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Production Mapping with Orthophoto Digital Terrain Models*

Digitized profile data, acquired during the production of orthophotographs, provided a cost/effective source for producing contours, cross sections, perspective views, etc.

(Abstract appears on following page)

Introduction

For the past twelve years the Riverside County Flood Control and Water Conservation District has produced digital terrain models for computing earth quantities used in the design of flood control channels, roads, borrow sites, and sanitary land fills. For most of this period the work was done on a Kelsh Plotter utilizing a three-axis digitizer.

Seven years ago the District first attempted to use digital terrain information for contour mapping. Using IBM's Numerical Surface Techniques Program, a contour map was produced that appeared to be satisfactory, but on close comparison with a map drawn by standard stereoscopic plotting procedures, left much to be desired. The two bore very little resemblance, prompting a return to using the digital data to determine volumes, to plot cross sections and profiles, and to turning out topographic maps by conventional methods.

In June 1973, the District started a county-wide mapping program which covered approximately 7,000 square miles, at a scale of 1:2400 with 4 ft contours. In the pursuit of economy through faster production, a Galileo Santoni 2C Orthophoto System was purchased. In the beginning, it was intended to produce orthophotos on the Santoni and contours on the Kelsh Plotters. However, it was soon evident that useful information was wasted by not capturing the X, Y, and Z movements of the Santoni as it scanned to produce the orthophoto.

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Before going to the expense of adding a digitizer to the Santoni and purchasing a flatbed plotter, testing was begun with the digital data from the Kelsh Plotters derived from 25 ft cross sections of sanitary land fills. For this series of trials, CalComp's General Purpose Contouring Program (GPCP) was selected to convert the data to contours drawn on a drum plotter. Several test maps were produced this way. When comparing these with maps of the same terrain drawn

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ABSTRACT: *Having produced topographic maps for the past twenty years for engineering, planning, and design, the District was faced with ever rising costs and sought means to obtain a quality product economically. A first step in that direction was the use of orthophotography as a base for topographic mapping. The second step was automating the drawing of contours, accomplished by digitizing the scan of the steroscopic image during production of the orthophoto. The digital data were then converted to a finished contour-orthophoto map through the use of specialized computer processing and a high speed flatbed plotter. By-products of the system we are presently producing are automatic cross sectioning from the digital data base, volumes, flood plain limits, plan and profile sheets, and three-dimensional perspective views. This automated process resulted in substantial reductions in map-building time and cost.*

by conventional methods, it was observed that in most cases the digital contours were as accurate as those drawn on a stereo plotter (Figure 1).

The savings in time looked promising and a feeling of some excitement prevailed. A pencil manuscript which took 16 hours to plot by regular methods was done in ink in only 8 hours, even though manually digitized on the plotter and drawn in ink on a slow drum plotter. It was realized that the use of automatically captured data from the orthophoto scan, combined with plotting on the high-speed flatbed plotter, would have the potential for impressive time savings.

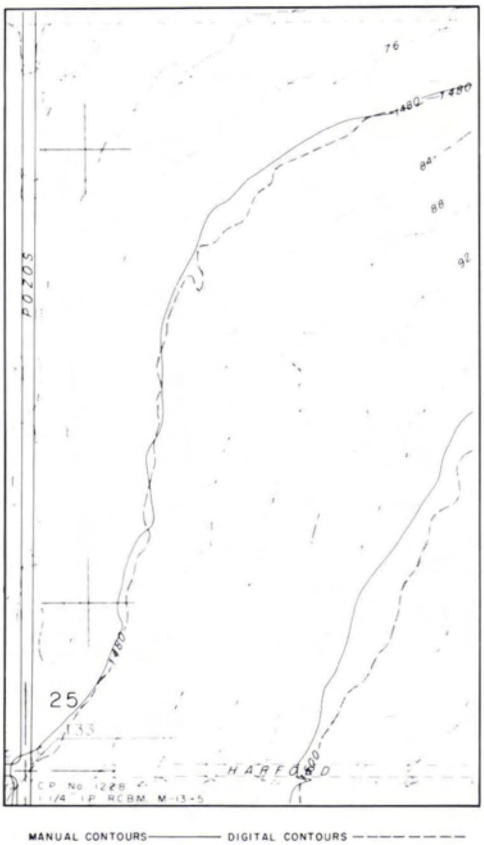


FIG. 1. Typical difference between manual contours and digital terrain contours.

At this point in the testing there were still major problems to solve. It was practical to produce a single model digital terrain orthophoto map that approached standard line-mapping quality. However, not all standard line-mapping techniques could be adhered to. The orthophoto itself had drawbacks as a base for digital contours: contours were drawn through houses and other buildings; conventional cartographic enhancement of contours where they crossed roads was not practical; and highway interchanges with multilevel crossings, bridges, vertical cliffs, storm channels, overlapping edge matches, spot elevations, and flow lines all created special contouring problems that had to be dealt with.

The contouring program did an excellent job of developing contours (Figure 2), but was not specifically designed for topographic mapping. To differentiate index contours from intermediate contours, it drew two lines close together instead of a heavier line weight. The labels appeared in reverse order on alternate index contours. There was no provision for spot elevations. The blanking routine used to eliminate intermediate contours in steep terrain was unsatisfactory. These limitations made the original version of the GPCP program unacceptable so far as standard mapping procedures were concerned.

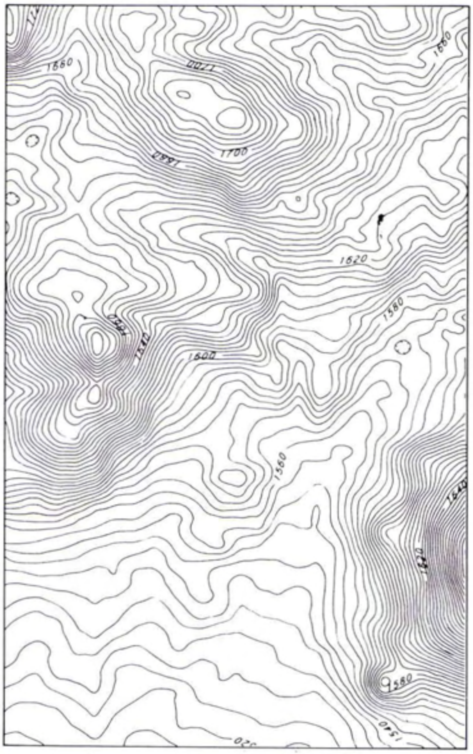


FIG. 2. Contours developed by GPCP from orthophoto digital terrain model before modification.

Most of the problems have been overcome by drastic modification of the CalComp program. Entirely new computer programs were developed to handle field survey information, to analyze the massive amounts of digitized data, to weigh spot elevations in relation to vertical scan data, and to plot titles and grids on map sheets. With this head start, and resulting confidence, it was decided that the high speed flatbed plotter should be purchased and that the Santoni be fitted with digitizing equipment.

EQUIPMENT

The system is built around several pieces of equipment: A Galileo Santoni IIC Orthophoto Plotter equipped with an Altek AC-74 Digitizer, a Hewlett Packard 3000 Series II Computer, a CalComp 748 High Speed Flatbed Plotter, and assorted photo lab equipment.

The Santoni IIC Orthophoto Plotter produces orthophotos by direct vertical profile scanning (Figure 3). It has three fixed scanning speeds and slot lengths. Using the smallest slot length (2.7 mm) and the slowest scanning speed (2.48 mm/sec), it requires about four and one-half hours to produce a single model orthophoto. By using the largest slot length (6.6 mm) and the fastest speed (4.38 mm/sec), an orthophoto can be produced in one hour.

