Large Scale Photogrammetric Maps for Land Planning

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Introduction

It is my purpose to give a brief explanation of the method of making large scale maps by photogrammetric methods, and some of its applications to certain fields of engineering. It is hoped that this brief discussion will enable the reader to better understand how to utilize a valuable engineering tool and will give him some idea of the many possibilities available to the engineer in the use of photogrammetry to large scale mapping. We will consider "Large Scale Maps" as those falling in the scale range of from 1″ = 20′ to 1″ = 200′.

The preparation of a good large scale photogrammetric map requires the proper tools, methods, and skills. It is even more important to consider these requisites when having the maps made by photogrammetric methods than if common classical methods are used. Therefore, the potential user should realize that if he wants a good map to suit a particular need (it being possible to make such maps to any particular scale by photogrammetric methods) he should consult someone with experience and reliability in this field, the same as he would if he were requesting any type of professional service.

It may require a number of consultations in order to determine: (1) the extent and usage of the map, (2) the proper scale and contour interval required, (3) the accuracy requirements needed to do the job properly, (4) the schedule of work and delivery time of materials, and (5) an estimated cost to do the work.

If such consultations are not made it is possible that the potential user might order materials not adaptable to his needs, specify certain accuracy requirements not needed, or expect certain accuracies in the work not obtainable when the photography is flown at the wrong scale or with the wrong type of camera. Also, the purchaser may specify certain photographic scales, focal length cameras, or unnecessary features to be shown within the map which may not only greatly increase the bidders quotation but may even prohibit a bidder from making a reasonable bid. For example, the bidder may not have a six-inch focal length distortion free lense taking camera but may have the best first order plotting equipment which is equipped with correction cams, suited to correct the distortion of his own make of mapping camera.

Sending out invitations to bid on certain types of maps, particularly large scale maps, is not always the best solution. Competitive bids may be more expensive in the long run. It has been proven many times that the client actually saved money, and received a much better job to satisfy his requirements when the work was done on a negotiated cost-plus basis. The performance of services for all large scaled photogrammetric mapping will some day, as it should be, be based on a negotiated basis, similar to other professional engineering services.

Preliminary Planning

In the preliminary planning stage of mapping a certain given area, the boundary of the location is outlined on the best available small scale source maps such as U.S.G.S. Quadrangle maps, county or township maps or city maps. Usually two of these maps are furnished to the contractor. He places the flight lines on these maps at certain spacings to give proper side lap coverage when flying at a predetermined altitude. The size of the camera image, scale of photograph desired, and focal length of the camera determines the altitude to fly. Usually the flight lines are drawn between the section or ½ section lines and not on them. When the photography is flown in this fashion it allows the field survey crews to secure the necessary field control along roads or fences that are usually located on section or ½ section lines. Since the overlap between adjoining flights cover these particular geographic boundaries, control obtained along them will fall in two adjoining flights, thus reducing the amount of field control required.

Control Requirements

Whenever the area to be mapped at a large scale is quite extensive, that is, consisting of more than one square mile, it is a good practice to make a perimeter survey before the photography is taken. As soon as the survey is checked, the section corners or other important turning points are marked by placing over them strips of white or dark colored muslin about 12′ long by 2′ wide to form a cross. (See Figure 1.) The white muslin is used for dark areas on the ground and preferably black or red colored muslin is placed over locations that are sandy or white in tone. This paneling should be done prior to the taking of the photography.

Whenever property corners do not allow the placing of such panels due to fences, buildings, trees, etc., then the panel can be off-set with witnesses made from its center to the control station. Of course, if time, weather, or other conditions do not permit the paneling of positions before the photography is done, the stations may be referenced to objects that are identifiable on the photos. There should be at least two such references, preferably three and the nearer they are located to the station the better. In areas not having prominent points suited for such references, it is best to adopt the paralleling method.

