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ANNUAL REPORT

OF THE

DIRECTOR, UNITED STATES COAST AND GEODETIC SURVEY

TO THE

SECRETARY OF COMMERCE

FOR THE

FISCAL YEAR ENDED JUNE 30, 1921

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1921

National Oceanic and Atmospheric Administration

Annual Report of the Superintendent of the Coast Survey

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REPORT

OF THE

DIRECTOR U. S. COAST AND GEODETIC SURVEY.

DEPARTMENT OF COMMERCE,
COAST AND GEODETIC SURVEY,
Washington, October 5, 1921.

SIR: There is submitted herewith my seventh annual report. This report is for the fiscal year ended June 30, 1921, and is the ninetieth annual report of this Bureau.

INTRODUCTION.

PART I. SUMMARY OF CONDITIONS AFFECTING THE BUREAU.

Chapter I. The fundamental trouble in the Bureau, pages 6 to 7.
Chapter II. The Bureau's most important problems, pages 8 to 18.

PART II. THE WASHINGTON OFFICE.

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PART III. IN THE FIELD.

Chapter I. Accomplishments in the field during the past fiscal year, pages 40 to 49.
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Chapter III. Program for current fiscal year in the field, pages 76 to 80.

PART IV. DETAILED STATEMENT OF FIELD WORK, PAGES 81 TO 141.

INTRODUCTION.

In the interests of Government economy it is my purpose to make this report as brief as a proper presentation of the work of and conditions affecting this Bureau will permit. While the report will be as brief as may be, it is believed that it would be a mistake to abridge it to the extent that it would not fully present to you the vital needs of the Bureau, the accomplishments during the fiscal year for which it is made, a general idea of the task still ahead of the Bureau, the program for the current fiscal year, and a general discussion of the matters affecting the Bureau.

Part I.—SUMMARY OF CONDITIONS AFFECTING THE BUREAU.

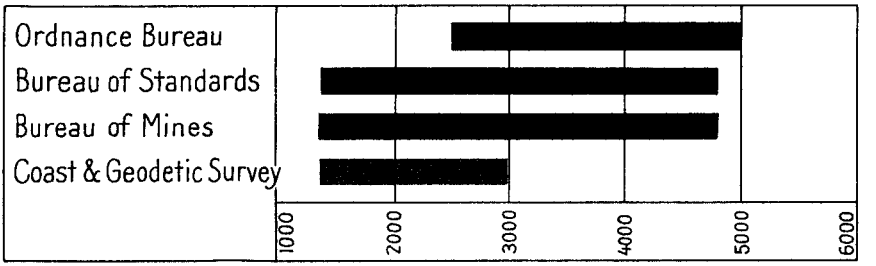
CHAPTER I.

THE FUNDAMENTAL TROUBLE IN THE BUREAU.

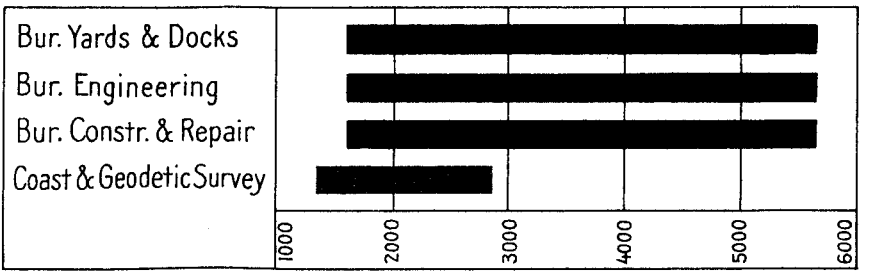
The first and most important matter to be brought to your attention is the condition of the Bureau as a functioning organization. To be perfectly candid, it is not up to the maximum of production, due primarily to the failure to provide adequate salaries throughout the service. Congress did prevent complete disintegration of the Bureau when it gave recognition to the field officers, and their pay is now fairly commensurate with the duties performed, but there are other highly technical as well as nontechnical employees of the Bureau who have been retained in the service only through the hope and continued promises of reclassification that have been held out to them; but now that this measure apparently will not be brought to maturity the technical employees and others that are highly qualified, though not members of the technical force, are openly signifying their intentions of leaving this Bureau to become identified with other branches of the Government service or to enter outside employment where the salaries are more commensurate with their abilities and the character of work actually performed by them. This will be a loss to the country, to the Bureau, and to the individual, because the Bureau has a field of its own not paralleled anywhere else in this country, and, consequently, the employee leaving the Bureau can not fully apply anywhere else the skill he has attained in the Bureau, nor can he be replaced by another employee of mature skill and judgment in carrying on the work of the Bureau. The direct failure of the Bureau to function properly at the present time is due to the justifiable dissatisfaction that exists among these employees. They feel, and rightfully so, that they have stood loyally by the Bureau through the war at a direct monetary loss to themselves, with the anticipation, based on definite promises, that conditions would be righted by reclassification; and, as I have stated in my 1920 annual report, it was only the zeal, painstaking care, and extra efforts of these seasoned employees, imbued with the old-time tradition that the Bureau should set the standard of scientific exactness, that prevented the disintegration which would mean the loss of fidelity of our nautical charts, tide tables, current, magnetic, and triangulation data. It may be of interest to you to know that many of these underpaid technical employees, as well as those of the less technical workers, are compelled to resort to outside work under the most trying conditions in connection with their regular duties in order to make a livelihood. It leads me to express the belief that both the Federal Government and the employees would be gainers by the early adoption of higher salaries and a more productive day. Under present conditions not a few but many of the employees must hurry from this Bureau at the

Comparison of Maximum and Minimum Salaries in some branches of the U.S.Coast and Geodetic Survey with those in other Government Bureaus

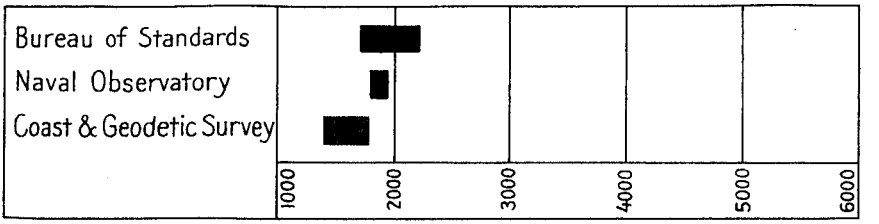
Mathematicians (Computers)



