OFFSHORE TECHNOLOGY CONFERENCE
6200 North Central Expressway
Dallas, Texas 75206

PAPER
NUMBER OTC 1656

A-1

THIS IS A PREPRINT --- SUBJECT TO CORRECTION

Baseline Establishment for Positioning Federal State Offshore Boundaries

By

Harland R. Cravat and Ronald K. Brewer, National Ocean Survey, NOAA

Offshore Technology Conference on behalf of the American Institute of Mining, Metallurgical, and Petroleum Engineers, Inc., American Association of Petroleum Geologists, American Institute of Chemical Engineers, American Society of Civil Engineers, American Society of Mechanical Engineers, Institute of Electrical and Electronics Engineers, Inc., Marine Technology Society, Society of Exploration Geophysicists, and Society of Naval Architects & Marine Engineers.

This paper was prepared for presentation at the Fourth Annual Offshore Technology Conference held in Houston, Tex., May 1-3, 1972. Permission to copy is restricted to an abstract of not more than 300 words. Illustrations may not be copied. Such use of an abstract should contain conspicuous acknowledgment of where and by whom the paper is presented.

INTRODUCTION

Since the beginning of history, the need has existed for one device or another to distinguish one man's territory from his neighbor's. Even the song of some birds proclaims sovereignty over an area within earshot of other feathered potential invaders.

Individuals, communities, and nations depend on agreements, treaties, contracts and laws to state the terms of boundary arrangements, but the most important prerequisite for an accurate geographic boundary is a modern map. In this age of specialization, establishing a baseline for positioning the offshore boundary between federal and state property requires a special map. Although such a map serves primarily as a tool for legal boundary determinations of state, federal and international ownership, it may also be useful for the control and development of the continental shelf resources, for research studies, to control the ecology of the coastal zone, and for other coastal zone management problems.

In the field of mapping tidal shoreline, NOAA's National Ocean Survey, (NOS) formerly the Coast and Geodetic Survey, whose expertise in these matters dates back 165 years, is recognized as an impartial technical expert, and its advice and guidance has been, and will be sought by the courts, the states, federal agencies and private interests in resolving technical problems related to shore and sea boundaries. Today, a photogrammetric method, described later in this paper, is available which permits the accurate compilation of the low-water line for the establishment of coastal baselines essential for the delimitation of coastal boundaries.

The low-water line, (necessarily interpreted as the mean low-water line along the Atlantic and Gulf Coasts, and the mean lower-low-water line bordering the Pacific Ocean), was adopted by the Conventions on the Law of the Sea in Geneva, 1958, as the baseline from which a nation's territorial sea would be measured. This, and various other claims, including the entire zonal pattern of offshore water must necessarily be measured from this line.

References & Illustrations at end of paper

Most of our coastal states have been granted jurisdiction over submerged lands extending a distance offshore from the baseline to three nautical miles, (also expressed as "geographic miles") which corresponds to one league, a former unit of measurement used in marine terminology. A commonly accepted, but not necessarily irrefutable statement attributes the three-mile breadth to the distance a cannonball could be fired. Because of claims existing at the dates of statehood, only Texas and the Gulf Coast of Florida have a propietary interest in a submerged belt of land nine miles wide along the coast. These claims were upheld by the Supreme Court decision of May 31, 1960.

The configuration of the coastline may vary from very straight and uncomplicated, to one with exceedingly complex irregularities, and may be fragmented with an intricate pattern of offshore islands. Thus, a baseline from which to measure offshore zones may range from a straight line or a smooth curve offering no problems to a complex land-water belt of contact requiring geometric principles on which a theoretical coastline may be established.

This paper describes the application of modern methods of infrared photography and photogrammetry to mapping of the mean low-water line where ground survey methods are prohibitively difficult and expensive.

ESTABLISHMENT OF TIDAL DATUMS

The establishing of boundaries determined by the course of the tides involves two engineering aspects: a vertical one predicated on the height reached by the tide during its vertical rise and fall and constituting a tidal plane; and a horizontal one relating to the line where the tidal plane intersects the shore to form the boundary desired. The first is derived from tidal observations alone and once derived (on the basis of long-period observations) is for all practical purposes a permanent one. The second depends on the first and can be determined therefrom by leveling from tidal benchmarks, or by photographing the shore at the proper instant of the tidal cycle, i.e., at mean low water, or mean lower-low water. The boundary line thus determined and mapped on the national horizontal datum is permanently recorded in horizontal position as the boundary on the specific date of the survey.

Tidal datums which have their origins in the rise and fall of the tides possess the advantages of simplicity of definition, accuracy of determination and certainty of recovery. It is for these reasons that tidal datums are used in hydrographic surveying and nautical charting, and in the demarcation of seaward boundaries. Of prime importance in this discussion is the tidal datum of mean low water which, as previously mentioned, serves as the basis for establishing the Federal-State offshore boundary line.

