AN EXAMPLE.)

FIG. 7. Farmer-District Cooperative Agreement.

cost to the farmer. In addition, the Soil Conservation Service will furnish technicians to lay out his contours and other land use treatments, and the location and grades of such features as terraces, diversion ditches, drainage ditches, waterways and others.

For the most part, this planning has been done on single aerial photographs. During the past winter, however, a trial was made in the use of stereoscopic pairs and met with considerable success. It was found that about 85 per cent of the farmers tested could see stereoscopically. It is believed that the use of these

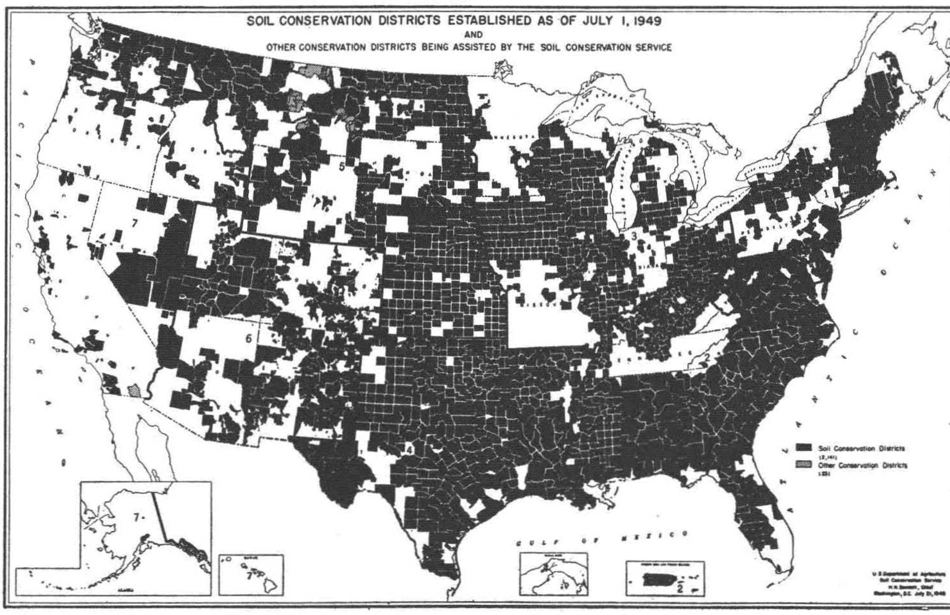


FIG. 8. Distribution of Soil Conservation Districts.

pairs of photographs will help even more to establish a better understanding between the technicians and the farmer.

Prior to the advent of aerial photography, all this field work had to be done on plane table sheets at more than double the expense. Without photography, the Soil Conservation Service program would have been seriously retarded.

The York County Soil Conservation District is only one of well over 2,000 districts scattered throughout our nation. Figure 8 shows the distribution of these districts. The district program has been very popular.

FLOOD CONTROL

The Soil Conservation Service is authorized to perform flood control operations in cooperation with the Forest Service, on specific watersheds as approved by Congress. For watersheds not authorized by Congress, local groups make their wishes known to representatives in Congress which has the sole authority to authorize the inclusion of watersheds in the flood control program.

Preliminary Examination.—First of all, a preliminary examination of the Congress-approved watershed is made. The purpose or objective of making a preliminary examination is to determine whether a remedial program of water flow retardation and soil erosion prevention in the interest of flood control appears to be sufficiently feasible to warrant further investigation, thus indicating whether a flood control survey should be undertaken.

The investigation for a preliminary examination is of a reconnaissance nature and aerial photographs at a scale of 1:20,000 and frequently mosaics at a scale of 1:31,680, are used in the gathering and portrayal of this information. The data shown thereon are obtained from field observation and examination, discussion with farmers, land owners and other interested parties, and other readily available secondary information.

Flood Control Survey.—If the report is favorable, it is submitted to the Secretary's office and budgets are prepared for making a flood control survey. Survey responsiblity has been assigned to the Soil Conservation Service and the Forest Service on a territorial basis. For surveys which have been assigned to the Forest Service, that agency will look to the Soil Conservation Service to collect data and make recommendations for treatment of all lands in the watershed administered by the Soil Conservation Service, and for treatment of farm and ranch lands. When the Soil Conservation Service has responsibility for a watershed survey, it will look to the Forest Service to collect data and make recommendations for the treatment of National Forest and other lands administered by the Forest Service.