Cartographers (Draftsmen)



Astronomical and Geodetic Instrument Makers



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close of the day to undertake other duties. Just to cite one specific case: One of the most valued technical men in the Bureau, whose services to the country can not be measured in dollars, has been compelled to go to his home each night and prepare his and his children's supper, while his wife works at night in order to meet the needs of the family; and each morning, as his wife must rest for another night's work, he prepares his and his children's breakfast, puts up his lunch, and leaves for his daily work. Isn't this deplorable, and would it be tolerated anywhere outside of the Government? There are many more such cases. How long must this go on? Under such conditions neither the Government nor the outside employer can have the services of a vigorous, wide-awake, self-reliant worker, but must put up with a man whose energy has been partly spent; and a continuance of this practice for a certain period results inevitably in the run-down, overworked, nervous, and irritable or dejected employee. It would be far more profitable for the Government to pay a higher salary and obtain the best efforts of the employees for a more productive day. I can not emphasize too strongly that unless this fundamental trouble is soon corrected a disintegration of the service will continue, with disastrous results of which the Government and the public will feel the effect for years to come. The question is, Will the pledge given some years ago, continually repeated and as often postponed with the usual excuses, be kept now with the men who are the backbone of our Federal institutions, or will the unredeemed promises continue to prevail? (See fig. A, opposite p. 6.)

Another phase of the salary question is important enough to bring to your attention, reiterating what I have said in former reports. It involves the entrance salaries, which are too low to tempt those who have the basic education required for the specific work involved. Instead of being in a position to accept only those who meet the necessary requirements, the Bureau has to take men with inferior qualifications and hold them simply as "temporaries." If they show special aptitude for the work their sojourn in the Bureau is of short duration, for the present rate of pay is too small to hold them. They are benefited by the help and coaching of more experienced men, and then leave for more lucrative positions. The balance of these temporary employees who do not improve nor measure up to a fair standard eventually must be dropped; and so it goes on, year after year, with an annual turnover of 50 to 100 per cent.

All this means unrest and disorder, and an unnecessary burden on the division chief and his principal assistants. Their time is wasted when it should be applied to important matters only. The Director's time, too, is more or less taken up with these unfortunate conditions. This method of doing business is wasteful, viewed from every angle. I can not fill vacancies with inefficient people just because vacancies exist. Until the long-recommended change for equitable salaries is made, just so long will this uneconomical condition exist.

I have given you the above facts frankly without obscuring the actual conditions, just as a manager would submit them to the head of a large business concern.

In this Bureau we are endeavoring to give the public a salable article, but with these handicaps the output is produced under unnecessary difficulties which mean delay and waste.

CHAPTER II.

THE BUREAU'S MOST IMPORTANT PROBLEMS.

NEW BUILDING WOULD PAY INTEREST ON INVESTMENT.

The second most serious condition that prevents this Bureau functioning to the fullest extent, and which I have dwelt on at length in previous reports, is the utterly inadequate space in which it is housed, and a lack of proper and sanitary quarters. The Bureau is operating in eight buildings, five larger and three smaller, all but two more or less detached, and connected as far as it is feasible by communicating bridges. Two of the main buildings were designed and built for dwellings and one of them was used for that purpose. One of the smaller buildings was built for and used as a stable, and another two of the main buildings were designed and constructed for use as a hotel and were rented to the Government for the use in this Bureau from 1871 to 1891 when they were sold to the Government to house part of this Bureau. As its work centers largely in the construction and production of nautical charts and it is therefore a manufactory, the Bureau operates under a signal handicap in buildings so little suited to its needs. It is a matter of economy to provide a respectable building for this service—it is waste to continue under existing conditions.

CURRENT OBSERVATIONS WILL SAVE LIVES AND VESSELS.

During the years from 1900 to 1921 there were stranded or wrecked on the Pacific coast of the United States more than 100 vessels involving a loss of hundreds of lives and millions of dollars in property, and this in spite of the fact that our navigators on the Pacific coast comprise an unusually able, keen, and alert group of men. To a large extent this loss was due to the lack of knowledge of the effects of the currents on the Pacific coast. Had there been adequate knowledge of these currents, a large part of this enormous loss certainly would have been prevented.

In the safeguarding of life and property on the Pacific coast a knowledge of the currents is of the utmost importance; for in the more than thousand miles of coast line that stretches from the Mexican border to the Strait of Juan de Fuca, harbors are many miles apart, sailing courses long, and periods of thick weather are of comparatively frequent occurrence.

Appropriations for the observation of currents have to the present time been so small as not to permit the maintenance of a vessel for making a detailed systematic study of the treacherous and little-known currents of the Pacific coast. By taking advantage of the five light vessels stationed along the coast, the Survey has at little cost

secured observations which have brought out the important fact that, contrary to the belief of the mariner, a wind creates a current not in its own direction, but in a direction about 20° to the right of the wind. The importance of this discovery lies in the fact that a wind blowing parallel with the coast may produce a current which tends to set a vessel on the shore, a fact which until now has been unsuspected by the navigator.

To bring out to the full the effects of the currents it is necessary to make a systematic study of the currents all along the coast. A modest appropriation that will permit the maintenance of a vessel for three seasons to secure observations at critical points between the light vessels is needed. Such a survey will bring out the effects of both the tidal currents and the wind currents along the whole coast. In this connection it is to be noted that while the Survey at present is engaged in the determination of the magnitude and nature of the currents that affect navigation, it has at the same time, and at no additional cost, secured data for a comprehensive study of oceanic circulation, which has an important bearing upon many problems in meteorology, climatology, and related subjects.

Given the modest appropriation necessary to carry into effect the plans outlined for a systematic survey of the currents along the Pacific coast, a long step will have been taken toward the safeguarding of life and property in the navigation along that coast.

The appalling loss of life and property in the wreck of the *Alaska* on August 7 on the coast of California is a compelling argument for the charting of the currents on the Pacific coast. Only one explanation of the wreck has thus far been offered. The second officer of the *Alaska* declares that an uncharted northeast current dragged the fog-bound ship several miles inshore into the reef.