The digitizing system was designed by Altek Corp. and Galileo Corp. of America. It records on magnetic tape using a dual buffered system. An Altek AC-74 Digitizer was selected to record the movements of the Orthophoto plotter. This unit, when coupled with a Digi-Data 1300 tape drive, allows for the continuous recording of three 6 digit counters plus one 4 digit event counter plus 15 digits of thumbwheel selectable fixed data input at a rate of up to 1000 readings per minute. The unit recording rate is normally set to 300-350 readings per minute to record the orthophoto scans. The digitizer is run in single point mode for recording control points and spot elevations.

The digitizer is connected to optical shaft angle encoders (DRC Model 77) which were mounted on the Santoni Orthophoto system by the Galileo Company. The digitizing system has a resolution of 0.001 millimetres.

When scanning a single orthophoto model at the slowest speed and the smallest slot length, between 36,000 and 43,000 points are recorded per model. Using medium speed and slot length, 29,000 points are recorded. The slowest speed and smallest slot length yield the most accurate and aesthetically pleasing map.

A Hewlet Packard 3000 Series II Computer System utilized in the project has 320,000 bytes of main memory, over 100 megabytes of disk storage, two 800 bpi magnetic tapes, and a line printer. Access to the computer system is by CRTs for both program development and program execution. All programs for this project were written in the FORTRAN programming language.

If computer selection were to be a part of the development of the automated orthophoto mapping program one should seek a system with a large main memory, sufficient disk storage, and a flexible file structure. The complexity of the computer processing involved in developing a contour map cannot be overstressed. For example, the computer time required for one contour map ranges between two and six hours depending upon the number of contours, whereas a multi-junction traverse triangulation network with a hundred stations will take 5 to 10 minutes to calculate. It is for this reason that contour map computation is scheduled during off-peak hours insofar as possible. The key to hardware selection was

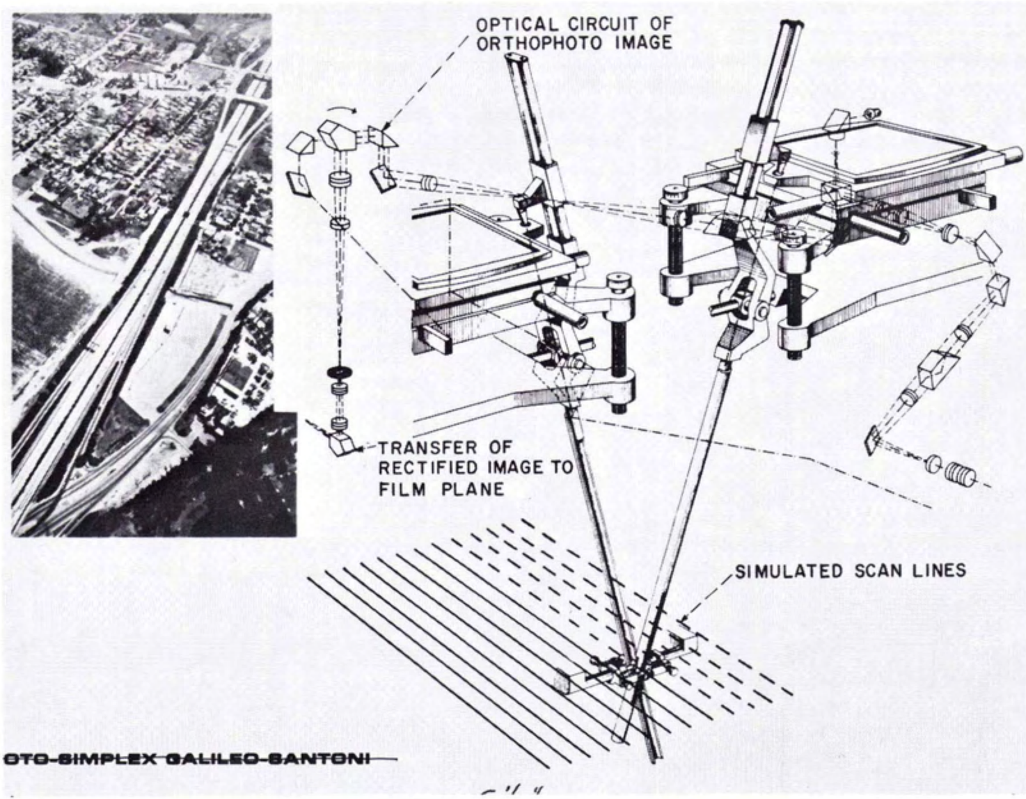


FIG. 3. Scanning procedure of orthophoto system.

compatibility between all devices and this was achieved by keeping the digitizing system and the plotter "offline" from the computer. The common element between all units is the 800 bpi-9 track magnetic tape.

The automated orthophoto mapping system required the development of a series of computer programs to convert the raw digital data from the orthophoto plotter to an engineering quality topographic map. The prime component of this program set is CalComp's General Purpose Contouring Program (GPCP). This program, as the title implies, is a general purpose program and was readily adaptable to the project needs. A discussion of each of the software elements follows:

Survey Control Data Base. The actual data base is a disk file storage system of survey information. The computer programs that support the data base allow survey control data to be entered and modified from a CRT. Each control point is assigned a unique identifier (up to ten characters) within a specific township and range. It is through this identifier that the ground coordinates along with the description associated with a particular point can be recalled. The Survey Control Data Base is accessed by the other programs in the automated mapping system.

Digital Terrain Modeling. A series of computer programs provide for the translation of the movements of the orthophoto plotter, as recorded by the digitizer in millimetres, to ground coordinates. Scaling and rotational parameters are first computed by comparing the digitized coordinates of the horizontal and vertical control points with their respective ground positions. The data points that comprise each scan line are then converted to X,Y ground coordinates plus an elevation value. Spot elevations are converted in a similar manner and all data pertaining to the model are stored in a disk file.

The next step in the creation of a Digital Terrain Model is the construction of the orthogonal grid. This is accomplished through the use of straightline interpolation of scan data to grid cells. In addition, the grid is adjusted to compensate for spot elevations since they are considered to have greater accuracy than the scan data. The resulting grid is stored in a disk file to later be combined with neighboring grids to produce a contour map.

Contouring Program. The basic CalComp General Purpose Contouring Program is utilized to generate contours from the combined grids of several stereo models. The program provides for the specification of plot boundaries, scale, contour levels, index contour levels, blanking of intermediate contours (based on ground slope), and labeling of index contours.

Extensive modifications were made to the CalComp program to accommodate the grid storage files, expand the size of grid that could be processed, provide "right reading" labels, and to insure that the labels are placed on tangent portions of the contours. In addition, the contour blanking algorithm was improved. The success of the project can be accredited to the way in which the technologies of photogrammetry and data processing were combined with reliable hardware into an integrated system.

The most fascinating part of the process begins when everything comes together on CalComp's 748 Flatbed Plotter. The 748 Flatbed Plotter has four inking heads all under variable regulated pressure to assure constant ink flow. It has been our experience that we can ink at the manufacturer's suggested speeds of 30 in./sec (76 cm/sec) on axis and 42 in./sec (107 cm/sec) diagonally at an acceleration of one "G" with excellent results.

The photo lab is equipped with a Process Camera, 4 by 8 foot enlarging back, automatic processor, and other assorted aerial photographic print equipment.