Aerial photographs at a scale of 1:20,000 are largely used in the making of the survey, and a mosaic of convenient scale is used to depict the watershed as a whole.

This survey includes investigations of the characteristics of the watershed; its land use and agriculture; rainfall, and intensity of rainfall; flood history and estimation of flood damages; determination of general recommendations for a treatment program to retard run off and reduce soil erosion and sedimentation; and estimates of the cost of the program and value of the benefits to be derived therefrom.

Estimates of the recommended program will be based largely on samples rather than on complete inventories. While this method will not furnish all the detail needed in planning a flood control program of a given watershed, carefully selected samples by the use of proper sampling techniques will yield results from which sufficiently accurate estimates of cost and damages can be made. Items concerning the extent of and plan of treatment and works will be procured in more detail for sub-watersheds, tributaries, and minor watersheds, in the subsequent planning stage during the preparation of work plans.

The following refers to Flood Control Surveys as carried out by the Soil Conservation Service in the Southeastern Region. Other Regions use basically the same methods.

The entire drainage area included in the survey is divided into "physical land units" which, under similar cover and treatment, produce fairly uniform run off, sediment production, and deterioration of soil resources. Sample tributary areas are then selected to represent these physical land units—one or more to each unit. In past surveys, these sample tributaries have varied in area from about 30 to over 1,400 square miles; a drainage area around 150 to 300 square miles is usually desirable. Aerial photographs, 1:20,000 scale, of the flood plain areas along the principal streams of each sample tributary, are used in the survey.

Each sample tributary is, if possible, the area above a U. S. Geological Survey stream gage having a reasonably long period of record.

An important part of the investigation is to determine the flood damage on each sample tributary, due to the flood of a given peak gage height. These peak heights vary from the lowest one which gives appreciable damage anywhere on the tributary area above the gage to the highest flood of record (or to the highest one considered likely to occur, even if it has not yet appeared in the record). In this investigation, three principal types of data are needed: economic, engineering, and hydrologic.

First, an economic investigation is needed to determine the actual flood damage which has occurred during the past floods on the sample tributary. Farmers living along the principal water courses of the drainage area are interviewed, and a schedule of their damages drawn up. Included in this schedule are damages to crops, land (by direct erosion or by deposition of sediment, etc.), livestock, farm implements, farm buildings, roads and fences, etc. These damage figures are supplemented by any others available. During the course of the investigation, a study is made for each important crop to determine the average damage, per acre of land inundated by flooding, caused by floods occurring during the different months of the year. The final result is a set of tables or curves giving the average damage to be expected per stream mile from floods of given peak stages occurring in each month. In this part of the work, aerial photographs are used only for general location, and to avoid overlooking open fields (where most of the damage occurs) hidden in the midst of wooded areas.

Second, an engineering investigation is made to determine the area of open land inundated in the sample tributary by floods of various gage heights, from the lowest rise causing appreciable damage to the highest expected to occur. Extensive use of aerial photographs is made during this investigation both in the field and in the office. In the field, an endeavor is made to locate a series of flood marks, on 1:20,000 scale aerial photographs, for two different floods, showing the extent of the area inundated by each of these floods. (See Figure 9.) One of the two selected floods is usually the greatest flood occurring (not too long ago) in the locality. The other should be some flood (probably fairly recent) considerably lower than this maximum flood, but one which has caused enough damage so that it is remembered. Residents in the area are interviewed and any definite flood marks from these two floods are located by small numbered circles on the aerial photographs. A brief description of each mark is put on the back of the photograph. The endeavor is to get a series of such flood marks, for each flood, on each side of the main streams of the sample tributary. Their location on the aerial photographs makes it unnecessary to connect them by traverse lines on the ground, thus saving considerable time and expense. Their elevations must be determined in the field, however. This is done as a part of the general field work needed also for other phases of the survey, such as an approximate profile and occasional cross-section of the stream (see Figure 10), and its flood plain. The cross-sections are selected to give various types of information needed for both a sedimentation survey and for a hydro-investigation, as well as information for the present purpose. Level lines are run as needed so that elevations of all reliable flood marks are determined. These elevations are written on the aerial photograph for each flood mark, each cross-section point, and any other points of known elevation found incidentally during the field work. For convenience in future uses, elevations with respect to the zero of the stream gage are used, rather than mean sea level elevations. The cross-section lines are also plotted on the aerial photographs so that no connecting traverse lines need be run. All horizontal control is eliminated by the use of these aerial photographs.