DELAYED SURVEYS ON LAND ARE WASTEFUL.

The need for control surveys, for precise triangulation, traverse, and levels has reached an acute stage. For years the appropriations for such work have been far short of what they should have been, until now there is an accumulation of demands which are so pressing that they command consideration.

In Alaska our geodetic surveys are far short of the immediate needs of our charts. In southeast Alaska the triangulation has no main scheme control, nor is it as yet connected to the North American datum. Western and central Alaska are entirely without control surveys or a connection to the North American datum. For years the Coast and Geodetic Survey has been importuned by other Federal organizations, especially the General Land Office, the Geological Survey, and the Forest Service, to supply precise control for the interior of Alaska. The proposed international cooperative arc of triangulation from Puget Sound through southeast Alaska to the Yukon, then down the Yukon and across to Cook Inlet, will do much to relieve the Alaska situation; but at the best that project will require four years to complete.

The demands of the business interests of the Nation for the completion of the topographic map of the entire country are yearly becoming more insistent. The extension of the good roads system, the

water supply problems of the cities, the colonization and industrial expansion programs of the railroads, the administration problems of Federal agencies, each in itself would be sufficient reason to complete the topographic map at the earliest possible moment at a saving to the country as a whole. But preceding the topography must come control surveys, the triangulation and levels. We are so far in arrears of current demands for such surveys that an immediate increase in the funds for such work is imperative. Detailed surveys and the attendant control surveys are too intimately connected with the economy and the welfare of essential industries to permit those surveys to wait longer for a time when funds will be abundant.

If funds are not provided for this Bureau to do this pioneer work for which it was created, then we must eventually pay dearly for the delay, mistakes, and disaster which are bound to develop complications and ultimately larger costs than if the control surveys, etc., were done prior to the detailed mapping work.

NEW VESSELS VERSUS OLD VESSELS.

Each year for the last seven years I have endeavored in my annual report to emphasize the urgent need for speeding up the hydrographic survey of the waters contiguous to our seacoasts, both at home and in Alaska and the insular possessions. Much has been accomplished in this line by reorganization of surveying parties, by improved methods, and by greater uniformity and standardization of methods; but there is, of course, a limit to the amount of work that can be accomplished by an organization without expansion and without the most efficient tools; and I believe that we have now approximated that limit. Further solution of the problem, therefore, appears to demand more surveying parties and more and better equipment.

This Bureau is in urgent need of vessels to increase the number of parties that can attack the vast unsurveyed waters under the control of this country, and to bring some of the present parties up to a higher degree of efficiency. It is as unreasonable to expect efficient work from a hydrographic surveying party in a worn-out or otherwise unsuitable vessel as it is to expect good work from a mechanic with defective tools. Vessels are the tools of the hydrographic parties; they have other tools, to be sure, such as sounding machines and instruments for navigation and surveying, but those are relatively inexpensive, and consequently can be supplied without difficulty from the funds annually provided. Vessels are relatively expensive, particularly during recent years, but it can be shown that the annual savings that would accrue from the use of entirely suitable vessels, instead of antiquated or otherwise unfit vessels, would soon pay for their cost.

It would undoubtedly be an economical procedure to take some of the vessels that are no longer required by other organizations of the Government and turn them over to the Coast and Geodetic Survey for hydrographic surveying, if there were any such vessels. But, unfortunately, there are not; at least, I have been unable to find any more vessels that could be used by this Bureau which can be spared by the organization to which they are now assigned. All of the vessels that are not now required elsewhere in the Government serv-

ice are either so large that the cost of operating them as survey vessels would be prohibitive, or else they are so worn out and defective that the cost of putting them in service would be an unwarranted outlay on a craft that could not be made really efficient. This subject was gone into thoroughly immediately after the war and seven of the most likely of the Navy's available vessels were taken over. Three have been turned back as entirely useless for this work, and the others, with possibly two exceptions, are far from satisfactory. Nor are there any suitable vessels to be had outside of the Government. Vessels are built always for a specific use and are designed to best meet the requirements of such. When put to some radically different use, there is necessarily loss in efficiency and heavy unproductive expenses.

This Bureau has learned from 100 years of experience that economical surveying can be accomplished only with the smallest craft that can be steadily operated on the body of water under survey. It may be a small power boat for entirely sheltered waters; a small steam or motor vessel where protection is less complete; or an able seagoing vessel where there is no shelter; but in every case the size must be held down to a minimum practicable for the nature of the work. It has been found that a seagoing vessel of 1,000 tons displacement is ample for the largest operations in the most exposed localities, and hence this has been fixed as the largest vessel this Bureau is willing to operate. In order to get the necessary personnel and appliances into a vessel of this size, it is necessary to give special consideration to its design; hence, the reason why a perfectly satisfactory vessel for some other purpose does not make a satisfactory surveying vessel.

Right here it is appropriate to quote what the present commander of the *Surveyor* has to say about the Coast and Geodetic Survey's *only* modern surveying ship:

> Having been aboard this ship for about six months and aboard most of the others in the service for various lengths of time, my opinion is that the others should be junked and more like this one gotten. She has power, accommodations for the men, a large fuel capacity—there is no worry as to whether you will burn 1 ton of coal too much upon starting for port—and she can work in rough weather. We can take aboard about 1,000 barrels of oil per hour, the equivalent of 200 tons of coal, and, at the present prices of oil and coal, is cheaper to operate than other vessels of small tonnage. She has stopped and backed from 10 knots ahead over three thousand times during the past couple of months, and there is very little vibration aft. The chief engineer has reduced the oil consumption considerably; it varies from 60 to 80 barrels per day when on hydrography from 16 to 19 hours, and to about 30 barrels per day lying idle. This vessel can operate most economically when a large area is assigned to the party, so that it will be more or less independent of local weather conditions.

