[Reprinted from the Annual Report of the Secretary of Commerce, 1936]

COAST AND GEODETIC SURVEY

REVIEW OF THE YEAR

The Coast and Geodetic Survey was considerably handicapped during the fiscal year 1936 by lack of funds required to enable it to meet all needs for the services it renders. The annual appropriations to the Survey during recent years have been materially reduced while at the same time there has been a continual and substantial increase in the demands of governmental agencies and the public for all products and related data which are derived from the various branches of the Bureau's operations.

This situation may be illustrated by comparing present conditions with those existing in 1932, the last year of normal operation prior to the depression. At that time the Bureau's annual appropriation was $3,075,933, an amount fixed after careful study as the minimum sum required for the satisfactory accomplishment of the essential projects which should be carried on at an approximately uniform yearly rate. The appropriation for 1936 was $2,360,900, a reduction of 23 percent. This amount, however, was augmented by certain allotments described in a subsequent section of this report.

On the other hand, although the publication of new charts has been confined to those most urgently needed, the number of different nautical charts now published is 775, as compared with 738 in 1932. The average issue of all nautical charts for 1935 and 1936 was 292,783 as compared with 276,994 in 1932. Individual surveys, received annually for compilation and revision of charts, increased from 2,329 to 3,049. Hand corrections required to correct charts between dates of printing and issue increased from about 1½ millions to 2 millions per year. The Bureau's Chart Division now has about 4 months' work laid out ahead, as compared with 1.3 months' work in 1932. Special requests for geodetic data for purposes other than mapping have more than doubled, and requests which cannot be supplied at present have now accumulated to a total of about 3,000 cases.

For several years prior to 1936 the operations of the United States Coast and Geodetic Survey were expanded considerably through allotments of emergency funds, granted primarily for the relief of unemployment. Until these funds became exhausted, early in 1936, it was possible to utilize them where necessary to supplement the regular appropriations, so that the present deficiency in the latter was not felt until 1936. An increase in the annual appropriations for the Bureau's operations during 1937 has been granted by the Congress and will provide a partial remedy for the situation existing during 1936. It is hoped, as conditions improve, that it will be pos-

National Oceanic and Atmospheric Administration

Annual Report of the Superintendent of the Coast Survey

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sible to restore fully the Bureau's activities to a normal basis in the near future.

Another matter, mentioned in last year's report, continues to cause concern—the lack of funds with which to complete the office processing of data from field operations, carried on during the fiscal years 1933, 1934, and 1935 with emergency funds. Approximately 40 percent of this office work remains to be done. Without this essential final step, required to make the results of field surveys available for use, a corresponding part of the expenditures for these surveys will have been wasted. Efforts to secure funds for this purpose during the past year were unsuccessful.

To the extent permitted by the funds at its disposal, however, the Coast and Geodetic Survey made good progress during 1936 in all branches of its work.

Improved methods of hydrographic surveying, notably echo sounding and radioacoustic position finding, continued as extremely important factors in increasing the efficiency and reducing the costs of this class of work. More detailed surveys of several submarine valleys, previously inadequately charted, and the discovery of new features of this nature provided the mariner with additional opportunities to ascertain his position and course by means of soundings. Of special interest are the encouraging results which have attended the efforts of the Bureau to develop an automatic buoy to replace the much more expensive station ships now used for radioacoustic position finding. Wire-drag surveys on the Pacific coast further safeguarded shipping by the discovery of a number of rocks dangerous to navigation.

The appropriation for geodetic surveys permitted the accomplishment of only a very small amount of this work but the Bureau was able to render considerable assistance in this class of operations by executing several special surveys required by other governmental agencies which supplied the funds required.

Special tide and current surveys, providing essential navigational information, were completed on the coast of the State of Washington and in Los Angeles Harbor and San Pedro Channel, Calif.

The Bureau's program of earthquake investigation continued to supply data of great value for governmental and private building operations. The work of measuring strong earth motions resulting from severe earthquakes, heretofore carried on chiefly in California, was extended to Montana following the destructive earthquakes which occurred at Helena on October 18 and 31, 1935.

Emergency funds continued to be available for aeronautical charting and excellent progress was made in this class of work. These and other operations of the Bureau are discussed more fully in subsequent sections of this report.

IMPROVEMENTS IN METHODS AND EQUIPMENT

A considerable amount of development work was accomplished in the Instrument Division during the year. As a result of studies and experiments with various color filters for level and theodolite telescopes, a number of instruments were equipped with improved filters, which increase definition and reduce the "boiling" effect of heated air over roadways.

Gravity pendulums were redesigned to accommodate a new style of agate knife-edge bearing, free from strain.

An entirely new form of recording element for strong-motion seismometers was designed and several units were built. Trial of these new recorders, which may be used anywhere where photographic recording is desired, whether seismographic or not, demonstrates the uniformity of the records obtained, "chatter" of the record sheet having been entirely eliminated. The setting and adjustment has been decidedly simplified over that of previous recorders.

An instrument was designed to facilitate the delicate operation of mounting fine cross wires in telescopes. These fibers are usually of spider-web or spun-glass and are from one to three ten-thousandths of an inch in diameter. The instrument rigidly controls all movements and measures any desired spacing of the wires. Uniform tension is applied to the material while mounting, practically all hand work being eliminated.

Compass declinometers were improved by the addition of a new type of telescope which materially increases the closeness with which the instrument may be pointed and permits sighting at high angles. In addition, a variety of improvements and economies were made, including the construction of a special high-speed tide gage for the study of peculiar local tidal phenomena in Los Angeles Harbor; the construction of a special plate rack; a new sounding engraving machine; a new chronograph for the gravity apparatus; and other elements of lesser importance.

The Division of Hydrography and Topography developed a new gasoline-driven sounding machine for use in verifying echo soundings and obtaining bottom samples in deep water. Several new hydrographic launches of improved efficiency were designed, secured under contract, and placed in operation.

An electrical laboratory maintained by the Division continued its work of maintaining and improving the Bureau's echo-sounding and radioacoustic equipment. An outstanding accomplishment of this laboratory was the development of a "sono-radio" buoy, an entirely new and completely automatic item of radioacoustic equipment designed to receive underwater sound and thereupon to transmit an instantaneous radio signal. Several of these buoys were constructed and placed in operation for surveys on the Atlantic and Gulf coasts. While still in the experimental stage, the results achieved to date warrant the belief that they can be used, at least to a considerable extent, to replace the station ships now used in radioacoustic position finding and thus further increase the economy of this type of surveying.