At the conclusion of this part of the survey, there exists a set of overlapping aerial photographs on which are plotted each point whose elevation is known, with the elevations shown, and also the date of the flood for the flood marks.

These photographs are now given to a stereoscope operator who runs on them the "flood lines" for the two selected floods; i.e., the boundaries of the area inundated by the floods. The flood lines are not actual contour lines since they represent the edges of the flooded area, and hence follow the stream profile in a general way, but they can be considered form lines. They are near enough level lines on any one aerial photograph so that ordinary stereoscopic methods may be used. In some of the early surveys, such stereoscopic lines were checked again in the field and found to be well within the limits of accuracy of the rest of the survey. Ordinary stereoscopic work is considered sufficiently accurate for the purposes of this survey. In the course of the field survey it almost always happens that some of the flood marks are incorrect due to faulty memory of the

FIG. 9. Showing the extent of area inundated by two different floods.

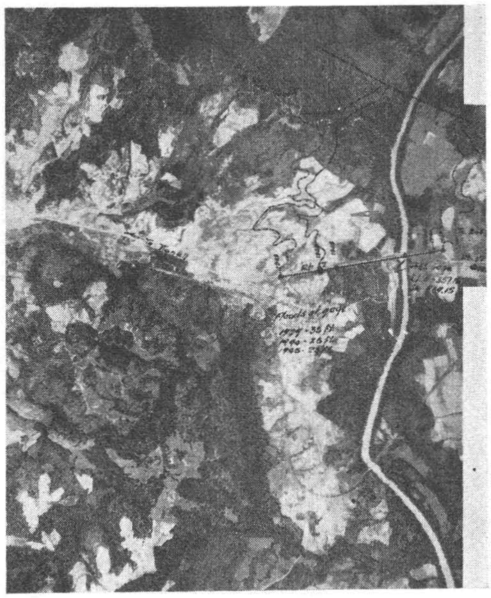


FIG. 10. Cross section at gage showing area inundated by two floods.

local residents, either as to location or as to the date of the flood on which it really occurred. The stereoscopic investigation shows at once which marks are clearly in error; in other cases, it merely shows that *something* is wrong and further field work may be needed to find out the correct results.

The set of aerial photographs now has on it two pairs of flood lines (boundaries of the flooded areas). These are labeled with the peak gage-height of the flood in question, although their actual elevation varies as we go up-stream. The area between each set is now planimetered to determine the total inundated area corresponding to each flood.

Since the flood lines correspond to floods of a known peak-height at the gage, the two planimetered areas thus determined are each connected with a peak-flood stage giving two points on the relationship curve between peak-stage (at gage) and inundated area, and hence two points of the relationship between peak stage and flood damage. Other points are determined by interpolation methods, with a sparing use of extrapolation above the higher or below the lower of the two selected floods.

