MAPPING THE BRAZOS RIVER OF TEXAS

BY
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THE COASTAL PLAINS OF TEXAS AND OF OTHER STATES BORDERING THE GULF ARE VERY FLAT, WITH AN AVERAGE GRADIENT FOR A NUMBER OF MILES INLAND OF LITTLE MORE THAN A FOOT TO THE MILE. SEVEN MAJOR RIVERS AND AS MANY MORE SMALLER STREAMS AND BAYOUS FLOW THROUGH THE STATE, AND EACH YEAR THERE ARE FLOODS WHICH COVER LARGE AREAS OF LAND CAUSING DESTRUCTION OF LIFE AND PROPERTY. NOT ONLY ARE THESE FLOODS DESTRUCTIVE ON THE COASTAL PLAIN BUT ALSO ON THE BOTTOM LANDS FOR MANY MILES UP-STREAM.

IT IS ESTIMATED THAT DURING THE MOST RECENT 1936 FLOOD ON THE BRAZOS RIVER, THE TOTAL DAMAGE AMOUNTED TO NEARLY EIGHT MILLION DOLLARS. AVAILABLE RECORDS SHOW A STAGGERING LOSS OF THIRTY-SEVEN MILLION DOLLARS AND 347 LIVES ON THE BRAZOS RIVER SINCE 1913. FOR THE PAST 50 YEARS, FLOOD LOSSES ON THIS RIVER HAVE AVERAGED OVER TWO MILLION DOLLARS A YEAR. THE STATE BOARD OF WATER ENGINEERS IN 1936 AN-NOUNCED A PLAN FOR CONTROLLING AND REGULATING THE FLOW OF THIS RIVER BY 13 MAJOR DAMS ON THE MAIN STREAM AND ITS TRIBUTARIES, TOGETHER WITH A NUMBER OF SMALLER DAMS PLACED STRATEGICALLY ON THE HEADWATERS. IN 1929, THE TEXAS LEGISLATURE CREATED THE BRAZOS RIVER CONSERVATION AND RECLAMATION DISTRICT, AND IN 1934 RE-MITTED TAXES TO THE DISTRICT AMOUNTING TO $309,000 A YEAR FOR 20 YEARS FROM TEN COUNTIES AT THE LOWER END OF THE BRAZOS VALLEY WHICH USUALLY SUFFER THE BRUNT OF THE FLOOD DAMAGE DUE TO THEIR LOCATION ON THE COASTAL PLAIN. THIS SUM IS TO BE USED AS PAYMENT OF INTEREST ON BONDS ISSUED BY THE DISTRICT.

THE BRAZOS IS 950 MILES LONG, EXTENDING FROM WITHIN THE STATE OF NEW MEXICO TO THE GULF OF MEXICO; AND HAS A TOTAL DRAINAGE AREA OF 44,600 SQUARE MILES, SOMEWHAT LARGER THAN THAT OF THE TENNESSEE VALLEY. THE BRAZOS RIVER CONSERVATION AND RECLAMATION DISTRICT IS ORGANIZED ON THE WATERSHED BASIS, WHICH HAS BEEN RECOMMENDED BY THE NATIONAL RESOURCES BOARD AS THE BASIS OF ALL FUTURE SIMILAR PROJECTS.

