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COAST AND GEODETIC SURVEY

REVIEW OF THE YEAR

The volume of work accomplished during the fiscal year 1935 far exceeded that of any other year in the Bureau's history.

This achievement resulted from the fact that the regular appropriation for the year was supplemented by grants of Public Works Administration funds. Whereas the last normal appropriation, that for 1932, was some $3,075,000, for 1935 there was available for expenditure a regular appropriation of $2,206,968 plus Public Works Administration allotments of $5,104,009, making a total of $7,310,977.

In carrying on the work financed by this unprecedented total the quality of results was held strictly to the exacting standard which normally characterizes the Bureau's operations. The volume of work accomplished was fully commensurate to the amount of money spent. This fact is strikingly confirmed by the following table showing, for the years 1929 to 1935, inclusive, the amount of work done on the principal technical operations to which the Bureau's funds are devoted.

Principal results accomplished, 1929–35

Year groups	Hydrography		Topography	Triangulation			Reconnaissance	Leveling		Gravity observations
	Soundings	Sounding lines		First order	Second order	Coastal		First order	Second order	
	Number	*Miles*	*Miles of shoreline*	*Miles*	*Miles*	*Miles*	*Miles*	*Miles*	*Miles*	*Number*
1929	846,517	74,481	1,726	1,200	85	878	2,155	1,290	--------	13
1930	780,049	71,433	2,273	1,430	--------	863	885	727	--------	7
1931	782,044	75,696	2,472	2,895	--------	812	2,720	5,737	156	--------
1932	767,322	72,186	1,959	3,400	--------	803	5,950	5,945	1,555	35
Total	3,175,932	293,796	8,430	8,925	85	3,356	11,710	13,699	1,711	55
1933	1,387,027	103,344	4,407	3,625	--------	2,476	4,350	11,324	2,940	148
1934	2,520,406	110,045	14,877	7,440	1,080	1,969	8,810	16,153	28,670	118
1935	3,523,749	138,382	20,330	14,113	3,335	2,574	23,715	10,713	113,980	170
Total	7,431,182	351,771	39,614	25,178	4,415	7,019	36,875	38,190	145,590	436

This table compares the results accomplished during the 3 years 1933–35, during which emergency relief funds were available, with the preceding 4 years when the work was financed exclusively by the regular appropriations. Comparing 1932 and 1935, it will be seen that, whereas funds for the latter year were about 240 percent of those for the former, the work accomplished in 1935 was in a much greater ratio to that of 1932. No attempt is made to fix the exact ratio because there is no common yardstick for measuring accom-

National Oceanic and Atmospheric Administration

Annual Report of the Superintendent of the Coast Survey

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plishment in such diverse fields as hydrography and triangulation or leveling. In a general way, however, it is obvious from the table that the amount of work accomplished in 1935 was several times as much as that of 1932.

In this conduct of work under a combination of regular appropriations and emergency allotments, the regular appropriations, by far the greater part of which were for the pay of the permanent Survey personnel, furnished the foundation upon which the part financed by emergency allotments rested as a superstructure. All projects undertaken consisted of work which previously had been authorized by the Congress and was in course of performance under regular appropriations. Accomplishments of the past 3 years mean that for a considerable period hereafter the Bureau's appropriations can be less than would otherwise be required. It is estimated that as a result of this work future appropriations for a considerable period can be some $300,000 less than was provided in 1932 without detriment to the public service with which the Bureau is charged.

Now that the work has been terminated, it is desirable to appraise the extent to which it fulfilled the expectation on which it was undertaken.

RELIEF OF UNEMPLOYMENT AND ECONOMIC DISTRESS

This was the primary purpose of the emergency allotments under which the Bureau has been working. These projects have demonstrated that surveying and mapping lend themselves admirably thereto.

In seeking the initial allotment the Bureau predicted that approximately 70 percent of the total amount spent in carrying on field surveying projects would be devoted to direct employment of labor. At the close of the project we find that the actual figure was 69.4 percent.

The number of persons employed varied somewhat from time to time, a special effort having been made to employ the maximum number during the winter months. The average for the entire period was about 2,350 persons. The great majority of them were of the white-collar class. Sixty percent were men of college training. The jobs given them were not white-collar jobs. Graduate engineers and others of comparable status were glad to get jobs as recorders, rodmen, truck drivers, and other subprofessional employments incident to surveying work. Their morale was exceptionally high. They were encouraged to feel that they were employed on useful and necessary work where they were giving the public 100 cents of value for every dollar spent. Their response was all that could have been desired, as is amply indicated by what has already been told regarding the volume of work accomplished.

Another contribution to the relief of economic distress derived from work of this character results from its wide geographic distribution. Work was performed in every State in the Union and almost entirely in the rural districts. Expenditures for subsistence of the parties, which the men pay from their own salaries, and the 15 to 18 percent of the total allotment which was devoted

to operating expenses, were spent in many small communities where they provided a material stimulus to retail trade.

The remaining 12 to 15 percent of the cost of field work was devoted to purchase or rental of equipment, to travel, and other administrative expenses.

PUBLIC VALUE OF THE PROJECT

The money spent was devoted to the following purposes:

1. Surveys to modernize nautical charts.
2. Extension of control surveys in the interior.
3. Tidal, magnetic, and seismological surveys.
4. Office processing of data resulting from the foregoing field operations.
5. Maps for the guidance of aircraft.

1. Fringing the Atlantic coast from New York to the Mexican border is a system of natural waterways; bays, sounds, and lagoons, linked together almost continuously by narrow, tortuous tidal channels. These waters support an extensive motor-boat traffic carrying local products to centers of distribution, other traffic incidental to the sea-food industry, for which the waters are famous, and for pleasure purposes. The growing importance of these waters has resulted in their extensive improvement under river and harbor appropriations, and when the projects now approaching completion are finished vessels having a draft of not exceeding 7 feet can proceed all the way from Delaware Bay to Miami, while from Choctawatchee Bay to Corpus Christi on the Gulf coast a controlling depth of 6 feet will be available with 9 feet available over the greater part of the route.

The existing charts of this system of waterways have been based principally on surveys made from 60 to 80 years ago and, necessarily, are obsolete in many respects. Mariners can derive full benefit from the millions of dollars which are being spent in the improvement of the waterways only if those improvements are shown on the charts. For the past several years, therefore, the Bureau has been urging that funds be provided for this purpose. The granting of Public Works Administration funds provided the needed opportunity. Through their use, while the entire area has not been surveyed, by concentrating on the through route and its most important tributaries, sufficient field surveys have been made so that charts of the entire route can be produced. Numerous other needed harbor revision or other local surveys were made, notably along both coasts of Long Island and the north shore of Long Island Sound. On the Pacific coast surveys were made around the islands off the coast of southern California. The newly improved channel for ocean-going vessels in the Sacramento and San Joaquin Rivers was surveyed and charted. Important and difficult wire-drag work along the outer coast was carried on to assure greater safety to coastwise shipping which, in stormy weather, follows the coast as closely as possible.

Use of emergency funds for employment of men on our sea-going surveying vessels made it possible to keep the entire fleet in operation throughout the year, except one vessel in the Philippine Islands. Along the Atlantic and Pacific coasts of the United States these vessels were employed on revision surveys of the continental shelves

necessitated by the recent developments in methods of navigation based on echo sounding. In Alaska two vessels continued work on the first survey of the Aleutian Islands.

2. For more than half a century the Bureau has been engaged in a small way in spreading its networks of control surveys (triangulation and leveling) over the continental United States. These surveys are of value to every kind of engineering work which requires accurate knowledge of distances, directions, and elevations on the earth's surface. Their principal Federal purpose, however, is to assure the accuracy and reduce the cost of producing the topographic map of the United States. In 1925 Congress passed the Temple Act which authorized completion of the control surveys and the topographic map within 20 years. Unfortunately, however, enactment of this legislation has had little practical effect on the situation, because the increased appropriations required to give effect to it never were made. Under Public Works Administration funds work on the control surveys was largely expanded. Today that part of the goal contemplated by the Temple Act, namely, that in general no point in the United States would be more than about 12 miles from a permanently marked point whose geographic position and elevation are known, is within sight of accomplishment. The necessary leveling is substantially completed, and about 2 years more of triangulation at the 1935 rate will complete the basic horizontal control.