The Bureau now operates 11 surveying vessels between 100 and 1,000 tons displacement and 2 under 100 tons, 2 of which belong to the Philippine Government. Three only of these vessels can work in exposed localities, and the others must be employed only where shelter can be had during stormy weather. Seven of these vessels, large and small, are considered really efficient for the work on which they can be employed, and the others are only makeshifts. This is the equipment with which the Bureau must keep up to date surveys of the Atlantic, Gulf, and Pacific coasts of the United States and extend the hydrography out to the edge of the continental shelf;

survey Alaska, Porto Rico, Virgin Islands, Hawaii, and the Philippines; and make such special surveys as may be requested by other bureaus of the Government.

The Navy has no vessels suited for carrying on hydrographic work with the exception of the mine sweepers. Request has been made by this Bureau for two of these vessels and refused on the ground that they were needed by the Navy for other duties.

EARTHQUAKE PREDICTIONS VITAL TO HUMAN LIVES.

Very recently important seismological investigations have been begun by the Carnegie Institution of Washington, and by other agencies, looking toward the prediction of earthquakes. Japanese seismologists already have, to an extent, proved their ability to predict destructive shocks in areas where a detailed study of conditions has been made. Seismologists agree that earthquakes are due to an abrupt adjustment of the accumulated strains in the earth's crust, often accompanied by sudden relative vertical and horizontal displacements of portions of the earth's surface. It is believed that the strains as they accumulate, prior to the actual convulsion, may cause a gradual distortion of the surface of the earth which can be detected by geodetic methods. As a preliminary step, it is necessary to have detailed precise triangulation and levels in regions of seismic activity in order that studies may be made of gradual distortions or displacements in the earth's crust prior to shock, the character and extent of the displacements at the time of the earthquake, and the extent of the later readjustments of the portions displaced.

AERIAL SURVEYING.

The Mississippi River delta was photographed by the Air Service of the Navy during March, April, and May, 1921, for the use of this Bureau in revising the chart of this area. Office work on these photographs is now in progress.

Atlantic City, N. J., and the vicinity was photographed in July, 1919, by the Air Services of the Army and Navy, and almost the whole of the outer coast line of New Jersey was photographed in March, 1920, by the Army Air Service. Revised charts of the New Jersey coast are now being compiled, and will soon be issued, showing corrections as obtained from these photographs. An officer of this Bureau established the ground control and verified the results of the office compilation, making an examination of the photographic mosaics in the field.

The results of this work have produced some interesting and important conclusions in regard to chart revision: (1) The cost of the revision of the topography of the New Jersey coast by means of aerial photography is about one-third of the estimated cost by plane-table methods; (2) the inaccuracies to which aerial photographs are subject become negligible when reduced to a scale of 1:80,000, the scale of our coast charts; (3) no better historical record could be kept of shore-line changes than that furnished by aerial photographs, as every detail is shown.

Owing to lack of trained personnel, the Air Services of the Army and Navy have not been able so far to carry out a program of

photographing portions of the Atlantic coast as requested by this Bureau for the purpose of chart revision. The situation is improving and these services are planning to cooperate more fully in the near future.

An officer of this Bureau has devoted practically all of his time during the year to the study of this subject and in keeping in touch with developments. Instruments for use in compiling data are being acquired. In June of this year a mathematician was assigned to devote a part of his time to the study of the mathematical problems connected with aerial surveying. A draftsman was also detailed for a portion of his time in order to become familiar with the process of compilation of data from photographs. In this way preparations are being made to handle photographs as they are received from the Air Services. The nucleus of an office and field force is being formed, so that when the time comes that the Air Services will be able to make extensive photographic surveys the Coast and Geodetic Survey will be ready to do its part with a small increase in personnel and the charts of the United States will be closer to perfection, as far as topographic features are concerned, than they ever have been before.

Too much stress can not be laid on this successful method of revising our shore topography, emphasizing *accuracy*, *economy*, and *speed*. But the Coast and Geodetic Survey does not maintain airships and seaplanes, and unless there is greater cooperation from the Army and Navy Air Services valuable time will be lost in supplying for charts and maps important information for commercial purposes on sea and land.

ALASKA.

There has been much said about Alaska and the development of her resources, and while the Federal Government should give every encouragement to the upbuilding of her great frontier country the primary and important need of Alaska at the present time is a complete charting of her great area of coastal waters and control surveys and levels in her interior.

Is it not good business to safeguard in every way possible the lives and property and wealth of a country, and to establish sure and perfectly charted lanes to other markets? Is it not a good investment to make an outlay of a comparatively small sum of money to make vast wealth available?

The Coast and Geodetic Survey must have suitable ships, men, equipment, etc., so that we can as quickly as possible chart safe and well-established lanes through which commerce can pour at will. All the mines in the country would be useless, all the railroads futile, if the products could only be brought to Alaska's shores and then be lost. Enough shipping has ended fatally these past years to prove the need and advisability of locating dangerous reefs and rocks and other dangers and making accurate and safe charts.

The outstanding needs are indicated as follows:

About 7,000 square miles of water area in southeastern Alaska remains to be *wire dragged*, but a part of this area is not frequented by large vessels to-day, and may not be for some years hence. However, this work should not be delayed until some vessel is lost due to an uncharted pinnacle rock. The main steamer route will be com-

pletely dragged this year from Dixons Entrance nearly to the head of Lynn Canal. The balance of this route down Chatham Strait to Icy Strait, and thence through Icy Strait and Cross Sound to the Pacific, should be completed next year. The additional work required to be done along the deep-draft steamer route, via Sumner Strait, Chatham Strait, and Frederick Sound, probably will be completed year after next. Thereafter the drag parties will be available to take up the other steamer routes in the order of their importance. It is believed that wire-drag work in southeastern Alaska is fairly well in hand now and that we have, or will have next year, equipment for carrying this work to completion as rapidly as possible.

In Prince William Sound there is a large amount of drag work that should be undertaken as soon as equipment is available, and the need for this work is almost as urgent as for the southeastern Alaska work.

That the improved wire drag fulfills its purpose is shown by the fact that in the 4,000 square miles of water area dragged, 3,500 uncharted obstructions have been discovered, a number of which were close to if not actually on the lines of ocean travel. A fast-moving liner striking a pinnacle rock in just the right way would suffer the fate of the *Titanic*, no matter what precautions were taken.