Procedure

The system that has evolved over the past two-and-one-half years starts with the introduction of all the field survey information into the computer to form a survey control data base. This information includes survey monuments set for mapping, section corners, quarter corners, U.S. Government benchmarks and triangulation stations, as well as location and description of County Sur-

MAPPING CONTROL POINT LISTING — TOWNSHIP/RANGE [05S 03W]

REF CODE	DESCRIPTION	SYMB	EASTING	NORTHING	ELEV
13	GRANITE ROCK 5"X 14" X 5" HIGH "X" ON TOP 6 NOTCHES ON E SIDE BROKEN OFF. PER FB888	16	1,699,121.87	585,532.08	
14	.75" IP. DN 6" W/RCE TAG 13234 PER PM14/83	15	1,701,760.99	585,515.31	
39	1" IP. IN CAPWELL MON. MRKD. M-24 PER RIV. CO. RM TIES	15	1,704,383.90	585,494.13	1422.34
40	1.25" IP DN 18" PER FB 768/63	15	1,707,043.15	585,479.34	
65	GRANITE STONE. DN 5" W/CUT "X" PER RS 25/7	16	1,709,705.21	585,464.43	
66	3/4" IP. DN 5"	15	1,712,352.32	585,437.15	
91	1" I.P. IN CAPWELL MON. MRKD. M-16-3 JULY 1963 PER RIV CO. RM TIES	16	1,714,999.78	585,415.87	1412.49
117	GRANITE STONE. DN 18" W/2X2 OVER STONE PER FB 495	16	1,720,293.97	585,379.13	
118	1.5" IP DN 1.4' PER RS 44/52	15	1,722,932.38	585,350.01	
143	10'X 12'X 10' HIGH BOULDER W/CUT "X" ON ELY FACE UP 6' PER FB 865	16	1,725,570.16	585,321.53	
144	1" IP. UP 6". W/SQ TO CO TAG MRKD 1/4 COR SEC 1 PER FB 865	16	1,728,207.79	585,298.46	
169	.5" IP. DN 1.2' PER FB 865	16	1,730,844.41	585,275.05	

FIG. 4. Listing of survey points that fall within limits of map sheet automatically extracted from control data base.

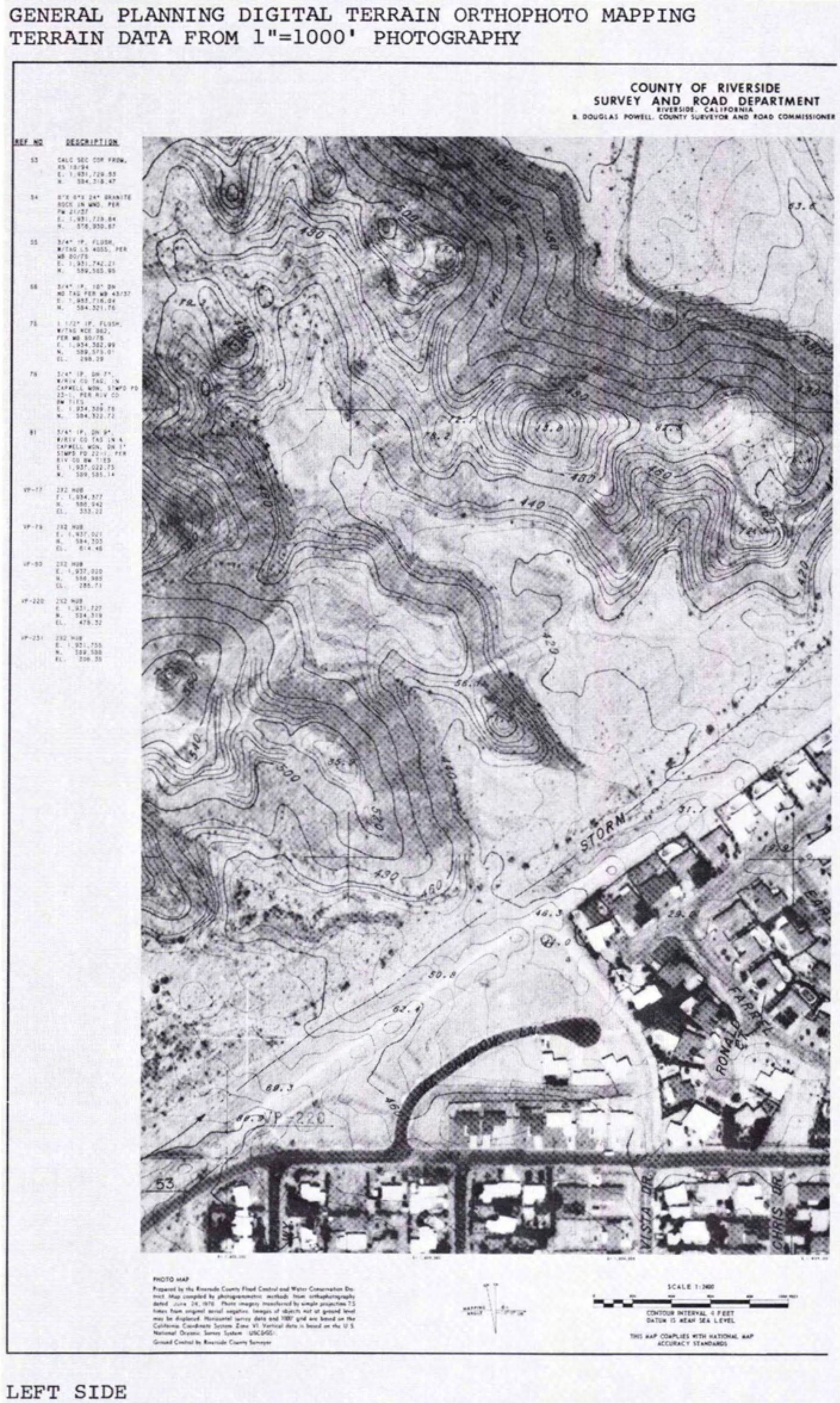
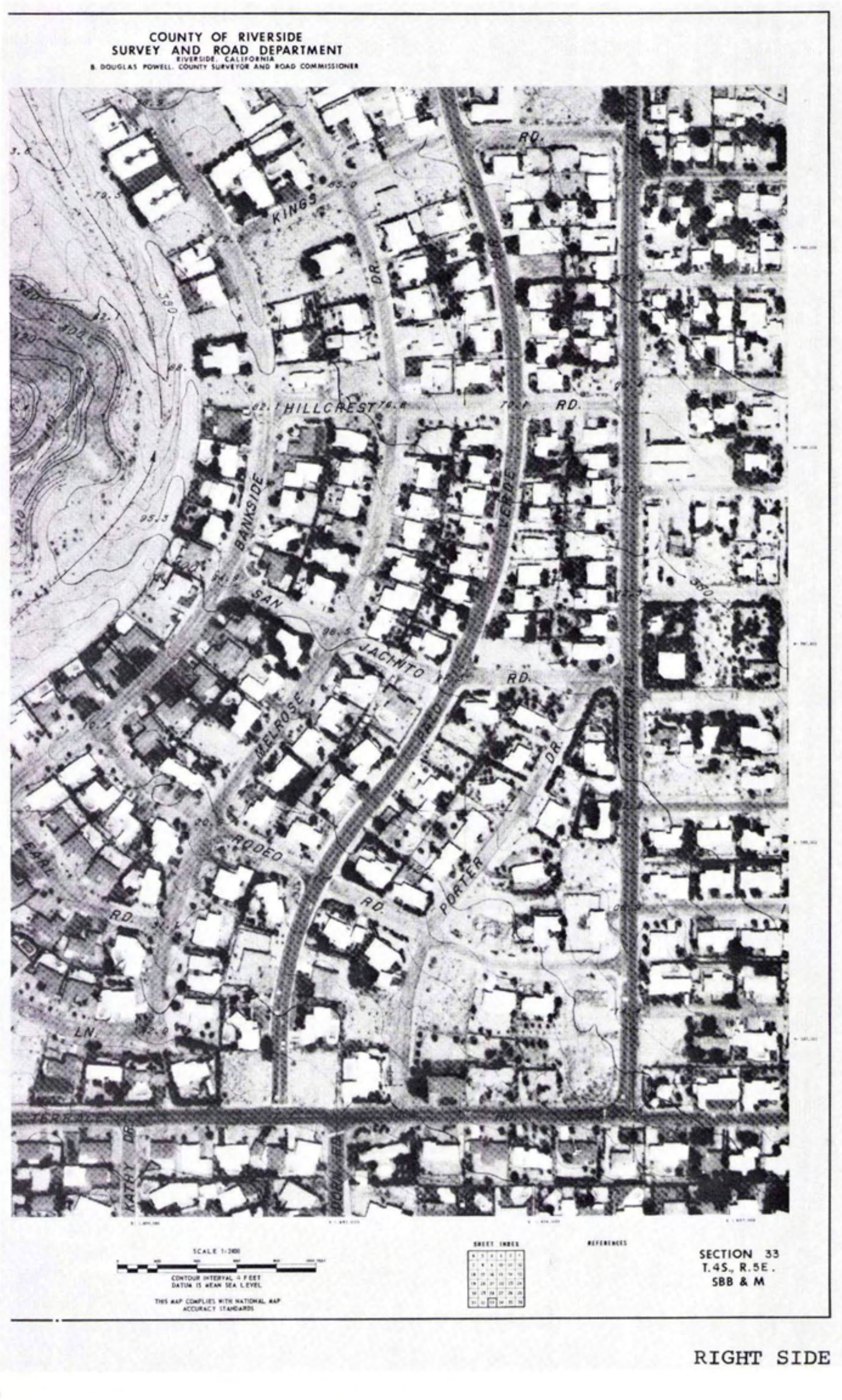