OBJECTIVES OF THE ORGANIZATION

THE OBJECTIVES OF THIS PROGRAM ARE FOUR-FOLD: THE FIRST AND SECOND BEING THE PRIMARY ONES, OF FLOOD CONTROL, AND THE RECLAMATION AND CONSERVATION OF FLOOD-WASHED LANDS. THE THIRD OBJECTIVE IS THE AVAILABILITY OF ADEQUATE WATER STORAGE FOR MUNICIPAL AND IRRIGATION PURPOSES, AND THE FOURTH IS THE AVAILABILITY OF A GENEROUS AMOUNT OF HYDRO-ELECTRIC POWER WHICH, IT IS PLANNED, WILL BE SOLD TO POWER COMPANIES. WITH THE PROFIT FROM THE SALE OF THIS POWER, IT IS PLANNED TO MAKE THE PROJECT SELF-LIQUIDATING, AND TO BUILD SOME OF THE SMALLER DAMS ON THE TRIBUTARIES. WHILE HYDRO-ELECTRIC POWER IS MORE EXPENSIVE TO PRODUCE IN TEXAS THAN STEAM-GENERATED, OWING TO THE FACT THAT NATURAL FUEL IS CHEAP, IT IS PLANNED TO SELL THIS SUPPLY OF POWER AT A PRICE COMMENSURATE WITH THE COST OF PRODUCTION FOR PEAK-LOAD CONSUMPTION BY POWER COMPANIES. OF COURSE, THE POWER-PRODUCING FEATURE IS SECONDARY TO THE PRIME PURPOSES OF FLOOD-CONTROL AND RECLA-MATION, CONSEQUENTLY WHEN RESERVOIR CAPACITY IS NEEDED TO CONTROL POSSIBLE FLOODS THE GENERATION OF POWER WILL BE NECESSARILY DISCONTINUED.

ORGANIZATION

THE BOARD OF DIRECTORS CONSISTS OF 21 REPRESENTATIVE BUSINESS MEN, RESIDENTS OF THE BRAZOS VALLEY. CHAIRMAN OF THE BOARD IS MR. A. MIMS OF FREEPORT. CON-SULTING ENGINEER IS MR. A. STREIFF OF NEW YORK WHO HAS HAD BROAD EXPERIENCE IN FLOOD CONTROL THROUGHOUT THE WORLD. CHIEF ENGINEER - GENERAL MANAGER IS MR. JOHN A. NORRIS, WHO FOR A NUMBER OF YEARS PREVIOUS HAD BEEN CHAIRMAN OF THE TEXAS STATE BOARD OF WATER ENGINEERS. CHIEF OF SURVEYS IS MAJOR ERIC HAQUINIUS WHO HAS HAD MANY YEARS OF EXPERIENCE IN, AND IS A PIONEER IN THE FIELD OF MAPPING BY AERIAL PHOTOGRAPHY BOTH IN EUROPE AND THE AMERICAS. RESPONSIBILITY FOR THE DE-SIGN AND CONSTRUCTION OF THE POSSUM KINGDOM DAM IN PALO PINTO COUNTY IS ENTRUSTED TO THE CORPS OF ENGINEERS OF THE UNITED STATES ARMY. THIS IS THE LARGEST DAM OF THE GROUP, WILL BE THE FIRST TO BE BUILT, AND WILL IMPOUND ABOUT 730,000 ACRE-FEET OF WATER. AT LEAST 14 OTHER DAMS ARE TO BE BUILT AT A LATER DATE. RESERVOIR AREAS OF THESE MAJOR DAMS RANGE IN SIZE FROM 100 TO 500 SQUARE MILES IN EXTENT.

IT IS PRIMARILY THE SURVEY AND MAPPING OF THE RESERVOIR SITES TO WHICH THIS ARTICLE IS DIRECTED. IT IS BECAUSE THE MAPPING METHODS ARE COMPARATIVELY NEW AND

HIGHLY EFFICIENT THAT IT IS DEEMED INTERESTING TO THE ENGINEER TO WHOM THIS ACCOUNT IS DIRECTED, AS A RESULT OF THESE METHODS, WE ARE PRODUCING MAPS IN A VERY PRACTICAL AND ECONOMICAL METHOD, RAPIDLY AND IN LARGE QUANTITY PER MAN, BY MULTIPLEX. ANY METHOD OF MAKING MAPS WHICH PROVES ITSELF TO BE BETWEEN FIVE AND SIX TIMES AS EFFICIENT, OR IN OTHER WORDS, COSTS ABOUT ONE-FIFTH OR ONE-SIXTH AS MUCH AS PLANE TABLE MAPPING, IS WORTHY OF OUR CONSIDERATION AND STUDY. IF WE ARE ON THE EVE OF STATE-WIDE AND NATION-WIDE MAPPING PROGRAMS, MEN IN THAT FIELD MUST BE PREPARED TO ACCOMPLISH THEIR TASKS WITH VERY EFFICIENT AND LARGE SCALE MEANS. THESE MEANS ARE: STEREOSCOPIC PLOTTING MACHINERY, USING AERIAL PHOTOGRAPHY, TOGETHER WITH HORIZONTAL AND VERTICAL FIELD CONTROL.