From the survey notes, each parallel position is computed to x and y coordinates for usage as primary positions in the grid system. These positions then, since they are discernable on the photos, are used in a stereoscopic plotter, capable of triangulation, to extend auxiliary horizontal control points within the area to be mapped. The number of these extended locations is determined by the number of photos required to do the mapping, usually there are at least two locations for each model. It is not a good practice to extend vertical control for maps having a one or two foot contour interval for the simple reason that it would cost just about as much to do such extension for these large scaled maps as it would to run level lines and it would be impossible to keep the accuracy of the map within "Standard Mapping Accuracies" which stipulates that 90 per cent of all contours should

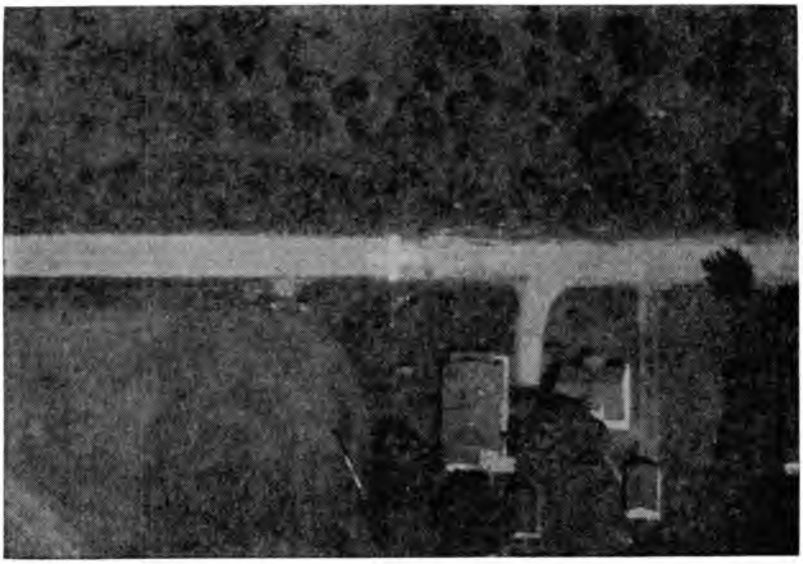

Fig. 1. A typical panel located at a center section corner.

be accurate in respect to the ground detail to within one half of the contour interval.

The Aerial Photography

The area to be mapped is flown to the previously established flight plan. Usually the flights either run north and south or east and west unless the photography is flown for a reconnaissance strip such as for a power line, highway, or stream. The flying height is determined by using the old scale formula that says scale of photography equals the focal length of the camera divided by the altitude, the altitude being the unknown. In temperate climates, the best results for topographic mapping are obtained when the trees have shed their leaves and the vegetation is at a minimum height. For this reason, most aerial photographic work is done in the fall or early spring in these regions. After each roll of film is exposed, it is rushed to the laboratory for processing and editing. It is important to have this done at once, even if it means all night work for the laboratory crew, so that a report on any reflights can be sent to the photographic crew while flying conditions are still good. The weather has its peculiarities and may affect the cost of a survey tremendously. Usually there are two or three clear days in a row and then possibly a week of weather unfit for flying.

All acceptable photographic negatives are numbered with black ink along the border of the negative so as to show the photographic date, indexing symbol, roll number, and serial number before contact prints are made. At first, only one set of contact prints are made on index paper. These are used in the assembly of a photographic index. (See Fig. 2.) This index shows the location of each individual negative, location of the survey, names of important features, scale of photography, and other pertinent information. While the photos are being laid into the indexes, they are again edited, using the proper flights and reflights to give the best overlap coverage.

An additional set of contact prints are made, after the indexes have been completed, of just the print numbers occurring in the photographic indexes for field control purposes. On these prints are identified the existing horizontal control locations (usually paneled positions) and auxiliary points to be used in the horizontal control extension and all existing bench marks. Also the approximate location of the required elevations are circled on the face of the photographs so that the rod-man of the level crew knows approximately the location to occupy when securing an elevation needed to level the stereoscopic models. There are several precautions which he must take in order to occupy the