Fig. 5. Typical orthophoto digital terrain map for general



RIGHT SIDE

planning. Terrain data from 1:12 000 scale photography.

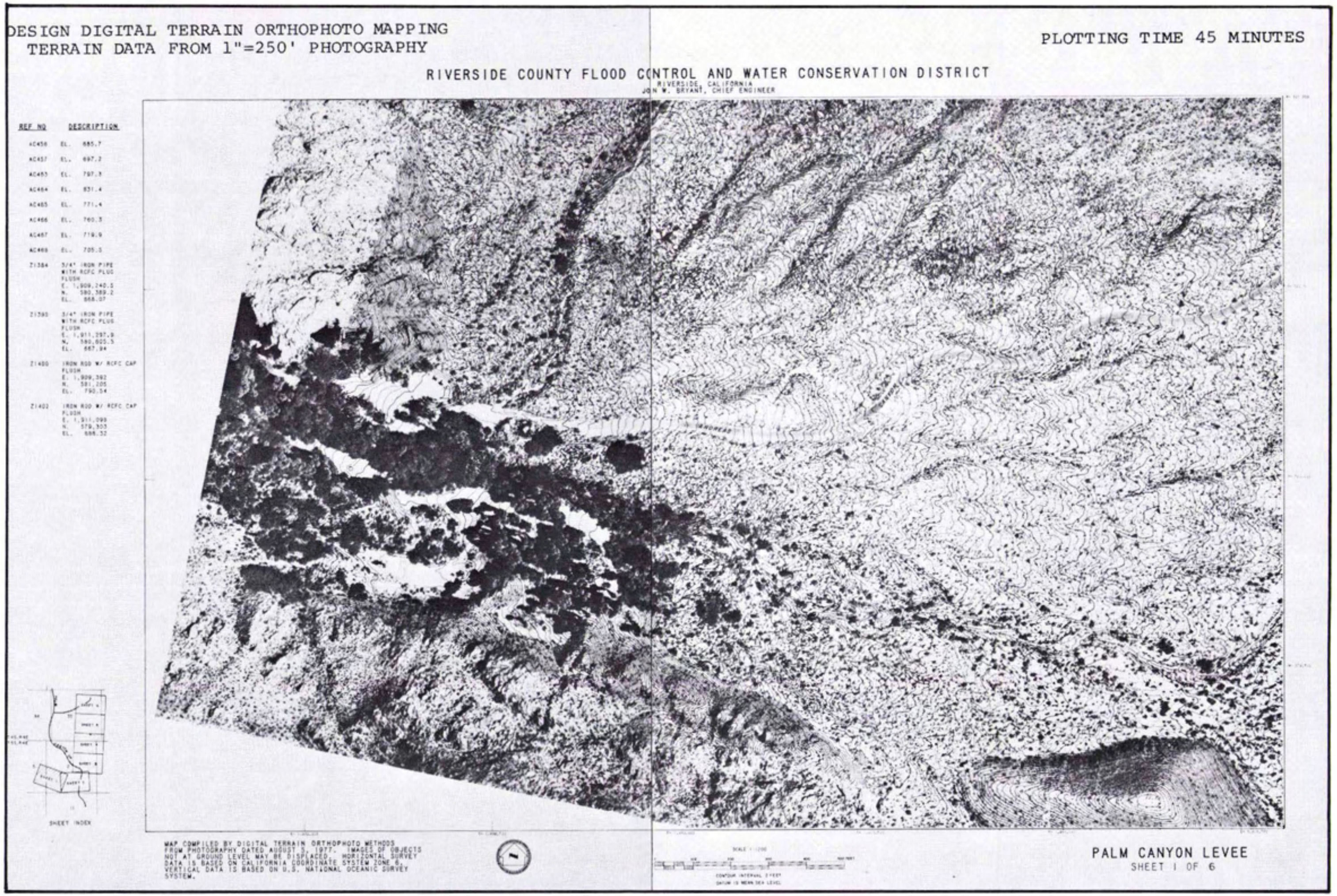


FIG. 6. Typical orthophoto digital terrain map for design mapping. Terrain data from 1:3000 scale photography.

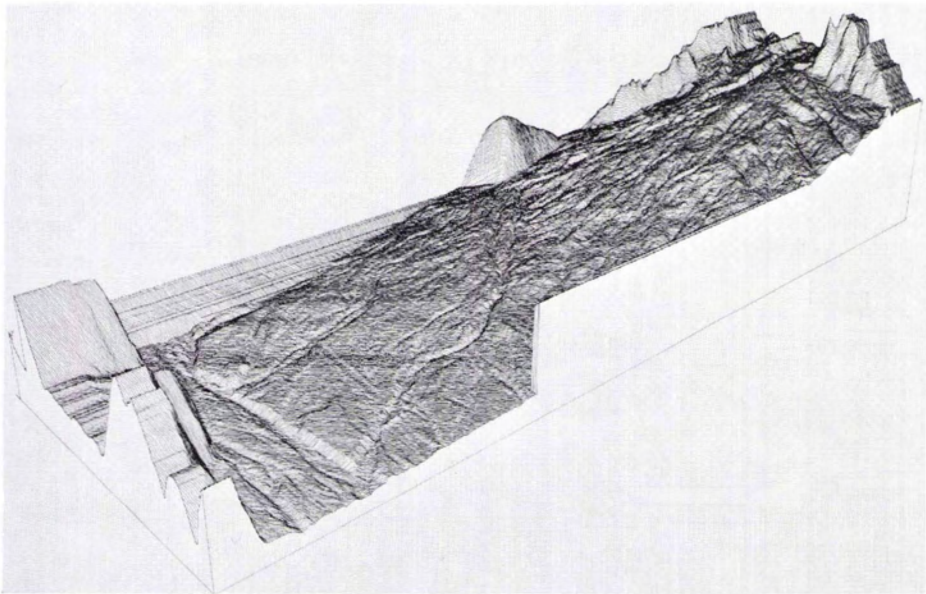


FIG. 7. Three-dimensional perspective of Palm Canyon, Palm Springs, California, Model 1, 2, 3, - X-Y rotation +135°, Horizon = 20.7°, View elevation = 3000 ft, Distance from view point to focal point = 6000 ft.

veyor's monuments (Figure 4). If horizontal position is not available on a particular monument, the position is determined by the photogrammetric process and added to the survey control data base.