3. Small sums were devoted to tidal, magnetic, and seismological work. The tidal work consisted of tide and current surveys of waters where the data obtained were needed in the interest of navigation or of marine engineering work.

One magnetic field party was kept continuously in operation measuring the direction and strength of the earth's magnetic field, thereby acquiring information needed by the mariner and the land surveyor in their use of the magnetic compass. Some urgently needed renovations of magnetic observatory buildings were made.

A small allotment supported an extensive but very important project in earthquake investigations. This was designed to promote the safety of life and property by determining the stresses to which large buildings, dams, bridges, and other monumental structures will be subjected when close to the center of a severe earthquake. The work involved measurement of the stresses transmitted through the ground and the response of different types of structures to the stresses which reached them. The results of the completed study are expected to furnish data which will enable engineers and architects to design at reasonable cost structures which will resist any stresses which may be expected in a major earthquake. Instruments have been designed and installed at strategic points where they stand ready for the occurrence of a severe shock, when they will record the ground motions which it produces. Other instruments are being used to measure the characteristic vibrations of structures. For this purpose it is not necessary to await an earthquake. Vibrations produced by the wind, by passing traffic, by the firing of explosives, and by other artificial means serve the necessary purpose. The project must be continued for some years before results of assured value can be expected, but since future costs will be limited

largely to the servicing of instruments heretofore installed it is expected that with some non-Federal cooperation the work can be continued without necessitating appropriations in excess of the more generous ones heretofore made.

4. The field operations heretofore briefly described produce certain raw materials. These raw materials must be delivered to the Washington office and there pass through a finishing process before the public can get any benefit from them. If they cannot be transformed into the charts, maps, and other publications which are the final product of the Bureau's work, there is no possible justification for doing the field work to which the greater part of their total cost is devoted.

This office work necessarily must follow the field work; in fact, in general little progress can be made on the office work until the field work has been completed.

The projects as originally set up made provision for this processing. It was so planned that the field work should begin to taper off early in the spring of 1935 so that the office work would be completed by the end of the fiscal year, when the money would be exhausted. However, on request, these original plans were modified, both to increase the volume of field work with the employment incident thereto and to continue the work at the augmented rate until the end of the fiscal year. In consequence, when the work was terminated for lack of funds there was on hand a very large volume of raw material to be processed.

Application has been made for additional funds to take care of this work, but to date approval thereon has not been secured. If such approval is not given, much of the money spent for field surveys will have been wasted, because the office force supported by the regular appropriations cannot possibly deal with the accumulation within a reasonable time, and results of work costing hundreds of thousands of dollars will have become obsolete before it can be given to the public.

5. The airplane pilot, like the mariner at sea, needs charts to guide him on his journey. The Air Commerce Act of 1926 vested in the Secretary of Commerce the duty of providing such charts, and the task was delegated to the Coast and Geodetic Survey.

The first work undertaken was to produce a series of strip maps extending from one important airport to another. Development of aviation, however, resulted in a very great increase in the amount of miscellaneous cross-country flying, and eventually it became apparent that the principal need was for charts covering the entire United States. Production of these maps was begun in November, 1929.

In the spring of 1934 the Department proposed a Public Works project for completing the series by June 30, 1935. The project was approved in October 1934.

If the standard topographic map of the United States had been available, it would have been a simple task. However, it was necessary to compile maps from a great mass of heterogeneous and conflicting information, and the resulting product was of such uncertain value that the Bureau did not dare ask the aviator to risk his

life by accepting it. Therefore, as each section of the map was compiled in the office it was turned over to an observer in an airplane and the observer compared the visible features on the ground with those shown on the map. In this way many inaccuracies were corrected. It should be emphasized, however, that not until the standard topographic map has been completed can this special product attain to the quality which the Bureau considers essential.

At the end of the fiscal year all charts of the series had been compiled, and all but 2 within the limits of continental United States and 8 along the Canadian border had been flight checked. Forty-one out of a total of 87 had been published. It is expected that the remainder will be published early in the fiscal year 1936.

IMPROVEMENTS IN EQUIPMENT

The efforts of the Bureau to increase the economy and efficiency of its operations through the development of improved methods and equipment were continued during the year with good results.

The shallow-water fathometer, now called the "Dorsey Fathometer", under development by the Bureau, as mentioned in last year's report, was installed on two survey ships, where the difficulties inherent in the development of a device of this nature were corrected as they arose during actual field use. This apparatus is now working quite satisfactorily in depths from 9 to 120 feet under the keel. Echo-sounding instruments previously in use have been remarkably effective in reducing the costs of hydrographic operations but, on account of limitations of accuracy, have been restricted to depths greater than about 90 feet. The value of this new apparatus, which will at least double the output of work formerly possible in the extensive areas where lesser depths occur, is obvious.

Experimental work on the velocity and path of sound in sea water in radio acoustic ranging, developed by this Bureau for offshore hydrographic surveying, was continued on the ships *Pioneer* and *Guide* off the coast of southern California, and by the *Oceanographer* and *Lydonia* off the Atlantic coast.

Echo-sounding and radio-acoustic equipment and methods are of inestimable benefit to the Bureau and to the users of its nautical charts, making it practicable for the first time to carry on hydrographic surveys, especially in offshore areas, with the accuracy and detail now required for modern navigation.

The report of this Bureau for last year included a brief description of a proposed 9-lens camera developed by the Bureau for increasing the accuracy and efficiency of aerial phototopography. This camera is now under construction and should be available in the near future.

A ruling machine was designed and is now in use that insures accuracy in the construction of the basic framework or projection of survey sheets and charts, tying together the geographic positions, soundings, and related charting data with greater speed than was formerly possible. Projections are prepared on celluloid for field airphoto reductions, on aluminum-backed drawing paper for cartographic compilations, and on copper plates for chart engravings.

Improvements to accelerographs for the study of strong earthquake motion, producing records more accurate and easier to interpret, have made it possible to record earthquakes of all degrees of intensity. A vibration meter was developed by which the periods of buildings and various other structures such as bridges, dams, and elevated tanks, were measured, and portable shaking tables for testing these instruments were developed.

In terrestrial magnetism the aim has been to secure instruments by which the desired observations may be made available in published form at least cost. This is being accomplished by the development of new instruments and by exhaustive studies of existing ones.

A new offset press, a vacuum printing frame for use in the transfer of negative work to the printing plate, and more photostat equipment were added during the year.

A number of improvements in instrumental equipment were developed in the shops of the Division of Instruments, by members of the Division and other officers of the Bureau. The Division also accomplished a great amount of extra work in the procurement and maintenance of instruments and equipment as required for the emergency work of the Bureau.

Notable among the improvements in equipment are:

1. The adaptation of commercially manufactured tapered roller bearings in the vertical axes of the most precise type of theodolites. With a small amount of added finishing to insure the maximum precision, they furnish a low-friction bearing, and initial tests disclose as great a precision as any heretofore used, with the added advantage of being reasonably free from the effects of temperature and of changes of viscosity of the lubricant.
2. A permanent and precise method of testing the graduated circles for precision theodolites and similar instruments, by the use of a testing stand and a set of 5 collimators erected in the Commerce Building basement.
3. A change in the design of the standard tide gage, permitting easy and quick adjustment of the float, counterpoise, and recording pencil, without the use of tools.
4. The construction of two new units of the Brown portable gravity apparatus, containing a new design of the precision knife-edge support of the pendulum to guard against change in the length and, consequently, of the constant when lifting and resetting the pendulum from its support at each observation.

COOPERATION WITH OTHER AGENCIES

Extensive cooperation, producing mutually beneficial results, was maintained with a large number of governmental and private agencies in this country and abroad.