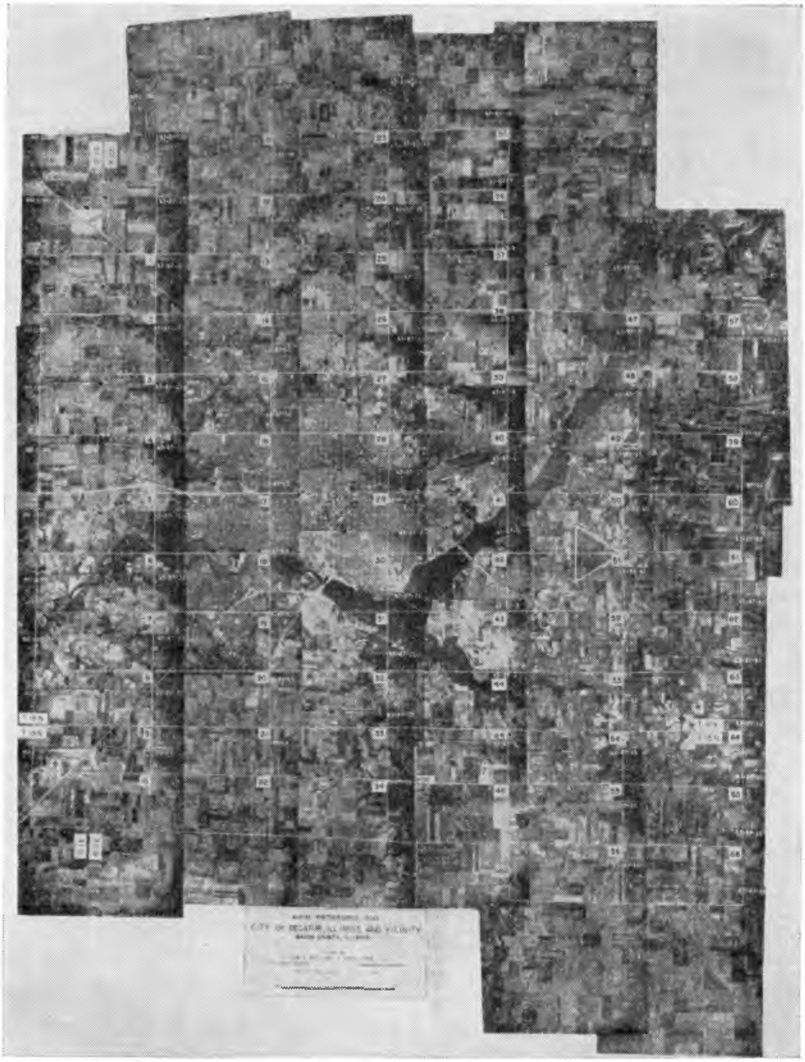

Fig. 2. A photographic index.

best location in stereoscopic plotting work. The rod-man, in our opinion, is the most important man in a level party. He must select a location that is relatively flat and easily identifiable on the photos.

Allied Materials

From the aerial negatives various materials can be prepared and furnished, each depending on the information required.

(1) The contact prints can be used with a stereoscope to study

the characteristics of the terrain and in the photo interpretation of numerous features such as heights of objects, drainage, soil pattern, and the identification of objects.

(2) Enlargements up to five diameters in size can be made to various scales for the study and measurement of planimetric features. These can be made, if the scale does not have to be exact, simply by enlarging them without a rectification to fit distances on existing maps or to any known distances.

(3) A mosaic map (See Fig. 3.) which is an assembly of a set of aerial photographs fastened together by matching the images and gluing them onto a mounting material. These are usually finished in two categories, called semi-controlled and controlled mosaics. Semi-controlled mosaics are those brought to a common known scale by known distances and kept in orientation by a "straight line control method" or by alignments taken from existing maps. Controlled mosaics are those brought to a definite scale by rectification, that is, tip and tilt in the negatives are removed when the prints are made and the prints are enlarged or reduced to fit known positions plotted on a base. On this type of mosaic, grid lines or geographic lines are shown.

