raphy in advance to prepare two identical backgrounds on which the figures can later be constructed.

Plate II shows two stereographs of an ellipsoid. The one at the top is an untilted view of the left front-quarter showing three dihedral angles of 30 degrees. The other is a tilted view of the full front-half showing four dihedral angles of 30 degrees, beginning at the left. The axis of tilt is the major axis of the ellipse shown, and it lies in the plane of the paper. The top of the ellipsoid has been tilted toward the observer through an arc of $7\frac{1}{2}$ degrees. A geodetic line spanning 30 degrees of latitude and longitude is shown, along with normals to the ellipsoid at each extremity of this line.

A complete description of the method used to construct the stereographs shown in Plate II would require more time than I have allotted myself for this comment. However, the basic principles used were identical to those used in constructing the pyramid. A somewhat better acquaintance with descriptive geometry than is required to draw the pyramid would naturally be needed, but only the fundamentals of the subject are involved. Accurate drafting of the curves is the critical factor.

The ellipsoid shown was used to clarify some of the figures involved in computing latitude and longitude. The time required for construction seemed insignificant when compared to the advantage gained by being able to visualize clearly the complex relations of the various lines to each other and to the spheroid. For example, the stereograph of the tilted figure illustrates very clearly the fact that normals do not intersect when differences of both latitude and longitude are involved. It also shows that latitude is measured, not at the center of the spheroid, but at the intersection of the normal with the equatorial plane.

Although the matter of illustrating text books and works on geodesy might seem to be outside the province of photogrammetric engineers, our familiarity with stereoscopy does place on our shoulders the responsibility to point out how the stereoscopic principle can be used to advantage in other fields. Why not solicit a talk on the subject at the next Annual Meeting from some prominent geometer or geometry teacher?

The Terrain Data Translator

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and
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INTRODUCTION

A NEW photogrammetric measuring device known as the Terrain Data Translator (TDT) has recently been developed and field tested by the Benson-Lehner Corporation of Los Angeles, California. The primary purpose of the TDT is to provide ground cross-section and profile notes in digital form directly from the stereo model as viewed in the double projection, or Kelsh type, stereoplotter, or directly from a topographic map sheet. Preliminary test results indicate that this unit permits increased accuracy and significant savings in terms of both time and money.

The TDT operator can select recorded output of the terrain data in any combination of three forms: typed records, punched cards, or punched paper tape.

The initial development of the TDT prototype was made possible through a close interchange of information between the California State Division of Highways, the Los Angeles aerial mapping firm of Pafford and Associates, and the Benson-Lehner Corporation. The valuable cooperation and great personal interest offered by these three groups in establishing the basic design criteria for the TDT has resulted in the production of an instrument that is both practical and economical in operation. The TDT system is easily installed and does not

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require special skill or training on the part of the average stereoplotter operator.

DESCRIPTION

The main components of the Terrain Data Translator system (less typer and keypunch) are shown in Figure 1. Figure 2 illustrates the TDT system as it is commonly used in conjunction with a projection type plotter.

The Distance Measuring Unit can be aligned very accurately with respect to the desired cross-section or profile line as plotted on the map manuscript sheet. The Elevation Measuring Unit consists of a modified Bausch and Lomb tracing table which can be attached to the traveling coupling plate on the distance unit by means of a small pin. In this position the tracing table continues to function normally, except for the fact that it is now constrained in such a way that the floating mark can travel only along the plan position of the pre-selected cross-section or other profile line. The Control Unit is mounted within convenient reach of the operator and is used to enter the station number, zero the counter, and actuate the readout.