There was the usual cooperation with the United States Geological Survey in the extension of triangulation and leveling to meet its needs for control in areas where topography is being executed.

For the Corps of Engineers, United States Army, triangulation was extended along the Atchafalaya River in connection with its

flood-control work, and at numerous times data with respect to the extensive coordinating coastal triangulation were furnished various Army Engineer districts. The Bureau also expedited the computation and adjustment of the detailed triangulation and traverse along the Mississippi River, which is being published by the Corps of Engineers, being assisted by additional computers provided by that Corps.

At the request of the United States Forest Service, second-order triangulation was extended over the Superior National Forest in Minnesota, and lines of second-order leveling were run in certain areas in New Mexico and Arizona. Control data were also furnished the Forest Service for the control of its topographic surveys of the forest reservation north of Charleston, S. C., and request was received for the latitudes and longitudes of a number of lookout towers in the West.

Vessels operating off the Virginia capes obtained observations to check distance finding from the synchronized radiobeacon and diaphone signal on Chesapeake Lightship. Hydrographic surveys were also made of Frying Pan Shoal and of the entrance and approaches to Hatteras Inlet for the Lighthouse Service to determine the present channels and their stability for placing aids to navigation.

Hydrographic surveys were made for the Bureau of Fisheries and advance copies of the data of various bays and sounds along the Gulf coast were furnished in connection with the study of fish culture.

For the purpose of conducting trial tests of vessels under mail contracts in connection with the classes to which various vessels must be allocated as to speed, this Bureau cooperated with the Post Office Department by measuring and laying down a speed trial course 1 nautical mile in length off Southwest Pass of the Mississippi River. Range beacons marking the ends of the course were erected on the Delta in the vicinity of Burrwood, La., by the party on the *Hydrographer*, and an officer was assigned from time to time to assist in conducting the tests.

Tide-prediction data were exchanged with England, Germany, France, Canada, and India. Primary tide gages were maintained on a cooperative basis by the United States Army Engineers at 4 stations, by the United States Navy at 6 stations, and the Woods Hole Oceanographic Institution and the Oceanographic Laboratory of the University of Washington, 1 station each.

One of the cooperative projects, requested by the Soil Erosion Service and the Bureau of Reclamation, consisted of leveling and triangulation of an accuracy better than first-order over the area adjacent to Boulder Dam and the reservoir, for the purpose of determining through repeat observations from time to time any deformation in the dam's structure and the earth's crust due to the water load which will result from filling the reservoir.

At the request of the Tennessee Valley Authority the 25-mile spacing of the triangulation and leveling over the area under its jurisdiction was expedited, and office computations and adjustments completed promptly. Extensive data, resulting from field surveys were also furnished to a considerable number of other governmental agencies engaged in recovery measures.

Additional lines of levels were run across fault zones in southern California, with bench marks more closely spaced than heretofore, at the request of the committee on seismology, Carnegie Institution of Washington. Cooperation with the Institution includes the development and testing of instruments, the maintenance of magnetic standards, the interloan of instruments, and combined activity producing results which otherwise could not have been accomplished. At the Bureau's magnetic observatory at Tucson, atmospheric electricity observations are thus carried on, and also earth current work, the latter through cooperation with the Mountain States Telegraph & Telephone Co. At Cheltenham, a cosmic ray meter was operated at the request of Carnegie Institution of Washington.

Interpretation of the scientific significance of its records, relating to terrestrial magnetism, while part of the Bureau's duties cannot be carried very far with the limited personnel available. This gap is in part filled by studies of records by the National Bureau of Standards, Naval Research Laboratory, National Broadcasting Co., division of terrestrial magnetism of the Carnegie Institution of Washington, and others in connection with radio studies, and by the Carnegie Institution of Washington in fundamental studies in magnetism. Part of the latter work is done by research associates of the Institution in England and Germany.

In seismology cooperative activities are country-wide and are very effective. Collaborators include the United States Weather Bureau, National Bureau of Standards, postmasters in earthquake regions, various Jesuit institutions, and many universities, other organizations, and individuals. Valuable assistance in conducting certain tests of buildings and other structures was rendered by the Navy Department and the Procurement Division of the Treasury.

Without interfering with its regular surveys, the Bureau cooperated with the Geological Society of America in an interesting project to determine the depth of the basement rock beneath the Atlantic continental shelf. The submerged plain east of the Virginia Capes where survey vessels were operating was selected for these experiments. The work was undertaken by a member of the faculty of Lehigh University under a grant of funds from the society, aided by an officer of this Bureau familiar with the seismic and marine problems involved. The reflection method regularly used in seismic prospecting for oil was adopted, with both the explosives and the seismographs on the sea bottom. During the 2 weeks the work was in progress a successful technique was developed indicating that data could be obtained at sea of the required accuracy on any continuing future program by the society.

MISCELLANEOUS DATA

There were received in the library and archives, 404 hydrographic and 793 topographic sheets, each representing new Bureau surveys. Other additions were 1,109 blueprints (mostly surveys by Army Engineers); 4,518 maps; 3,564 charts; 30,523 field, office, and observatory records; 138 negatives; 261 prints; 128 lantern slides; 1,314 books; and 4,150 periodicals.

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A total of 3,582 employees was serving the Bureau on June 30, 1935, shown in the table following, compared with 2,691 in 1934 and 2,024 in 1935:

Staffs	Commissioned	Civilian				Staff total		Total
		Classified	Unclassified					
			Laborers	Seamen	Hands	Washington	Field	
Regular appropriations:								
Washington office	14	230	3			247		247
Field service	156	62		[1] 521	[1] 88		827	827
Total	170	292	3	521	88	247	827	1,074
Public Works funds:								
Washington office		517				517		517
Field service		189			1,802		1,991	1,991
Total		706			1,802	517	1,991	2,508
Grand total	170	998	3	521	1,890	764	2,818	3,582

[1] Includes 40 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 regular appropriations for the year totaled $2,126,061. These were supplemented by allotments of $11,536 from "Air Navigation Facilities, 1935", $300,000 from "Public Works Administration, 1935", and $1,489,800 from "National Industrial Recovery, 1933–35." In addition to these sums, there was available an unexpended balance on account of "Air Navigation Facilities" allotted during the fiscal year 1934.

Collections on account of the sale of nautical charts and other publications, deposited in the Treasury Department to the account of miscellaneous receipts, totaled $76,575.14, as compared with $72,621.50 during the preceding year, an increase of nearly 5½ percent.

Disbursements during the year ended June 30, 1935, totaled $7,017,082.64, distributed among the various appropriations as follows:

Pay and allowances, commissioned officers, 1934	$68,886.70
Party expenses, 1934	97,250.00
Repairs of vessels, 1934	10,653.77
General expenses	35,684.04
Pay, officers and men, vessels, 1934	100,929.78
Air navigation facilities, 1934	638.75
Pay and allowances, commissioned officers, 1935	626,033.91
Salaries, 1935	505,816.54
Party expenses, 1935	293,635.87
Repairs of vessels, 1935	49,871.63
General expenses, 1935	42,145.54
Pay, officers and men, vessels, 1935	353,968.64
Air navigation facilities, 1935	11,080.03
National Industrial Recovery, 1933–35	4,594,304.37
Public Works Administration, 1935	224,089.12
Chicago World's Fair Centennial Celebration	682.17
Second polar year program (State transfer to Commerce Department) 1932–34	1,388.42
California Pacific International Exposition	23.36
Total	7,017,082.64

CHARTS

With modern surveys supplying the new and more detailed information required for ships of today, as well as a more comprehensive knowledge of the changes which are constantly taking place along our coasts, there was a steady advance in new and revised editions of nautical charts. Sixteen new charts were published during the year, making a total of 766 nautical charts of different areas and various scales now issued. A total of 155 revised editions was also published during this 12-month period.