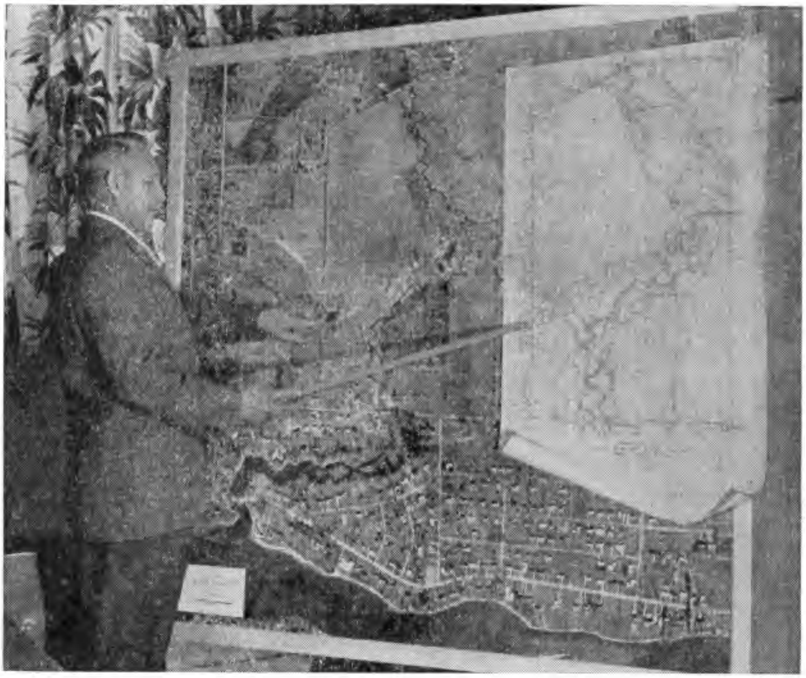

Fig. 3. Comparing a mosaic map, which is to be used as a mural in the land developer's office, with a photogrammetric map.

(4) Often planimetric maps (See Fig. 4.) are all that are required to serve an intended purpose. These can be made by tracing the detail direct from rectified enlargements, mosaics or by using a steroscopic plotter. The most accurate method to use in the compilation of these maps is by the use of a stereoscopic plotter, since it brings all the detail to an orthographic projection (their true positions in a plane) whereas if drawn from a mosaic or enlargement, numerous scale changes due to relief displacement or tilt will affect the true placement of all details.

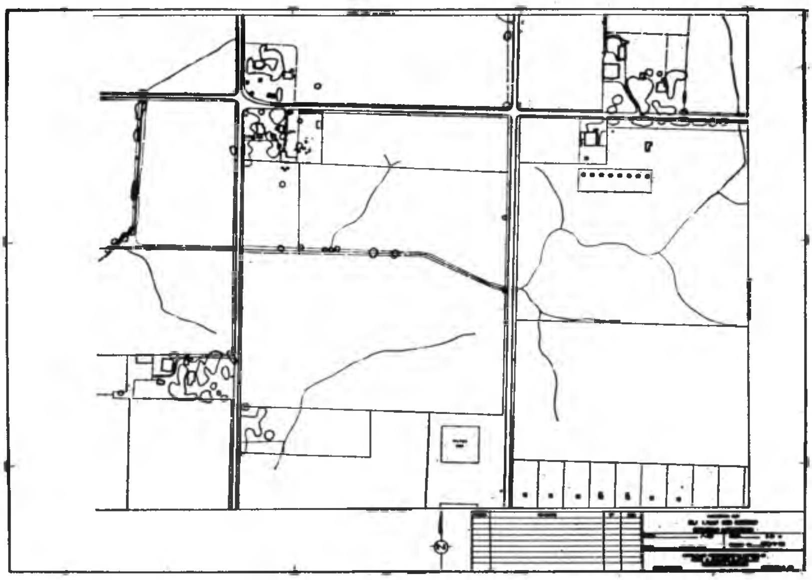

Fig. 4. A planimetric map.

The most accurate, true to scale, position of an aerial photo is near and around the center of each photograph. This is particularly true in rough, rugged terrain where relief displacement plays an important part.