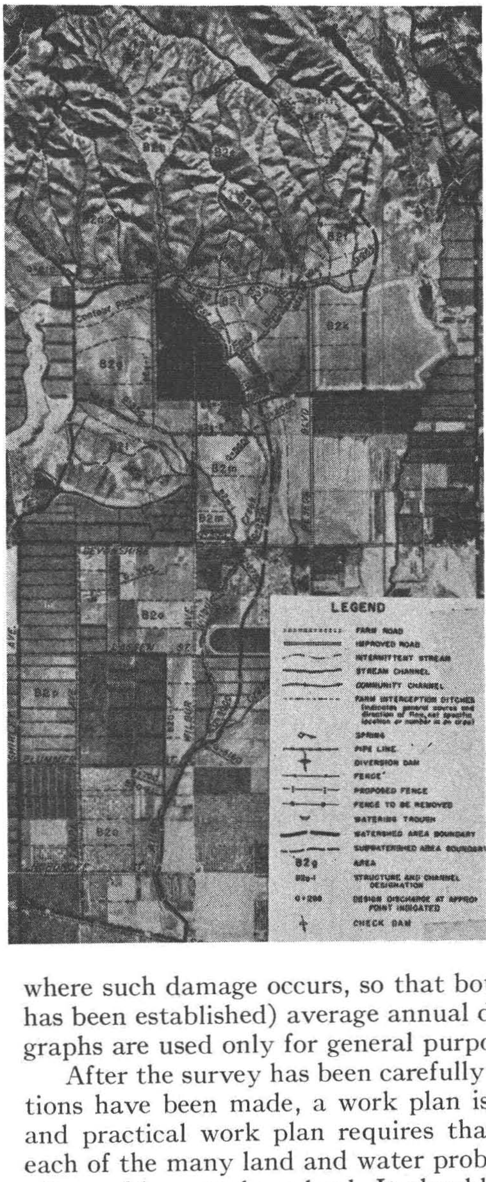
The interpolation method usually employed has several steps. First, at the end sections of each stream "reach," the approximate peak stage elevation (with respect to the zero of the gage) for a selected intermediate flood is determined by hydraulic methods, usually based on simple formulas for "concordant flow," checked by comparison with the known peak stage elevations of the two base floods. The elevation of each selected intermediate flood stage being thus known, its boundary location (flood mark) on the cross-section is found by the usual methods used to interpolate contours on a map (stereoscopic checks may be needed in some cases). Second, the width of the inundated area for each selected intermediate flood being now known at each cross-section (or "reach" end) by direct measurement on the aerial photograph, an approximate formula is used to determine the inundated area for each intermediate flood in each reach. This approximate formula is similar to the "mean end area" formula used for volumes in earth work computations, and gives the area as a percentage of one or the other two known inundated areas (whichever is nearest or seems best). In some early surveys, complete stereoscopic methods were used for these assumed intermediate floods, and their flood lines drawn on the aerial photograph, and then the inundated area planimetered, exactly as for the two base floods. The approximate formula method is used to save time and expense; comparison of the results by each method has shown that the present computational method has an accuracy well within the requirements of the survey, although some adjustment by comparison may be needed occasionally. Third, the total inundated area for each assumed intermediate flood is now found by simple addition. The "open land" inundated is also determined as a percentage of this, by comparison with the percentage of open land in the inundated areas of the two base floods, checked and adjusted if needed by direct examination of the location of the open land as shown on the aerial photographs. Each assumed intermediate flood gives another point on the relation curve between peak stage and inundated area, and hence also on the relation curve or curves between peak stage and flood damage.

The connection between peak-flood stage and flood damage is now established. This must next be connected to the list of floods actually occurring within a reasonably long period in order to compute average annual flood damage. The connection is made by considering the third type of data mentioned previously; hydrologic data. By hydrologic methods, now more or less standard, an average relation is first established between the actual total flood runoff of an event (flood) and the rainfall causing this event, and also between the rainfall (or flood runoff, if we prefer) and the peak stage of the flood. This rainfall versus peak-stage relation, applied to each flood occurring during the period of record, makes it possible by use of the flood stage versus damage relation previously explained, to compute the total flood damage suffered during the period of record and hence the average annual flood damage.

In order to decide whether the improved land use methods recommended in the survey report are feasible economically, it is also necessary to compute an estimated annual flood damage assuming the recommended program is in effect. This is done in exactly the same way as just described for present damages, except that a new (and lower) series of peak stages is used. These new peak stages are those estimated to follow from the same series of flood-producing rains used above, if they had occurred *after* the program was in effect. The future peak stages are computed by hydrologic methods based upon the infiltration theory of runoff.

The results from any sample tributary are finally expanded to the physical land unit represented by the sample, by methods depending on circumstances. Usually, an expansion based on mileage of tributaries has been used, rather than on area.