The gradual increase in the demand for this one product alone is illustrated by the following tabulation of annual chart issues for certain years. It may be noted that the issue for 1935 is only 1,934 less than the maximum annual issue resulting from the World War, which at that time was thought to constitute an all-time peak:

Average pre-war annual issue	109,290
Maximum issue resulting from World War (1920)	311,699
Minimum post-war issue (1923)	197,426
Minimum issue during depression (1933)	241,894
Issued during 1935	309,765

The Survey has endeavored constantly to simplify these charts and at the same time make changes and additions improving their usefulness to the maritime public. New features incorporated during the year include:

Track lines for full-powered steamers, printed in red on general charts of the Pacific coast.

Isogonic lines in purple, on certain sailing charts.

More distinctive marsh areas on large-scale charts.

A blue tint for water areas shoaler than 18 feet.

A new arrangement showing temporary changes to navigational aids.

Scale divisions changed to the decimal system, replacing the old fractional division.

As the surveys of our coasts required for charting purposes have been carried on almost continuously since 1816, they have many by-product uses of importance. These include references to office records and previous surveys for official information at different periods with respect to the location of shorelines, low-water lines, details of depths, and the like.

Every safety aid, whether it be for transportation over the air or sea, expedites progress and the increase of over 128 percent within 2 years in the number of the Department's aeronautical charts used, indicates their value to air transportation.

Great strides were made during the year toward the completion of this series of specialized charts—virtually one large map of the United States, issued in 87 sections. With the augumented staff available, the initial flight checking of all of the charts was completed and during the year 16 new charts and 52 revised editions of existing charts (section and strip) were produced by the Survey, making 41 of the 87 required now available.

The constantly accumulating data with respect to changes in beacons, radio ranges, or airports, of importance to air navigation, changes wrought by man and nature that should be known to the mariner, are of practical value only when they appear on the chart. The reliability of any chart becomes impaired, therefore, unless revised editions are issued when needed.

Nautical and aeronautical charts again greatly exceeded the number used in the preceding year as shown in the following table of charts and related publications:

Item	1935	1934	1933
Nautical charts [1]	291,300	273,816	224,139
Coast and route pilots	7,020	8,073	5,515
Tide and current tables	29,572	32,503	31,609
Tidal current charts	1,705	701	958
Aeronautical charts	67,106	47,685	29,369

[1] Including Manila office.

HYDROGRAPHY AND TOPOGRAPHY

All the hydrographic and topographic work of the Survey, including the collection of data for Coast and Intracoastal Waterways Pilots, is done under the supervision of the Division of Hydrography and Topography.

Two large sea-going vessels, the *Oceanographer* and *Lydonia*, and two tenders, the *Gilbert* and *Welker*, were engaged on offshore work along the Atlantic coast. Off the Louisiana coast, the *Hydrographer* and two tenders, the *Faris* and the *Pratt*, carried on similar work. During the progress of this work several deep submerged valleys—probably former river courses—indenting the Atlantic continental shelf were discovered and adequately surveyed. These interesting submarine topographic features not only furnish the mariner with definite means of position-finding well offshore, but supply the geologist with data of value in studying original land forms. One discovered last season indenting the shelf 60 miles off the Virginia coast was traced during the present season 60 miles beyond the edge of the shelf to a depth of 1,500 fathoms (9,000 feet), indicating an apparent change of that amount at some geologic period in the relative elevation of sea level and the continent.

Entirely new surveys were made of the principal changeable areas of the intracoastal waterways along the Atlantic and Gulf coasts, from New York to Corpus Christi, and the construction of larger scale charts is now in progress. This accomplishment does not reduce the regular appropriations necessary for Bureau work during a normal year. It simply means the accomplishment with relief funds of work sorely needed for many years to modernize charts, previously beyond the means of the Bureau's normal appropriations. Fourteen shore parties were engaged on this work during the year.

On the Pacific coast two vessels, the *Guide* and *Pioneer*, engaged on offshore surveys along the California coast, two shore parties accomplished inshore work along the California coast, and around off-lying islands, and one party carried on wire-drag operations for the detection of pinnacle rocks inside the 20-fathom curve along the coast. The *Guide* also made several detached surveys in the vicinity of San Francisco Bay. The *Explorer* carried on combined operations in the Puget Sound area, including triangulation of first-order accuracy over the Seattle metropolitan area.

In Alaska and in the Philippine Islands only regular appropriations were allotted for field surveys. In Alaska, the *Surveyor* and

Discoverer, with several tenders, continued the surveys of the Aleutian Islands, to the westward from Unimak Pass. This work was started in 1934, as the beginning of a complete and comprehensive survey of that chain. In the Philippines, the steamer *Pathfinder* was continued in a decommissioned status. The Philippine civil government steamer *Fathomer* continued surveys on the northeast coast of Luzon Island and the west coast of Palawan Island. While surveys of the former area are practically complete, those of the Palawan coast require several years for completion. These two surveys are the only areas remaining to complete the initial surveys of the entire Philippine Archipelago. About 10,000 square miles of offshore work also remains to be done in the southern part of the Sulu Sea, north of the International Boundary.

United States Coast Pilots and Intracoastal Waterway Pilots, which furnish reliable information to the mariner that cannot be shown on charts, are revised at intervals of 6 to 7 years. Field examinations were made during the year for a complete revision of United States Coast Pilot, Atlantic Coast, section D, Cape Henry to Key West; United States Coast Pilot, Gulf Coast, Key West to the Rio Grande; and the Intracoastal Waterways Pilots, New York to Key West, and Key West to the Rio Grande.

The work done by the Division of Hydrography and Topography during the year ended June 30, 1935, is listed in the following table:

Hydrography, topography, and coastal triangulation

Locality	Hydrography			Topography		Coastal triangulation		
	Sounding lines	Area	Soundings	Shoreline	Area	Length of scheme	Area	Geographic positions
	Miles	*Sq. mi.*	*Number*	*Miles*	*Sq. mi.*	*Miles*	*Sq. mi.*	*Number*
Bar Harbor to Penobscot Bay, Maine						150	3,500	400
Boston and Cape Cod, Mass	1,548	126	44,385	54	22	94	617	471
Buzzards Bay to Housatonic River, Mass., R. I., Conn	3,141	148	115,435	308	193	150	722	950
Vicinity New York City and Long Island, N. Y. and N. J	5,887	902	215,486	2,254	645	99	339	282
Hudson River, N. Y	746	35	25,359	90		52	52	346
Metedeconk Neck to Cape May, N. J	1,748	49	86,789	331	141	81	335	94
Delaware River, N. J						14	9	130
Chesapeake Bay, Md	3		169	699	369	40	92	78
Ocean City to Virginia Beach, Md. and Va	14,528	9,160	174,443	10	4	20	46	37
Nansemond and Back Rivers, Va	182	9	12,125	63	26	18	80	71
North Landing to Neuse River, Va. and N. C	6,495	205	218,699	1,260	322	253	1,286	514
Wilmington to Charleston, N. C. and S. C	4,192	191	170,185	2,163	1,369	35	120	57
Charleston to Fernandina, S. C., Ga., and Fla	2,227	136	66,825	1,980	2,177	70		54
Fernandina to Titusville, Fla	6,150	242	284,442	649		187	642	460
Port Everglades to Key West, Fla	12,186	1,019	436,006	494	130	222	1,620	440
Apalachee Bay to Mississippi Sound, Fla., Ala., and Miss	12,751	612	383,789	4,335	2,980	514	4,727	796
Mississippi Delta to Port Arthur, Miss., La., and Tex	17,225	5,302	317,791	1,753	681	9	60	26
Galveston Bay to Corpus Christi, Tex	7,640	773	249,785	2,369	1,235	10	40	21
Mexican Border to Estero Bay, Calif	14,503	2,860	241,349	330	267	34	128	57
Estero Bay to San Francisco, Calif	3,372	299	82,294	166	49	15	4	78
Columbia River, Oreg	716	42	25,558	150	32	50	226	927
Puget Sound, Wash	3,489	188	114,633	320	90	123	254	166
Aleutian Islands, Alaska	10,592	12,090	99,148	408	194	313	1,344	363
Balabac to Luzon, P. I	9,061	1,382	159,054	144	163	21	166	268
Total	138,382	35,770	3,523,749	20,330	11,089	2,574	16,409	7,080

Many of the topographic surveys were compiled from aerial photographs. These serve admirably for the construction and correction of nautical charts, and are also used extensively by engineers for projects for which preliminary surveys would otherwise be necessary. Requests often come from commercial companies for copies of these maps before the originals are received from the field for reproduction.