(5) Topographic maps (See Fig. 5) are those not only showing the planimetry but also the topography which includes the known elevations, spot elevations, and contours. In photogrammetric mapping this information is obtained by a stereoscopic plotter. The accuracy of such maps is determined by many factors: the scale of the photography, the focal length of the camera; the amount and type of vegetation cover; contour interval used; type of stereoscopic plotting equipment used; the experience of the machine operator; the amount,

accuracy and distribution of field control; and the quality of negatives and plates used in the plotting equipment. The amount of plan detail to be shown, or other information, should be determined before the plotting commences. For instance, in order to keep the cost to a minimum, a map made by leaving the houses off in a built-up area may provide sufficient information needed in determining a sewer system study. This alone can reduce the cost of compiling the map at least 50 per cent.

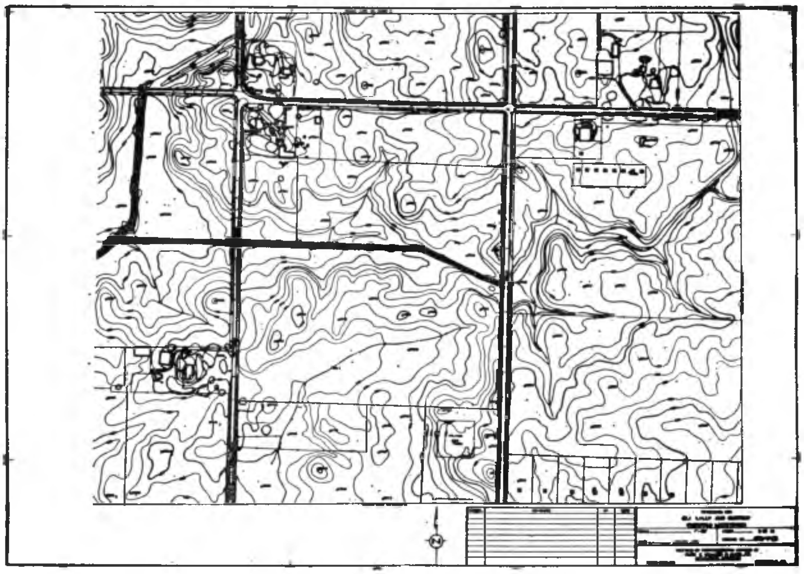

Fig. 5. A topographic map.

(6) Plan and profile maps are made easily and quickly at large scales by the photogrammetric method. These require a reconnaissance strip of photographs flown over the proposed route. Both horizontal and vertical control can be established with a minimum of field control by aerial-triangulation of segments of the line through the use of a first order plotting instrument. The aerial photographic method of providing this type of work prohibits stirring up the curiosity of the land owners over whose property the line will run, thus minimizing the chances of them banding together to hold up the price of the property before easements are prepared.

(7) A service relatively new in photogrammetry is the "Positive Film Transparency Enlargement." They are made on a plastic film at some common scale. These transparencies provide an excellent

medium on which engineering information such as sewers, water lines, power lines, property lines and names of owners, names of streets, etc. can be drawn in ink to fit the detail selected. Likewise, by use of stereoscopic plotting equipment elevational readings can be provided at street intersections, alley intersections, high and low spots, or at any other important location, after which each can be drafted onto the film in ink. This finishes all the topographic information required for built-up areas and greatly decreases the cost in preparing maps of such areas. The contours are drawn direct on to the transparency by adjusting the contour overlay so that selected picture points fit identical points on the transparency. This provides a large scale photo-map with a transparent base from which any number of *Bruning* or *Ozalid* prints can be made. Corrections can always be made on this original film transparency.

(8) With modern access to computers, it is rapidly becoming the trend to use them in conjunction with large scale photography in the computations of earth volumes. Cross section elevational readings made by a first order stereoscopic plotter can be entered onto tape or cards adaptable to a computer. Two to three miles of such readings can be made in one day by a single operator. Of course, in order to do this type of work most satisfactorily all operations governing its phases must be done in their correct procedure.