The combined Distance Counter and Readout Unit provides a visual display on the decade counters of distances "left" and "right" from centerline, as determined by the position of the measuring unit on the stereoplotter. The Readout Unit also provides the means of feeding the digital settings on the various system components to the typer and/or keypunch for recording. When used for recording terrain notes, the operator positions the distance measuring unit over the desired cross-section, attaches the tracing table, and then enters the proper station number on the Control Unit. The floating mark is positioned over the center-

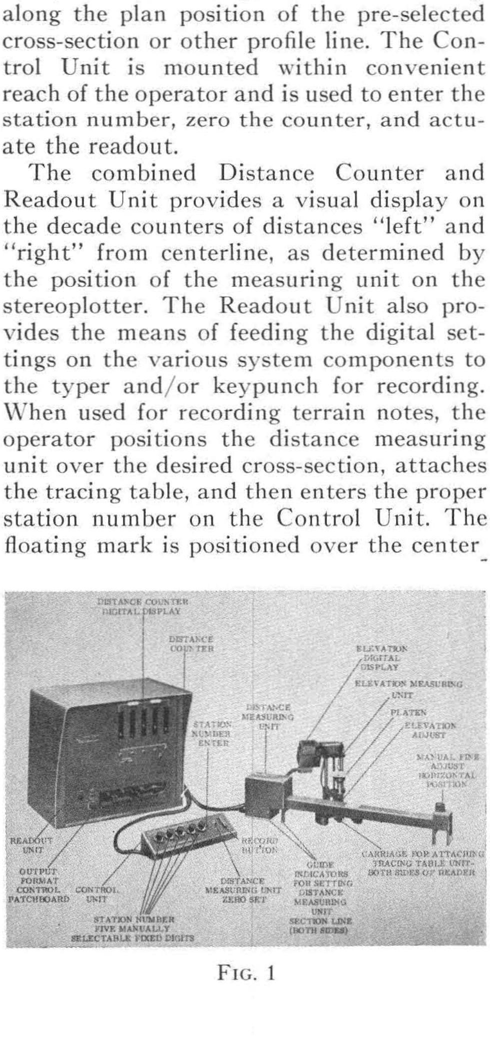

FIG. 1

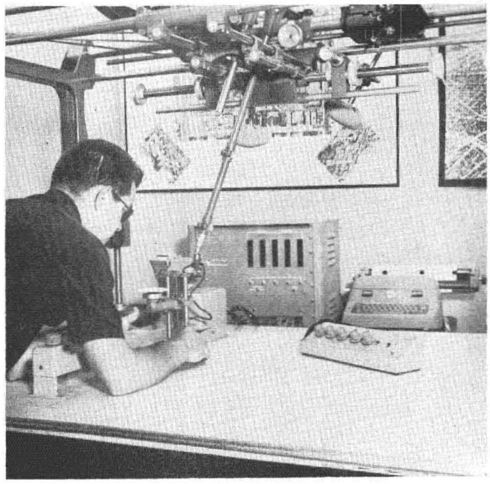

FIG. 2

line intersection and the distance counter is set to zero by means of a button on the Control Unit. The operator indexes the direct reading elevation counter and then proceeds to take spot height readings at various points along the cross-section. The elevation reading at each point, together with the distance left or right of the centerline, is automatically recorded when the operator depresses the record button located on the Control Unit. Gear boxes on both elevation and distance measuring units allow for true readings in feet within the common scale ranges.

When reading cross-section or profile data directly from topographic maps, the contour elevations are entered manually, and the offset from the centerline is read out from the TDT Distance Measuring Unit.

Other applications of the TDT involve volume determination of coal piles, slag heaps, borrow pits, dump sites, and reservoir areas. In addition, the TDT system is applicable to the difficult problem of tracking and recording ground surface subsidence in and around mining and oil producing areas. The TDT system could also be used for the digitizing of non-topographic surfaces to reduce costs in certain lofting and master mold forming operations.

ECONOMIC FACTORS

Many photogrammetric mapping firms would consider adopting a system of the TDT type if it were demonstrated that the investment in this type of instrumentation equipment would permit broadening the services that they have to offer. It is currently the practice for the map user to utilize his own technical staff and surveying crews to obtain the required cross-section and profile notes in the field by conventional measuring procedures using tape, transit, level, and rod. These terrain notes are then reduced in the office and transcribed in a form to be used for the final calculation of quantities of earth. This phase of the highway design procedure is monotonous, and requires an excessive amount of man-hours for a given unit of data. Many of these organizations would prefer to contract for these same services if it were proven economical and practical to do so.