The above methods refer particularly to agricultural and farm land damage. If urban damage occurs, it is determined by standard methods. A relation between urban damage and flood stage is established, if possible, for each locality



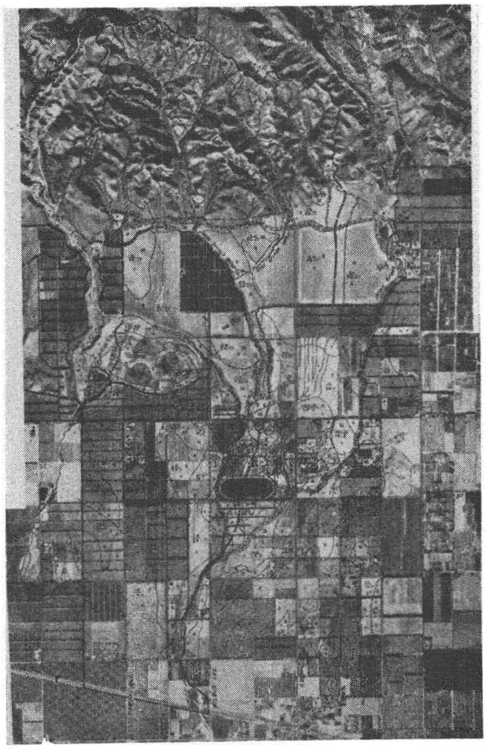


FIG. 12. Conservation survey of a sub-watershed.

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FIG. 11. Flood control survey showing recommended measures to be applied.

where such damage occurs, so that both present and future (after the program has been established) average annual damages may be computed. Aerial photographs are used only for general purposes in this phase of the survey.

After the survey has been carefully worked out and the necessary appropriations have been made, a work plan is prepared. The development of a sound and practical work plan requires that appropriate consideration be given to each of the many land and water problems which exert an influence on the specific problems to be solved. It should indicate what the watershed treatment measures should consist of, and where they should be installed or carried out. The closest possible cooperation is maintained with the directors of the soil conservation districts, landowners, and operators concerned, and all other interested local, state, and federal agencies in the development of work plans for a