Tide observations are required at select locations along the coast to establish the local mean low water datum. By definition, this mean value is determined by the average height of the low waters over an approximate 19-year period. However, shorter periods of observation can be made and corrections applied to eliminate known variations and reduce the result to the equivalent of a 19-year value. In general, an observation period of one year is used as the basic period of record from which to derive the datums. The reduction to mean values is made by referring these observations to a tidal epoch of 18.6 years through comparison with simultaneous observations at a control tide station.

Preliminary tide gage locations are selected in the office, and final site selection is made after a thorough field reconnaissance is completed and all necessary permissions are obtained. A Fischer-Porter Automatic Data Recording (ADR) tide gage (Fig. 1) is installed at each selected site and indexed to a fixed, graduated tide staff. Five permanent tidal benchmarks are also established in the vicinity of each station and connected to the staff by precise leveling. These marks provide a means of recovering the local datums if the staff should be removed or destroyed and, by periodic releveling, can be used to verify that the staff has not moved vertically.

The punched tape record is collected from each gage once each month and forwarded to the office for reduction and comparison with simultaneous observations at the control tide station. The basic data provided by the tape are the water height and the time of observation, taken around the clock at six-minute intervals. The end products of the reduction process are the local mean high water and mean low water datum planes at each tide station, relative to the staff and the tidal benchmarks. (Only the mean low water datum is required in determining the Federal-State boundary baseline).

SURVEY PLANNING

Once the tidal datum planes are established, planning commences for the mapping phases which include field surveys, aerial photography, surface support for the mean low-water line photography, aerotriangulation and map compilation. The mapping scale is selected, based upon the job requirements, which is generally 1/20,000 scale (1" = 1,666 ft.) for offshore Federal-State boundaries. Modern mapping cameras and films permit considerable enlargement of the aerial photographs, so the photographs may be taken at scales between 1/20,000 and 1/60,000 depending upon the terrain, configuration of the shoreline and density of existing control.

The project planner prepares a job diagram upon which he plots the map sheet layout, locations of tide gages and tide staffs, including tide ranges and time differences for each location. He also indicates locations of horizontal control stations and draws the proposed photographic flight lines to take best advantage of the control stations and to fit the configuration of the shoreline between the tide gages and staffs.

Using Tide Tables published by the National Ocean Survey, the project planner then selects a tentative group of dates when low waters are predicted to occur during photographic daylight hours, and schedules the photography during a season of the year when good weather is anticipated. In his instructions to the photo mission and the field support party, the planner indicates the predicted dates and times for photographing each flight line at mean low water. Those times are of course modified in the field to agree with actual tide observations and field conditions.

FIELD SURFACE SUPPORT OPERATIONS

Support by field parties is programmed into the aerial photography system for achieving a high degree of photogrammetric precision. Such an operation requires close cooperation between air photo mission personnel and the field party. Therefore a photogrammetric field party that is expert in performing 1) tide observations (Fig. 2), 2) horizontal control surveys (Fig. 3), and 3) establishing a radio communication system between tide staff observers, a central command post and the aircraft, arrives on the working grounds, and completes those phases before photography is scheduled to commence. Transportation for the surface units is usually by a combination of truck, skiff, and leased helicopters.

The tides experts at National Ocean Survey headquarters furnish to the field party the water level value of mean low water for each tide staff in the project. A few hours prior to, and during aerial photographic operations, tide observers continually report staff readings to the central command post. From an analysis of those observations the

Chief of Party, who is in radio contact with the aircraft, schedules photography over each flight line when the water level is at the local mean low water datum plane.

AERIAL PHOTOGRAPHY

The air photo mission (Fig. 4) arrives on the working grounds a day or two in advance of the date aerial photography is scheduled to commence. This permits a "dry run" for perfecting radio communications, checking adequacy and completeness of the surface support and finalizing the plan of operations.

Tide observers are on station a minimum of one hour before aerial photography is scheduled to start, reporting their observations to the command post. The aircraft arrives overhead a few minutes before optimum tide conditions are expected to occur and the aircraft commander is briefed as to the tide conditions by the command post. Weather, sea conditions, sun glitter on the water, and haze add variables to the many problems that continually confront the aerial photographic operation, and are taken into account as each line is flown.

The aircraft is equipped with three cameras (Fig. 5). Photographs are taken with 60% forward lap, which permits three dimensional viewing, and accommodates stereoscopic instrument plotting during the map compilation phase. On the Mississippi Delta project, two aerial cameras were operated simultaneously. One camera took true color aerial photographs for mapping interior features, and the other camera took black-and-white infrared photographs for mapping the mean low-water line.

