crease in the amount of new photography that can be "processed" by a given photogrammetric facility.

The benefits envisioned from the integrated mapping system presented in this paper are believed to be of such magnitude that continued study leading to the development of requisite equipment is warranted. It is the hope of the authors that disclosure of this integrated system will stimulate further analyses and refinement by others, and, with the cooperation of photogrammetric instrument designers and manufacturers, efficient profiling instrumentation will be forthcoming.

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*Utilization of Photogrammetric Mapping and Electronic Computers for Highway Design**

PETER T. GAVARIS,
Partner of King and Gavaris,
Consulting Engineers,
425 Lexington Ave., New York City

THE subject of this paper in my opinion, is of the utmost interest not only to members of the American Society of Photogrammetry but to all Federal, State, local and Consulting Highway Engineers who are dedicated to the purposes of increasing engineering productivity by the utilization of modern scientific methods.

Previous speakers at this meeting have described how photogrammetric maps are used by the New York State Department of Public Works in the initial stages of highway design, namely route selection. I will start from that point and present some of our organization's experiences in using photogrammetric mapping in connection with highway design and construction, as well as some of our initial experiences in using an electronic computer in connection with highway design computations.

About a year and a half ago our organization was retained to render survey and design services for the New York State Dept. of Public Works in connection with a section of the proposed Interstate Route No. 5 in the Watertown Area. In order to meet the requirements of a desired schedule, we studied the feasibility of utilizing photogrammetric mapping for the preparation of the necessary survey maps and bridge site plans, at the scales of 50′ to 1″ and 20′ to 1″ respectively, which are ordinarily used to prepare preliminary design plans as well as contract plans for highway and structures required. Consideration of such a plan required the approval of the State Department of Public Works. We were favored by the fact the photogrammetric mapping at scale of 200′ to 1″ and with 5′ foot contours had been accomplished for the entire section of this proposed highway, for purposes of route selection.

With the encouraging approval and guidance of District Engineer Robert Sweet, under whose supervision our engineering services for this project were performed, we were able to convince the Chief Engineer of the State Department of Public Works at Albany to accept contract plans designed and prepared from photogrammetric mapping at scale of 50′ to 1″ and contoured for vertical control at 2 foot intervals. In order to do this, we agreed to

* Presented at Meeting of Central New York Region, American Region of Photogrammetry, Watertown, N. Y., April 26, 1957.

make necessary ground surveys at locations on the proposed highway where existing roads and railroads would intersect; we agreed to prepare topographic maps at 50′ to 1″ scale with 2 foot contours at these locations and to check the photogrammetric mapping for these particular areas. If any discrepancies beyond the realm of reasonable tolerance were apparent by this check comparison, we agreed that we would then complete our survey maps for the entire section utilizing ground methods. Needless to say, we did not have to make any additional ground surveys since the checks indicated beyond any reasonable doubt that maps prepared from photogrammetric methods were as accurate as the design would require. And agreements for new work that followed this experience, did not include such checking reservations.

Having made these stipulations with the State Department of Public Works we were able to sit down with Lew Dickerson and Pete Warneck of Sargent-Webster-Crenshaw and Folley and schedule the photogrammetric work. Being the middle of the Fall season when all the leaves were down and with no snow, the time was opportune for initiating such aerial surveys as had to be made. Ground control surveys were to be made by Sargent-Webster-Crenshaw and Folley; the agreed-upon ground surveys at intersecting highways and railroads were begun by our organization. Both of these surveys were of course tied into the C.&G.S. horizontal and vertical control systems.

In the meantime the selected route was more or less finalized on the basic 200″ to 1′ photogrammetric scale already mentioned. We were thus able to indicate to SWC&F the band needed for compiling the 50′ to 1″ maps. Upon receiving these photogrammetric maps, contoured at 2 foot intervals, we could enter the preliminary phase of alignment and profile design.

The advantages of these contoured topographic maps as regards highway alignment, grade, and drainage design were very apparent. The maps were able to provide us with areas of a band width varying from 1,000 to 1,400 feet. This band width was sufficiently wide to cope with basic and specific problems of highway design such as problems of alignment, geometrics, drainage, snow disposal, right of way and gradeline. Cross sections could be taken from photogrammetric maps normal to a finalized alignment, rather than normal to an arbitrary base line laid down for convenience of ground survey. Thus a more accurate set of cross sections was available for determining toes of slope and tops of cut, for drainage design, and for proposed section design as well as a more accurate estimate of earthwork involved. The labor involved in taking cross section notes from the contour maps was relatively minor as compared with the time and labor for resetting models in the plotter to produce cross section notes from it.