PHOTOGRAPHS

OF A TOTAL OF 44,600 SQUARE MILES WITHIN THE DISTRICT APPROXIMATELY 5.9% OR 2,632 SQUARE MILES, COMPRISING ALL OF THE PROPOSED MAJOR RESERVOIR AREAS, HAVE BEEN PHOTOGRAPHED BY CONTRACT, ACCORDING TO STANDARDS SET BY THE BOARD OF SURVEYS AND MAPS, AND THE SPECIFICATIONS OF THE AMERICAN SOCIETY OF PHOTOGRAMMETRY. AN 8.25" FOCAL LENGTH CAMERA WAS USED. THIS CAMERA HAD A FOCAL PLANE SHUTTER AND WAS UNCALIBRATED. PICTURES WERE TAKEN FROM AN ELEVATION OF 10,000 FEET, WITH 60% OVERLAP IN LINE OF FLIGHT AND 20% OVERLAP BETWEEN LINES OF FLIGHT.

HORIZONTAL CONTROL

IN ORDER TO ACCURATELY PLOT THE MAP FROM AERIAL PICTURES, THIRD ORDER TRANSIT TRAVERSE IS RUN WITH POSITION CLOSINGS OF 1:7,500. THE 1927 NORTH AMERICAN DATUM IS USED, AND ALL AVAILABLE U.S.G.S. AND U.S.C. & G.S. TRANSIT TRAVERSE AND TRIANGULATION STATIONS ARE TIED INTO CIRCUIT WHEN FOUND IN GOOD CONDITION. GEODETIC POSITIONS OF TRAVERSE POINTS ARE COMPUTED TO THE NEAREST HUNDREDTH OF A SECOND OF LATITUDE AND LONGITUDE.

TRANSIT TRAVERSE PARTIES CARRY THE AERIAL PICTURES WITH THEM IN THE FIELD AND IDENTIFY THE CONTROL POINTS ON THEM AS THEY RUN THE TRAVERSE. THESE IDENTIFIED OBJECTS ARE POPULARLY TERMED "PICTURE POINTS". THE BEST IDENTITIES IN GENERAL FOR HORIZONTAL CONTROL PROVE TO BE SUCH OBJECTS AS: ROAD OR TRAIL INTERSECTIONS, FENCE CORNERS, CORNERS OF BUILDINGS (ON SIDES OPPOSITE THE SHADOWS), LONE SMALL TREES OR SHRUBS, OIL DERRICKS, BRIDGE ABUTMENTS, AND INTERSECTIONS OF ROADS AND TRAILS WITH NARROW CREEKS (FORDS), ALSO A NUMBER OF OTHER OBJECTS OCCURRING LESS FREQUENTLY SOMETIMES BEING USED.

TRANSIT TRAVERSE, TRANSVERSE TO LINES OF FLIGHT, IS USUALLY RUN ON THE SIXTH, SEVENTH OR EIGHTH OVERLAP INTERVAL. PARALLEL TO LINES OF FLIGHT, IT IS RUN MERELY ON EXTREME FLIGHT TO THE LEFT AND RIGHT, TYING IN THE ENDS OF TRANSVERSE LINES. ABOUT THREE PICTURE POINTS TO THE LINEAL MILE IS THE AVERAGE DENSITY OF CONTROL ON TRANSIT TRAVERSE.

