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*Philippine—Numerical Photogrammetric Cadastre**

G. T. MARZAN, G. UMADHAY and T. C. JIMENEZ,
Geodetic Engineers—Photogrammetrists†
Under the supervision of
Prof. Micanor G. Jorge, Director of Lands

THE CADASTRAL SYSTEM IN THE PHILIPPINES

LAND registration in the Philippines is based on the Torrens System which originated in Australia and presently has been used in the State of Massachusetts, U.S.A. The title to the land rather than the evidence of ownership is registered in a registry of property. The underlying principle of the Torrens System is the indefeasibility of titles. Once a certificate of title is issued by offices of registry on order of our courts after due hearing, the technical descriptions of the land for which the title was issued become fixed and inalterable. This principle is necessary for the permanency of land ownership, The title issued contains among others: (1) the directions and lengths of boundary lines, (2) the adjoining lots or owners, (3) the direction and distance of corner one of each lot to a location or conservation monument, and (4) the area of the land. With these descriptions, the identity of the property—its location and orientation on the ground, its size and shape, and its relation to other lots or property—becomes definite.

The Philippines, though consisting of several thousands of islands, is subdivided into provinces. Each province in turn is subdivided into municipalities. All the unregistered land in a municipality may be the subject of mass registration. When in the opinion of the President of the Philippines the public interests require that the titles to the lands in that municipality be settled and adjudicated, he orders our Director of Lands to execute a cadastral survey. Upon the completion of the survey, the maps or plans of the cadastral survey and the technical descriptions of all lands subject to registration are forwarded to the Court for the settlement and adjudication of titles.

THE PRESENT METHOD OF CADASTRAL SURVEY

In the technical descriptions of a piece of land contained in our titles, the directions of boundary lines are given to the nearest minute of arc, the lengths to the nearest centimeter, and the area of each lot to the nearest square meter. These data are all derived by computation from ground corner coordinates. We also require in the position of a lot corner a precision of ± 30 cm. in our agricultural regions and ± 10 cm. in our urban areas. Towards these end results we execute our cadastral surveys. Ours, therefore, is a purely numerical cadastre.

Once an order of a cadastral survey is issued by the President of the Philippines, the following are the steps we take:

1. *Notification of the survey.*—The cadastral survey is published in our Official Ga-

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† Department of Agriculture and Natural Resources, Bureau of Lands, Manila, Philippines.

zette, notices are posted in the location of the land, and individual notices are sent to owners or claimants of landed properties in the municipality, these notifications are important so that each one having interests in any property is afforded the chance to protest his rights. Since the underlying principle of the Torrens System is the permanency of land titles, whatever descriptions of the land are placed in the title should be the result of the agreement of all concerned or the result of what is just under the circumstances.

2. *Control survey for the project.*—Only a small portion of the Philippines is covered by either 2nd order or 3rd triangulation controls. When there is a cadastral survey of a municipality, therefore, we run a control traverse survey for each project, connecting it, where possible, to the nearest triangulation stations or to stations of traverse control for previous cadastral projects. The precision of control traverses depends on the area of the project.

3. *Lot Sketching and Identification.*—Owners or claimants are required to indicate on the ground their boundary corners and together with the adjoining claimants to agree on the common boundaries. Simultaneously, agreements are sketched by our fieldmen producing what we call lot sketches. Sketches are made by means of a plane table and are tied to control traverses. This, then, is one of the more tedious parts of the work. Besides showing the layout of all the lots, the lot sketches serve as the guide for our final lot survey and plotting.

4. *Final lot survey.*—In that part of the project where lot sketching has been completed, we then execute the final lot survey. Traverses are run from stations of traverses of higher order covering all lot corners.

5. *Computations and Maps Preparation.*—After the final lot survey, the tremendous amount of work of computing the coordinates of corners and subsequently the directions and distances of boundary lines and areas of lots is undertaken. At the same time the lots are plotted on the final cadastral maps, which are 1′ quadrangles at the scale of from 1/1,000 to 1/4,000. All these records are subsequently prepared for submission to our Courts.

Cadastral surveys as described above started in the Philippines in 1909. To date about 10.5 million hectares of the total 30 million hectares area of our country had been surveyed. Based on the statistics of cadastral survey projects already completed we have averaged thus far 268,000 hectares per year. There remains approximately 19.5 million hectares; apparently if we were to continue at the same rate, at least another century would be required to finish the survey of our country.

THE PHOTOGRAMMETRIC METHOD

It is no mere coincidence that development in areas of our country where titles have been cleared has been faster. The issuance of land titles accelerates the economic development of an area. Since cadastral survey is a prerequisite to title issuance, the rate at which we execute cadastral surveys sets the pace of economic development. Our government, therefore, has turned to photogrammetry—to find out whether with this method we can attain (1) the desired acceleration of cadastral survey, (2) a decrease in the cost of cadastral survey, and (3) a better assurance of the accuracy of the results, which is very important because of the requirement that technical descriptions are permanent and inalterable.