Improvements in reproduction methods employed by the Chart Division have reduced the amount of labor involved in the Division's activities. Without such economies in time and cost, the Bureau would have been unable to handle the increased volume of work while preserving the requirements of accuracy.

The copper engraver is now furnished with intaglio etchings on zinc in order that he may secure sharper outline and fuller body in the impressions of his transfer of chart compilations to the copper.

The use of type on copper-engraved charts has entirely replaced hand engraving, after a thorough test proved that the high Bureau standards were maintained by the new method.

A method was found to bleach to a paper whiteness the aluminum plates used in the reproduction of charts which required extensive changes in lettering. The method permits superseded lettering to be painted out, new type stuck up on the bleached plates, and duplicates of the former negatives plus the changes required in lettering to be obtained, all of which results in a minimum amount of engraving on the glass negatives.

Standardized symbols for aids to navigation, such as lights, beacons, and buoys, are now provided on gummed paper for use on both copper and lithographic engraved charts.

COOPERATION WITH OTHER AGENCIES

Cooperation in carrying out various projects was extended to practically every bureau in this Department and with many other governmental and private agencies.

The Bureau cooperated with the Lighthouse Service in preparing the Weekly Notice to Mariners and made numerous specialized charts and graphs for the Bureau of Air Commerce, the Lighthouse Service, and the Bureau of Foreign and Domestic Commerce of this Department and for various other agencies, including the Command and General Staff School, Fort Leavenworth, Kans.; United States Engineers; Navy Department; United States Marine Corps; United States Weather Bureau; United States Biological Survey; Bureau of Agricultural Economics; National Archives; National Capital Park and Planning Commission; Division of Airways and Airports of the Works Progress Administration; Social Security Board; and others. This special work often required that hydrographic surveys and air-photo compilations be verified and reviewed ahead of schedule in order to furnish advance prints to interested Federal agencies.

A cooperative arrangement with the Lighthouse Service which promises valuable results was inaugurated during the year. This consists of an exchange of officers between the two bureaus, in order that each may become more familiar with the closely related work of the other service. An officer of the Survey also was assigned to the headquarters of the Charleston, S. C., lighthouse district, where, by maintaining close contact with the superintendent of the district and the United States Engineers, the Bureau obtained much valuable chart information at a nominal cost. It is believed that this plan will further tend toward standard practices in matters of mutual benefit.

A representative of this Bureau also continued on intermittent duty with the Post Office Department as a member of a board conducting speed trials of vessels holding ocean-mail contracts.

Of popular interest was the detail of two officers, who were successful in helping to find, by the use of the Bureau's wire-drag equipment, an airplane and crew lost in Great Salt Lake, Utah.

The following geodetic projects were handled on a cooperative basis for the organizations named:

District of Columbia-Virginia Boundary Commission: Arc of second-order triangulation along a portion of the Potomac River.

Senate Oil Investigation Committee of California: Lines of levels and traverse along the coast in the vicinity of Huntington Beach, Calif., to determine the position of the high-water line.

Soil Conservation Service: Second-order triangulation in the Papago, Hualapai, and Mescalero Indian Reservations, for use in controlled mosaics from air photos. Similar work was begun near the close of the year in reservations in South Dakota, Utah, Washington, and Wyoming.

Internal Improvement Board of Florida: Establishment of 20 gravity stations.

Tennessee Valley Authority: Strengthening of level lines and connections with local leveling.

Galveston District Engineer, Corps of Engineers, United States Army: Some 250 miles of leveling in the vicinity of Galveston Bay, including connections made with an intricate system of leveling along the Houston Canal, to establish bench marks for the use of the Corps of Engineers in its local activities.

Seismologists of the University of Montana, with funds allotted by the Public Works Administration: Rerunning of old lines of levels and new leveling extended in Helena, Mont., and vicinity.

Florida mapping project, under the auspices of the Works Progress Administration and the United States Engineers at Jacksonville: Extension of triangulation from Orlando to Titusville and from Orlando to Lake Okeechobee.

Works Progress Administration project of King County, Wash.: Detail of an officer to assist in air-photo mapping and extending necessary triangulation.

The Bureau continued serving in an advisory capacity with 14 States in carrying on horizontal and vertical control surveys, as part of the Works Progress Administration program on surveys continued as projects initiated by this Bureau in November 1933 under the Civil Works Administration.

There was assigned to each of the computing offices of the State geodetic survey projects in Arkansas, Connecticut, and Oklahoma, an officer to organize and instruct the personnel, paid by the Works Progress Administration, in geodetic computations. Computing machines and logarithm tables were loaned and computing forms supplied.

The activities of the Division of Tides and Currents included the establishment of tide stations for the United States Engineers, in order to supply important data for use in connection with the Passamaquoddy tidal power project; a study of the tides in Barnegat Bay, to determine with precision the relations between local datum planes in that body of water, for the New Jersey Board of Commerce and Navigation; and a tide and current survey, including a special study of seiche and surge, of Los Angeles Harbor, for the harbor department of Los Angeles.

Cooperation with the Carnegie Institution of Washington, which carries on several activities closely related to those of the Bureau, has been noteworthy. In terrestrial magnetism there has been joint effort in development and test of instruments, maintenance of magnetic standards, and interloan of instruments, which have all been of mutual benefit. The joint activity has resulted in the operation of a cosmic ray meter at Cheltenham and of atmospheric electric and earth current instruments at Tucson, the last with the added

cooperation of the Mountain States Telephone & Telegraph Co. At the request of the committee on seismology of the Carnegie Institution of Washingon, additional level lines were run in California and there was cooperation with the seismological research laboratory at Pasadena, which is operated jointly by that institution and the California Institute of Technology.

In seismological work there is so much cooperation that only a few examples can be mentioned. The Weather Bureau and University of California aid especially in the collection of earthquake information. Organized groups of engineers and architects in California and State educational institutions, especially the California Institute of Technology and Stanford University, have taken an active part in strong-motion work and related activities and in utilization of results. In immediate location of earthquake epicenters there is close cooperation with Science Service and the Jesuit Seismological Association.