Eight compilation parties, operating from temporary offices in various cities along the Atlantic and Gulf coasts, and one party in southern California, were engaged on this class of work during 1935.

Under the emergency allotments a total of 15,647 square miles of phototopography was accomplished, 9,598 square miles during the present fiscal year and 6,049 square miles in 1934. This work was done in highly developed regions, such as the area along the north shore of Long Island Sound, from New York to Bridgeport, and over the intricate waterways along the Atlantic and Gulf coasts, all representing the highest type and most expensive class of topographic work by the old ground methods.

All these survey projects for modernizing nautical charts were rigidly controlled by an intensive net of coastal coordinating schemes of triangulation, aside from the basic arcs which cover the interior of the country. Basic control stations were established along the greater part of the Atlantic and Gulf seaboards, from Eastport, Maine, to Corpus Christi, Tex., along the lower California coast, and the greater part of the Puget Sound area. Since all stations were permanently monumented, this work is available for revisional surveys for many years to come.

GEODESY

Horizontal and vertical control surveys, consisting of triangulation and leveling, and related measurements, including office computations and adjustments, necessary for all hydrographic and topographic activities, are extended throughout the United States under the supervision of the Division of Geodesy.

All but a small portion of the geodetic field work was devoted to the extension of the control nets of triangulation and leveling toward the goal, where eventually no place in the country will be more than about 12 miles from a triangulation station and a bench mark.

Through the use of emergency funds and the regular annual appropriation, 76 leveling instruments and 51 theodolites were kept in daily operation, resulting in the addition of over 17,000 miles of triangulation and over 124,000 miles of leveling to the control nets. These amounts exceed by more than 100 percent the totals for the previous year, which up to that time had been the highest for any like period in the Bureau's history. At the end of the year the triangulation net was composed of 65,000 miles of arcs, and the leveling net comprised 253,000 miles of lines.

The control surveys are the framework for detailed mapping and charting. They furnish basic positions, elevations, distances, and directions needed for nautical and aeronautical charts published by

the Coast and Geodetic Survey. Most engineering operations depend upon one or more classes of these data. The increased requests for data evidence the growing demand on the part of engineers and surveyors for accurate geographic positions and elevations.

In extending triangulation over the country, the rather complicated computations and adjustments necessarily have to be made on the basis of the curved surface of the earth. Engineers engaged on local projects are not familiar with the resulting so-called "spherical coordinates" and hesitate to use them. This difficulty has been overcome by devising plane coordinate systems for each State, treating a State area as one or more single-plane surfaces. While a single surface can be used for a number of States, as many as six surfaces are employed for some of the larger States. The adjusted geographic positions of triangulation stations in 22 States have been transformed into plane coordinates, from tables for reducing the spherical coordinates. These tables are available for public use.

Base-line measurements, varying from 4 to 10 miles in length, depending on the character of the country, furnish the lengths of triangle sides at intervals of 100 to 200 miles along arcs, to control the distances between stations of the triangulation.

A base is measured with the utmost care, and the probable error of the length is seldom greater than 1:1,000,000, or a small fraction of an inch per mile. This extreme accuracy obtained at moderate cost is needed in order that the computed lengths of the triangle sides may be of high order. Invar tapes, having a very small coefficient of expansion, are used, after being standardized at the National Bureau of Standards.

The astronomical work carried on is designed to furnish Laplace or true azimuths referred to the spheroid, for use in the adjustment of arcs of triangulation. As a triangulation arc tends to swerve to the right or left even though angle measurements are made with the greatest precision possible, the true azimuths keep true positions and directions and add to the strength of the triangulation net.

At some of the stations at which observations are made for true azimuth, latitude observations are also made. This is done with little added cost, and the longitude and latitude data furnish very valuable information for use in determining the shape and size of the earth.

A party was in continuous operation in eight States and the island of Cuba, to furnish the values of gravity or the pull of the earth at scientific laboratories and at stations, furnishing valuable data regarding buried geological structure. The work in Cuba was done in cooperation with the American Geophysical Union and the Atlantic Refining Co., of Cuba.

The variation of latitude stations at Ukiah, Calif., and Gaithersburg, Md., were in continuous operation. These are two of a group of stations established around the world on the parallel latitude 39°08′, operated with a view to keeping a record of the changes in latitude. The results are essential to astronomical computations and investigations at most of the astronomical observatories of the world. The observations at Ukiah have been continuous since 1900, while

those at Gaithersburg have been carried on since 1900, except for the period between 1915–32.

The following table shows the work done by the Division of Geodesy during the year ended June 30, 1935:

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

Locality	Length of scheme	Area
TRIANGULATION, FIRST ORDER		
	Miles	*Sq. mi.*
Lakefield to Alexandria, Minn.	150	1,500
Aitkin to Roosevelt, Minn.	190	1,900
Havana to Belleville, Ill.	55	550
Topeka, Kans., to Blair, Nebr.	60	600
Potomac River, Md. and Va.	50	600
Chesapeake Bay, Md.	100	1,000
Johannesburg to Bridgeport, Calif. (Owens Valley)	80	1,500
Hanna, Wyo., to Opheim, Mont.	185	3,145
Hermann, Mo., to Wykoff Minn.	360	3,860
Alma to Marinette, Wis.	220	2,640
Hayward, Wis., to Princeton, Minn.	115	1,380
St. Paul, Minn., to Ladysmith, Wis.	125	1,250
Wellington to Sweetwater, Tex.	160	1,600
Sweetwater to Brackettville, Tex.	210	2,100
Blair, Nebr., to Adrian, Minn.	140	1,540
White Water to Hardin, Mont.	260	3,900
Austin, Nev., to Caldwell, Idaho	300	7,000
Crisfield to Elkton, Md.	190	1,520
Helena to Missoula, Mont.	145	2,900
Minot, N. Dak., to Presho, S. Dak.	300	3,600
Cottonwood, S. Dak., to Scottsbluff, Nebr.	150	1,500
Picacho, N. Mex., to Slaton, Tex.	140	1,400
Sarles, N. Dak., to Chamberlain, S. Dak.	355	3,550
Salina, Utah, to Grand Canyon, Ariz.	240	6,000
Columbia River, Wash. and Oreg.	90	1,350
White Sulphur Springs, Mont., to Belfield, N. Dak.	330	4,400
Hopkinsville, Ky., to Washington, Ind.	135	1,800
New Freedom to Scranton, Pa. (Susquehanna River)	180	2,450
McClenney, Fla., to Columbus, Ga., and Satilla River spur	280	2,700
Boulder Dam, Nev., to Grand Canyon, Ariz. (Colorado River)	180	5,400
Ada, Okla., to Abilene, Kans.	290	3,200
Hartford, Ark., to Pittsburg, Kans.	170	2,550
Abilene, Kans., to Columbus, Nebr.	160	1,600
Havana, Ill., to White Creek, Wis.	225	2,315
Columbus, Nebr., to Sioux Falls, S. Dak.	155	1,500
Hawthorn to Sulphur, Nev.	190	3,230
King Hill to Kimama, Idaho	70	1,750
Martinsburg, W. Va., to Newville, Pa.	85	850
Danville, to Brooksville, Ky.	85	900
Franklin to Parks, Nebr.	150	1,500
Towanda, Pa., to Syracuse, N. Y.	85	850
Fairmont to Reeder, N. Dak.	290	4,350
McCracken, Kans., to Cordell, Okla.	270	2,700
Hobart, Okla., to Cisco, Tex.	130	1,000
Cisco to Hondo, Tex.	200	2,000
TRIANGULATION, FIRST ORDER—continued.		
	Miles	*Sq. mi.*
Scottsbluff, Nebr., to Hugo, Colo.	200	2,000
Sharon Springs, Kans., to Texhoma, Tex.	160	1,600
Felt, Okla., to Fort Stockton, Tex.	390	3,900
Hondo to Mission, Tex.	210	2,100
Sherburn, Minn., to Kansas City, Mo.	315	3,150
Harrisonville, Mo., to Pittsburg, Kans.	85	850
McAlester, Okla., to Palestine, Tex.	210	2,100
Palestine to Bay City, Tex.	190	1,900
Moscow, Tenn., to Slidell, La.	335	3,350
Gulfport to Corinth, Miss.	270	3,240
Yuma to Stewart Dam, Ariz.	185	2,220
Phoenix to Winkelman, Ariz.	95	1,110
Florence to Tucson, Ariz.	90	1,000
Tucson to Nogales to Ajo, Ariz.	150	1,850
Lake City to Lake Stearns, Fla.	240	2,400
Sarasota to Stuart, Fla.	130	1,300
Miami to Key West, Fla.	135	1,080
Appling, Ga., to Live Oak, Fla.	250	2,500
Osgood to Canton, Mo.	80	800
Vicinity of Washington, District of Columbia, Maryland, and Virginia	15	120
Catesby, Okla., to Anthony, Kans.	120	1,200
Chamberlain, S. Dak., to Broken Bow, Nebr.	170	1,700
El Centro to San Diego, Calif.	60	600
Broken Bow, Nebr., to Wakeeney, Kans.	160	1,600
Jacksboro to Texarkana, Tex.	240	2,500
Boulder Dam, Nev., to Yuma, Ariz. (Colorado River)	220	2,640
Riceboro to Atlanta, Ga.	220	2,200
Alice to Encinal, Tex.	100	900
Lampasas to Leon Powell, Tex.	190	1,900
Lubbock to Seymour, Tex.	135	1,350
Newport to Freehold, N. J.	90	1,260
Woodville, Tex., to Redell, La.	95	900
Jacksboro, Tenn., to Albany, Ky.	65	780
Franklinville, N. Y., to Newcastle, Pa.	150	1,650
Greentree, Tenn., to Rowland, Ky.	125	1,500
Navasota to Woodville, Tex.	95	950
Boulder Dam, Nev. and Ariz.	13	150
Austin to Navasota, Tex.	100	1,300
Total	14,113	168,580
TRIANGULATION, SECOND ORDER		
Lucerne Valley to Needles, Calif.	130	1,300
Rice to Kingston, Calif.	100	1,000
Saulsbury, Tenn., to Princeton, Ky.	130	1,350
Paducah, Ky., to Martin, Tenn.	50	450
Sparta, Tenn., to Gadsden, Ala.	130	1,300