In 1958, we started to undertake the cadastral survey of the Province of Bulacan, as a pilot photogrammetric project. The project has an area of 149,000 hectares involving 15 municipalities and approxmiately 61,000 lots. After our President issued the necessary order for cadastral survey, negotiations were conducted for the acquisition of photogrammetric instruments and equipment, resulting in our now having two first-order stereoplotting machines equipped with electronic coordinate registering devices and card punching machines, and two automatic aerial film cameras. At the beginning of our project we also had at our disposal an aerial plate camera. Recently we acquired a rectifier-enlarger having a lens of high resolving power. Together with an electronic data processing machine, this equipment forms the bulk of our photogrammetric installation.

The Project is a joint undertaking of the Philippine Air Force, which takes charge of the aerial photography, and the Bureau of Lands, which takes charge of the photogrammetric work including the requisite ground work. In greater detail, this division of work is as follows:

Philippine Air Force: (a) flight-planning, (b) the taking of aerial photography, and (c) photographic processing. Bureau of Lands: (a) assisting in flight-planning, (b) preparing notification of survey and lot sketching, (c) monumenting and signalizing lot corners, (d) establishing photo-control points, (e) aerial triangulation, (f) stereoplotting and stereocoordinating, (g) transforming coordinates and adjustments, and (h) final lot computations and maps preparations.

We shall now discuss how we have adopted photogrammetry to our local conditions:

1. *Aerial photography*. The choice of the scale of our photography has been guided by practical considerations rather than by the size of our corner monuments or by the precision we require of the position of a lot corner, although the latter has not been sacrificed. We are using corner monuments with a diameter of 15 cm. Preliminary estimates were that a scale of 1/6,000 would be required for their recognition. With our requirement of ± 30 cm. in the position of a corner and considering 10μ as the attainable overall mean square error in the plane of the negative for the whole photogrammetric procedure, this scale is clearly acceptable from the standpoint of precision. But, is this the most economical scale?

Before we started photography in the project, we had test flights using different flying heights over a test area where we had placed different sizes of signals. The test flights showed that the 15 cm. signals were still visible at a photo scale of 1/12,500 and some were even identifiable at 1/15,000 photo scale. This perhaps is attributed to the very high resolving power of the camera lens and also to the good contrast between the white signals and the surrounding area. Based on the experience in the test flights, we decided that photography for the final survey flight, taken by the plate camera with wide-angle lens, should be 1/8,000, and that to be taken by the film camera with a normal-angle lens 1/7,500. Both will have 60% forward overlap and a 30% lateral overlap. These are the scales of photography we took in the first area of Bulacan. In the other areas, we subsequently used the plate camera for photography at the scale of 1/12,500.

It was also first decided that our flight planning was to be done on available 1/50,000 U. S. Army Map Service maps. We found that these maps were outdated and that some planimetric features were not correctly represented. Thus they were not suitable for the flight plans for the final survey flight. Consequently photographic coverage at the smaller scale of 1/15,400, which we called preliminary photography, was taken of each area. This was assembled into semi-controlled mosaics and then reproduced at a scale of 1/25,000. On the resulting reproduced mosaic, the flight plans for the final survey flight were drawn.

2. *Lot identification on photographic enlargements*. The preliminary photography served a second purpose. We divided each photograph into quadrants, each quadrant was enlarged to a scale of 1/4,000. These enlargements, mounted on a hard board, were used for our lot sketching. Boundary corners agreed upon by the owners were simply located and pricked on the enlargements. This made lot sketching much more convenient and increased the rate of work four times. Even more heartening was the psychological effect on the owners when they saw that the details of the ground definitely corresponded with those on the photographs. The lot sketches attained more meaning than mere points and connecting lines representing their properties. These lot sketching enlargements became the guide for stereoplotting, insuring the coverage of all points visible in the stereoplotting machine. It should be noted that before the lot sketching, notification of claimants were made in the usual manner.

3. *Signalization*. One queston which we were not able to resolve during the test flights was that of signalization. Since one frequent source of error is the mis-identification of points, signalization of corner monuments is important. But what should be the minimum amount of signalization that will give no mis-identification or at least minimize it? In order to answer this question, the first area photographed was divided into two sectors. In one sector we signalized corner monuments by whitewashing the top with carbide waste so that they were simply white spots 15 cm. in diameter. In the other sector we signalized monuments by whitewashing the top and painting cross bars of 15 cm. width and 70 cm. length radiating at a distance of 80 cm. from the corner monument. We signalized without the cross bars because usually boundary corners in our agricultural areas were also intersections of ricefield dikes which, we reasoned, would make them easily identifiable. However, in the actual stereoplotting we found that there were many other dike intersections that were not corners at all, and white spots on them sometimes led to mis-identification. In that area where we used cross bars we were able to identify almost all corners easily. In the subsequent areas of

the project, therefore, corner monuments were signalized with cross bars.