In the matter of *offshore hydrography*, the Survey is most seriously handicapped by lack of vessels suitable for this work. From Dixons Entrance to Cape Spencer there are about 12,000 square miles yet to be surveyed. From Prince William Sound to Unalaska there are 40,000 square miles that should be surveyed immediately. All of this work requires able seagoing vessels, of which we have available just one, the *Surveyor*. It, therefore, appears that the most serious problem confronting this Bureau is the outside survey and in particular the outside surveys of western Alaska. This, for the reason that, while we yet have much work to be done in southeastern Alaska and in Prince William Sound, we have vessels that can be employed on this work and some of it can be accomplished by large launches, of which we have a few available, and will have others when the wire-drag work is completed; but on the outside work we are entirely dependent on one vessel.

This very important part of the United States has been sadly neglected. Not only are the field surveys of Alaska far in arrears, but in addition it has been impossible to produce accurate charts of many areas of which surveys have been made.

The subject of corrections of our Alaska charts presents a different but equally serious and difficult problem. The rapid development of that Territory combined with our insufficient facilities for making adequate surveys as rapidly as that development demanded has resulted in a condition from which we are still suffering and under the most favorable circumstances must continue to suffer for some years to come.

Owing to the insistent demand for Alaska charts the first surveys were rushed. They were nothing more than reconnoissances. The control was crude; signal positions were plotted graphically on the survey sheets before they were computed.

Ever since those charts were constructed we have been making surveys to be applied to them. But in order to apply such a new survey to the small-scale charts we must distort it to fit the dis-

torted chart or else construct an entire new chart to fit the survey. It is an actual fact that to-day if a wire-drag party reports a newly discovered danger by giving its latitude and longitude we can not plot it on our charts in its accurate relation to adjacent features until we know the chart or sheet from which the position was taken.

If this were the whole story, the solution of the present condition would be an immediate adjustment of the existing Alaskan triangulation and subsequent reconstruction of our charts to conform thereto. But the matter is still further complicated. We have just begun the field work on a main scheme of triangulation through southeastern Alaska and the Canadian Government is carrying a similar scheme through British Columbia, by means of which our Alaska triangulation will be connected with that of the United States. When these two measurements are completed all the southeastern Alaska triangulation will be adjusted to the North American standard datum. But to make any adjustment of triangulation prior to such completion would involve months of work, which would all have to be done over when the final connection was made.

When this triangulation is adjusted almost all of the charts will have to be made over. As we lack the draftsmen necessary to undertake this work, the preliminary adjustment could not in the near future be utilized to an extent sufficient to justify its cost to the short-handed division of geodesy. Our future policy should be to apply the essential information obtained from new surveys and to postpone further reconstruction of small-scale charts until the triangulation is completed and adjusted, by which time it is hoped that the force of draftsmen will have been increased sufficiently to enable us to take up a systematic reconstruction of all necessary southeastern Alaska charts.

I am informed that the work of the Canadian Government may possibly be completed this calendar year, and if not that we may expect its completion in 1922. In my opinion, therefore, it now becomes of first importance that the divisions concerned study this subject carefully to ascertain precisely what additional data are needed for a complete adjustment of all southeastern Alaska surveys, to the end that any field work which may be required for supplementing our present control data may be furnished this office by the time the Canadians furnish their part of the task. The control is needed along the whole Alaskan coast, and should be rapidly completed.

In the interior of Alaska we have no fundamental control surveys whatever. This is not a creditable condition of affairs. The U. S. Geological Survey, the General Land Office, and the Forest Service are carrying on their operations in furthering the industrial and commercial development of Alaska, but are badly handicapped by lack of accurate latitudes, longitudes, and elevations for the proper location of surveys and maps.

Every year's delay in starting the control surveys in Alaska aggravates the confusion and retards the surveying and mapping of the area which are so essential to its development.

The yearly increase in the productivity of Alaska, resulting from the control surveys, will be greater than the entire cost of these surveys.

HAWAIIAN ISLANDS.

The increased commercial importance of the Hawaiian Islands makes it desirable to carry on hydrographic surveys in the waters surrounding them. At present there are many parts of the island coasts along which there are no soundings whatever and the water between islands is frequently inadequately surveyed. There are many places in the waters surrounding the Hawaiian Islands at which current observations should be made.

The more adequate charting of the waters of the Hawaiian Islands and of the reefs to the westward of this group is necessary both to save life and property and to save time to the ships in sailing from island ports to various points in the Pacific. There are many places where the waters are dangerous because of submerged reefs while at the same time there are undoubtedly safe channels between the reefs, but in the absence of accurate charts the navigator does not dare venture in the dangerous zone.

This matter of charting the waters of the Hawaiian group is of such importance that urgent appeals have been made to the Coast and Geodetic Survey by the governor of the islands and by commercial bodies at the important ports of the group, requesting that the completion of the charting of the Hawaiian waters be expedited.

In addition to the charting of the waters there is work ashore in the form of primary triangulation to properly coordinate the charts and maps of the several islands. Without this precise control the charts and maps of the group can not be carried on to the best advantage.

The U. S. Geological Survey, in cooperation with the Territorial government, is now making topographic maps on some of the islands and in this work triangulation which has been done by the Coast and Geodetic Survey and by the government of the Hawaiian Islands before annexation to the United States, is being used. This triangulation has never been properly computed and adjusted and this should be undertaken at an early date. The expense would be small, but the benefits to the charting and mapping would be very great.

Practically no work has been done in the Hawaiian group for a number of years by the Coast and Geodetic Survey because of lack of proper equipment and inadequate funds and also because of the necessity of using such equipment, funds, and personnel as we have on the coastal waters of the United States and Alaska, but the time has certainly arrived when this neglect of the Hawaiian Islands should cease. Their importance to the country is very great, as is shown by their commerce, and it would seem that some part of the activities of the Federal Government should be directed toward giving the islands the charting and mapping facilities needed in their further industrial and commercial development.

OCEANOGRAPHIC RESEARCH ESSENTIAL TO NATION'S WELFARE.

Another subject that should receive early attention by this Bureau is ocean surveys. From 1845 until 1860 the Coast and Geodetic Survey, then known as the Coast Survey, employed one or more vessels almost continuously on deep-sea hydrography in the Atlantic Ocean contiguous to our coast and principally along the Gulf Stream.