The ability to retrieve any survey point automatically within an area has proven to be a great asset. The Santoni IIC Orthophoto Plotter is set up either in the normal fashion or by using the rotational elements from an analytical bridge. The procedure starts with the recording of all horizontal and vertical control points by the digitizer. The stereo model is then scanned for the production of the orthophoto in a series of vertical profiles. As mentioned earlier, relative coordinates and elevations of more than 40,000 points for a single model are recorded in terms of X,Y,

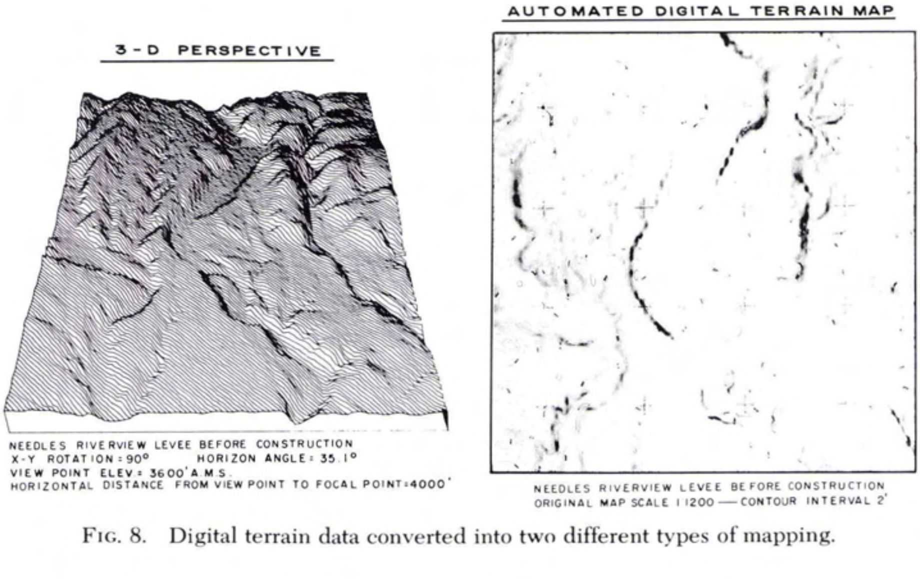


FIG. 8. Digital terrain data converted into two different types of mapping.

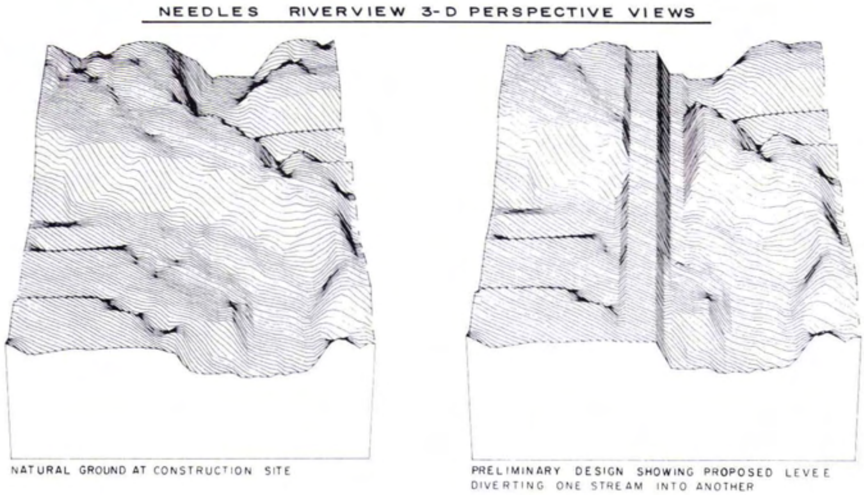


FIG. 9. Perspective view showing design data inserted into digital data base.

and Z. When the scanning is complete, spot elevations are read and recorded at normal locations: the hilltops, saddles, culverts, street intersections, stream beds, and, most importantly, where scanning of the vertical profile might have lost contact with the

CROSS SECTION: PALMCYN.PUB.SECTIONS DEC 5, 1977 PAGE 1
PROJECT: 8-8-398 PALM CANYON LEVEE
STATION 0+00.00 THRU 109+65.40 ENGINEER
DATE FILE CREATED 11/21/77 DATE LAST MODIFIED 11/21/77

(STA)	DIST	ELEV	DIST	ELEV	DIST	ELEV	DIST	ELEV
STA	0+00.00	PTS= 25	-60.00	810.07	-55.00	810.15	-50.00	810.32
	-45.00	810.67	-40.00	810.79	-35.00	810.68	-30.00	810.65
	-25.00	810.64	-20.00	810.77	-15.00	811.72	-10.00	812.16
	-5.00	813.16	.00	814.13	5.00	814.15	10.00	813.95
	15.00	814.12	20.00	814.43	25.00	814.84	30.00	815.41
	35.00	815.92	40.00	816.19	45.00	816.81	50.00	817.33
	55.00	817.80	60.00	818.86				
STA	0+50.00	PTS= 25	-60.00	813.75	-55.00	814.99	-50.00	816.33
	-45.00	816.42	-40.00	816.86	-35.00	817.27	-30.00	817.71
	-25.00	817.92	-20.00	818.05	-15.00	817.64	-10.00	816.53
	-5.00	815.04	.00	813.57	5.00	813.26	10.00	814.20
	15.00	815.10	20.00	814.95	25.00	815.01	30.00	814.69
	35.00	814.41	40.00	813.69	45.00	812.95	50.00	811.36
	55.00	810.20	60.00	809.65				
STA	1+00.00	PTS= 25	-60.00	814.09	-55.00	814.34	-50.00	814.66
	-45.00	814.89	-40.00	814.98	-35.00	815.12	-30.00	815.41
	-25.00	815.58	-20.00	814.89	-15.00	814.22	-10.00	812.89
	-5.00	811.53	.00	811.57	5.00	811.82	10.00	812.20
	15.00	812.60	20.00	812.68	25.00	812.59	30.00	812.12
	35.00	811.30	40.00	810.26	45.00	808.77	50.00	807.29
	55.00	806.24	60.00	805.29				
STA	1+50.00	PTS= 25	-60.00	810.03	-55.00	810.26	-50.00	810.26
	-45.00	810.31	-40.00	810.03	-35.00	809.78	-30.00	809.88
	-25.00	809.47	-20.00	809.31	-15.00	808.93	-10.00	809.26
	-5.00	810.01	.00	810.26	5.00	809.65	10.00	809.04
	15.00	808.43	20.00	807.61	25.00	806.50	30.00	805.39
	35.00	803.45	40.00	801.53	45.00	800.84	50.00	800.36
	55.00	800.22	60.00	800.50				
STA	2+00.00	PTS= 25	-60.00	806.33	-55.00	806.48	-50.00	806.71
	-45.00	807.04	-40.00	806.98	-35.00	806.45	-30.00	806.06
	-25.00	806.15	-20.00	806.20	-15.00	806.23	-10.00	806.27
	-5.00	806.13	.00	805.78	5.00	804.87	10.00	803.88
	15.00	802.26	20.00	800.48	25.00	798.79	30.00	796.98
	35.00	795.53	40.00	794.67	45.00	794.44	50.00	794.79
	55.00	795.29	60.00	796.00				
STA	2+50.00	PTS= 25	-60.00	802.27	-55.00	802.33	-50.00	802.36
	-45.00	802.53	-40.00	802.72	-35.00	802.89	-30.00	803.07
	-25.00	803.24	-20.00	803.33	-15.00	802.34	-10.00	800.97
	-5.00	799.49	.00	797.44	5.00	795.67	10.00	794.48
	15.00	793.51	20.00	793.49	25.00	793.43	30.00	793.53
	35.00	793.54	40.00	793.52	45.00	793.58	50.00	793.55
	55.00	793.33	60.00	793.27				

FIG. 10. Automatically extracted cross-sectioning from digital data base.