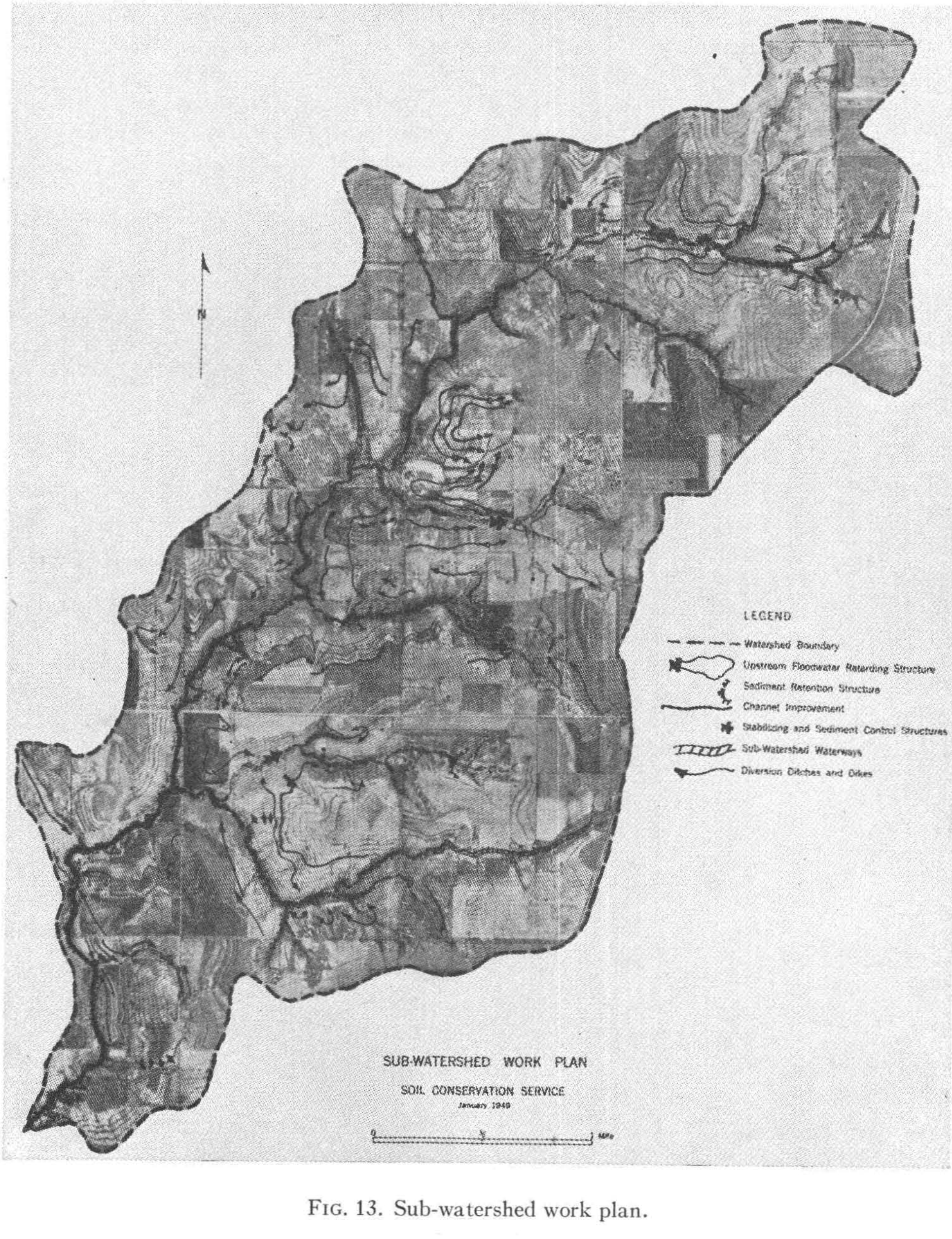

FIG. 13. Sub-watershed work plan.

sub-watershed. At this stage, definite arrangements are made with respect to the specific measures to be carried out, the participation and responsibilities of the cooperating parties including construction, operation, and maintenance. The priority of undertaking work in sub-watersheds is based upon the critical flood and sediment source areas, and is determined in consultation with the cooperating parties. Figure 11 is a mosaic on which has been indicated measures for works of improvement and on which specific measures have been indicated by symbols; the discharges to be taken care of at critical points are also indicated. Figure 12 is a conservation survey and is basic data upon which recommendations for land use and conservation practices and other measures in connection with flood control are made. A mosaic is used for this also. Figure 13, also a mosaic, is a sub-watershed work plan showing location of measures to be installed primarily for flood control, as well as conservation practices, applied for the conservation of the land on which they are located.

Aerial photographs have been of inestimable value to the flood control program of the Soil Conservation Service.

USE OF AERIAL PHOTOGRAPHS FOR RESERVOIR SEDIMENTATION SURVEYS

Sediment is of vital concern in the planning and development of water control and utilization projects. The rate of sediment production from a watershed depends on the nature of soils, slopes, land use, and other watershed and climatic conditions. In order to evaluate the relative effects of each of these factors on soil loss and sediment production, the Soil Conservation Service, since 1934, has carried on reservoir sedimentation studies throughout the country. By measuring the amount of sediment accumulated in reservoirs of known age, and correlating this with watershed and climatic factors, it is possible to determine the effects of individual factors on sediment production.

The volume of sediment accumulated in a reservoir may be determined by one of two methods: (1) By determining the present storage capacity of the reservoir and assuming that the difference between it and the original capacity is a measure of the volume of sediment, and (2) by direct measurement of the sediment deposits. No matter which method is used, a complete hydrographic survey is made of the reservoir. The contour method is used only when an accurate original contour map of the reservoir is available, such as in the case of Lake Mead as described later in this paper. In such cases, a sufficient number of bottom elevations are determined by sounding to reconstruct the contours where changes have occurred. The area enclosed by each contour is determined by planimetering and the volume between two consecutive contours computed. The summation of volumes for the different contour intervals gives the total capacity of the reservoir.

If no accurate original contour map of the reservoir is available, which generally has been the case in most of the reservoirs surveyed by the Soil Conservation Service, the range method of survey is used. This consists of laying out a series of parallel, or nearly parallel, ranges across the reservoir and determining the present water depth and sediment thickness at regular intervals across each range. These data are plotted on cross-sectional paper and the cross-sectional areas of water and sediment determined by planimetering. The segment area, or the surface area of the reservoir enclosed by two bounding ranges and the crest contour, is determined by planimetering. This, together with the cross-sectional areas of the bounding ranges, provides a basis for computing the volume of each segment. The summation of the volumes of the segments gives the total capacity of the reservoir.

In both methods of survey, the contour method and the range method, the shore line of the reservoir must be known; in the contour survey to determine the area of the uppermost contour, and in the range method to determine the surface area of each segment between ranges. Before aerial photography it was necessary, in most cases, to prepare a shore-line map of each reservoir to be surveyed before actual sounding could be started. The shore lines of many reservoirs were covered with a thick growth of vegetation, generally willows, which made shore-line mapping a tedious and time-consuming job. It is estimated that nearly 50 per cent of the field party's time was spent in mapping shore line.