4. *Photo-control point survey.* Each model was provided with at least four control points, either surveyed on the ground or by aerial triangulation. We had to select photo-control points following the photography. The Philippine Air Force has not had experience in the exacting requirements of cadastral survey flights so that it was not possible to pre-select points and employ pinpoint navigation. Selection of control points in the common overlap of models was made in the office from the diapositives using mirror stereoscopes with 8× magnification. The layout of the photography allowed the formation of five blocks for aerial triangulation to reduce ground survey of points. For models not included in the blocks, full ground-control was provided.

Simultaneously with the other ground preparation, field parties were extending our triangulation work until there were stations every 2.5 to 5 kms. Traverses run for the survey of photo-control points were connected to triangulation stations or to traverses of higher order. Elevations of points were determined either by running level lines or simultaneously with the traverses.

5. *Aerial Triangulation.* Strips were all provided with full ground-control in the first and last models. In addition, the first and last strips of each block were also provided with ground-control at the outer edges. Since our stereoplotting machines are first-order, aerial triangulation was carried on continuously along a strip with the base-in base-out method.

6. *Stereocompilation.* Models with full ground-control were immediately plotted after the ground coordinates of the photo-control points were computed. Both relative and absolute orientations were done with the use of the numerical method. In the process of stereocoordinating, which is done twice for each model, machine coordinates of points were automatically punched on cards, and in stereoplotting, points were directly plotted on map sheets. We had to maintain two shifts with two persons per shift in each machine—an operator and a cartographer assisting him on the plotting table.

7. *Transformation and adjustments.* Transformation of machine coordinates into ground coordinates was done either with the Helmert or affine transformation. For the adjustment of three blocks of aerial triangulation, a new method called the "Sequential Least Squares Affine Adjustment" (or SELESAFF) was developed by one of our photogrammetrists. We are now conducting research on another method of adjustment for the other two blocks which might be less cumbersome than the first method. To all these new procedures, also, we dovetail our adjustment of previously approved surveys that are scattered among lots undergoing survey, so that all coordinates are transformed into one uniform system. This phase we have termed "old surveys adjustment." All these computations are done by means of an electronic data processing machine (EDPM).

8. *Final lot computations and Map Preparation.* After points had their transformed ground-coordinates, there followed computations of the directions and lengths of boundary lines, the areas of lots and the directions and lengths of the line from a location or conservation monument to corner one of each lot followed. These computations are programmed and done in our EDPM. At the same time, the cadastral maps are finalized, inked, and prepared for the signature and approval of the Director of Lands. Records will then be ready for submittal to the Courts for the land registration proceedings.

9. *Personnel Requirements.* Photogrammetry being a new method in our cadastral survey, we had to take stock of the availability of the required technical personnel and their training requirements in the different work operations of the project. The University of the Philippines since 1937 has been offering the degree course in geodetic engineering including theoretical subjects in photogrammetry. From the pool of graduate geodetic engineers we drew the technical personnel for the project including our incumbent Director of Lands. He was sent in 1952 on an MSA grant to the U. S. and Europe to make studies and observations in photogrammetry, geodesy, and cartography. Eight Colombo Plan scholars took up the diploma course in photogrammetry at the University College London from 1953 through 1955. At the beginning of the project, however, two European photogrammetric firms made available two of their photogrammetrists to help us during the initial work stages as no one in our country had had a considerable experience in such a large undertaking. We retained one of them as a technical consultant; he together with our engineers

trained abroad formed the working staff that guided, and trained other personnel for, the project. During the progress of the project, we were recipients of fellowships and scholarships abroad, such as from the Netherlands, Australia, the UN FAO, West Germany, Switzerland, Italy, and France. Thus we have taken advantage of the offers of the more advanced countries of the world to assist the developing areas. Their readiness to render such assistance is a great source of encouragement.

Advantages of the Photogrammetric Method over the Conventional Ground Method

In the beginning of this paper we gave a triple purpose for our adoption of photogrammetry, namely, (1) accelerated rate of survey, (2) lower costs, and (3) more confidence in the accuracy of results.

On the rate of doing the work, our overall performance is not spectacular. There are even observations that if the project had been executed by the conventional ground-method we would have accomplished more by now. But because a pilot project we have been beset and delayed by all sorts of problems—technical, administrative, and other practical considerations. But it seems noteworthy to state that if we are able to stick to our timetable, we hope to finish the project by this year. This will be a record of completing 15 municipalities in four years, whereas for the conventional ground-method we spend from three to five years to complete a cadastral survey of one municipality alone.