VERTICAL CONTROL

IMMEDIATELY BEHIND THE HORIZONTAL CONTROL PARTIES AND RUNNING CONCURRENTLY AS NEARLY AS IS PRACTICAL, LEVEL PARTIES FOR VERTICAL CONTROL ARE SENT INTO THE FIELD. THIRD ORDER LEVELING IS ACCOMPLISHED WITH AN ACCURACY OF 0.04 TIMES THE SQUARE ROOT OF THE DISTANCE OF THE CIRCUIT IN MILES. HERE AGAIN, ALL AVAILABLE U.S.G.S. AND U.S.C. & G.S. BENCH MARKS IN GOOD CONDITION ARE TIED INTO THE LEVEL TRAVERSES, AND ALL LINES ARE RUN AS CLOSED CIRCUITS. FINAL ADJUSTMENTS ARE MADE ON OUR OWN LOOP CLOSURES, EXCEPT IN CERTAIN CASES WHERE WE TIE IN TO PREVIOUS EXISTING FIRST OR SECOND ORDER LEVELS. THE LEVEL PARTIES TAKE WITH THEM IN THE FIELD THE AERIAL PHOTOGRAPHS AND IDENTIFY PICTURE POINTS SUITABLE FOR VERTICAL CONTROL IN STEREOSCOPIC PLOTTING.

LEVEL CIRCUITS OF THIRD ORDER ACCURACY FOLLOW IN GENERAL THE TRANSIT TRAVERSE. IN ADDITION TO THIS, HOWEVER, SECONDARY LEVELS ARE RUN PARALLEL TO LINES OF FLIGHT ON THE LATERAL OVERLAP OF EACH FLIGHT. THIS IS DONE IN ORDER TO MAKE A PICTURE POINT DENSITY OF VERTICAL CONTROL SUFFICIENT TO GIVE AN ELEVATION AT THE FOUR CORNERS OF EACH MODEL.

PRELIMINARY OFFICE METHODS

TRANSIT TRAVERSES ARE CONTROLLED IN POSITION BY REFERENCE TO EXISTING U.S. G.S. AND U.S.C. & G.S. TRANSIT TRAVERSE AND TRIANGULATION. IN ADDITION TO THIS, ALL REFERENCE AZIMUTHS ARE NOTED AND SOLAR OR POLARIS OBSERVATIONS FOR AZIMUTH,

ARE TAKEN AT INTERVALS OF ABOUT THREE MILES. AS PORTIONS OF THE TRAVERSE NET ARE RUN, THE NOTES ARE SENT TO GENERAL HEADQUARTERS IN TEMPLE WHERE THE POSITION CLOSURES AND THEN THE GEOGRAPHIC POSITIONS OF POINTS ON TRAVERSE ARE COMPUTED. THE NOTES ARE FINALLY WRITTEN UP ON STANDARD DESCRIPTION FORMS WHICH GIVE: (1) LOCATION OF TRAVERSE BY QUADRANGLES, (2) NAME OF TRANSIT MAN, (3) NAME OF COMPUTER (4) DESCRIPTION OF POINT ON TRAVERSE, (5) BOOK AND PAGE REFERENCE, (6) PHOTOGRAPH NUMBER, (7) LATITUDE AND (8) LONGITUDE.

LEVEL NOTES ARE HANDLED IN A SIMILAR MANNER AND ELEVATIONS ADJUSTED TO EXISTING U.S.G.S. AND U.S.C. & G.S. CONTROL, ACCORDING TO THE 1929 GENERAL ADJUSTMENT FOR MEAN SEA LEVEL. THE NOTES ARE THEN WRITTEN UP ON A SIMILAR STANDARD FORM FOR ELEVATIONS INSTEAD OF POSITIONS.

PROJECTIONS

FOR INDIVIDUAL UNITS OF THE MAPS OF RESERVOIRS, DOUBLE-MOUNTED HEAVY WEIGHT DRAFTING PAPER ON ALUMINUM SHEETS OF 18" x 24" SIZE ARE USED. THIS IS A CONVENIENT AND SUITABLE SIZE FOR CONSTRUCTING QUADRANGLES TO THE SCALE OF 1:12,000 OR 1" TO 1,000 FEET, CONSISTING OF 3-1/4' OF LONGITUDE AND 3-3/4' OF LATITUDE. EACH QUADRANGLE IS GIVEN A SUITABLE NAME, USUALLY OF AN IMPORTANT TOWN, CREEK, MOUNTAIN, OR THAT OF A LARGE LAND SURVEY OR RANCH OWNER OCCURRING LOCALLY ON THE QUADRANGLE.