The inability of the Bureau to find much time for interpretation of its results is partly compensated for by studies in radio based on its records by the National Bureau of Standards, Naval Research Laboratory, National Broadcasting Co., and others, and in basic research in magnetism by the Carnegie Institution of Washington.

MISCELLANEOUS

There were but 1,335 employees on duty in the Bureau on June 30, 1936, shown in the table following, as compared with 2,024 and 3,582, respectively, on the last day of the fiscal years 1934 and 1935.

Staffs	Commissioned	Civilian				Staff totals		Total
		Classified	Unclassified			Washington	Field	
			Laborers	Seamen	Hands			
Regular appropriations:								
Washington office	14	256	5			275		275
Field service	163	73		[1] 503	[1] 287		1,026	1,026
Total	177	329	5	503	287	275	1,026	1,301
Public Works funds:								
Washington office		12				12		12
Field service		1			21		22	22
Total		13			21	12	22	34
Grand total	177	342	5	503	308	287	1,048	1,335

[1] Includes 51 civilian employees on duty at the Manila field station and 50 members of the crew of the ship *Fathomer*, paid by the Philippine insular government but under the jurisdiction of this Bureau.

The library and archives acquired during the year 231 hydrographic and 324 topographic sheets, representing new Bureau surveys. Other additions were 939 blueprints (mostly surveys by Army engineers); 2,588 maps; 3,319 charts; 14,960 field, office, and observatory records; 276 negatives; 378 prints; 231 lantern slides; 673 books; and 3,940 periodicals.

As heretofore stated, the regular appropriations for the year totaled $2,360,900. These were supplemented by allotments of $37,450 from Air Navigation Facilities, 1936; $360,300 from National Industrial Recovery, 1933–37; $28,000 from Public Works Administration (allotment to Commerce), 1935–37; $5,000 from Texas Centennial Exposition; $1,000 from trust fund, topographic survey of United States, contributions; $25,000 from Public Works Administration (allotment to Interior and transferred to Commerce, Soil Erosion Prevention), 1935–37; and $22,300 from Salaries and Expenses, Soil Conservation Service (transfer to Commerce), 1936. In addition to these sums, there were available small unexpended balances on account of appropriations and allotments for the fiscal year 1935.

Collections on account of the sale of nautical charts and other publications and miscellaneous Government property, deposited in the Treasury Department to the account of miscellaneous receipts, totaled $95,589.74, as compared with $75,575.14 during the preceding year, an increase of approximately 25 percent.

Disbursements during the year ended June 30, 1936, totaled $3,625,895.61, distributed among the various appropriations as follows:

Pay and allowances, commissioned officers, 1935	$61,089.31
Party expenses, 1935	123,377.59
Repairs of vessels, 1935	7,183.30
General expenses, 1935	7,468.43
Pay, etc., officers and men, vessels, 1935	101,530.40
Air navigation facilities, 1935	343.85
Pay and allowances, commissioned officers, 1936	698,031.22
Salaries, 1936	544,038.59
Party expenses, 1936	362,567.56
Repairs of vessels, 1936	51,707.85
General expenses, 1936	29,914.07
Pay, etc., officers and men, vessels, 1936	388,259.67
Air navigation facilities, 1936	34,499.66
National Industrial Recovery, 1933–37	1,109,743.94
Public Works Administration, allotment to Commerce, Bureau of Air Commerce, 1935–37	102,873.08
Chicago World's Fair centennial celebration	39.22
California Pacific International Exposition	63.24
Texas Centennial Exposition	1,971.93
Trust fund, topographic survey of United States, contributions	999.75
Salaries and expenses, Soil Conservation Service (transfer to Commerce, C. and G. Survey, act of Apr. 27, 1935), 1936	192.95
Total	3,625,895.61

CHARTS

As alterations and natural changes are constantly occurring, many nautical charts become obsolete within a few months after their publication. Constant revision of existing charts therefore is essential to the safety of navigation, and during the past year new editions for 130 charts were printed for this purpose.

Extension of detailed field surveys made possible the construction of 17 new charts, as listed below, showing the latest marine improve-

ments on scales larger than those which had been previously printed of the same localities.

MASSACHUSETTS: Wellfleet Harbor and approaches from Cape Cod Bay.
MARYLAND: Herring Bay to Magothy River, Chesapeake Bay.
NORTH CAROLINA:
New River Inlet to Southport.[1]
Westward from Southport.[1]
SOUTH CAROLINA: Wadmalaw River to Port Royal Sound.[1]
FLORIDA:
Miami Harbor and entrance channel.
Mosquito River to Eau Gallie.[1]
Eau Gallie to Walton.[1]
Walton to Delray.[1]
LOUISIANA:
Calcasieu Lake and Pass from the Gulf.
Calcasieu River and Canal, Lake Charles to Sabine River.
CALIFORNIA:
Santa Catalina Island and adjacent waters.
San Nicolas Island and adjacent waters.
Sacramento River, from Sacramento to Andrus Island.
ALASKA:
Portland Canal, north of Hattie Island.
Coast, from Coronation Island to Lisianski Strait.
Kodiak Island, Chiniak Bay to Dangerous Cape.

[1] Intracoastal Waterway charts.

In the above list there are included six of the proposed series of charts covering the new Intracoastal Waterway from Norfolk, Va., to Miami, Fla., published on a scale showing clearly all the essential information and depths required for convenient use of the waterways, with sufficient land area adjacent to them to identify the general locality and nature of the country traversed. This series will meet a popular demand not only for pleasure boats cruising the entire waterway but by barge tows engaged in local freighting between various communities on inland waters along the South Atlantic coast.

Distribution of nautical and aeronautical charts and related publications during the year is shown by the following table:

Item	1936	1935	1934	1933
Nautical charts [1]	275,800	309,765	293,889	241,894
Aeronautical charts [1]	178,973	61,268	38,313	17,889
Strip maps	12,186	9,210	11,304	20,919
Compilation sheets	4,236	2,907	558	
Miscellaneous maps	2,857	2,192	1,339	2,992
United States coast pilots	6,167	6,077	7,046	4,116
Intracoastal waterway pilots	1,022	943	1,027	1,399
Distances between United States ports	429	588	1,435	330
Tide tables	24,184	21,984	24,851	24,879
Current tables	9,002	7,588	7,652	6,730
Tidal current charts	1,607	1,705	701	958
Practical air navigation	5,167			
Total	521,630	424,227	388,115	322,106

[1] Annual reports prior to 1936 did not include charts withdrawn from sale because of the issue of revised editions.