As to the unit cost, to date, our computations for that part we have completed show that we are getting a unit cost of $22.01 per lot or approximately $9.00 per hectare. For our surveys on the conventional method we are, at present, averaging $35.00 per cadastral lot or approximately $12.00 per hectare. Photogrammetry has, therefore, proved to be cheaper. When the procedures of the work have been systematized further as a result of our experiences in this project, there is reason to believe that this unit cost will be even lower.

The most encouraging part of the work is the accuracy we have obtained. Of the models we so far completed we are obtaining an average mean square error of ± 23 cm. in the position of a point. However, a number of big discrepancies have been discovered between positions of points obtained by the photogrammetric method and positions of the same points from conventional ground surveys of several years ago. Studies we have made attribute this to the precision of the previous surveys. This is one of the technical problems that considerably delays the project.

One distinct advantage of photogrammetry is that one can prescribe checks at the various stages of the work that will insure the maintenance of the overall precision of the work. Such checks are not very convenient with the conventional ground method. Also the automation of several phases of the work greatly minimizes chances of human errors. All these cannot but lead to a greater confidence in the accuracy of the result, and, therefore, a firmer foundation for our Torrens System of land registration.

Besides these advantages in cadastral surveys, photogrammetry offers more far-reaching benefits not obtainable with the conventional method. The photographs can also be utilized in the compilation of topographic maps vital to the socio-economic development of the country. Furthermore, photographs contain an unlimited wealth of information that can be analyzed through photo-interpretation for various requirements of forestry, soil conservation, geology, and others.

Favorable Effects of Adoption of Photogrammetry on Socio-Economic Development of the Country

The Philippines is basically an agricultural country. Agriculture for many years to come will be the base of our economic progress. The survey of a property and the consequent issuance of the title to it obtains for the owner the security of his possessions. Delimitations of land boundaries, therefore, become a necessary condition to a well ordered society.

In such an atmosphere of settled conditions in our communities there arises a faster tempo of economic activity. As more landowners obtain their titles, lending institutions have brisker business operations because more properties will be available as collaterals for loans that may be needed in agricultural, commercial, or industrial undertakings. Idle capital is therefore released for productive enterprises.

A speedy survey of the country also becomes in effect a faster assessment of the land resources of the country resulting in (1) a more accurate assessment of the sources of revenues for the government; this when channeled to the different development programs of the country leads to more improved facilities and conditions of living for all citizens; (2) the utilization of every available piece of land to production which together with the intense application of scientific methods in agriculture will lead to a greater agricultural production and thus, to national self-sufficiency.

Proposed Long Range Program of Photogrammetric Survey

As a result of our experience in the Bulacan Pilot Photogrammetric Cadastral Project, our Director of Lands has drawn up a long range plan for a nationwide survey of the Philippines. He proposes a 15-year period within which to finish the remaining two-thirds of the country's area. Under this plan we hope to achieve a unit cost of less than $6.00 per hectare. To implement this program, we are recommending to our Congress the passage of a bill appropriating $25 million for this purpose. We are also looking forward to possible aid from the UN Special Fund which we are negotiating through the local UNTAB representative.

Thus we have shown how we are utilizing science and technology in our cadastral surveys. And in proposing to do it in a nationwide scale we are striking at the heart of our country's socio-economic program of alleviating the living conditions of the masses of our people and securing continued prosperity for them, their children and their children's children.

*Development of Programs for Strip and Block Adjustment at the National Research Council of Canada**

G. H. SCHUT, *Photogrammetric Research, Div. of Applied Physics, National Research Council, Ottawa, Can.*

ABSTRACT: *A description is given of recently developed programs for strip and block adjustment. The strip adjustment consists in three-dimensional transformation of strip coordinates by means of various polynomials. Conformal transformations are used systematically. Block adjustment consists in transformation of the coordinates of the individual strips by means of polynomials. It is performed separately for horizontal coordinates and for heights. Use is made of a direct solution of the complete system of normal equations for all strips. Results obtained with a block of RC9 super-wide angle photography are shown.*

At the National Research Council, the use of analytical methods in photogrammetry has been a subject of research since 1953.

First, a method of analytical aerial triangulation was developed and programmed for electronic computation. In addition, a three-dimensional strip transformation was programmed for the conversion of strip coordinates to a geodetic coordinate system. This transformation did not include corrections for strip deformation. Subsequently, methods were developed for the adjustment of the horizontal coordinates of single strips and of blocks of overlapping strips. Here, strip deformation was corrected by means of conformal transformations. Reports about these methods were published in PHOTOGRAMMETRIC ENGINEERING and in *The Canadian Surveyor* [1, 2, 3] in 1960 and 1961.

* Presented at 1953 Semi-Annual Meeting of the Society.