ON THESE BASE SHEETS, THE POLYCONIC PROJECTION IS THEN CONSTRUCTED, SHOWING ONE MINUTE INTERVALS OF PARALLELS AND MERIDIANS. THE HORIZONTAL CONTROL IS THEN PLOTTED DIRECTLY UPON THESE BASE QUADRANGLES, AND CONTROLS THE PLOTTING OF THE PLANIMETRY, TOPOGRAPHY, AND LAND OWNERSHIP. THE PLOTTING OF DETAILS UNDER THE MULTIPLEX IS MADE DIRECTLY ON THE BASE SHEETS IN PENCIL.

FINAL OPERATIONS

THE PENCILED MAP AS TURNED OUT BY THE MULTIPLEX OPERATOR IS THEN ROUTED TO THE DRAFTING DEPARTMENT WHERE THE SHEET IS INKED IN THE VARIOUS CONVENTIONAL MAP COLORS AND PRELIMINARY LETTERING IS DONE, SUCH AS NAMES OF RIVERS, CREEKS, VALLEYS, MOUNTAINS, TOWNS, RAILROADS, LAKES, ETC. THEN IN ORDER TO REDUCE TO THE SCALE OF THE BASE GRIDS, THESE SHEETS ARE PHOTOSTATED TO THE CORRECT SCALE. OF THESE, SEVERAL COPIES ARE MADE AND DISTRIBUTED TO OTHER DEPARTMENTS. ONE COPY IS SENT TO THE FIELD FOR FIELD INSPECTION AND CORRECTION, WHERE A NUMBER OF ITEMS WHICH WERE DIFFICULT TO INTERPRET UNDER THE MULTIPLEX ARE EXAMINED AND REPORTED ON BY VERIFICATION ON THE GROUND. FOR EXAMPLE, IN SOME CASES IT IS DIFFICULT TO INTERPRET THE EXACT QUALITY OF ROADS UNDER THE MACHINE, WHEREAS THE FIELD INSPECTION PARTY CAN VERIFY OR CORRECT THESE INTERPRETATIONS MERELY BY DRIVING ALONG IN A CAR; THE LOCATIONS IN THEIR TRUE POSITIONS, HAVING BEEN ACCOMPLISHED BY THE STEREOSCOPIC PLOTTING.

ANOTHER SCALE PHOTOSTAT COPY IS TURNED OVER TO THE EDITORIAL DEPARTMENT, WHICH ALSO RECEIVES IN DUE COURSE THE FIELD INSPECTED COPY. IN THIS DEPARTMENT, EVERYTHING THAT IS TO BE TRANSFERRED TO THE BASE GRID IS THOROUGHLY INSPECTED AND VERIFIED AND GENERALLY PREPARED FOR THE DRAFTSMEN TO DO THE FINAL INKING.

WOODLANDS ARE NOT DEPICTED ON THE BASE MAPS BUT ARE PAINTED ON OVERLAY SHEETS OF TRANSPARENT CELLULOSE ACETATE, USING A LIGHT GREEN SHADE OF LACQUER.

SCALE, CONTOUR INTERVAL, ACCURACY AND CHECK SURVEYS

THE MAPS BEING PRODUCED ARE AT A FINAL SCALE OF 1:12,000. THE VERTICAL ACCURACY ON THE FINAL MAP IS TO WITHIN FIVE FEET OF TRUE VERTICAL POSITION AND THE HORIZONTAL ACCURACY IS 1 PART IN 800. THESE ACCURACIES ARE CHECKED THROUGH TWO TYPES OF SURVEYS, NAMELY:

A) PROFILE SURVEYS TO AN AVERAGE LENGTH OF APPROXIMATELY 1 MILE, WITH AN AVERAGE OF 40 SET-UPS AND 40 TURNING POINTS. SO FAR, THESE PROFILES HAVE SHOWN THAT AN AVERAGE OF 95% OF THE CONTOURS HAVE BEEN WELL WITHIN THE FIVE FOOT ALLOWABLE ERROR.