Following the review and approval of the preliminary phase designs by the State Dept. of Public Works and the Bureau of Public Roads, contract plans and final design were begun. Again photogrammetry was used to trace on the contract plans the original ground topography. Final plans were almost 90 per cent completed, when the Bureau of Public Roads established revised Interstate Highway Standards. When applied to our designs these standards necessitated considerable changes, reverting to a per cent completion stage equivalent to approximately 60 per cent.

We widened considerably our mall widths in various locations to conform to the changes in standards. The value of the photogrammetric maps was again indicated by it not being necessary to resurvey because the band of compiled material being wide enough to accommodate such revision. As the final centerline, and the right-of-way lines, were mathematically computed in the office, these were staked in the field prior to construction, by using calculated ties to the control survey monuments.

Throughout the design phase and the preparation of appropriation right-of-way maps, the aerial photographs themselves were constantly referred to, as further aids in our design.

Contract plans for the first construction portion of our design sections were completed and approved 14 months after our designation for the project. And when the entire project was reviewed, it was found that despite two major revisions during the design, we could accomplish our mission of helping to get under construction a portion of the Interstate Highway system quicker and more economically, by the utilization of photogrammetric mapping.

This first construction contract is now

under construction. Acting as agents for the State Dept. of Public Works for the supervision of this construction, we have established certain groundwork which we feel necessary for adequate photogrammetric practices being developed and completely accepted. Although ground survey methods are being utilized to take cross sections for payment, a comparision to these cross sections, obtained in our design phase utilizing photogrammetric mapping, indicates slight descrepancies but all within the specified tolerances. We feel reasonably sure that such construction engineering features as setting of slope stakes, determining pay quantities of earthworks and the like can utilize photogrammetric mapping.

We believe that photogrammetry has a definite place in highway construction as well as in a highway design. If it is to be an accepted method in construction, we should be assured of the following:

1. A standard method for determining quantities should be adopted for use throughout the United States, preferably by established AASHO specifications.
2. A definite accuracy requirement should be specified.
3. A minimum of 2 foot contour intervals should be specified.
4. To assure the contractor that photogrammetric methods are proper, all necessary field checks and corrections should be made.

We began about a year ago to make inquiries regarding electronic computers and the utilization of electronic computers in highway and structure design. We finalized our thinking recently in purchasing an electronic computer, type LGP-30, manufactured by Librascope and General Precision Company.

We have trained a few in our organization in the computer operation and in preparing the necessary programs for various problems.

Our approach before any programming is started is as follows:

1. The repetitive and time consuming problems are determined. In this we include information concerning time spent, and degree of skill required for solution.
2. Priority to the programs is assigned.
3. We find out if anyone else has programmed these problems. A flow diagram of a problem, even if prepared for a different type of computer, can be of considerable help.
4. The problem to establish scope is outlined.

To date we have established the following programs as regards the Highway Dept. which can be applied to repetitive problems. We can't say that we have completed a program because refinements always suggest themselves as the work progresses.

1. Computations of traverse coordinates and balancing of traverse by transit rule. We are preparing an alternate program to utilize the compass rule in traverse balance.
2. Profile grade elevation computation including vertical curve grade elevation computations.
3. Earthwork cut or fill computation for determining the locations of toes of slope, tops of cuts and cross section area for estimate purposes.
4. Computation of earthwork pay quantities from field notes during construction.

We are developing at the present time, programs involving the following problems.

1. Horizontal alignment.
2. Bridge geometrics (that is, all the horizontal and vertical dimensions necessary to completely setting the framing plan for a bridge superstructure.
3. Reinforced concrete pier design computation.

Photogrammetry can be married to the use of electronic computers. Research is now underway to develop converters so that information can be punched on tapes directly from plotters, introduced into a computer so that earthwork quantities can be obtained. We are enthusiastic about the utilization of electronic computers in highway and bridge design. We believe that a tremendous amount of the time of engineers can be released for performing design engineering functions as a result of necessary tedious and uninteresting calculations being performed by the electronic computer.

We believe that the effective application of photogrammetry, electronic computers and other modern devices to the procurement of data processing, analysis and presentation will make possible planning designing and building expeditiously the current large highway program in an economical and efficient manner.