The year 1936 saw the greatest increase in the compilation, reproduction, and issue of aeronautical charts of any year since this Bureau began their compiling and printing. More copies were issued in 1936 than in the 5 preceding years, and as many new sectional charts were completed in 1936 as in the 4 preceding years. Nearly three times as many copies were issued in 1936 as in 1935.

This increase was occasioned by three main factors: Many new charts were completed and made available; the Air Corps of the military services discarded the use of the old strip maps and made greater use of the new sectional charts; and these charts are now better known and of more value to the public than when the adjoining sections were not available.

Forty-one new aeronautical charts were printed, including two regional charts of the proposed new series covering a much larger area on a smaller scale than that of the series of sectional charts. In addition to the production of these new charts, 66 new editions of existing charts were printed. The safety of the air navigator requires accurate data of conditions existing at the time of his flight. This service is perhaps the most essential feature of chart production to the aviator and confronts the Bureau with the never-ending task of collecting and revising information. It is therefore necessary to declare obsolete older editions when the accumulation of extensive changes in topographic and aeronautical information make the use of them unsafe.

HYDROGRAPHY AND TOPOGRAPHY

Hydrographic and topographic survey work which had been accelerated for the preceding 2 years by emergency funds was reduced during the period of this report to the output obtainable under regular appropriations. Early in the fiscal year 14 shore parties operating on the Atlantic, Gulf, and Pacific coasts were disbanded when emergency funds were exhausted. While, unfortunately, not all of these projects were brought to a state of completion, a large amount of work was done which helped fill a serious need for new and adequate inland waterways charts. Although a great amount of similar work yet needs to be done in other areas, the surveys have been made to cover most of the important regions and bring up to date many charts which for years were based on very old surveys, inadequate for present-day use.

On the Atlantic coast the two large vessels, *Oceanographer* and *Lydonia*, and the tenders *Gilbert* and *Welker*, continued surveys of the continental shelf, together with inshore hydrographic work and necessary control surveys on the Virginia coast, for revising the inshore and offshore charts of this region. In May 1936 these ships took up the work of modernizing the charts of the approaches to New York Harbor, where the outer submerged valley of the Hudson River was surveyed accurately for the first time by the use of echo sounding and radioacoustic ranging.

Such submarine valleys are of great navigational importance to merchant vessels equipped with echo-sounding apparatus, especially when they lie along main shipping routes. In addition to the value to navigation, the discovery of those valleys undoubtedly will be of wide influence in the science of geology and may change the fundamental concepts of the geology of our Atlantic coast. Much interest has been shown by geologists in all of these new offshore surveys, including those of 1933–35 which disclosed numerous other valleys in the coastal shelf off Delaware and Chesapeake Bays. These modern detailed surveys, made possible by methods developed in this Bureau, furnish a wealth of detail heretofore unavailable.

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In the Gulf of Mexico the ship *Hydrographer*, with the tenders *Faris* and *Pratt*, continued surveys between the shore and the approximate 100-fathom curve west of the Mississippi Delta. This party also found a submerged valley, assumed to be the ancient course of the Mississippi River, lying about 100 miles west of the present mouth of the river.

Coastal triangulation data (Atlantic and Gulf coasts), accumulated from the work of the expanded units during the past 2 years, including descriptions and positions together with index sketches, were assembled and lithographed in temporary form to satisfy requests for these data from Bureau parties and other engineers. A compilation of datum differences between the 1927 North American datum and the old North American datum was also made and published in lithographic form to aid hydrographic and topographic surveys using this control.

In the Pacific, offshore areas were surveyed on the California and Oregon coasts by the ships *Guide* and *Pioneer*. Wire-drag surveys of many important areas along the coastwise traffic lanes again demonstrated the efficiency of this method of finding dangers which in certain areas remain undisclosed by the usual hydrographic surveys. A particular instance was at Chetco Cove, Oreg., where an extensive lumbering project is being carried on. Owing to a vessel touching on an uncharted pinnacle rock in this cove, other shipmasters refused to go into the loading berth, anchoring some distance offshore without shelter from prevailing northwesterly winds and thereby slowing up loading and increasing the cost of operation. A party detailed from the *Guide* swept the area with a wire drag and found four other rocks with less than 30 feet of water over them in addition to the rock on which the vessel struck. A safe passage for approaching the cove was found and an unobstructed area in sheltered waters charted for a loading berth. The manager of the timber company, in expressing his appreciation for this valuable work, stated that by virtue of this survey a whole community, dependent on these loading operations, had been maintained in a self-supporting status during the summer.

The *Explorer* spent the year on coastal triangulation and surveys for chart revision in Puget Sound.

In Alaska, the *Surveyor* and *Discoverer*, with tenders *Westdahl*, *Wildcat*, and *Helianthus*, continued surveys in the Aleutian Islands westward from Unimak Pass, as part of the program of charting the entire Aleutian chain to enable ships sailing between Puget Sound and the Orient to use the great-circle route through Unimak Pass and the Bering Sea. This route is not used because more than 800 nautical miles of uncharted water lie between Unimak Pass and Cape Wrangel in the Bering Sea. Bogoslof Island, an active volcanic island in the Bering Sea lying near this proposed route, was surveyed accurately for the first time and the surrounding region charted. In the spring of 1936 the *Westdahl* took up surveys in the vicinity of Juneau, and also triangulation up the Chilkat and the Skagway Rivers in cooperation with the International Boundary Commission.

In the Philippine Islands the *Pathfinder* remained in a decommissioned status and the *Fathomer*, working under Philippine Civil Government funds, continued surveys in the vicinity of Balabac Island and Eastern Luzon.