Trial tests of the TDT unit in use with a stereoplotter have demonstrated that data may be obtained in final form on punched cards or punched tape with the elimination of costly errors and a saving in man-hours. Eliminating the requirement of a keypunch operator to transcribe hand-written notes into punched card form alone represents the saving of one man-year. Additional saving is realized in that the stereoplotter operator need only make an alignment and push a readout button; the transcription of the data is automatic. Transcription errors are eliminated because it is not necessary for the operator to read dials and write numbers or for a keypunch operator to reread the notes and transcribe them into cards.

Potential users of this equipment will be interested in two important economic factors pertaining to actual use of the unit: 1) Relatively low installation and maintenance cost, and 2) reasonable amortization charge. The impact of automation on conventional engineering practices and procedures has emphasized the importance of the obsolescence factor in evaluating true amortization charges for certain items of capital equipment in this category. In the case of the TDT, its price and design flexibility allow for the calculation of a nominal amortization figure without undue threat of a large loss arising from early obsolescence.

Development of the TDT-Stereoplotter System

CONVENTIONAL PROCEDURES

In order to evaluate the application of the TDT system to the great variety of route location problems, a brief review will be made of the procedures and practices used in the determination of earthwork data for route design purposes. Since highway location is of great current interest, the discussion will be limited to this particular type of route location problem.

A good description of highway practice in earthwork determination is found in an article published in the magazine *California Highways and Public Works* (Sept.–Oct. 1952) titled "Contour Grading Highway Maps" by C. V. Kane.

> "The volume of earthwork—both excavation and embankment—for practically all highway construction projects is determined during the design stage. This volume is used to ascertain the balance between excavation and embankment and as an estimate of quantities for comparing bids for contract work. The quantity determined at that time may or may not, depending on job conditions, be used as final pay quantities. Earthwork volume is determined by what is known as the cross-section method. The routine is for survey parties to take ground elevations across the proposed roadbed at intervals of about 50 feet throughout the length of the job.
>
> "After these elevations are plotted by drafting to scale in the office, the finished construction section proposed (a template when feasible) is superimposed, and the area between the two lines determined as a basis for volume calculations by the 'average and area' method."

A simplified illustration of the above described procedure is presented in Figure 3. The end areas BCDFG and KLMOP are contained in a vertical plane situated normal to the centerline of the route at stations 115 +00 and 115+50 respectively. By averaging these end areas and multiplying by the 50-foot separation distance, a good approximation of the earth quantity within the figure can be calculated.

In years past, these end area sections were laboriously drawn to scale by a draftsman on sheets of cross-section paper, and the areas determined by traversing the section with a planimeter. Final volume calcula-

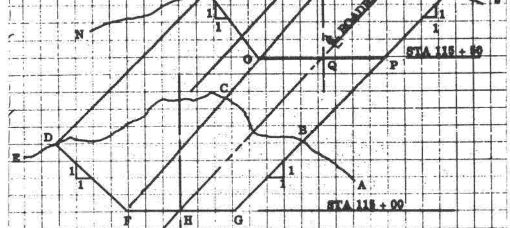

FIG. 3

tions were performed on a desk calculator. These data were then used to plot a "mass diagram" curve in which the abscissas represent the stations of the survey and the ordinates represent the algebraic sum of excavation and embankment quantities from some points of beginning on the profile, considering cut volumes positive and fill volumes negative.

The "mass diagram" is a very important display for the design engineer, since it enables him to determine the following for a given route location problem:

a. The proper distribution of excavated material
b. The amount and location of waste
c. The amount and location of borrow
d. The amount of Station-yards pay overhaul distance
e. The direction of haul

MACHINE COMPUTING TECHNIQUES

With the introduction of modern high speed computing machinery, it became apparent that the time-consuming work normally required for the calculations of earth quantities in the route design procedure could now be handled in a more efficient manner. Basic input data for the machine computer would consist of 1) ground cross-section terrain notes corresponding to the curve ABCDE in Figure 3, and 2) roadbed data for the particular route illustrated by the section DFHGB at Station 115+00.