B) LARGE SCALE PLANE TABLE SURVEYS ON A SCALE OF 200' = 1" WITH A TWO FOOT CONTOUR INTERVAL OVER APPROXIMATELY 20 SQUARE MILES AND DISTRIBUTED OVER THE DAMSITES HAVE BEEN MADE. THESE CHECK WITH THE MULTIPLEX MAPS VERY CLOSELY AS TO POSITIONS AND ELEVATIONS. ACTUAL SHAPES OF THE GROUND, HOWEVER, ARE MORE ACCURATELY DEPICTED BY THE MULTIPLEX THAN BY THE PLANE TABLE.

Rate of Work and Cost of Operation

So far the rate of mapping on the Multiplex has averaged 18.06 miles per man-month on the basis of 6-hour shifts, 3 shifts per day. The costs to date including all technical and administrative overhead of the Engineering Department, but exclusive of the general overhead of the district, are shown below:

		Cost per Square Mile
(A)	Horizontal control (includes computation)....	$ 10.30
(B)	Vertical control (includes computation).....	13.10
(C)	Plotting by pencil on Multiplex.....	10.86
(D)	Field inspection and editing.....	4.70
(E)	Smooth drafting.....	5.60
	Total.....	$ 44.56

Progress to Date

Mapping in this manner has been done on about 450 square miles on the Possum Kingdom area, the largest of the reservoir units, 185 square miles on the Leon which is one of the main tributaries, 175 square miles on Cordova Bend, and 190 square miles on the Whitney. Field work has been completed on six more of these areas and is in process on the others. The stereoscopic plotting by Multiplex of these areas is being performed on each of these areas successively. It is planned to complete the mapping of the 13 major reservoir sites within the next two years.

Discussion of Mr. Fenton's Article by Eric Haquinius

It should also be brought out that costs shown by Mr. Fenton are averages over one year's operation and the longer the work continues the lower the average cost will be until a downward limit is reached. This I believe will be about $35.00 per square mile. We are shifting to wide angle Multiplex equipment and wide angle precision camera for future work which will further reduce the cost.

The cost per square mile for horizontal and vertical control is high for the reason that we, of necessity, have to have quite a density of vertical control to offset the fact that a precision camera is not used.

In comparing costs, remember that we are using a scale of 1:12,000 with ten foot contour intervals. Some years back, bids were taken by the U. S. Engineer District in Rock Island on mapping on the same scale and contour interval. The low bid was about $136.00 per square mile. Another bid was about $180.00 per square mile and the highest bid was around $220.00 per square mile. These figures are quoted from memory, they are approximate only. We did some plane table work of a small area on this same scale before we got the Multiplex equipment which cost us $86.00 per square mile to which should be added the horizontal and vertical control as well as the planimetric map we made for base by using the radial line method.

I believe it is reasonable to say that the cost of work we are doing using the Multiplex equipment and the method of organization and correlation of field and office work as developed by us is nearly five times as cheap for the same scale and accuracy as standard plane table methods.

You will note that I say nearly five times and that Mr. Fenton in his paper has said between five and six times as cheap as ground methods. This depends upon what is considered the proper figure for work on this scale and if there is any doubt that this may be an overstatement, the figure may be changed to three or four times as cheap in both my letter and in Mr. Fenton's paper. However, as present costs are about $44.00 per square mile, five times this would be $220.00 per square mile. I doubt if this is unreasonable, and it should be remembered that if it is attempted with ground methods to secure as much detail as is obtained with stereoscopic methods, the cost will run up very high.

Comment by the Editor

The Editor will welcome written discussions of Mr. Fenton's paper from members of the Society with respect to costs and accuracies obtained elsewhere on work similar to that discussed by Mr. Fenton with particular reference to flying height, focal plane shutters and precision camera equipment in relation to vertical accuracy of contours.