The 13 United States Coast Pilot volumes published by the Bureau contain a wide variety of important information supplemental to that shown on the chart, such as a description of the coast and information concerning waterways as well as maritime data for all the ports of the United States and possessions. It is essential that these pilots be kept up to date, and this is done by annual supplements and revisions based on field examinations. During the year nine supplements were published and three new editions were written. One of these new editions, United States Coast Pilot, Gulf Coast, Key West to the Rio Grande, contains the former Inside Route Pilot, Key West to the Rio Grande.

Two field examinations were made, one of the section of the Atlantic coast from Sandy Hook to Cape Henry, including Chesapeake and Delaware Bays, and the other of the New Jersey Inland Waterway.

The base topographic maps compiled from aerial photographs of coastal areas have found wide popularity among many engineering and private surveying organizations. This most economical method of surveying inaccessible regions has made accurate surveys on a large scale available for many important sections.

Hydrography, topography, and costal triangulation

Locality	Hydrography			Topography		Coastal triangulation		
	Sounding lines	Area	Soundings	Shore line	Area	Length of scheme	Area	Geographic positions
	Miles	*Square miles*	*Number*	*Miles*	*Square miles*	*Miles*	*Square miles*	*Number*
Buzzards Bay to New Haven, Massachusetts, Rhode Island, and Connecticut	438	7	15,193	144	84	25	230	101
Approaches to New York Harbor, New York and New Jersey coasts	5,855	4,274	48,616					
Vicinity of New York City and New Jersey coast				942	189			
Metedeconk Neck to Cape May, N. J.	878	8	37,711	422	160	34	151	55
Delaware River, New Jersey and Pennsylvania				24	187	6	6	40
Chesapeake Bay, Md				218	123	4	13	7
Approaches to Chesapeake Bay, Va.	6,783	3,134	79,531					
Norfolk to North Landing River, Va.				164	85			
Alligator River to Neuse River, N. C.	2,690	113	93,542	685	542	68	54	80
St. Johns River, Fla	482	23	34,343	369	48	35	100	34
Fort Lauderdale to Key West, Fla.	1,388	243	47,723	200	132			1
Apalachee Bay, Fla	354	23	13,114	25		3	25	6
Louisiana coast, offshore	9,471	5,276	93,807					
Louisiana coast, Morgan City, La.	926	118	22,103	41	10			1
Coast of southern California	7,410	11,181	43,894	11	5	2	6	2
Coast of northern California	3,056	936	47,692	52	24	2		10
Columbia River, Oregon and Washington	643	30	23,869	91	2	30	84	35
Puget Sound, Wash	2,485	115	71,660	270	61	86	93	223
Aleutian Islands, Alaska	11,221	17,716	109,481	270	423	172	1,472	154
Southeastern Alaska	136	4	7,049	17	2	24	137	18
Philippine Islands	1,987	217	50,580	134	255	33	72	33
Total	56,203	43,418	839,908	4,079	2,332	524	2,443	800

GEODESY

Geodetic operations, consisting principally of triangulation and leveling, furnishing the fundamental control for all maps and charts, were largely curtailed shortly after the beginning of the fiscal year, with the exhaustion of emergency funds. On account of lack of funds for office processing, much needed data that could be derived from field work already done cannot be made available for other Government bureaus and private engineers. These data are essential prerequisites in any national mapping plan adopted by the Government, as the bases for topographic mapping and for the extension of additional arcs of triangulation and lines of levels. Until the office computing has been completed the mapping cannot go forward nor can other triangulation and leveling be extended since all depend upon geographic positions and elevations to be fixed by the preceeding work.

During the year, 2,720 miles of first- and second-order triangulation and 6,924 miles of first- and second-order leveling were completed. All of this work was directed toward the plan to provide a triangulation station and a bench mark within 10 to 15 miles of every point in the United States.

Two astronomic parties and a base-line party conducted field operations for the establishment of Laplace stations and base lines to control the directions and lengths in the arcs of triangulation.

A gravity party was in operation during most of the fiscal year establishing stations in Connecticut, Florida, Massachusetts, New York, Pennsylvania, and Rhode Island. Two new sets of the Brown gravity apparatus and a new gravity chronograph have been completed in the Instrument Division of the Bureau.

In August 1935 a gravity apparatus of the Holweck-Lejay type was purchased from the inventor and manufacturer, whose headquarters are in Paris, France. This apparatus has not been placed in field use due to necessary adjustments and replacements of some parts. It is very rapid in operation and will probably give more than double the number of stations obtainable with the Brown apparatus. The latter, however, is capable of greater accuracy and it is expected that the fundamental stations will continue to be established by it.

The variation of latitude stations at Ukiah, Calif., and Gaithersburg, Md., were in continuous operation. These are two of a group of five stations established around the world on the parallel of latitude 39°08′ north, operated with a view to keeping a record of the changes of latitude, which are due mainly to the change of the instantaneous pole of rotation in the body of the earth. The results are essential to practically all astronomical observatories where work is done in the astronomy of position and are also of importance in various geophysical investigations.

Geodetic triangulations, base lines, reconnaissance, and leveling, and astronomical and gravity observations