A report was recently published in an issue of the *Photogrammetric Magazine* presented by a group meeting held at the University of Illinois on a discussion concerning "Photogrammetric Applications to Highway Work." A couple of their conclusions are as follows: "Photogrammetric methods are 40 per cent faster than corresponding ground methods and there is less possibility of having observational mistakes in photogrammetric procedures than there is in ground procedures." "Information obtained by photogrammetric methods is generally more reliable, although perhaps not as precise, as that obtained by classical methods" (In other words, measurements are not shown to hundredths of a foot). "That is, photogrammetric methods may have larger errors than classical methods, but they have fewer mistakes (Blunders)."

As the perfection of photogrammetric equipment improves and as proper methods and techniques are put into practice, field methods will become less and less desirable in large scale mapping as it already has in small scale mapping as being too slow and too costly. This does not mean that field men will not be needed, for primary first and second order control will always be needed. Also, the annotation of the contact prints and the field check of the finished maps will eventually become a primary requirement.

Stereoscopic Plotters

When all necessary flying, laboratory work, and field control is complete, the information is given to the stereoplotter operator for compilation. Most of the work that requires a two foot contour interval or less should be done with a First Order Instrument such as the Stereocartograph Model IV. (See Fig. 6) which is a first-order universal plotting instrument, manufactured in Florence, Italy. This particular instrument is rated as having the highest "C" factor accuracy of any instrument manufactured anywhere in the world. The "C" factor is the ratio of the altitude of the airplane to the contour

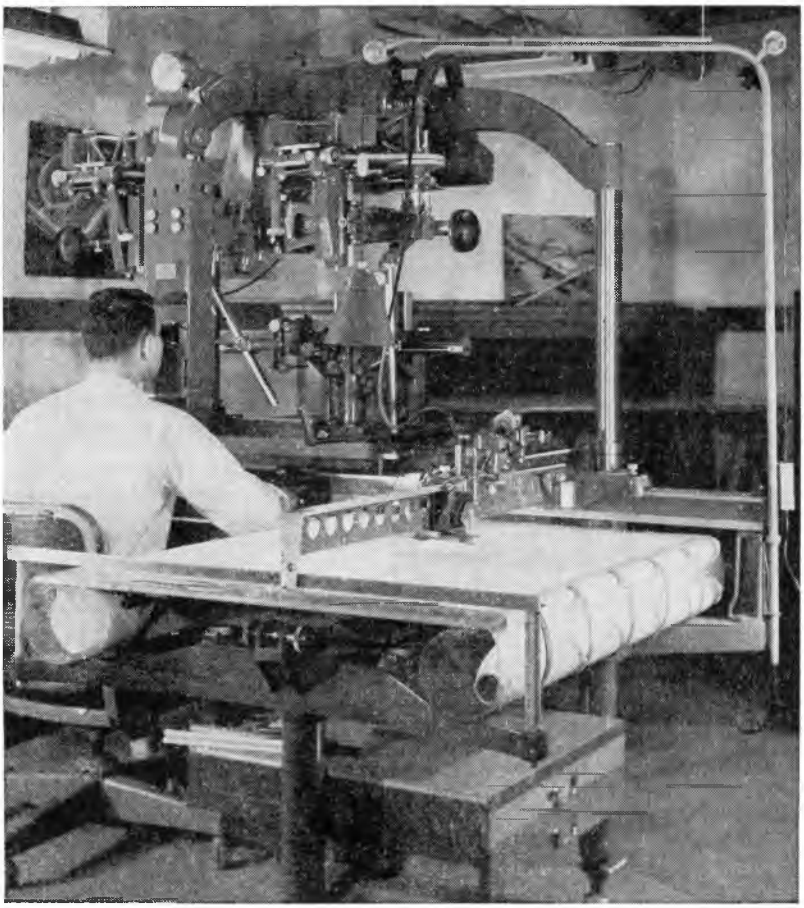

Fig. 6. The Santoni Stereo-Cartograph Plotter.

interval. Two glass diapositives are put into the instrument, and the "Cartograph" recreates the natural terrain features using an optical-mechanical projection system. The binocular viewing system permits one eye to see one projector image while the other eye obtains an independent view of the second projector image at a magnification of nine times the negative scale. The combined effect of the simultaneous view is to produce a stereoscopic or three-dimensional model of the terrain. A floating mark centered in the optical train of the viewing system provides the means of measurement within the stereoscopic model. Apparent vertical motion of the floating mark with respect to the model is obtained by raising or lowering what is known as the "bz" carriage; this motion is measured by an elevation counter calibrated in feet and meters. Horizontal motion is obtained by sliding what is known as the "by-bz" carriage around the steroscopic model; this motion is translated to the coordinagraph by a series of rods and gears, which draws the detail from the photographs to the map manuscript. The scale of the map in relationship to the photographic scale may vary from 10-times enlargement to a 10-times reduction.