Color photography portrays the landscape as it is viewed in nature. It is particularly useful for charting aids to navigation and for the interpretation of natural and cultural features to be mapped. It provides a wealth of detail not visible on the black-and-white infrared photographs and saves a considerable amount of field time which would otherwise be necessary to clarify details on the photograph, thus reducing field inspection and field surveys to a minimum.

Care is exercised to take the black-and-white infrared photographs exactly at mean low-water or slightly below and repeated again slightly above, thus bracketing the mean low-water line. The camera, film and filter combination produces photographs (Figures 6 and 7) which portray water as a black tone, and land by a light grey tone, thus enabling the compiler to trace accurately the water line at the moment the pictures are taken.

The reason for the water photographing black has nothing to do with thermal radiation; it is the result of an extremely low, near infrared energy return from the water to the film in the camera. The water absorbs the near infrared energy whereas the sand beach and vegetation on land are excellent reflectors of near infrared energy, and the filter absorbs the blue and green radiation.

At the close of operations each day, the exposed aerial film is shipped via air to the National Ocean Survey laboratory in Washington, D.C. for developing and evaluating (Fig. 8) followed by print processing (Fig. 9). Prints are then forwarded to the field for inspection and verification purposes.

FIELD INSPECTION

The next step after completion of photography is to examine the photographs in the field which is done in conjunction with an inspection of the mean low-water line. This is best accomplished by helicopter and requires observers at the selected tide staffs to inform the field inspector continually as to the height of tide.

Such an inspection is necessary to confirm or negate the existence of borderline detached low water elevations such as small shell banks, sand bars (Fig. 10), and mud lumps which materially affect the offshore placement of the Federal-State seaward boundary, and to aid the office compiler in his interpretation of the mean low-water line. The field inspector records his findings directly on the infrared photographs and supplements them whereever necessary by survey records and hand held photographs.

AEROTRIANGULATION

In order to use aerial photographs for mapping, the elevations and positions of several well distributed points on each photograph are required. Formerly this information was obtained by laborious field survey methods, but modern technology, known as aerotriangulation, eliminates much of this field work.

A few control stations for aerotriangulation are selected, recovered and premarked (Fig. 3) in the field in advance of aerial photography. The control requirements are furnished to the field party on a job diagram as described above in survey planning. Premarking of control is accomplished by paneling with plastic or muslin material. The target dimensions are specified as a function of aerotriangulation photography scale, but must sometimes be modified because of terrain conditions. In instances where the control station may be obscured by shadows or relief displacement, or where the target is subject to vandalism, two photoidentifiable points are selected and located for use as substitute stations.

Results of the analytical aerotriangulation are used for the precise orientation of the black-and-white infrared photographs and the color photographs in a three-dimensional plotting instrument.

Duplicate transparencies are used in lieu of prints. Six pass points, chosen in pairs along the center and edges of the flight strips are marked on each aerotriangulation transparency for use in the orientation of the stereoscopic plotting instrument for map compilation.

All pass points for the aerotriangulation are marked with a point transfer device (Fig. 11) using a drill 60 micrometers in diameter. The photo-coordinates of aerial camera fiducial marks, the pass points and the control points are measured on the aerotriangulation transparencies using a two-plate stereocomparator (Fig. 12) equipped with a one micrometer readout. Multiple readings are taken for all points and camera fiducial marks.

As each flight strip is measured the raw photograph coordinates and correction factors for systematic errors such as atmospheric refraction, film deformation and radial lens distortion are processed thru a series of computer programs, resulting in final coordinate values for subsequent mapping.

COMPILATION

Data processed through aerotriangulation is furnished for automatic plotting of the base compilation manuscripts at the required scale. State plane coordinate grid lines and tick marks for a polyconic projection are placed on a stable base mylar manuscript by means of an automatic plotter (Fig. 13). Positions of control points, landmarks and aids to navigation, and other points located during aerotriangulation, are also plotted at the same time. This skeletal manuscript is then used as the base for further compilation with the stereoscopic plotting instrument (Fig. 14).

Stereomodels of color photography are set in the instrument and oriented to provide a three dimensional orthographic view of the area being mapped. Land and offshore features are traced from these models onto the base manuscript. The mean low-water line is compiled in similar manner from the tide-coordinated, black-and-white infrared photography.

After compilation and review of the map manuscript, any discrepancies or inadequacies which cannot be resolved in the office are noted and forwarded to the field for verification. As a result of field inspection, changes to the manuscript in the form of additions or deletions are applied as appropriate.

The final version of the edited compilation is printed as a conventional line map, with the mean low-water line symbolized as a fine dotted line. This map, or a set of such maps as would normally be the case, is provided to a special committee of State and Federal representatives who use them as a basic tool for the arbitration of selected points along the mean low-water line. The points selected form a segmented baseline from which the offshore boundary will be projected.

The baseline points are indicated on the maps, which are then returned to the NOS compiler for scaling state plane coordinates of each point. A final printing of the maps is made, indicating the selected points and giving the coordinates of each point (Fig. 15).