Locality	Length of scheme	Area
TRIANGULATION, FIRST ORDER		
	Miles	*Square miles*
Watertown, S. Dak., to Cedar Lake, Minn	155	1,550
Lancaster, Pa., to Elkton, Md	45	720
Zion City, Ill., to Sinsinawa, Wis	130	1,300
Guttenberg to Waverly, Iowa	65	650
Rothsay to Frazee, Minn	35	420
Belfast to Hornell, N. Y	30	300
Harrisburg to Boalsburg, Pa	70	700
Watertown to Gettysburg, S. Dak.	145	1,450
Buena Vista to Antonito, Colo	140	1,400
Parks, Nebr., to Longmont, Colo	160	2,400
Hackettstown, N. J., to Staten Island, N. Y	95	900
Featherville to King Hill, Idaho	20	300
Missoula to Charlo, Mont.; Missoula, Mont., to Headquarters, Idaho; Grave Peak to Lookout Mountain, Idaho	175	3,500
Sulphur, Nev., to Andrews, Oreg	100	1,400
Tigerville to Douglass, S. C	70	840
Elizabeth Base Net, N. J	5	25
Total	1,440	17,855
TRIANGULATION, SECOND ORDER		
Jasper to Wheaton, Minn	125	1,250
Stepstone to Louisville, Ky	105	1,050
Veseli to Troy, Minn	80	800
Sherburn to Hector, Minn	65	650
Vicinity of Portland, Oreg	70	980
Potomac River (District of Columbia—Virginia boundary)	10	15
Papago Indian Reservation, Ariz	565	5,665
Hualapai Indian Reservation, Ariz	115	1,725
Mescalero Indian Reservation, N. Mex	100	1,500
Pawcatuck River, Conn. and R. I	10	50
Clarcona to Titusville, Fla	35	245
Total	1,280	13,930
TRAVERSE, SECOND ORDER		
Huntington Beach, Calif	3.8	-------
BASE LINES, FIRST ORDER		
Missoula, Mont	5.3	-------
Battle Mountain, Nev	7.1	-------
Elko, Nev	4.3	-------
Reed, Nev	5.5	-------
Romeo, Colo	6.2	-------
Elizabeth, N. J	4.9	-------
Total	33.3	-------
RECONNAISSANCE, FIRST ORDER TRIANGULATION		
Lowell, Mass., to Albany, N. Y	135	1,350
Circleville to Fairhaven, Ohio	95	1,350
Lancaster, Pa., to Elkton, Md	45	720
Underwood to Earl, N. Dak	130	1,560
Henderson, Ky., to Matthews, Ill	100	1,000
Missoula to Trail Creek, Mont	130	1,820
Georgetown, Ohio, to Adrian, Mich	210	2,100
Aznoe, Mont., to Rathdrum, Idaho	190	2,850
Laramie River Valley, Wyo	55	825

Locality	Length of scheme	Area
RECONNAISSANCE, FIRST ORDER TRIANGULATION—continued		
	Miles	*Square miles*
Gunnison, Colo., to Walcott, Wyo	240	3,360
Longmont to Youghal, Colo	185	2,275
Elkhart to Alexandria, Ind	105	945
Muncie to Holton, Ind	80	720
Tuscarora, Nev., to King Hill, Idaho	110	1,100
Norheim to Columbus, Mont	205	3,075
Tigerville to Douglass, S. C	70	840
Spokane to Seattle, Wash	230	3,220
Durkee, Oreg., to Cloverland, Wash	140	1,680
Bloomington to Michigan City, Ind	170	1,700
Pulaski to North Manchester, Ind	45	450
Stilesville to Rushville, Ind	60	480
Grand Rapids to Basswood Lake, Minn., and Cotton to Pelican Lake, Minn	150	2,700
Leavenworth to Liberty, Wash	40	600
La Grand to Imnaha, Oreg	60	720
Vicinity of Livingston, Mont	20	400
Vernal to Fruitland, Utah	100	1,200
Tallassee, Ala., to Ebro, Fla	175	1,750
Total	3,275	40,790
RECONNAISSANCE, SECOND ORDER TRIANGULATION		
St. John to Danzig, N. Dak	190	2,280
Stepstone to Louisville, Ky	105	1,050
Pittsburgh, Pa., to Wellsville, N. Y	140	1,400
Sherburn to Hector, Minn	65	650
Potomac River (District of Columbia—Virginia boundary)	10	15
Hamburg to Cortland, N. Y	140	1,400
Encinal to Goodlett; Encinal to Indio; Menard to Abilene; and Benjamin to Goodlett, Tex	200	2,000
Cortland to Ravena, N. Y	105	1,050
Skull Springs to Lost Valley, Oreg	170	3,000
Logdell to Sumpter, Oreg	60	700
Marlboro, N. Y., to Nicholson, Pa	95	950
Venturia, N. Dak., to Reliance, S. Dak	130	1,300
Mount Vernon to Harrisburg, Ill	30	350
Clark to Mount Vernon, S. Dak	75	750
Fredericksburg to Danville, Va	150	1,500
Kurtz to Paoli, Ind	20	360
Contreras to Encino; and Cedarvale to Ancho, N. Mex	120	1,440
Lee to York, Fla	110	990
Shady to Lily, Fla	120	1,080
Clarcona to Titusville; and Orlando to Okeechobee, Fla	130	1,300
Carrabelle, Fla., to Colquitt, Ga	100	1,000
Early, Fla., to Opelika, Ala	190	1,900
Winslow to Winkelman, Ariz	140	1,680
Blue Earth, Minn., to Lakota, Iowa	15	150
Papago Indian Reservation, Ariz	565	5,665
Hualapai Indian Reservation, Ariz	115	1,725
Mescalero Indian Reservation, N. Mex	100	1,500
Pleasant Gap to Cusseta, Ala	105	1,050
Niceville, Fla., to Calhoun, Ala	115	1,150
Total	3,610	39,385

Geodetic triangulations, base lines, reconnaissance, and leveling, and astronomical and gravity observations—Continued

Locality	First order	Second order	Locality	First order	Second order
LEVELING	*Miles*	*Miles*	LEVELING—continued	*Miles*	*Miles*
California	148	697	North Carolina	569	231
Colorado	9	555	Oklahoma		41
Georgia	80	5	Oregon	48	180
Idaho	50	809	Pennsylvania	29	255
Kansas		390	Tennessee	238	691
Maine	99	824	Texas	227	38
Maryland		46	Utah	2	87
Minnesota	147	840	Vermont	3	85
Montana	147	688	Virginia	12	1,064
Nevada		308	Washington	59	70
New Hampshire	1	9	West Virginia	16	79
New Mexico	26	154			
New York	27	41	Total	1,937	8,187

Locality	Number of determinations				Locality	Number of determinations			
	Astronomical			Gravity		Astronomical			Gravity
	Latitude	Longitude	Azimuth			Latitude	Longitude	Azimuth	
ASTRONOMICAL AND GRAVITY DETERMINATIONS					ASTRONOMICAL AND GRAVITY DETERMINATIONS—con.				
Arizona	3	3	3		Montana	6	6	6	
Arkansas	1	1	1		Nebraska	4	5	5	
California	3	3	3		Nevada	3	3	3	
Colorado	2	2	2		New Mexico	3	4	4	
Connecticut				21	New York				6
Florida				20	North Dakota		8	8	
Georgia	1	1	1		Oklahoma	2	2	2	
Idaho	1	1	1		Pennsylvania	2	2	2	31
Illinois		1	1		Rhode Island				6
Iowa	1	1	1		South Carolina	1	1	2	
Kansas	5	5	5		South Dakota		3	3	
Kentucky	1	1	1		Texas	14	17	17	
Louisiana	1	1	1		Washington	3	4	3	
Massachusetts				6	Wyoming	1	1	1	
Minnesota		2	2						
Missouri	2	2	2		Total	60	80	80	90