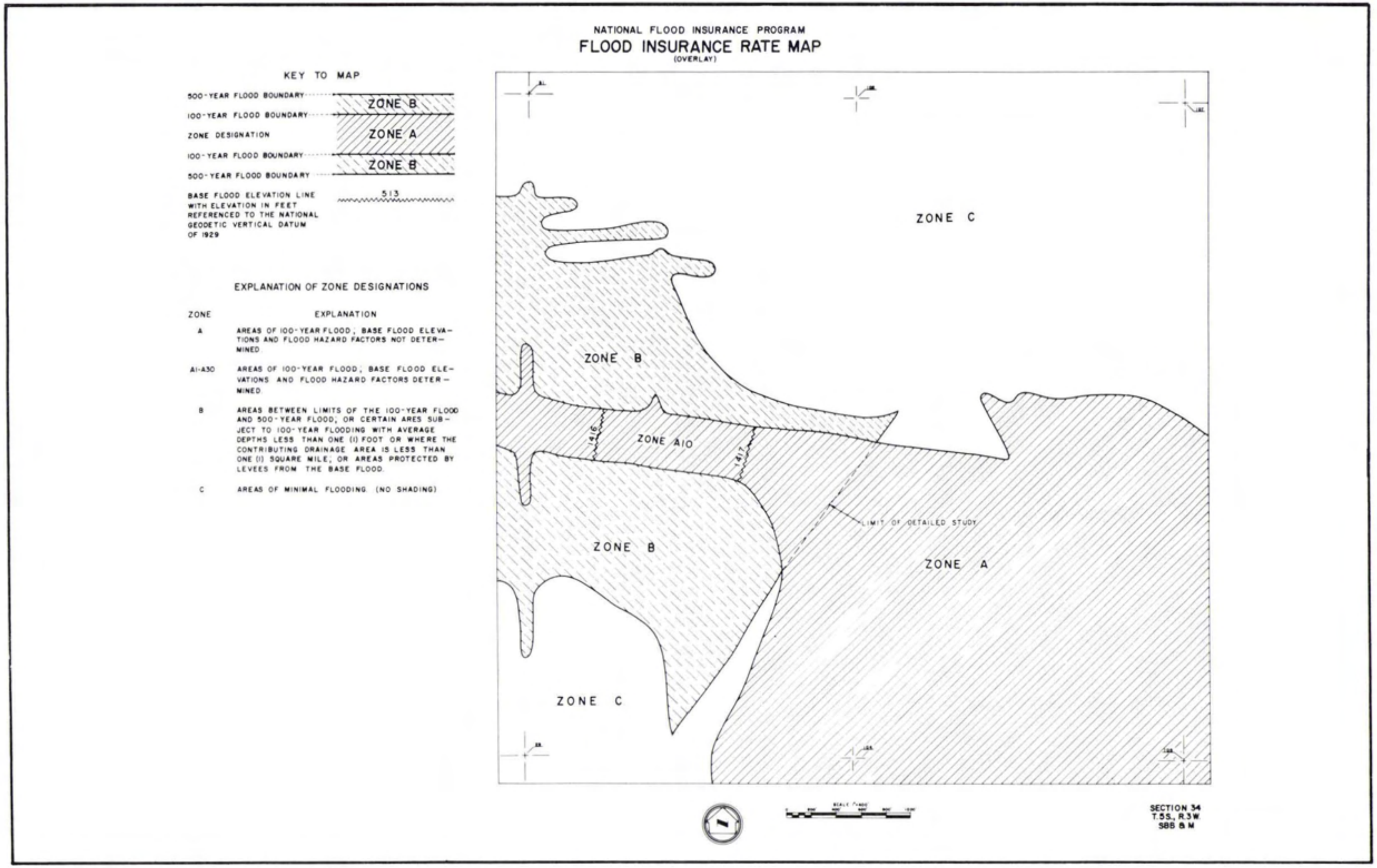


FIG. 11. Floodplain overlay from automatic cross-sections.

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PROJECT 8-8-398-70          RUN: SAN TIM EARTH DIVERSION DIKE

EARTHWORK CONTROL:  START=    0+00.00  STOP=     4+40.00
         ORIGINAL GROUND = SANTDDIK   INPUT DATA =
           SAVE TEMPLATE = SANTTDDK     OVERLAYS =
                NEW O.G. =

** WARNING FILE SANTTDDK  WAS PURGED

TEMPLATE SECTION SAVE IN FILE SANTTDDK
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PROFILE GRADE

CARD	STATION	VPI	CL
3	0+00.00	1810.94	.00
4	2+00.00	1811.54	.00
5	4+35.00	1812.15	.00
6	4+40.00	1812.15	.00

TEMPLATE SECTIONS

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CARD  STATION    NPT      CPL    CSL    FSL    CSR    FSR        CPR    T F FR FL
  7     0+00.00   5       .00    .00   1.50    .00-50.00         .00         0 0

     -7.50       .00      .00          .00     7.50        .00     23.50     -8.00
     83.50    -11.00

CARD  STATION    NPT      CPL    CSL    FSL    CSR    FSR        CPR    T F FR FL
  9     4+35.62   5       .00    .00   1.50    .00-50.00         .00         0 0

     -7.50       .00      .00          .00     7.50        .00     23.50     -8.00
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PROJECT 8-8-398-70   RUN: SAN TIM EARTH DIVERSION DIKE

AREA / VOLUME COMPUTATIONS

STATION	LEFT C P	RIGHT C P	CUT AREA	FILL AREA	TOTAL VOL CUT	TOTAL VOL FILL	MASS ORDINATE
INITIAL CONDITIONS	100.0 SHRINKAGE	100.0 SWELL			0.	0.	0.
0+00.00	-8.64 F	83.50 C	851.41	1.37	0.	0.	0.
0+50.00	-55.47 F	118.59 C	.00	2677.34	788.	2480.	-1692.
1+00.00	-74.13 F	146.08 C	.00	4627.55	788.	9244.	-8456.
1+50.00	-71.09 F	183.64 C	.00	4889.23	788.	18056.	-17268.
2+00.00	-61.35 F	178.71 C	.00	3746.32	788.	26052.	-25263.
2+50.00	-42.83 F	235.54 C	.00	3752.81	788.	32995.	-32207.
3+00.00	-25.35 F	330.33 C	.00	4224.85	788.	40382.	-39594.
3+50.00	-41.50 F	201.16 C	.00	1948.89	788.	46099.	-45310.
4+00.00	-30.39 F	125.54 C	.00	979.83	788.	48810.	-48022.
4+40.00	-7.50 C	129.09 C	331.71	531.63	1034.	49930.	-48896.

PROJECT 8-8-398-70   RUN: SAN TIM EARTH DIVERSION DIKE

SLOPESTAKE LOCATION

STATION	LEFT GROUND INTERCEPT					RIGHT GROUND INTERCEPT				
	DIST	ELEV	CUT/FILL		SLOPE	DIST	ELEV	CUT/FILL		SLOPE
0+00.00	-8.64	1810.18	F	.76	1.50	83.50	1799.94	C		.00
0+50.00	-55.47	1779.11	F	31.98	1.50	118.59	1800.79	C	.70	50.01
1+00.00	-74.13	1766.82	F	44.42	1.50	146.08	1801.49	C	1.25	50.00
1+50.00	-71.09	1769.00	F	42.39	1.50	183.64	1802.39	C	2.00	50.00
2+00.00	-61.35	1775.64	F	35.90	1.50	178.71	1802.44	C	1.90	50.00
2+50.00	-42.83	1788.12	F	23.55	1.50	235.54	1803.71	C	3.04	50.00
3+00.00	-25.35	1799.90	F	11.90	1.50	330.33	1805.74	C	4.94	50.00
3+50.00	-41.50	1789.26	F	22.66	1.50	201.16	1803.28	C	2.35	50.00
4+00.00	-30.39	1796.80	F	15.26	1.50	125.54	1801.90	C	.84	50.00
4+40.00	-7.50	1815.00	C	2.85	.00	129.09	1802.06	C	.91	50.00

FIG. 12. Earth volumes from digital terrain model - double end area method.

ground. These spot elevations replace data obtained from the vertical profile scan. When the digitizing is completed, the data tape is fed into the computer where the scan data are rotated and translated into a uniform elevation grid based on the State Plane Coordinate System. Several models are processed and held in the computer's disk storage until an area larger than the defined limits of the desired map sheet is processed. Contour mapping begins by defining the limits for each map sheet in terms of the California Coordinate System. The computer extracts all survey data and elevation grid values falling within these limits. Overlapping grid values for common points from various stereo models are converted to single values. In addition, an extra one-inch strip of vertical data is extracted for the area immediately outside the limits to insure proper edge matching of adjoining models.