For some users of National Ocean Survey maps and charts, the series of small dots paralleling the shoreline are of only casual interest. However, for users such as yourself, who are engaged in the development of the submerged tide lands and the continental shelf, those dots are important, and they are financially significant to the States and Federal Government because they represent the line which is the base for positioning the coastal boundary. We appreciate the opportunity you have given us to explain how this is done and the next time you see our field people wading the shell banks and mud lumps you will know that we are mapping the mean low-water line.

REFERENCES

Jones, B.G., and Shofnos, W.: "Mapping the Low-Water Line of the Mississippi Delta", International Hydrographic Review (January 1961)

Shalowitz, A.L.: Shore and Sea Boundaries (Vol. I), U.S. Government Printing Office, Washington (1962)

U.S. Department of State: "Sovereignty of the Sea", Geographic Bulletin No. 3 (Oct. 1969)

Brewer, R.K. and Heywood, A.K.: "Coastal Boundary Mapping:", Proceedings of the ASP-ACSM Annual Meeting, (1972)

Cravat, H.R. and Glaser, R: Color Aerial Stereograms of Selected Coastal Areas of the U.S., U.S. Government Printing Office, Washington (1971)

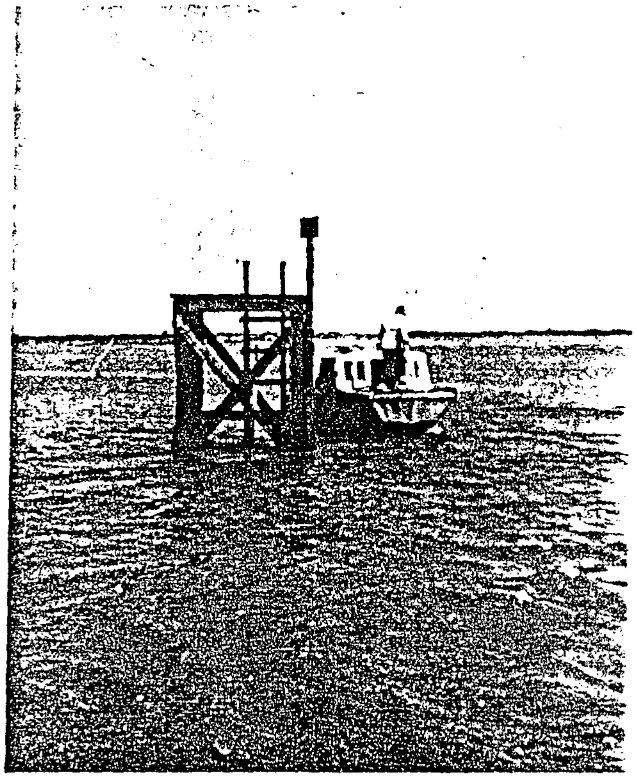

Fig. 1 - Tending a tide gage on Louisiana coast.

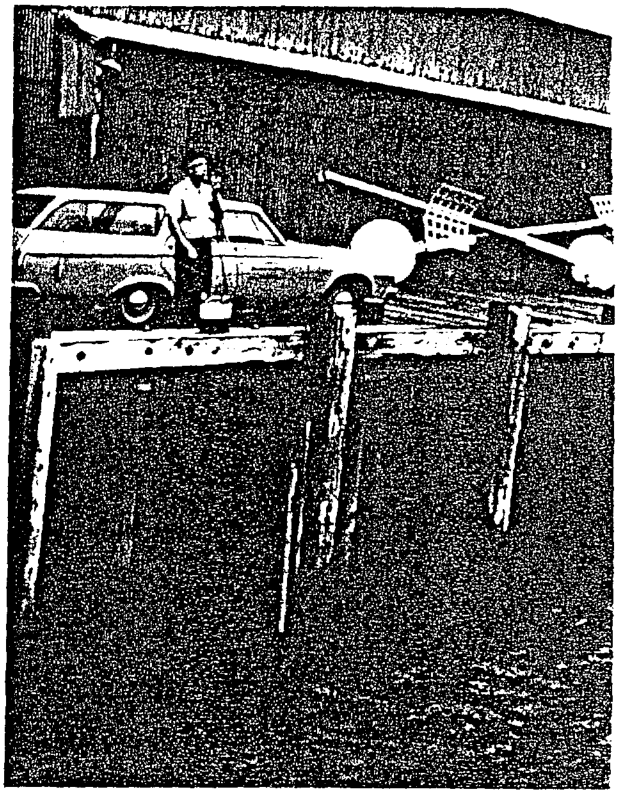

Fig. 2 - Tide staff observer radios water level readings to command post.

Fig. 3 - An enlarged section of an aerial photograph showing a triangulation station target.