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

Locality	Length of scheme	Area
TRIANGULATION, SECOND ORDER—continued		
	Miles	*Sq. mi.*
La Fayette, Ga., to Union City, Tenn	240	2,400
Greenville, Fla., to Hartwell, Ga	260	2,600
Delaware River, New Jersey and Delaware boundary	10	30
Superior National Forest, Minn	100	2,000
Chancellor, Tex., to Clayton, N. Mex	360	3,600
Silver City, Ga., to Hardeeville, S. C	200	2,000
Huntington, W. Va., to Pennington Gap, Va	140	1,960
Beattyville, Ky., to Roanoke, Va	200	2,700
Reidsville to Rentz, Ga	50	500
Reddell to Napoleonville, La	140	1,260
Chappells to Charleston, S. C	150	1,200
Lowndesville, S. C., to Gastonia, N. C	110	1,100
Americus, Ga., to Monticello, Fla	110	1,100
Sahuarita, Ariz., to Pratt, N. Mex	105	1,050
Osceola to Bucksport, S. C	130	1,170
Texhoma to Thurston, Tex	400	4,000
Allendale, S. C., to Odum, Ga	90	900
Total	3,335	34,970
TRAVERSE, FIRST ORDER		
Miami to Estero, Fla	76.8	--------
BASE LINES, FIRST ORDER		
Edina, Mo	5.5	--------
Chandlerville, Ill	6.0	--------
Antigo, Wis	6.5	--------
Hayward, Wis	4.8	--------
Shooks, Minn	5.2	--------
Aberdeen, S. Dak	7.5	--------
Pingree, N. Dak	8.9	--------
Huff, N. Dak	5.5	--------
Lenapah, Okla	5.8	--------

Locality	Length of scheme	Area
BASE LINES, FIRST ORDER—CON.		
	Miles	*Sq. mi.*
Avard, Okla	4.2	--------
Arabella, N. Mex	6.0	--------
Presidio, Tex	4.2	--------
Alexandria, La	5.3	--------
Lonoke, Ark	9.3	--------
Columbia, S. C	4.2	--------
Perky, Fla	4.5	--------
Berwick, Pa	6.8	--------
Petty, Tex	5.6	--------
Asbury, Mo	4.9	--------
Newkirk, Okla	7.5	--------
Huff, N. Dak. (remeasurement)	5.5	--------
Angela, Mont	5.4	--------
Total	129.1	--------
RECONNAISSANCE, FIRST ORDER TRIANGULATION		
Alabama, Arizona, Arkansas, Colorado, Florida, Georgia, Idaho, Illinois, Iowa, Kansas, Kentucky, Louisiana, Maine, Massachusetts, Michigan, Minnesota, Mississippi, Missouri, Montana, Nebraska, Nevada, New Jersey, New Mexico, New York, North Dakota, Ohio, Oklahoma, Oregon, Pennsylvania, Rhode Island, South Dakota, Tennessee, Texas, Utah, Virginia, Washington, West Virginia, Wisconsin, Wyoming	18,075	203,315
RECONNAISSANCE, SECOND ORDER TRIANGULATION		
Alabama, Arizona, Arkansas, California, Delaware, Florida, Georgia, Louisiana, Michigan, Minnesota, New Jersey, New Mexico, North Carolina, Oklahoma, Oregon, South Carolina, Tennessee, Texas, Wyoming	5,640	60,280

Locality	First order	Second order
LEVELING	*Miles*	*Miles*
Alabama	177	2,449
Arizona	573	2,526
Arkansas	197	4,440
California	1,226	4,540
Colorado	300	3,136
Connecticut	29	380
Delaware	29	48
Florida	226	711
Georgia	226	2,740
Idaho	290	1,455
Illinois	66	3,201
Indiana	61	1,995
Iowa	252	3,449
Kansas	142	4,977
Kentucky	196	2,075
Louisiana	88	1,647
Maine	--------	546
Maryland	94	342
Massachusetts	--------	124
Michigan	593	3,283
Minnesota	62	3,368
Mississippi	292	2,779
Missouri	242	3,449
Montana	176	5,057
Nebraska	65	3,974

Locality	First order	Second order
LEVELING—continued	*Miles*	*Miles*
Nevada	874	2,158
New Hampshire	--------	330
New Jersey	--------	285
New Mexico	240	4,072
New York	308	2,121
North Carolina	29	1,873
North Dakota	283	3,915
Ohio	538	2,545
Oklahoma	6	2,671
Oregon	31	1,988
Pennsylvania	153	3,416
South Carolina	--------	894
South Dakota	506	3,575
Tennessee	297	1,956
Texas	356	7,587
Utah	593	2,207
Vermont	--------	642
Virginia	85	1,930
Washington	4	1,468
West Virginia	78	347
Wisconsin	237	3,012
Wyoming	493	2,297
Total	10,713	113,980