The uniform elevation grid data are processed by the Modified CalComp General Purpose Contouring Program. The magnetic tape output generated by this program is used later to draw and label the contours on the flatbed plotter. At the same time another tape is prepared to plot the survey data, State Plane Grid, spot elevations, and title information. Meanwhile, the orthophoto conforming to the previously defined map limits is enlarged, screened, and photographically printed on a title block.

After the orthophoto is printed on stable

SYCAMORE DAM

GRID VOLUME PROCESS Thu. Aug. 3, 1978 8:40 AM
DESCRIPTION... SYCAMORE DAM BORDER June 1978
JOBID... SYCAMORE DAM ORIGINAL GROUND Aug. 1962
EXISTING GROUND FILE... SYCD0678.MAPS June 1968
JOBID... SYCAMORE DAM COMPOSITE GRID 10 FOOT
JOBID... SYCAMORE DAM RESULTANT GRID FROM VOLUMES
VOLUME CALCULATIONS IN CUBIC YARDS

NORTH GRID	VOLUME FOR GRID CUT	VOLUME FOR GRID FILL	ACCUMULATIVE VOLUME CUT	ACCUMULATIVE VOLUME FILL	BLANK GRIDS
651,960	10.0	276.1	3267.3	57020.6	0
651,970	5.5	254.4	3272.9	57275.0	0
651,980	4.3	220.0	3277.2	57495.0	0
651,990	11.6	214.7	3288.8	57709.7	0
652,000	13.7	369.5	3302.5	58079.2	0
652,010	17.3	425.7	3319.8	58504.8	0
652,020	20.7	487.4	3340.5	58992.2	0
652,030	21.1	529.8	3361.6	59522.0	0
652,040	23.3	478.6	3384.9	60000.6	0
652,050	19.2	'43.7	3404.1	60444.3	0
652,060	32.1	404.9	3436.2	60849.2	0
652,070	63.7	458.6	3499.9	61307.8	0
652,080	106.2	530.7	3606.1	61838.6	0
652,090	42.3	651.6	3648.4	62490.2	0
652,100	5.2	726.4	3653.6	63216.6	0
652,110	2.3	670.7	3655.9	63887.3	0
652,120	2.3	751.7	3658.1	64639.0	0
652,130	.0	657.4	3658.1	65296.3	0
652,140	1.9	415.6	3660.1	65711.9	0
652,150	3.3	309.2	3663.4	66021.1	0
652,160	12.8	280.1	3676.2	66301.1	0
652,170	26.8	251.1	3702.9	66552.2	0
652,180	2.6	206.1	3705.5	66758.3	0
652,190	.0	141.1	3705.5	66899.4	0
652,200	.0	111.0	3705.5	67010.5	0
652,210	.0	66.1	3705.5	67076.6	0
652,220	.0	.0	3705.5	67076.6	0

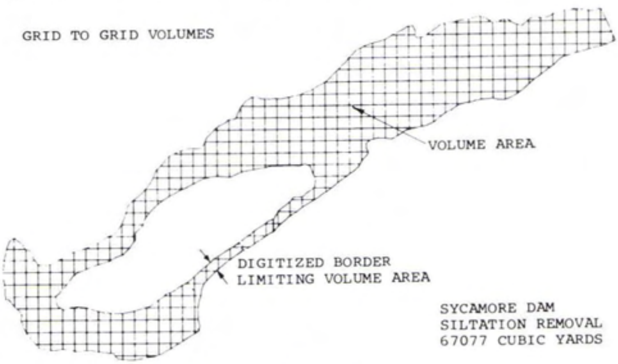

FIG. 13. Earth volumes by subtracting one digital terrain model from another.

base material suitable for processing on a Diazo White Printer, the finished orthophoto transparency is placed on the CalComp 748 Flatbed Plotter and registered to the ground control, then all the data stored on the plot tapes are plotted directly on the orthophoto in ink (Figures 5 and 6). Currently, inking and labeling of the contours is done on the reverse side, while control points, grid, borders, title, spot elevations, and control descriptions are drawn on the right side. This technique permits correction to be made to contours without disturbing grid values or control point information and vice versa.

To finalize a map a draftsperson letters street names and performs minor corrections to such items as spot elevation locations, eradicates contours through large buildings, and adjusts contour blanking. The drafting time ranges from 30 minutes to an hour for each map.

To date, the most time consuming and complicated map drawn on the 748 Flatbed Plotter required only one-and-one-half hours to plot. The map was of the scale 1:2400 with 4 ft contours and covered one square mile with a vertical range of 1300 feet.

CONCLUSION

The potential benefits from digital terrain orthophoto mapping are exciting to contemplate. Significant time savings have already been realized. It now takes an average