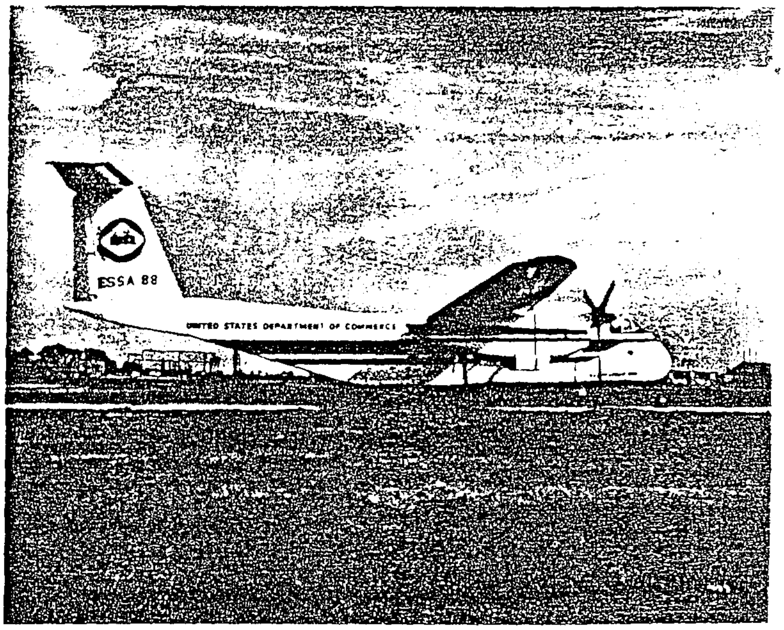

Fig. 4 - The platform used for obtaining photography is the DeHavilland Buffalo aircraft.

Roll 31-05
65-L-3703-R

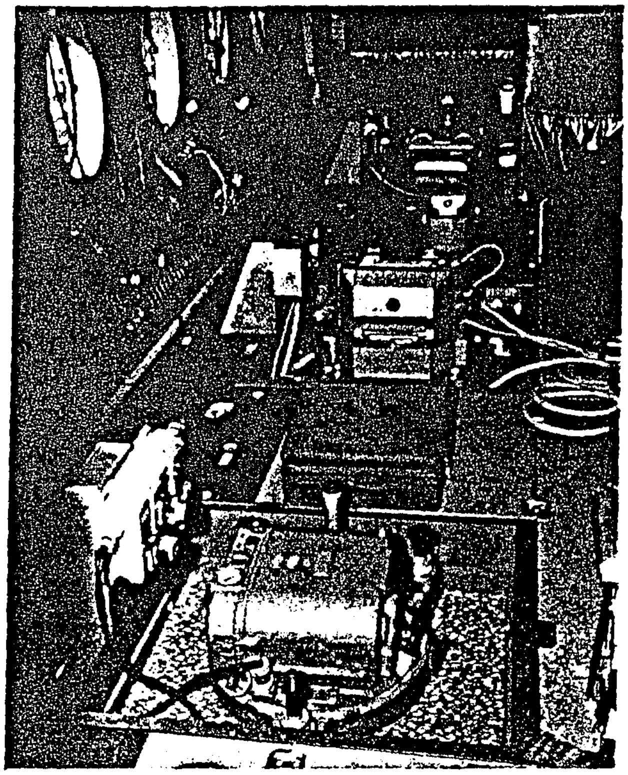

Fig. 5 - Aerial camera arrangement inside the aircraft.

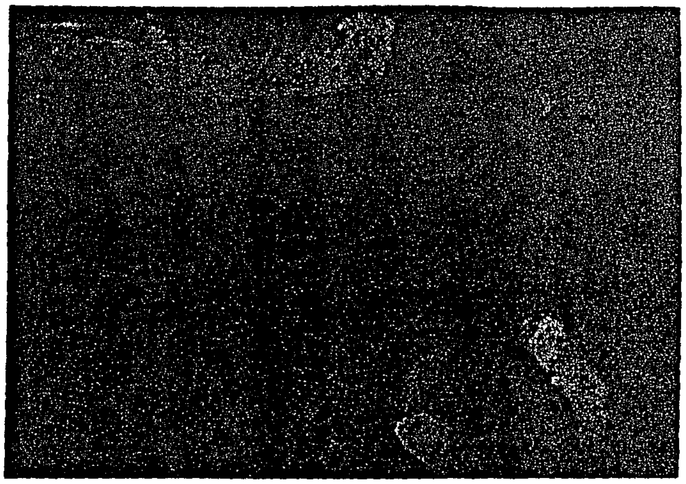

Fig. 6 - Infrared photograph taken at mean high water.