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

Locality	Number of determinations			
	Astronomical			Gravity
	Latitude	Longitude	Azimuth	
ASTRONOMICAL AND GRAVITY DETERMINATIONS				
Arkansas	1	1	1	
Connecticut				20
Cuba				84
Florida	14	14	14	
Georgia	7	7	7	
Illinois	2	2	2	1
Indiana	2	2	2	
Iowa	3	3	3	
Kentucky	1	2	2	
Louisiana		1	1	
Maryland		1	1	1
Massachusetts				11
Minnesota	1	1	1	
Mississippi	5	5	5	
Missouri	1	1	1	
Montana				29
ASTRONOMICAL AND GRAVITY DETERMINATIONS—continued				
Nebraska	1	1	1	
New Hampshire				1
New York		1	1	
Ohio	1	1	1	
Oklahoma	2	2	2	
Oregon	1	1		
Pennsylvania	1	2	2	20
South Carolina	6	6	6	
Tennessee	2	2	2	
Virginia	2	2	2	
Washington	1	1	1	
Wisconsin		4	4	
Wyoming				3
Total	54	63	62	170

Activity	Stations	Miles
SUMMARY		
Triangulation:		
First-order		14,113
Second-order		3,335
Traverse, first-order		76.8
Base lines, first-order		129.1
Reconnaissance:		
First-order triangulation		18,075
Second-order triangulation		5,640
Leveling:		
First-order		10,713
Second-order		113,980
Astronomical determinations:		
Latitude	54	
Longitude	63	
Azimuth	62	
Gravity determinations	170	
Total	349	166,061.9

The office computations and adjustments of 22 arcs of first-order and 51 arcs of second- and third-order triangulation were completed during the year, with computations of 20 arcs of first-order and 25 arcs of second- and third-order triangulation in progress. Computations were made of 15 first-order and 2 second-order bases. A field party in New York City was also engaged on triangulation, leveling, and plane coordinate computations.

About 300 separate lines of levels were adjusted to the level net during the year and information concerning descriptions and elevations of bench marks for 445 lines of levels were distributed to engineers and surveyors.

The personnel detailed to the Washington office by the Chief of Engineers, United States Army, prepared the manuscript for the publication containing the results of the triangulation along the Mississippi River between Memphis, Tenn., and Vicksburg, Miss. Results of the triangulation between Cairo, Ill., and Memphis, Tenn., were issued during the year.

The manual of plane coordinate computations was received from the printer during the year, together with publications covering triangulation in Missouri, Texas, and Oklahoma; triangulation and traverse in Louisiana and Arkansas; and leveling in Massachusetts, Rhode Island, Connecticut, New Hampshire, Vermont, Maine, Florida, and Arkansas. Others are in press or about to be sent to the printer.

TIDES AND CURRENTS

The Division of Tides and Currents is the clearing house of all tidal observations conducted by the Bureau. It is here that the observations made in connection with hydrographic work are tabulated and reduced. The expanded hydrographic work program has resulted in a large increase in office work, as observations from 965 stations were received for reduction and the determination of datum planes.

Thirty-four primary tide stations were operated during the year: 21 on the Atlantic coast, 3 on the Gulf coast, 7 on the Pacific coast, 2 in Alaska, and 1 in the Hawaiian Islands. Fourteen of these were conducted on a cooperative basis with Army Engineers at Wilmington and Southport, N. C., Miami Beach and Mayport, Fla., and Mobile, Ala.; Navy Department at Newport, R. I., Annapolis, Md., Portsmouth, N. H., Portsmouth and Hampton Roads, Va., and San Diego, Calif.; Woods Hole Oceanographic Institute, Woods Hole, Mass.; Harbor Department, Los Angeles, Calif.; and the Surveyor of the Territory of Hawaii, Honolulu.

The data obtained at these stations were supplemented by observations at 433 secondary stations, 69 of which were maintained throughout the year and the others for periods of 1 month or longer. These included cooperative stations with the Army Engineers, Fort Worden, Wash.; University of Washington, Friday Harbor, Wash.; Biological Research Bureau, Bermuda; Washington Suburban Sanitary District, Bladensburg, Md.; California State authorities, Santa Monica, Calif.; Portland Canal Power Co., Hyde, Alaska.; and the port of Willipa Bay, Raymond, Wash.

In the interests of navigation and engineering, special tide and current surveys are conducted at various coastal sections where precise tidal information is lacking. The comprehensive tide survey is a relatively new development made necessary by modern conditions which have enormously increased land values along tidal waters. During the year, such a survey was in progress for the Washington coast. The special current surveys are made of important harbors and waterways to make available the characteristics of the current movement essential to navigation and harbor engineering. The Bureau is the recognized authority in this line of work and numerous requests for such surveys are continually being received. During the year, the waterways of Nantucket and Vineyard Sounds and the harbors of San Diego, Galveston, and Mobile, were covered by current surveys. This Bureau, in cooperation with the Lighthouse Service, also began a comprehensive series of current observations in San Pedro Channel.

In addition to their utilization in the construction of charts, the tide and current data obtained by the Survey are made available to the public in tide and current tables, and miscellaneous publications.

Tide tables are issued annually to meet the demand for advance information as to the times and heights of high and low waters, required by modern commerce with its deep-draft vessels moving on exacting schedules. For convenience to the public, the tide tables are published in two volumes, one for the Atlantic Ocean and another for the Pacific and Indian Oceans. Together, they give daily predictions of the high and low waters for 96 of the more important ports of the world, together with data for obtaining predictions at some 3,900 other places. Through cooperative arrangements, international exchanges of predictions for the annual tide tables are made with England, 21 stations; Germany, 6 stations; France, 4 stations; Canada, 5 stations; and India, 5 stations.

Current tables are also issued annually to give the mariner information relative to the currents which affect the speed and course of his ship. The Current Tables, Atlantic Coast, have been enlarged to include daily predictions for 3 new stations (Baltimore Harbor approach, St. Johns River entrance, and Miami Harbor entrance), making a total of 16 stations for which daily predictions are now given. Through the use of differences given in the tables, daily predictions are also obtained for some 850 other stations. The Current Tables, Pacific Coast, give daily predictions for 10 of the more important waterways on our Pacific coast and for 1 in the Philippine Islands, together with data for obtaining predictions at some 500 other stations.

The results of current surveys were also utilized in the preparation of a new set of tidal current charts for Long Island and Block Island Sounds, and a revised edition for New York Harbor.

To supply the engineer with the elevations of the tidal datum planes along our coast, copies of the descriptions and elevations of the tidal bench marks are prepared for each of our coastal States. During the year, such information was made available for the State of Oregon.

TERRESTRIAL MAGNETISM

The Division of Terrestrial Magnetism and Seismology conducts the magnetic survey of the United States, the results of which are available primarily for the use of the sea and air navigator, and secondarily for the land surveyor and investigator of radio and other problems.

Continuous photographic records of the changes in the earth's magnetism were made at the magnetic observatories near San Juan, P. R. (1926); at Cheltenham, Md. (1901); near Tucson, Ariz. (1909); near Honolulu, Hawaii (1902); and Sitka, Alaska (1902). (The dates in parentheses indicate the year in which the operation of the observatory began.) In this period of more than three decades a notable contribution to the study of the earth's magnetism has been made. With recent repairs and additions to buildings and instruments, the observatories are now well equipped for still more valuable additions to our sum of knowledge of the subject.

Field work was devoted primarily to observations at "repeat" stations to determine the change in the earth's magnetism during the interval of about 5 years. This year's results complete the data needed for bringing up to 1935 the results of observations at over 6,000 stations all over the country, and the preparation of magnetic maps for that year. Further progress was made in establishing new repeat stations at triangulation stations situated in the open country, which should be more likely to continue available for future use than those near cities and towns.

To provide reference points for local surveyors, magnetic stations were established at numerous county seats where observations had not been made previously and at other places where old stations had ceased to be available, especially in Georgia and South Carolina. Continued cooperation with State civil works administrations has secured results of mutual benefit and demonstrated more fully to local authorities how Federal surveys may be useful to them.