The planimetric detail is compiled by guiding the floating mark so that it follows the feature being delineated. The floating mark is kept on the ground during this operation by the manipulation of the "bz" control motion of the instrument. The features are delineated on the map manuscript by a pencil that exactly coincides with the floating mark, and reproduce the movement of the mark in a horizontal plane. Contours are drawn by maintaining the floating mark at the appropriate fixed elevation and guiding it so that it is in apparent contact with the terrain. After a model is completed, auxiliary control points are dropped to facilitate the set-up of the next model. This procedure is repeated until the area concerned is completely mapped. Once the topographic and planimetric details are plotted, the manuscript is given to a draftsman who traces the details onto linen or some other suitable drafting medium. Each completed sheet is given thorough photographic and drafting edit before delivery to the client to insure compliance to all specifications.

When the work load becomes heavy and a high "C" factor is not required, the Kelsh plotter (See Fig. 7) may be used in conjunction with the first order plotter, particularly in drawing in the plan and possibly the contours wherever the terrain is rough leaving the first order instrument to do the control extension and the contours of areas having a minimum grade.

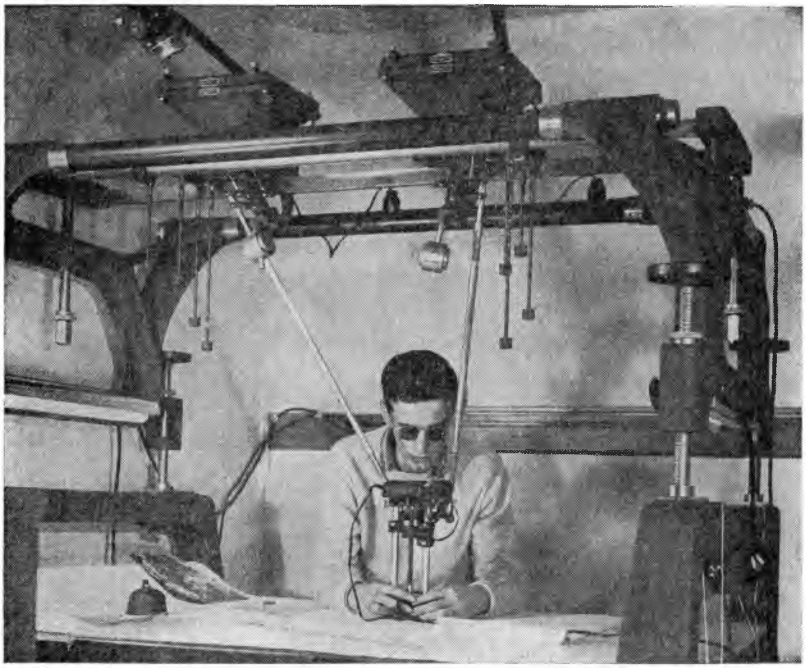

Fig. 7. The Kelsh Stereoscopic Plotter.

A Photogrammetric Comparison

There has been a great deal of literature published and discussions made comparing photogrammetry with field methods of land mapping. These usually fall in three main categories of speed, cost, and accuracy.

(1) As to speed of making a map by photogrammetric methods compared to field methods, there is without a doubt, proof and knowledge that photogrammetry is the fastest method by far. One good stereoscopic operator can compile all the plan and show one foot contours on from 80 to 160 acres in one work day when the terrain is relatively flat. This amount of work would take a field crew about a week to do with a plane table. After the field data information is obtained, it must then be correlated and compiled into a map whereas the stereoscopic plotter draws the information direct onto a base. This being the case, a map made by photogrammetric methods can be made about five times as fast. Once the photography has been obtained the plotting can proceed rapidly, utilizing a number of plotting instruments on a multishift basis if necessary.