Roll 31-05
3687-R
65-L-~~3616-R~~

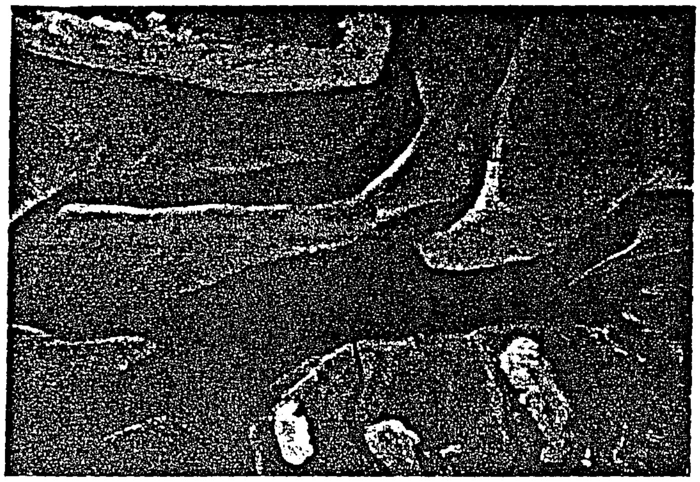

Fig. 7 - Infrared photograph taken of identical area, but a few hours later when the ~~[illegible]~~ tide was at mean low water. Note the mud flats and sand bars that are exposed at low water.

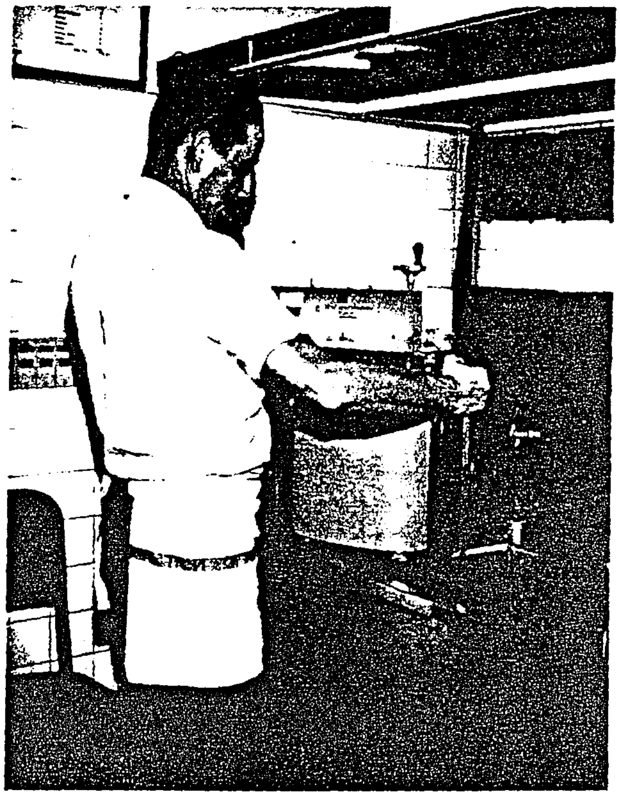

Fig. 8 - The aerial film is custom processed, using motor-driven wind-rewind developing machines which have sensitive clutch mechanisms that prevent tugging and stretching of the film.

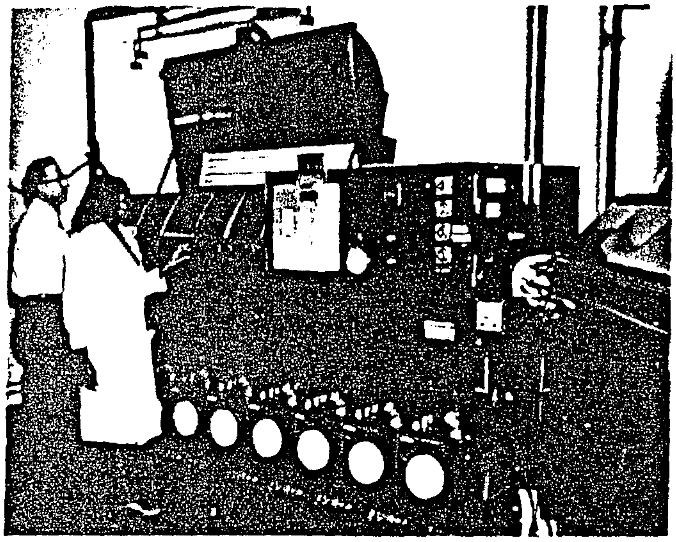

Fig. 9 - Print processing is automated. This machine develops color or black-and-white prints.