Early trials of the machine computation approach to the earthwork data problem were quite encouraging, although it was now quite apparent that the most time-consuming and costly aspect of the entire procedure was the determination of accurate terrain notes. This information was usually obtained in the field by survey parties utilizing conventional cross-section measuring methods. Before submitting the problem to the computation center it was necessary to transfer field notes and roadbed notes to standard earthwork data sheets (see Tables 1 and 2) from which keypunch operators could transcribe the figures into final digital form for computer input.

The following comments have been offered by highway engineers* using the machine computation techniques on this type of problem:

1. This service relieves engineering personnel of the routine plotting of cross-sections and calculation of earthwork data, giving them more time for actual engineering work.
2. It is possible to use terrain data submitted for one preliminary route location for subsequent "P" lines and the final line.
3. It will also be possible to process

* Instructions for Calculation of Earthwork Data by Punched Cards, California Division of Highways, November 8, 1955.

TABLE 1

EARTHWORK DATA SHEET

	PUNCHED
	VERIFIED

ROADBED NOTES

ROD READINGS ☐
ELEVATIONS ☑
DIFF. FROM ELEV. AT ℄ ☐
DIFF. FROM ELEV. AT ____ ☐

DIST. 13 | CO. SAM | RTE. 30 | SEC. C | GROUP B | LINE A

Date____________ Sheet____of____
Recorder____________
Party____________

WH-67-A

STATION	+	+ HI. − ELEV.													
	50													89^{55}	
												82^{0}		61^{0}	
	50	−2:1	89^{59}	88^{3}	88^{8}	90^{25}	88^{45}	90^{25}	88^{8}	88^{34}	89^{62}		89^{59}		
			58^{0}	57^{0}	19^{5}	18^{0}	0	18^{0}	19^{5}	55^{0}	55^{7}		58^{0}		
625		−2:1	88^{59}	87^{3}	87^{8}	89^{25}	87^{45}	89^{25}	87^{8}	87^{34}	88^{62}		88^{59}		
			58^{0}	57^{0}	19^{5}	18^{0}	0	18^{0}	19^{5}	55^{0}	55^{7}		58^{0}		82^{0}

TABLE 2

EARTHWORK DATA SHEET

PUNCHED
VERIFIED

TERRAIN NOTES

ROD READINGS ☐
ELEVATIONS ☑
DIFF. FROM ELEV. AT ℄ ☐ / ______ ☐

DIST. CO. RTE. SEC. GROUP LINE
13 SAM 30C B A
Date______ Sheet____of____
Recorder______
Party______

WH 67

STATION	+	+	HI.		−	ELEV.											
625				109^{5}										79^{6}		79^{5}	
				120^{0}										120^{0}		100^{0}	
625			107^{0}		106^{4}	99^{5}	96^{3}	96^{0}	99^{3}	95^{0}	95^{9}	97^{8}	89^{3}		78^{9}		77^{5}
			79^{0}		62^{0}	53^{0}	32^{0}	20^{0}	0	20^{0}	34^{0}	42^{0}	51^{0}		60^{0}		86^{0}
	50															80^{3}	
																120^{0}	
	50		108^{4}		106^{1}	105^{3}	99^{1}	95^{3}	98^{6}	94^{5}	95^{6}	98^{1}	81^{3}		82^{1}		82^{2}
			120^{0}		81^{0}	61^{0}	51^{0}	24^{0}	0	21^{0}	30^{0}	45^{0}	50^{0}		73^{0}		89^{0}
624				107^{5}										94^{1}		94^{0}	
				120^{0}										120^{0}		100^{0}	
624			105^{2}		103^{1}	98^{1}	96^{3}	96^{2}	97^{5}	97^{3}	97^{4}	95^{0}	95^{2}		96^{0}		95^{2}
			98^{0}		85^{0}	63^{0}	45^{0}	24^{0}	0	20^{0}	31^{0}	45^{5}	50^{0}		79^{0}		89^{0}

simultaneously several alternate lines if roadbed data are furnished.