(2) The cost at which a photogrammetric map can be made is undoubtedly cheaper than conventional field methods since the speed

is so much increased. Through the whole map compilation procedure the costs to employ one or two men in photogrammetric mapping must be compared to the cost to employ four or five field men. Also the photogrammetrists will do about four to five times as much work as the field men in the same time period. The factor that tends to equalize the speed and cost of the two systems is the fact that more operations are required for the photogrammetric method. Aerial photography must be taken, contact prints must be made and marked for control, and certain amounts of field control must be obtained before the compilation of the maps can be made.

When the size of the area becomes very small, say less than 40 acres and it is a considerable distance from the base of operations, due to the greater number of operations in the photogrammetric method and/or adverse weather conditions, it becomes just as economical and fast to do the survey by classical methods.

Legitimate comparisons on costs of surveys made by field methods involving cross-section work against those made by photogrammetric methods find that the cost varies from 5 to 8 times greater for the field method. This applies, of course, only when the area becomes large enough to merit the use of photogrammetry.

(3) As to the accuracy of a photogrammetric survey compared to field methods, much depends on several factors which have previously been mentioned. A reliable photogrammetrist will endeavor to control all factors governing the accuracy so as to achieve a map having what is called "Standard Mapping Accuracies." This states that 90 per cent of all contours shall be correctly placed to the planimetric detail within an error not greater than one half contour interval and that the remaining 10 per cent must not be in error greater than one contour interval. Of course, in some regions where it is impossible to obtain photography void of vegetation, at any season of the year, it may be impossible to hold to the 10 per cent accuracy especially when the contour interval is small. In such areas, contours are usually shown as broken lines and if it becomes a necessity to have exact contours in such areas, they will have to be run in by the standard field procedure.

Again quoting an exerpt from the article on the "Report on Group Meeting on Aerial Photography and Photogrammetric Applications to Highway Work", we have this conclusion: "In the past, photogrammetric work has been checked against field work. This practice is questionable however, since many photogrammetric techniques provide more accurate results than their corresponding ground-techniques. In general, the ground survey standard is much lower than the photogrammetric standard."

Conclusion

When using maps made by photogrammetric methods the user must realize certain limitations. He must not expect, for instance, to have certain distances, which have been measured in the field, to read to hundredths of a foot on the map. Spot elevations shown on a photogrammetric map may not be the exact tenth or hundredth of a foot as was determined in the field. But, as an overall comparison of a good photogrammetric map against a map made by field methods, he will find that the photogrammetric map will win out. Contours up minute streams will appear on a photogrammetric map whereas they will cross over many of them on a map made by field methods. As a whole, the plan detail will be truer to scale and location on the photogrammetric map.

In the application of photogrammetry to land development and engineering studies, aerial photography should be obtained for each project just as soon as possible in order that the planner may have it to use in making the engineering study and report. This allows the engineer to make use of the photography first in their preliminary study and eventually in all phases of the final plans and layout whether it is a dam and reservoir site, a subdivision, a sewer and sewage system, water power and lines, airports, highway and bridge construction or volume inventories. The aerial photograph will become their most valuable tool. It is used not only to provide a reliable base on which to make their design, but they are also able to obtain other information through photo interpretation of the photos such as soils structure, vegetation, drainage, size of objects, etc. This has in many cases saved the time and expense of the engineer making a trip to the site to obtain this information.

Photogrammetry is also playing important roles in many fields. By photo interpretation, data on such items as residential housing types and densities, traffic studies of congested areas, coastal water and underground obstructions, the classification of types of timber, geological studies and size and nature of the land usage may be determined.

Every county should have a set of recently taken aerial photographs. They should be taken at the proper scale and with a precision mapping camera so that all county agencies, such as the tax assessor's office, the city planning office and the county surveyor's office may have access to them. If all county agencies would join together in the venture of procuring the aerial photographs, it would be a small investment for each considering the value they would receive from them.