This work was interrupted between 1860 and 1867, but was then resumed and was carried forward with only short interruptions until 1890. Since that time this Bureau has made only minor contributions to our previous knowledge of the deep waters off our shores, and through which all our shipping, except the coastwise, must pass. The earlier work was performed mostly from sailing vessels and with such crude apparatus that incomplete and often contradictory results were obtained. The later work, particularly that of Mitchell, Sigsbee, Bartlett, and Pillsbury, was excellent, but was, of course, limited in detail to the capacity of the instruments that had been devised up to their time. This work, however, was confined to the Atlantic Ocean, Gulf of Mexico, and the Caribbean Sea, and principally to an exploration of the Gulf Stream; it was discontinued, not because sufficient information had been obtained or any of the large problems of oceanography had been solved but because vessels were no longer available for this work and also to carry on inshore surveying, the demand for which had been insistent. Consequently, investigations in oceanography had to give way to hydrography that was more urgently needed than by our merchant marine.

Since the war there has developed a very urgent demand for more exact information concerning the oceans, and in particular the Atlantic and the Pacific. This demand comes from scientists as well as from mariners, fishermen, and cartographers, and the information sought concerns the advancement and welfare of the country in many respects. There would result from a better knowledge of the oceans direct savings from a decreased loss of ships, their passengers, and cargoes, from shorter and quicker passages, and from reduced passenger, freight, and insurance rates because of the greater safety. There would result a better knowledge of the present fishing banks, the discovery of new fishing banks, and a better knowledge of the distribution and movement of food fishes and of their food, which would have an enormous economic value to the country. A better knowledge of the configuration of the ocean bottoms, of the materials deposited upon those bottoms, and of the ocean currents may result in discoveries that will materially modify our ideas of some of the laws of nature. Meteorology is believed to be closely related to ocean conditions, and it seems more than probable that systematic observation of meteorological data over the oceans will contribute to more complete and more dependable weather forecasts.

Ocean surveys should be resumed in the Atlantic for the purpose of supplementing and extending our earlier surveys. Unexplored areas off our coast should be examined and a sufficient number of soundings taken to give at least a general knowledge of the relief of the bottom. Where the earlier surveys are known to have been made with crude apparatus and by doubtful methods, a reexamination should be made to verify the earlier work and, if found to be appreciably in error, these areas should be resurveyed. Accompanying the hydrography there should be taken a sufficient number of observations of current, density, temperature, and salinity to permit a thorough study of the ocean currents. These are the phases of oceanography that come properly within the scope of activities of

this Bureau, but there appears to be no reason why other investigations in oceanography could not be conducted at the same time at small additional cost by scientists detailed to the party from the bureaus having cognizance of such subjects.

In the Pacific the same lines of investigation should be carried out, but there even a beginning has hardly been made; the areas of totally unexplored ocean are of vast dimensions. There is reason to believe that fishing banks of which we have no reliable information may lie just outside our coastal waters; the supposed locations of these banks should be investigated without delay. Off the southern California coast and also westward from the Hawaiian Islands are dangerous reefs in the track of our shipping. Until these and other uncertain areas are thoroughly explored we may expect unavoidable wrecks and loss of life.

Within the last few years great advancement has been made in instruments for precise measurement of ocean currents, temperature, and salinity; and by means of radio communication and radio direction determination the position of a vessel at sea can be fixed with far greater accuracy than was possible at the time of our last oceanographic work. We are therefore justified in expecting much more accurate investigation in oceanography now than has ever been possible heretofore.

The Pan-Pacific Scientific Conference which met at Hawaii during August, 1920, adopted the following resolution:

Oceanographic investigations yield results which constitute a basis essential for scientific exploration and research in the Pacific region, notably in meteorology, geology, botany, and biology. Moreover, such investigations are of importance to navigators in disclosing dangers to vessels sailing the ocean, and are of economic value in enabling vessels to save time and fuel in their navigation.

The present knowledge of the oceanography of the Pacific is deficient in every branch, and constitutes but a meager array of data scattered widely.

In the oceanographic investigation of the Pacific waters the configuration of the bottom should be determined, specimens of the bottom deposits collected and their thickness and stratification revealed, the physical and chemical characteristics of the water at different depths and times determined, and the horizontal and vertical circulation of the waters observed.

The field work involved in such investigations must be carried on almost entirely by the governmental hydrographic organizations of the countries bordering on and contained within the Pacific Ocean, owing to the great expense involved in creating new and special agencies, and because the governmental agencies have the personnel trained in this work. Those carrying on oceanographic surveys in the Pacific should avail themselves of the services and advice of individuals and organizations dealing with those branches of science depending upon the results of such surveys.

This conference feels that a systematic oceanographic investigation of the Pacific should be undertaken as soon as possible.

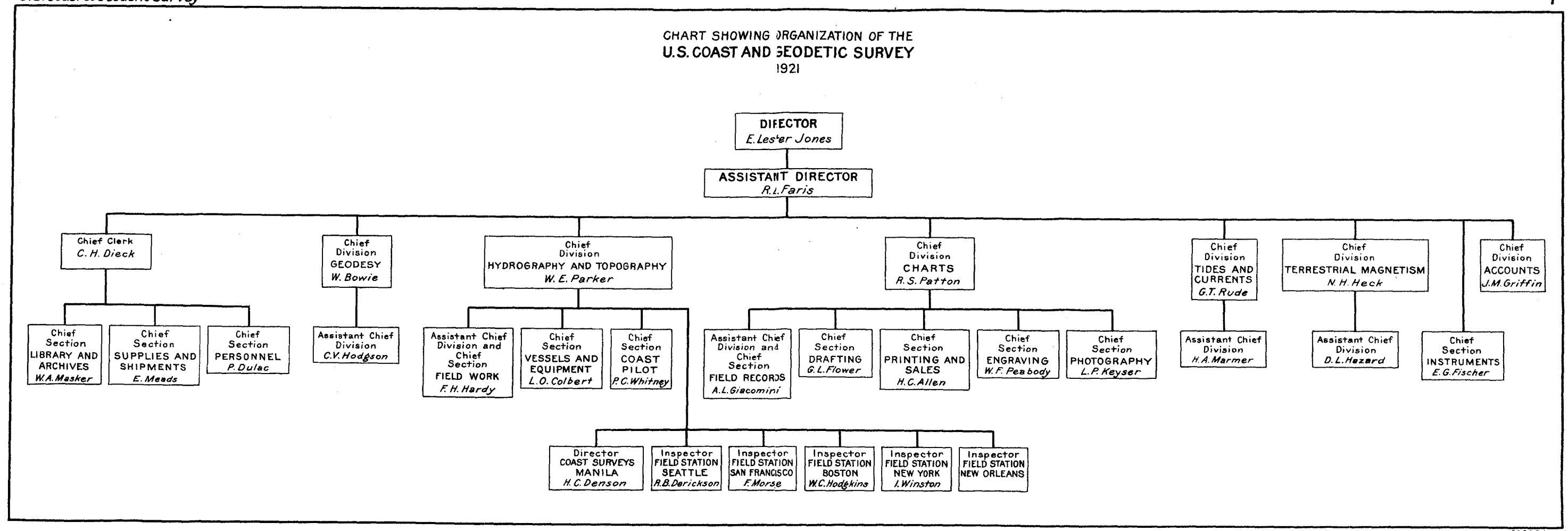
The plan adopted should be designed to complete the survey of the most critical areas at an early date, and eventually the whole Pacific region.