4. It should be unnecessary to resubmit roadbed data for subsequent lines and require the engineer to recopy information already available in notes previously submitted, since instructions can be given to the tabulating section to re-use portions of the roadbed data.

Following the development of machine computation techniques the primary problem remaining to be solved was the time-consuming and costly procedure of determining terrain notes through the use of field survey parties.

SOLUTION OF THE PROBLEM OF TERRAIN NOTE DETERMINATION

A solution to the problem of replacing terrain note determination as done by field survey parties was suggested by the following factors:

1. Modern procedures in highway route planning call for the photogrammetric compilation of strip maps encompassing an area containing possible final route locations.
2. Over 90% of these strip maps are compiled in a Kelsh type stereoplotter.
3. In theory, a precisely scaled and leveled facsimile of the terrain surface is formed optically in the double projection type stereoplotter.
4. The optical mechanical method of obtaining measurements from the anaglyphic model formed in the plotter could be adapted by known techniques to digital readout.

Working along this line, developments were made by several groups, including the Massachusetts Institute of Technology, Battelle Memorial Institute on contract to the State Highway Department of Ohio, Mr. E. S. Preston of Photronix, Inc., Columbus, Ohio, and Benson-Lehner Corporation of Los Angeles, working to the specifications of Pafford and Associates of Los Angeles.

The Benson-Lehner Terrain Data Translator was the first production machine available to the general market. Since then development of these units tests has been performed, and it has been demonstrated that terrain notes compiled by the TDT-stereoplotter combination can replace cross-section data normally obtained by the field survey party. These tests also emphasized an important factor that is common to both field and manual photogrammetric procedures: that human errors can and do creep into the data with unfortunate frequency. The TDT was designed to eliminate most of the sources of human errors normal to conventional measuring and recording methods. This has been done by limiting the principal function of the human operator to setting the floating mark on the ground at points along the selected profile or cross-section. Station number, distance in feet left and right from centerline, and elevation of individual points on the line are all automatically recorded in digital form by the TDT when the record button is depressed.

Terrain notes compiled in this manner by the TDT are free of human and machine errors providing the stereo model is accurately scaled, leveled, and free from excessive warpage. The photogrammetric engineer can best assure this model accuracy by:

1. Utilizing precision "distortion free" mapping photography.
2. Establishing sufficient horizontal and vertical ground control points (signalized if possible for positive identification in the plotter).
3. Maintaining the stereoplotter in good calibrated condition.
4. Performing a rigorous and exact relative and absolute orientation when setting up the model.
5. Checking model accuracy from spot height readouts on known elevation control points.
6. Possible use of convergent photography in place of the normal vertical photography in order to achieve a "harder" model.

The Terrain Data Translator successfully automates one aspect of the terrain data problem. Many groups are working on additional automatic devices and soon equipment should be available which will further enable the production of engineering data using only a minimum of human effort and time.

Some Applications of Terrestrial Photogrammetry to the Study of Shorelines

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(*Abstract is on next page*)

INTRODUCTION

THE analysis of shoreline processes requires accurate descriptions of the ephemeral features of the shore zone. The investigator usually requires a sequence of dated topographic maps, each having been completed with sufficient rapidity as regards changes in shore features so that it is, in effect, synoptic. The sequence of synoptic maps then provides the basis for identifying and analyzing processes which vary with the passing of time. One seeks to map variations in size, shape, and slope of beaches and bluffs; changes in inshore hydrography; height, period, length, and direction of approach of water waves; and trajectories and velocities of water currents.

Conventionally, the topography of beaches, bluffs, and nearshore shallow areas has been mapped by plane-tabling. The recording echo-sounder has provided inshore hydrography in depths greater than the safe draft of the survey vessel. These mapping techniques usually require so much time that parts of a shore sector often change radically by the time the survey party has worked the length of the sector.

Typically, data on currents and waves have been obtained by hydrologic and oceanographic methods which are fairly