Activity	Stations	Miles	Activity	Stations	Miles
SUMMARY			SUMMARY—continued		
Triangulation:			Leveling:		
First-order		1,440	First-order		1,937
Second-order		1,280	Second-order		8,187
Traverse, second-order		3.8	Astronomical determinations:		
Base lines, first-order		33.3	Latitude	60	
Reconnaissance:			Longitude	80	
First-order triangulation		3,275	Azimuth	80	
Second-order triangulation		3,610	Gravity determinations	90	
			Total	310	19,766.1

The office computations and adjustments of 17 arcs of first-order and 18 arcs of second-order triangulation were completed during the year, with the computations of 12 arcs of first-order and 9 arcs of second-order triangulation in progress. Office computations were also made of 12 first-order and 4 second-order bases. A field party

in New York City was engaged on triangulation, level and plane coordinate computations during the first 6 months of the year.

About 50 separate lines of levels were adjusted to the level net and lists of descriptions and elevations of bench marks for 41 lines of levels were distributed to engineers and surveyors on special mailing lists.

Personnel detailed to the Washington office by the Chief of Engineers United States Army, adjusted the triangulation along the Mississippi River from New Orleans to the Delta. The manuscript for the publication containing the results of this adjustment was also prepared.

Four geodetic manuals were received from the printer during the year, two on plane coordinates, one of special gravity tables, and one giving factors for the new international spheroid. A large publication covering triangulation in California, and a small gravity publication were also printed, while one on the triangulation of Minnesota was nearly completed.

TIDES AND CURRENTS

Besides directing the related field operations, tide and current activities include the tabulation and reduction of tide and current records, the determination of tidal datum planes, and the preparation of the annual tide and current tables, tidal current charts, tidal bench mark descriptions, and other publications.

Long series of tide observations are essential for the derivation of data for hydrographic control, for the reduction of the results of short series of observations to mean values, for the accurate determination of datum planes, and for the determination of secular changes in relation of land to sea. During the year 38 primary tide stations for such observations were in operation, of which 22 were on the Atlantic coast, 4 on the Gulf coast, 9 on the Pacific coast, 2 in Alaska, and 1 in the Hawaiian Islands. Sixteen of these stations were conducted in cooperation with other organizations: United States Engineers, six stations; Navy Department, six stations; and one station each with the Woods Hole Oceanographic Institute, the Los Angeles Harbor Department, the city of Santa Monica, and the territorial survey of Hawaii.

Data obtained at the primary stations were supplemented by observations at 546 secondary tide stations. These include stations operated on a cooperative basis with the United States Engineers; University of Washington; Biological Research Bureau, Bermuda; Washington Suburban Sanitary District, Maryland; Portland Canal Power Co., Alaska; Port of Willipa Bay, Wash.; State of Delaware; and the Port of Oakland, Calif.

Comprehensive tide surveys of coastal sections supply detailed data for the accurate determination of local datum planes and their relation to mean sea level. The constantly increasing value of water front property makes such information of prime importance in the determination of boundaries. Special current surveys of important waterways are also required for an understanding of the complex circulation of the tidal water, essential to both navigation and harbor engineering. The tide survey of the coast of Washington, started in May 1934, was completed in October 1935.

Special current observations were obtained on *Stone Horse Shoal*, *Cross Rip*, *Handkerchief*, and *Pollock Rip* Lightships. The series of current observations started last year in San Pedro Channel, Calif., through a cooperative arrangement with the Lighthouse Service, was completed October 30, 1935. Observations were taken hourly throughout the period of the survey from a relief lightship anchored for that purpose in approximately 60 fathoms of water. In addition to the current observations, wave movements, temperature, and salinity of the water and the velocity and direction of the wind were observed.

Aside from their utilization in the construction of charts, the tide and current data obtained by the Bureau are made available to the public in tide and current tables and miscellaneous publications.

The tide tables, an indispensable aid to navigation of modern deep-draft vessels, are issued annually in two volumes. The Tide Tables, Atlantic Ocean, 1937, contain daily predictions of the times and heights of the tide for 49 ports together with data for obtaining predictions at some 2,350 other places. Much new and revised data for our South Atlantic and Gulf States were incorporated from information derived from extensive hydrographic surveys made in those areas during the past several years. The Tide Tables, Pacific Ocean and Indian Ocean, 1937, contain daily predictions for 47 ports and differences and constants for obtaining predictions at about 1,800 other places. New and revised data for the State of Washington were incorporated in the tables from information derived from the recent tide survey of that State.

Two current tables are also issued annually, that the mariner may have advance information relative to the velocity and direction of the current likely to be encountered at any time in our coastal waters. The Current Tables, Atlantic Coast, 1937, contain daily predictions of the times of slack water and the times and velocities of strength of flood and ebb for 18 reference stations, together with data for obtaining predictions for about 900 other places. All data for Nantucket and Vineyard Sounds were revised in accordance with the results from a recent current survey. The usefulness of these tables was further extended by the inclusion of daily predictions for Mobile Bay entrance, Alabama, and Galveston Bay entrance, Texas, together with data for a number of places in the Gulf of Mexico and in Puerto Rico. The Current Tables, Pacific Coast, 1937, contain daily predictions for 11 reference stations with differences for obtaining predictions for some 500 other places.

Tidal bench mark publications for the use of engineers were issued for the States of California, Rhode Island, and Massachusetts, and those for South Carolina, Georgia, New York, and Florida are in progress.

A manual of tide observations was published for the purpose of giving the general requirements of the Bureau in carrying on its tidal work and to serve as a guide for those engaged in taking tide observations.

The manuscript of a special publication giving in detail the results of current surveys in Narragansett and Buzzards Bays, and Nantucket and Vineyard Sounds was completed.

The basic data compiled in the preparation of the publications have been utilized to supply information to the public for various other purposes. Tide and current data have been furnished to private corporations, universities, municipal governments, and Federal departments for use in diverse engineering and scientific activities. Considerable data were also prepared and certified for use in admiralty cases and special tide predictions supplied to newspapers and almanacs throughout the country. An increasing demand has been noted for tide and current forecasts for use in sports.