The primary purpose of the shore-line map is to locate survey stations for future reference, and to determine the surface area needed to compute water and sediment volumes. The Service has found it convenient to use aerial photographs for this purpose whenever possible. If the reservoir is at crest, or nearly so, on the date the photograph is made, the shore line may be traced and obtained directly from the photograph. If the reservoir is not at crest at the time the photograph is made, it is necessary to determine the areas of the exposed sections by multiplex methods. If the reservoir is approximately at crest, the aerial photographs are "blown up" to a convenient scale depending on the size of the reservoir to be surveyed. On large reservoirs, with surface areas of several thousand acres, a scale of 500 feet equals one inch is used. A scale of 200 feet equal to 1 inch is used for reservoirs with areas of 100 to 1,000 acres and 100 feet equal to 1 inch, for reservoirs with areas of less than 100 acres.

Due to probable inaccuracies on the outside borders of aerial photographs, only the center portions of photographs are used. These are "blown up" to the desired scale. In order to check the scales accurately in the field, at least two base lines are chained for each enlargement, each base line being laid out normal to the other. In some cases as many as six base lines have been chained to check the scale of the borders of the photographs as well as the centers. The accuracy of the photographs used so far is extremely good with the scale of the photographs differing generally less than one per cent with the true scale as determined by chained base lines. These blown up photographs are then cut to plane table size and mounted on standard plane table sheets with commercial photographic dry mounting tissue. These are carried into the field and used in the same manner as regular plane table sheets. The survey stations are clearly marked on the photographs, their locations determined either by triangulation or by traverse from some clearly identifiable object on the photograph. The plane table sheet is oriented by back sight on established stations, and foresights are taken on points where soundings and sediment thickness measurements are made. The locations of all observations are plotted directly on the aerial photographs for future reference. Shore line changes, which occurred after the photographs were made, are mapped directly on the photographs.

During the past three years, the Soil Conservation Service has been cooperating with the Illinois State Water Survey Division and the Illinois Agricultural Experiment Station in an intensive program of reservoir sedimentation studies in Illinois. During this time, detailed sedimentation surveys were made on eight reservoirs using aerial photographs exclusively.

Aerial photographs have also been used to good advantage in special cases of sedimentation surveys such as that of the San Carlos Reservoir in Arizona. The agricultural economy of a sizable irrigated area below this reservoir is dependent on the water stored in this reservoir. Since large quantities of sediment are deposited in this reservoir annually, the water users are naturally concerned as to how much storage remains in this reservoir. Several years ago the reservoir was nearly dry with the exception of a small pool just above the dam. This afforded an excellent opportunity to map the silted area by multiplex methods. Through the cooperative efforts of the Federal Agencies, including the Soil Conservation Service, represented on the Federal Inter-Agency Drainage Basin Committee, a special flight was therefore arranged to photograph the reservoir basin. The small area in the pool was sounded by a small field party in less than a week's time. The entire survey would have taken a six-man field party many months to complete, but by the use of aerial photographs the job was completed in several weeks. Moreover, the multiplex compiled map was far more accurate than the more generalized topographic map of the basin prepared many years ago.

Probably one of the most unique uses of aerial photographs is that made of aerial photographs to determine the original capacity of Lake Mead. (For details of this see "Mapping Lake Mead" by Carl B. Brown, *Geographical Review*, July 1941.) Lake Mead, impounded by Hoover Dam on the Colorado River, is the world's largest man-made lake. The latest survey places its capacity at 32.5 million acre feet.

On January 24, 1935, eight days before the gates of Hoover Dam were to be closed and Lake Mead would begin to form, it was found desirable to secure data necessary for estimating the measure of erosional removal in the hydrographic basin of the upper Colorado, by measurements of silt in the reservoir. It was determined that only a complete and detailed topographic survey of the entire lake basin would give a basis devoid of controversial elements for determining accurately both the original capacity and future capacities and volumes of deposited sediment.