To undertake this work a vessel specially adapted is essential, and it should be kept continuously on the work, in order to accomplish definite results, much that the country should already know about.

The failure to have undertaken oceanographic work years ago only emphasizes the fact that soon our country will be looking for certain information regarding the seven seas, just as the farmer seeks information about his land, and it will not be available. The work should not be put off.

U.S. Coast & Geodetic Survey

Effective Oct. 15, 1915
Revised to Oct. 5, 1921



C.&G.S. Print

Part II.—THE WASHINGTON OFFICE.

CHAPTER I.

ACCOMPLISHMENTS IN THE WASHINGTON OFFICE DURING THE FISCAL YEAR.

The organization of the Washington office of the Bureau is presented by the organization chart opposite. The accomplishments during the fiscal year by divisions and sections follow.

DIVISION OF GEODESY.

The following important pieces of work were completed during the fiscal year or were in progress at the end of the year.

The computation and adjustment of the following pieces of triangulation:

1. Precise triangulation in the Yuma district, Ariz.
2. Precise triangulation from the eastern oblique arc to Sanford, Calif.
3. Precise triangulation along the Rio Grande arc, Tex.
4. Precise triangulation from the vicinity of Waco, Tex., to Mansfield, La.
5. Precise triangulation along the California-Oregon arc.
6. In Florida (complete to date).
7. In Massachusetts (complete to date).
8. In North Carolina.
9. In New Jersey.
10. In Virginia (field work by Virginia Fisheries Commission).
11. Along the Potomac River.
12. In New York.

In connection with the triangulation listed above, the computation of the following base lines:

1. Jacksonville base, Tex.
2. Belen base, Okla.
3. Savanna base, Okla.
4. Eight bases along the coast of North Carolina.

The computation of the following lines of precise traverse:

1. North Vernon to South Bend, Ind.
2. Beloit, Wis., to Vandalia, Ill.
3. Beloit to Racine, Wis.
4. Memphis, Tenn., to Little Rock, Ark.
5. Sanford to Wilmington, N. C.
6. Pascagoula to Boonville, Miss.

The computation and adjustment of the following lines of precise levels:

1. Tenaha to Gallatin, Tex.
2. Hillsboro, Tex., to Natchez, Miss.
3. Klamath Falls to Ontario, Oreg.
4. Rockford, Ill., to Prairie du Chien, Wis.
5. Weed, Calif., to Auburn, Wash.
6. Rockton to Vandalia, Ill.
7. Portland to Astoria, Oreg.

The computation of the following astronomic stations:

1. Preliminary results for field use at 44 azimuth stations.
2. Final results at 88 azimuth stations.
3. Final results at 36 latitude stations.
4. Final results for 13 differences of longitude.

The preparing of the manuscript and proof reading of the following publications:

1. Special publication No. 67: Latitude developments connected with geodesy and cartography, by O. S. Adams.
2. Special publication No. 68: Elements of map projection, with application to map and chart construction, by C. H. Deetz and O. S. Adams (in cooperation with the division of charts).
3. Special publication No. 69: Modern methods for measuring the intensity of gravity, by C. H. Swick.
4. Special publication No. 70: Triangulation in Kansas (supersedes appendix 3, report for 1902).
5. Special publication No. 71: Relation between plane rectangular coordinates and geographic positions, by W. F. Reynolds.
6. Special publication No. 75: Radio-compass bearings, by O. S. Adams.
7. Special publication No. 74: Utah-Washington arc of precise triangulation, by C. V. Hodgson (in press).

The manuscripts for several other publications are in course of preparation and at least two of them are ready for publication, namely, Triangulation in Massachusetts, and Precise Leveling in Texas.