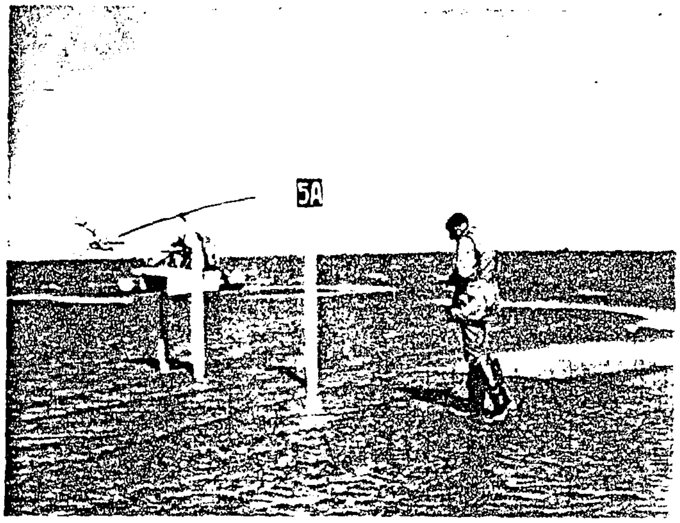

Fig. 10 - A field inspector determines the low water elevation of a sand bar that barely provides room for landing the helicopter.

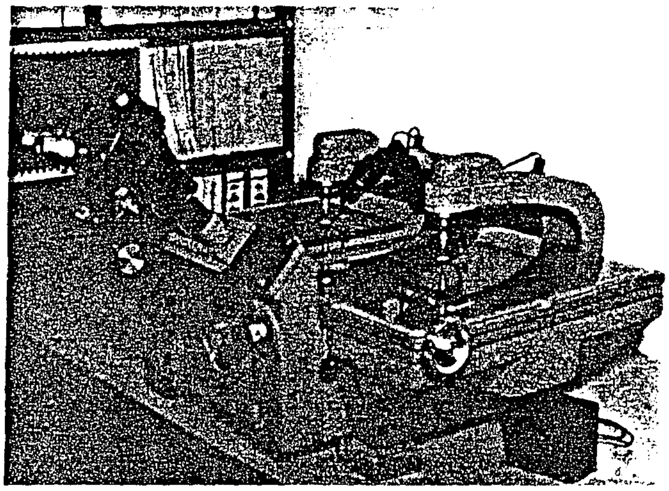

Fig. 11 - Point transfer device for precision transfer of photo points.

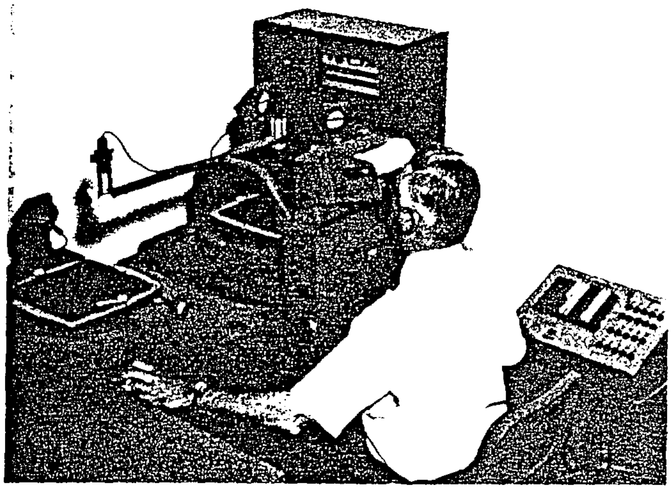

Fig. 12 - Stereocomparator.

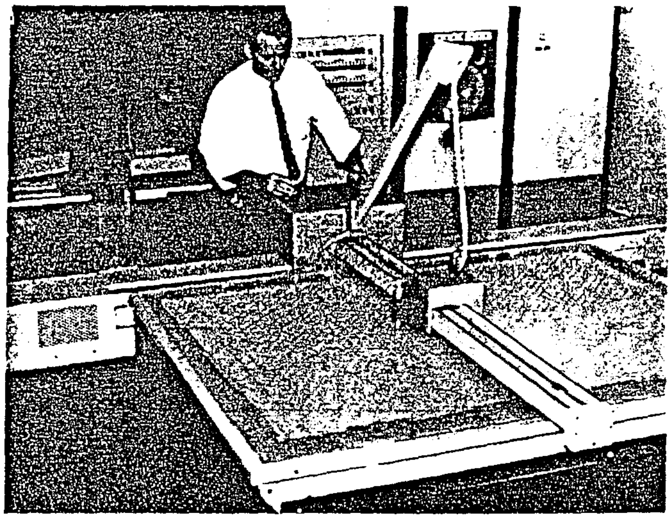

Fig. 13 - Automatic plotting instrument.