No such survey was in existence, and inasmuch as the lake was about to begin filling, only aerial photographic methods could be considered for the mapping. After the solicitation of bids, a contract was awarded to Fairchild Aerial Surveys, which received telegraphic notification of the bid at 8:00 a.m., February 23, 1935, and five hours later had photographed the critical area which would have been inundated within the next few days. The basic photography for the entire reservoir area was completed on February 27. (For details see account by L. T. Eliel: The Boulder Reservoir Survey, PHOTOGRAMMETRIC ENG. Vol. III, 1937 no. 1, pp. 23–28.)

Aerial photography served many and varied purposes on this project. Space prevents detailing all of them. Considerable reconnaissance aerial photography had to be carried out to devise a satisfactory scheme of control. Stereoscopic verticals and stereoscopic obliques were flown, and the most practical system of tying Coast and Geodetic Survey stations to stations on the rim were spotted thereon. Ranges were located at intervals of 1,000 to 1,500 and accurately located on the photographs. Where slopes were so slight that contours of less than ten feet interval were needed, the lake surface was photographed at successively higher stages. This procedure also furnished additional control for the stereoplanigraph over all the lower elevations of the reservoir.

Topographic maps were made with the Zeiss stereoplanigraph at a scale of 1 inch equals 1,000 feet, contour interval 10 feet. The sheets were reproduced by the copper engraving method.

Capacity of Lake Mead was obtained by using the weight apportioning method for finding the area at each contour interval, and using the formula $V=h/3(A+\sqrt{AB}+B)$, where V=capacity in acre feet, h=contour interval in feet, A=area of upper contour in acres, B=area of lower contour in acres.

The use of the aerial photographs for this survey showed that the reservoir capacity was sufficient to provide many more years of life for the project than had been assumed by other earlier surveys. This knowledge alone justified much of the cost of the survey.

IRRIGATION AND DRAINAGE

Most irrigation projects cover considerable area, and in order to be properly planned, would necessitate considerable mapping. Aerial photography is an invaluable tool in this branch of the Soil Conservation Service. The first requirement of the technicians in any sizeable irrigation project is a good mosaic of the entire area under consideration. Over-all planning is done on this mosaic. Proposed locations of canals, ditches and structures are carefully studied in relation to surrounding culture and tentatively located on the mosaics. Next a field study is made, and if found satisfactory the locations and other pertinent data are inked in. Enlargements are made of small areas of the mosaics and used as the plan on plan and profile sheets.

In mountainous areas, where an effort is made to locate storage possibilities for irrigation water, the topography is carefully studied on the aerial photographs, and likely looking dam and reservoir sites are marked thereon. These are then visited on the ground and preliminary investigations are made to determine their feasibility.

In areas where river stabilization is an important conservation work, aerial photographs are studied to determine the flow characteristics of a stream or river. It is possible to trace the old channel on the photographs, to locate and study bar formations, and it is often possible to find the critical areas in the present stream location. Stream channel stabilization work on a river must be related to the sections upstream and downstream from the critical areas, and nothing offers a better way to study these than aerial photographs. A quick general picture of these conditions is readily revealed which can then be checked on the ground with detailed surveys where necessary.

In areas where faulting is the serious consideration for structural installations, engineering geologists will use the aerial photographs to locate the faults and their projections. The geologist will also be able to locate alluvial fans that may possibly be used for water spreading areas or for well locations.

OTHER USES

The Soil Conservation Service also uses aerial photography for geological studies, forestry, range management, wildlife, and other activities which perhaps can be described at a later date.

ACKNOWLEDGEMENTS

The cooperation of all those who contributed material for this article is acknowledged and deeply appreciated by the author.

USE OF AERIAL PHOTOGRAPHS IN CONNECTION WITH FARM PROGRAMS ADMINISTERED BY THE PRODUCTION AND MARKETING ADMINISTRATION, U.S.D.A.

Ralph H. Moyer, Chief, Aerial Photographic and Engineering Service

THE Production and Marketing Administration of the U. S. Department of Agriculture has recorded on aerial negatives the most extensive panorama of the surface of the United States that has been achieved to date by any public or private agency. Approximately seventy per cent of the total area of this country, including ninety per cent of the agricultural land, has been photographed from the air, for the P.M.A. A considerable area has been rephotographed, and there are now in P.M.A. files aerial negatives for over 3,000,000 square miles.

Aerial photography was secured by the P.M.A. as the most accurate and economical method of determining the extent of the farmers' participation in