On the initiative of a New Jersey civil works representative, a plan was formed for cooperation with airport authorities to provide compass-testing stations at airports. In spite of such remarkable devices as the radiocompass and directional gyro, these aids to navigation still have to refer to the magnetic compass for their basic control. The directional gyro has to be reset every 20 minutes by the magnetic compass and the radiocompass is no more complete in itself on board an airplane than it is on board a ship. To obtain a bearing it must be referred to the magnetic compass. In addition, the radio becomes useless in times of heavy thunderstorms, since then the antenna is grounded to prevent damage to the plane by lightning. With this in mind and as rapidly as available funds permit, astronomical and magnetic observations are being made at the principal airports. These enable the aviator or airport engineer to test the airplane compass at frequent intervals and thus insure greater accuracy in navigating the plane by compass, furnish proper corrections to the compass courses, and thus promote safer navigation.

The channel ranges in navigable rivers offer a convenient means for navigators of sea-going vessels to test their compasses when following the channels. Such observations have advantages over those made by astronomic methods. Magnetic observations were made at many places along the river approaches to Jacksonville, Fla., Charleston and Georgetown, S. C., and Wilmington, N. C., and the magnetic bearings of the ranges were determined. Magnetic observations were also included in the general survey of the Aleutian Islands in progress during the year.

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

State	Complete observations at repeat stations		Observations at other stations		Total	State	Complete observations at repeat stations		Observations at other stations		Total
	Old	New	Complete	Declination			Old	New	Complete	Declination	
Alaska	2			34	36	Nevada	5	2		1	8
Arizona	1			1	2	New Mexico				1	1
California	2		1	16	19	New York	1	1			2
Colorado	1			3	4	North Carolina	7	2		22	31
Florida				37	37	North Dakota	4		7		11
Georgia	4		4	10	18	Ohio	2	2			4
Hawaii	1				1	Pennsylvania	3	2	1	4	10
Idaho	1		1	3	5	Puerto Rico	1				1
Illinois			1	1	2	South Carolina	1			47	48
Indiana	2				2	South Dakota	3				3
Kansas	3		2		5	Utah	2			1	3
Kentucky	2	1	1		4	Virginia		1		1	2
Maryland	2	1	1	3	7	West Virginia	1				1
Massachusetts				6	6	Wyoming	2			4	6
Michigan	3	1			4						
Minnesota	3				3	Total	65	13	19	201	298
Montana	6			6	12						

Cheltenham has been designated as the observatory in this country for international comparisons of magnetic instruments. It is also the base station for standardization of instruments of this Bureau. With the cooperation of the department of terrestrial magnetism of the Carnegie Institution of Washington, the sine-galvanometer of that institution was installed at Cheltenham as the standard horizontal intensity instrument for all comparisons. In cooperation with the cosmic ray committee of the Carnegie Institution of Washington, a cosmic ray apparatus installed at Cheltenham is being operated by the observatory personnel. Information regarding the magnetic character of days is now supplied by the Cheltenham observatory for the daily broadcast of cosmic data sent out by science service under the auspices of the International Scientific Radio Union.

At the Tucson observatory the recording of variations of atmospheric electricity and of earth currents was continued throughout the year, through the cooperation of the Carnegie Institution of Washington and the Mountain States Telegraph & Telephone Co.

The demand for information derived from the magnetic observations of the Bureau is growing. The results are made available to the public in various forms of publication, on nautical and aeronautical charts, and by correspondence. Land surveyors are writing constantly for assistance in retracing the lines of old compass surveys. For the southeastern quarter of the country and for California and Nevada, the information is available in the form of publications of magnetic declination by States or State groups. A number of these were prepared, issued, or revised during the year, although most of them are in mimeographed form, because of frequent changes in available data.

The observatory results are used extensively by those engaged in the study of radio transmission. Knowledge of the changes in the earth's magnetic field from hour to hour is an important factor in the use of magnetic methods in prospecting for oil, magnetic iron ore, and other minerals.

Information is made available at nominal cost as rapidly as possible, and the observatory results are issued in final form, each volume covering 2 years for an observatory. At the close of the year the 1927–28 series had been issued, the 1929–30 series was ready to put in final form, and a good start was made on the 1931–32 series. Preparation for publication of data obtained during the polar year was well advanced.

SEISMOLOGY

The work in seismology is that part of a broad cooperative study, without regard to locality, which can be carried through only by a Government agency.

Earthquakes can be neither prevented nor controlled, and there are only two ways in which they can be dealt with for the benefit of man. One is to predict so as to be ready for them, and the other is to find out how the damage caused by them to life and property may be kept to a minimum.

Little progress has been made in prediction, but the Bureau is making several contributions which, in addition to other present value, may eventually be useful for that purpose. One is the collection of earthquake statistics, including complete descriptions, and the other is the measurement of earth tilt at a station at the University of California, operated in cooperation with that institution. Japanese experience indicates a relation to earthquake prediction. Closely related to prediction is the special geodetic work in earthquake regions, which permits measurement of changes in the earth's crust.

The collection and publication of earthquake information is made possible through cooperation. The part taken by the Bureau is the operation of 8 seismograph stations either directly or cooperatively, the interpretation of the records of 6 others, and the assembling and publication of reports of visible and felt effects of earthquakes. The stations at San Juan, P. R., Tucson, Ariz., Sitka, Alaska, and Ukiah, Calif., are operated by the Bureau; those at Columbia, S. C., Chicago, Ill., Bozeman, Mont., Honolulu, Hawaii, are cooperative. Plans were completed for another cooperative station at College, near Fairbanks, Alaska, which will be in operation early in the next fiscal year. Immediate location of 23 earthquake epicenters was made possible through the cooperation of many stations, Science Service, and the Jesuit Seismological Association. Complete earthquake information is published annually.

Better results, though still far from perfect, are obtained in the field of prevention of damage, the only great difficulty being that it is necessary to have an earthquake in order to appraise the effectiveness of the preventive measures.

The work of the Bureau in this particular field has been done principally in California, not because there is not need elsewhere, but because it affords a convenient laboratory for the work, there is a better chance of immediate economic use, there are other related activities going on there which fit particularly well into the program, and, finally, because the Government has an active interest, owing to the large sums of Federal funds advanced for various projects such as the great dams, including Boulder Dam, bridges, and buildings.

The work has for its purpose the measurement of strong earth motions, and includes the measurement of acceleration, ground displacement, periods and duration of the shocks, these being the factors which account for destructiveness. Observations were made on the ground and in various places above the ground in various structures. It was found that much useful information in this connection can be obtained without waiting for an earthquake, and instruments developed in this Bureau have made it possible to determine the periods of buildings, elevated tanks, bridge piers, dams, and of the ground itself. In addition, with the cooperation of Stanford University, a building vibrator was developed by which the period and amount of energy of the shaking device can be controlled.

Fifty strong motion instruments were kept in operation in California, 1 in Panama, and 1 each were kept available in Chicago and Washington for use if there should be a large earthquake in middle west or east. These reserve instruments were loaned for short periods for determination of velocity of seismic waves resulting from large explosions, the Bureau benefiting by the results.

Twenty-five strong motion records were obtained from 9 earthquakes, 8 in California and Nevada and 1 in Panama, which were analyzed in such a way as to obtain from them complete information.

Vibration observations were made in 212 buildings, on 37 elevated water tanks, 1 completed and 2 uncompleted bridges, 2 dams, 6 pavement sites, at 2 places to determine ground vibration periods, and on several structures of special design. The measured movements were in most cases normal structural vibrations, but a specially constructed vibrating machine was used in the work on 2 buildings, 2 dams, 1 bridge, and on 1 ground vibration test.

Special cooperative work included the test on a shaking platform at the National Bureau of Standards of a number of types of high magnification seismographs, thereby obtaining hitherto unavailable information. Cooperation and advice have helped to make possible active seismological stations at Pennsylvania State College and the University of Utah.

Most of the information collected each year appears in an annual publication on earthquakes. In view of the large amount of special work done in strong motion and related work, a special publication giving results in this field was prepared during the year. Quarterly instrumental reports are issued as are also preliminary reports on California earthquakes and preliminary interpretation of strong motion records.

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