TERRESTRIAL MAGNETISM

Most of the Bureau's work in terrestrial magnetism is for the purpose of determining the changes in magnetism with time, so that the values of the magnetic declination at about 6,000 stations can be kept up to date. This is accomplished by means of field surveys and the operation of five magnetic observatories.

Principal uses of the information obtained are made by the navigator and aviator, the geological prospector using magnetic methods, and the investigator of radiotransmission problems and difficulties.

The field survey consists principally of observations at repeat stations at 5-year intervals. Observations at other places are generally confined to magnetic declination and include observations at airports to provide data for testing magnetic airplane compasses; outlining of areas of local magnetic disturbance; and more detailed values at various places along the coast, especially near channels where vessels correct their compasses.

The field work during the year was sufficient to make it possible to prepare the manuscript for the usual five-yearly publications (Declination in the United States) and the isogonic chart for 1935. Observations were made at an airport in New York, at an area of local disturbance on the Delaware River near Wilmington, Del., and in Alaska, to provide better data for the charts by the hydrographic parties engaged in general surveys.

The distribution of the magnetic observations made during the year is shown in the following table:

State	Observations				Total	State	Observations				Total
	Repeat stations		Other stations				Repeat stations		Other stations		
	Triangulation	Other	Complete	Declination			Triangulation	Other	Complete	Declination	
Alabama	1				1	Minnesota	2	1		3	6
Alaska				12	12	Missouri	2	1	1	2	6
Arkansas	1		1	1	3	New Jersey				7	7
California				2	2	New York				1	1
Connecticut				1	1	Ohio		1	2	3	6
Delaware				9	9	Oregon				3	3
Illinois	1	2	1	2	6	Pennsylvania			1	1	2
Indiana		2	3	3	8	Washington				26	26
Iowa	1			3	4	Wisconsin		4		1	5
Louisiana	2	1	1		4						
Maryland			1	1	2	Total	10	14	13	81	118
Michigan		2	2		4						

The magnetic observatories have continued to make magnetic observations which began in the year following the name of the observatory, as follows: Cheltenham, Md. (1901); San Juan, P. R. (1926); Tucson, Ariz. (1909); Honolulu, Hawaii (1902); and Sitka, Alaska (1902).

At the Cheltenham observatory particular attention has been given to comparison of instruments of various kinds with a view to elimination of errors and improvement of records so that there will be less work necessary in field and office in obtaining records and preparing them for publication.

The steady demand for magnetic information has been met through letters or through publications. Land surveyors have received assistance in connection with the retracing of lines of old compass surveys. During the year a number of publications of magnetic information by States, chiefly prepared during the previous year, were issued so that the information is available in this form for 18 States.

The observatory records are in demand for several purposes besides their basic one of furnishing information regarding changes in the magnetism for correction of field results and similar purposes. In the search for oil and minerals investigators of geological formations by magnetic methods use observatory data, especially information regarding magnetic storms which vitiate their results. Announcement of this is furnished by telegram so that the necessary precautions can be taken or the work stopped until the storm has ceased. Investigators of radio transmission find it necessary to receive weekly copies of the records of one or more observatories. At the request of the International Meteorological Organization, magnetic character of days was prepared for several observatories for the year 1906 and earlier.

SEISMOLOGY

The seismological work of the Bureau includes the collection and publication of earthquake information derived from cooperative sources; the operation of seismographs, and the interpretation of their records; the immediate determination of earthquake epicenters; the operation of strong-motion instruments and the analysis of their records; the determination of natural periods of buildings and other structures, and of the ground and the measurement of tilt. Related activity described elsewhere is geodetic work in regions subject to earthquakes.

The basis for dealing with earthquakes of the future is the knowledge of what has occurred in the past. The history of an earthquake is obtained from reports of visible and felt effects and from instrumental observation, the former of which come from widespread cooperation on the part of organizations and individuals. Instrumental data are derived from a number of seismological observatories, of which the Bureau operates four directly—San Juan, P. R.; Tucson, Ariz.; Honolulu, T. H.; and Ukiah, Calif., at the International Latitude Observatory; and five cooperatively—Columbia, S. C.; Chicago, Ill.; Bozeman and Butte, Mont.; and College near Fairbanks, Alaska. A number of independent stations also make their records available. Many of these records are furnished to various organizations for special studies.

Immediate determination of earthquake epicenters is made with the cooperation of Science Service and the Jesuit Seismological Association from advance information from some of these records and from other sources. Information in regard to earthquakes from the various sources mentioned is published in the form of mimeographed reports of instrumental results and preliminary reports of earthquake activity for various parts of the country, and in printed form in the annual United States Earthquakes publications.

The study of strong earth motions and related activity heretofore carried on chiefly in California was extended to Montana where valuable records were obtained at Helena. The work as a whole including recording and analysis of strong earth motions by means of accelerographs, displacement meters, and Weed instruments. In addition, the natural periods of buildings, other structures, and of the ground must be obtained because much earthquake damage is now ascribed to resonance or the presence of the same periods in the earth waves as in structures.

Fifty instruments were operated in California; one in Montana; one in Panama, Canal Zone; and one each were held in reserve for emergency use in Washington, D. C.; and Chicago, Ill.

Ten strong-motion records were obtained in California, 35 in Montana, and 1 in Panama. Of these, one was completely analyzed by extended mathematical treatment. Good progress was made in developing a graphical method of analysis.

One hundred and seventeen vibration observations were made in 88 buildings and 5 tests were made to determine ground periods. Fifty observations were made on bridges, exclusive of 20 special observations; 2 were made on elevated water tanks; 9 special observations were made in buildings; 1 observation was made on a dam; and 1 test on a dam, and 23 ground tests were made with a specially designed shaking machine. Much attention was given to the preparation of the data obtained chiefly during the previous year with augmented funds. The publication was nearly ready for issue at the close of the year.

Four tiltmeters continued operation with the cooperation of the University of California.

Improvements were made in the design of strong-motion accelerographs, four of which have been under construction for use in Montana. A publication was prepared on The Selection, Operation, and Installation of Seismographs.

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