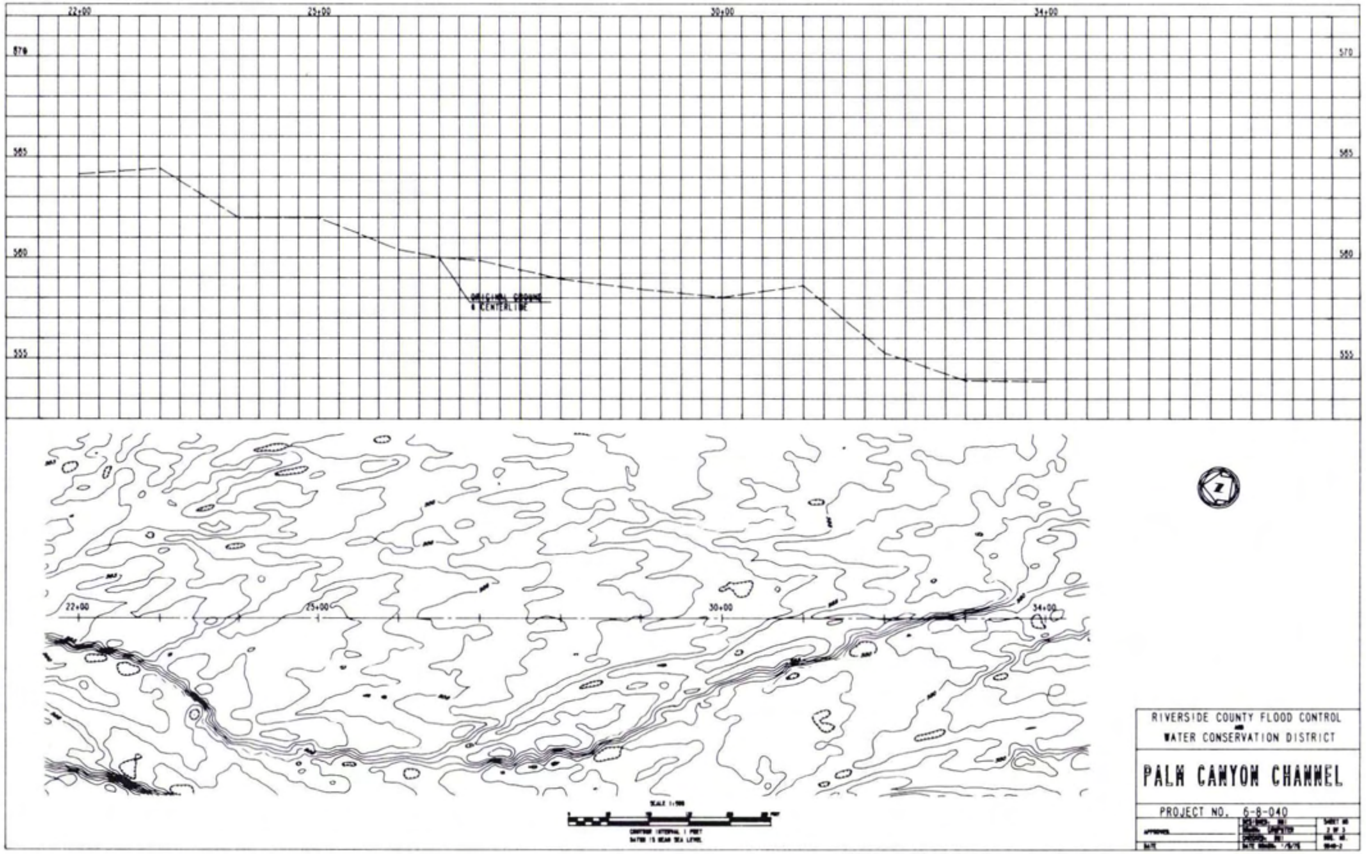

FIG. 14. Plan and profile sheet automatically extracted at any scale or contour interval and plotted from digital terrain data base.

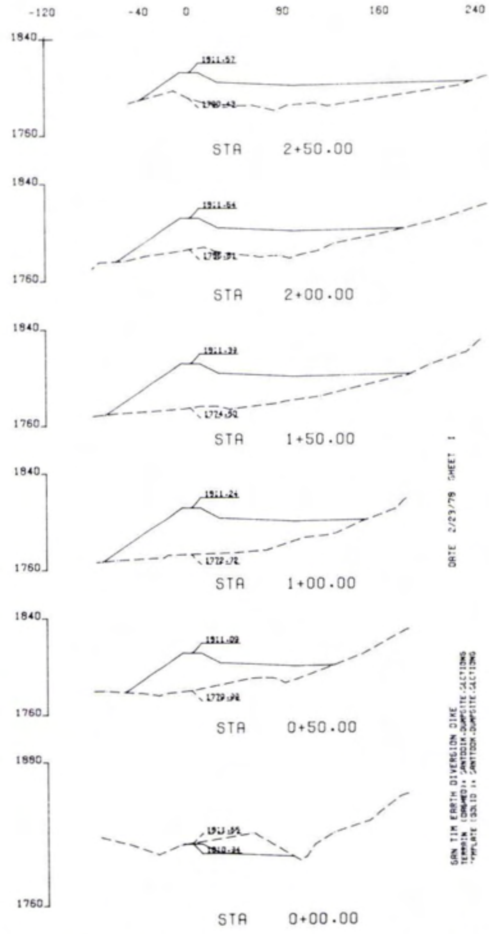

FIG. 15. Profile plot of original ground and design template automatically extracted from earth volumes.

of 8 to 12 hours from start to finish through the entire procedure to produce one 34 by 34 inch map of two stereo models covering an area of one square mile. The result is a finished, inked, and labeled orthophoto contour map. This compares with 40 to 80 hours using the previous conventional line-mapping procedure, depending upon the amount of detail required. Field map-checking of the contours on the Digital Terrain Orthophoto maps has yielded a calculated C-factor between 1800 and 2900. This is the same range formerly obtained in the standard topographic mapping program.

An attractive by-product of the digital terrain procedure is the ability to construct three-dimensional perspective drawings from the X, Y, and Z scan data (Figures 7 and 8). The plot program allows one to view (plot) the topographic map in perspective from any direction, distance, or elevation. For the layman a topographic map is much easier to understand when viewed in perspective. The engineer can design a project, integrate the design data with the digital terrain data, and view the completed project and its relationship to the surrounding terrain (Figure 9). Errors in design also become most apparent prior to actual construction. Other applications include automatic extraction of cross sections from any defined centerline (Figure 10); flood plain limits (Figure 11); reservoir capacities; volumes from double end area calculations or from substracting one grid surface from another (Figures 12 and 13); individual plan and profile sheets showing contours and profile grades at any interval or scale (Figure 14);

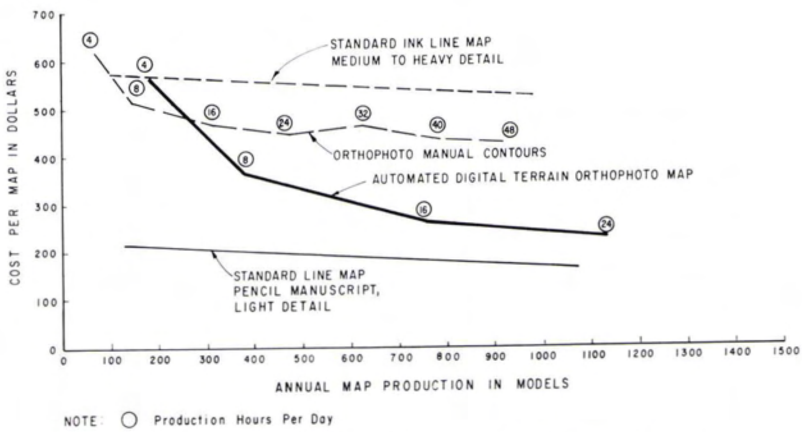

FIG. 16. Cost/effectiveness of automated orthophoto mapping.

resultant contouring showing volumes as cut/fill contours, allowing one to see where material is removed or deposited; automatic plotting of profiles at any scale (Figure 15); and digitizing of contours to convert existing mapping to a digital data base for use in any of the above options.

Estimating the expense and time for a proposed project becomes greatly simplified as digital terrain orthophoto mapping techniques are not appreciably affected by extremes in terrain or density of population in the proposed mapping area. Thus, the cost and time factors for mapping become more nearly uniform from project to project. Figure 16 demonstrates the cost effectiveness of automated orthophoto mapping by comparing different types of aerial mapping. Fewer people and less time are needed to produce the maps. As more organizations become experienced with the digital terrain orthophoto mapping techniques, many new applications will be developed to utilize the fundamental X, Y, and Z data base, which is ideal for easy and economical manipulation. With the digital terrain orthophoto map, time and money are saved and the topographic map will acquire new features enhancing its value.

Short Course
Introduction to Renewable Resource Inventory Methods

March 5-9, 1979
University of California, Berkeley

This five-day intensive course is jointly sponsored by three of the university's units—the Remote Sensing Research Program of the Space Sciences Laboratory, the Department of Forestry and Resources Management, and University Extension—in cooperation with the EROS Data Center, U. S. Geological Survey, Department of the Interior, Sioux Falls, South Dakota.

Intended for personnel involved in planning and executing wildland resource inventories, the course focuses on the inventory design process, emphasizing sampling and measurement systems and the integration of aerial photography, satellite spectral data, and conventional ground data into such systems. Forest and rangeland inventory problems will be used to illustrate the principles and techniques discussed in lecture and workshop sessions. Workshop exercises will cover sampling skills, aerial photography and satellite imagery for stratification, and measurement techniques applicable to large- and medium-scale photography.

The course faculty will include Robert N. Colwell, Randy W. Thomas, and Lee C. Wensel, all from UC Berkeley, and Wayne G. Rohde, from the EROS Data Center. Enrollment is limited, and participants will be selected on the basis of their field of inventory interest and their job responsibilities. For a detailed course description and application form, write to

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