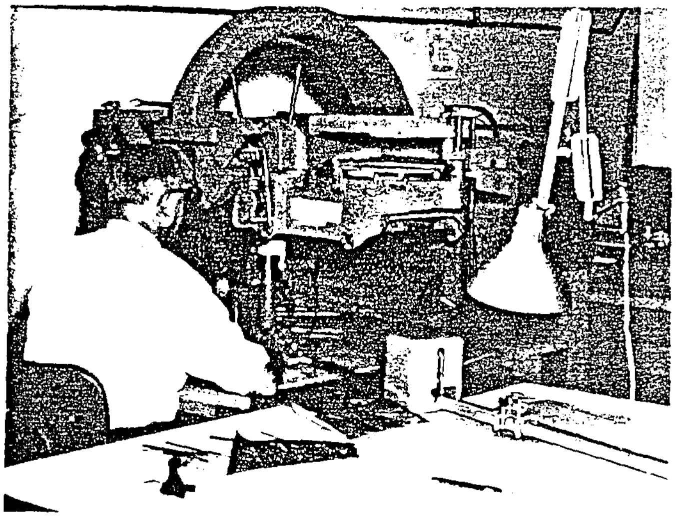

Fig. 14 - Stereoscopic plotting instrument.

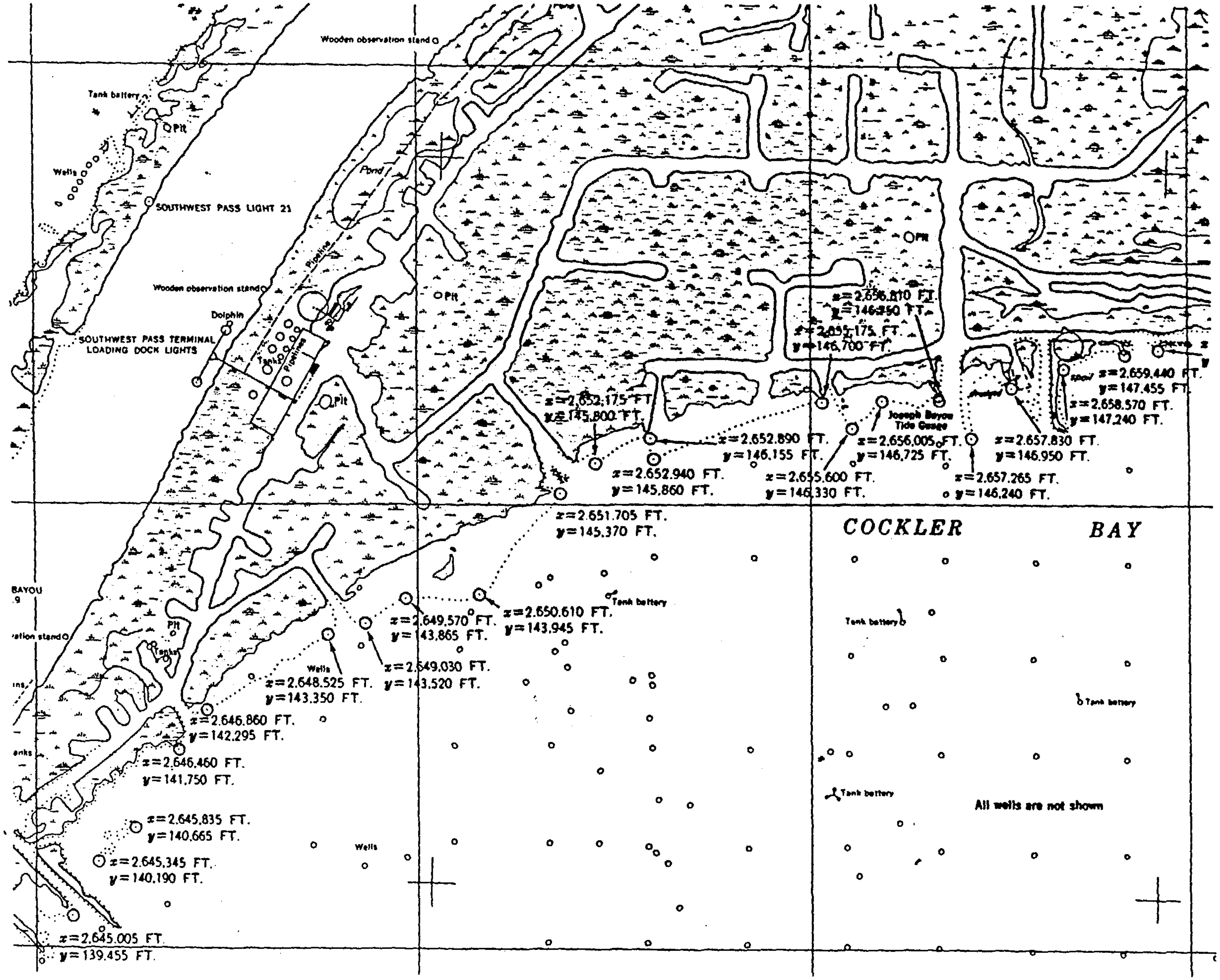

Fig. 15 - Section of Louisiana coast map showing turn points with state coordinate values.