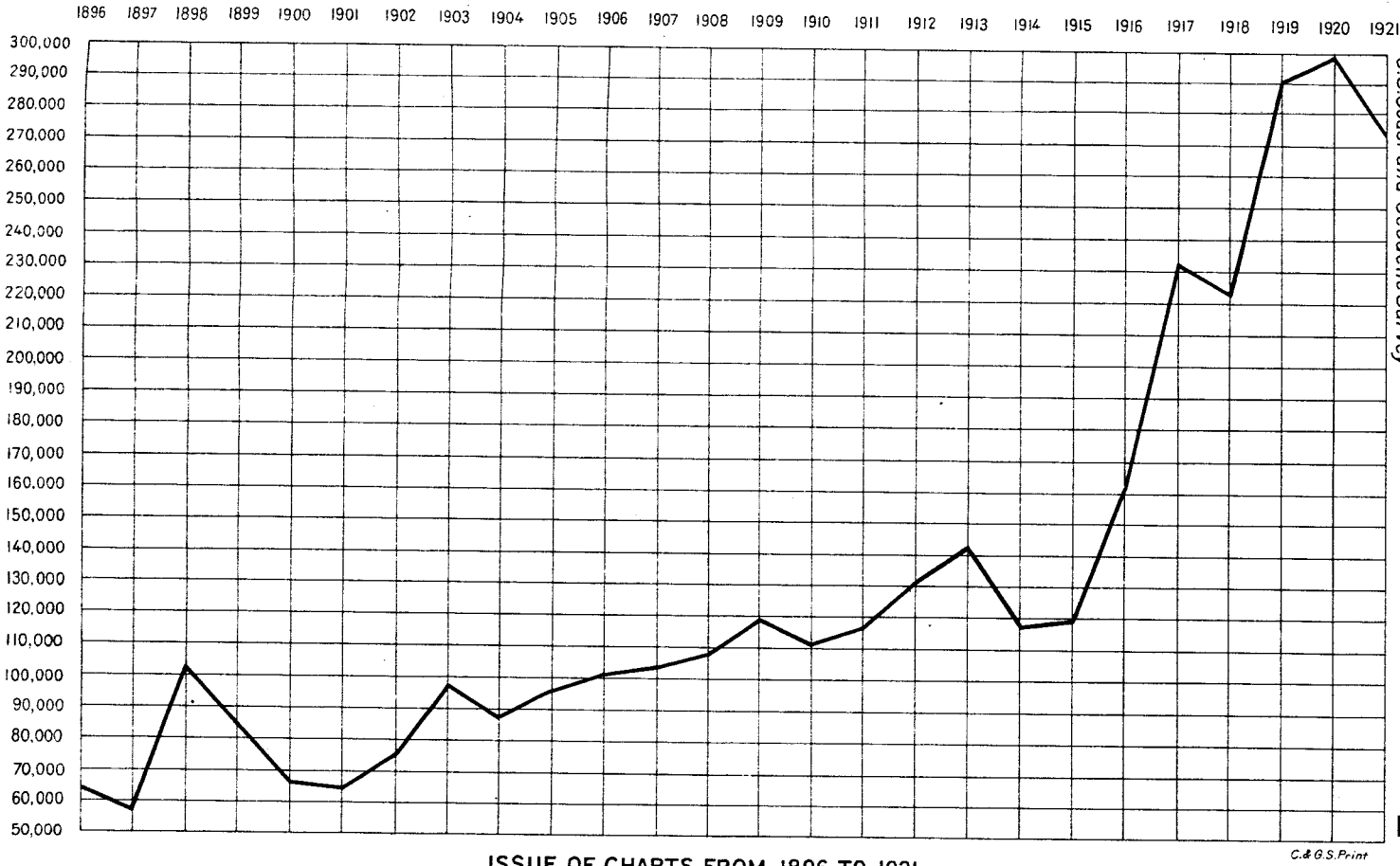
In addition to the routine work of the division, several special problems have been studied and investigations made. These include a study of the movement of the earth's crust in the earthquake region of California, a study of earth dynamics in connection with the Stokes theorem, and a continuation of the study of map projections.

This Bureau has become one of the leaders of the world in geodetic work largely because the methods for carrying on the work are being improved continually by careful study and experiments, both in the field and office. A scientific bureau like this must devote a part of its energies to this class of work if it would progress rather than retrograde.

The number of computers or mathematicians, who were assigned to the division of geodesy at the Washington office, varied slightly from month to month during the year. The average force during the year was 18.6 persons .

Whenever an engineer from the field was brought to the Washington office, after a season's work on geodesy, he was assigned to the division of geodesy, but these field engineers were engaged most of the time while here in preparing reports on their past season's work, in completing their field records, and in preparing for a new season's work. Very little work, therefore, was done by them to supplement what is being accomplished by the regular computing force.

The duties of the division of geodesy at the Washington office consist largely of the administration of the office and field forces; the computation and adjustment of triangulation, including astronomic observations; the computation and adjustment of precise leveling; the computation of field observations made for the determination of the intensity of gravity and researches in the subject of isostasy in which gravity determinations play an important part; geophysics in the form of research of the subject of the strength of the earth's crust or isostatic shell and certain physical properties of the material of that shell; and furnishing information to officials of



ISSUE OF CHARTS FROM 1896 TO 1921

the Coast and Geodetic Survey and other Government organizations and to the public in response to written or oral requests.

As soon as practicable after the computation and adjustments of the field observations are made at this office, the results are printed in order that they may be available for general use.

DIVISION OF HYDROGRAPHY AND TOPOGRAPHY.

This division has supervision of all hydrographic and topographic surveys executed by the Bureau, which supervision includes determination of where surveys or resurveys are required, how they shall be conducted, the preparation of instructions for surveying parties, the organization of the parties, the examination of the records, and inspection of field work. The division is also charged with the construction, maintenance, and repairs of the vessels and other field equipment (except instruments), the records of the seamen employed on this work, and the compilation of the coast pilot in the field and office.

The division also has supervision over the five field stations located at Boston, New York, New Orleans, Seattle, and San Francisco, respectively, and over the office at Manila, P. I. The field stations are for the purpose of maintaining close relations between the Bureau and those who have occasion to use its charts, publications, and data, and to keep the Bureau informed of the needs for further work in these general localities. The office work incident to the above duties was kept current during the year.

DIVISION OF CHARTS.

The energies of the division during the year have been devoted, first, to keeping our charts in print and keeping them corrected from all new information received in the Bureau; and, second, to striving for improvements in facilities, processes, and morale, so as to increase our production without any corresponding increase in expenditure.

Under the first heading the division has lived up to the admirable record of previous years. Back orders have been kept down, in general, to a few charts at a time, and these have been on the back-order list for short periods only. Information that has come to the office necessitating the correction or addition to charts has been applied promptly. There has been considerable increase in such information received during the year, due, no doubt, to renewed activities by the various governmental surveying organizations.

ISSUE OF CHARTS.—As was expected, the prevailing stagnation of the merchant marine has been reflected in a reduction of the number of charts issued during the year, though the reduction was less than had been anticipated. Slightly less charts were issued than in 1919 or 1920, but aside from these two years the issue for 1921 was the largest in the Bureau's existence. The following shows the issues for the years from 1916 to 1921: 1916, 176,395; 1917, 248,144; 1918, 236,577; 1919, 302,155; 1920, 316,699; 1921, 290,188.

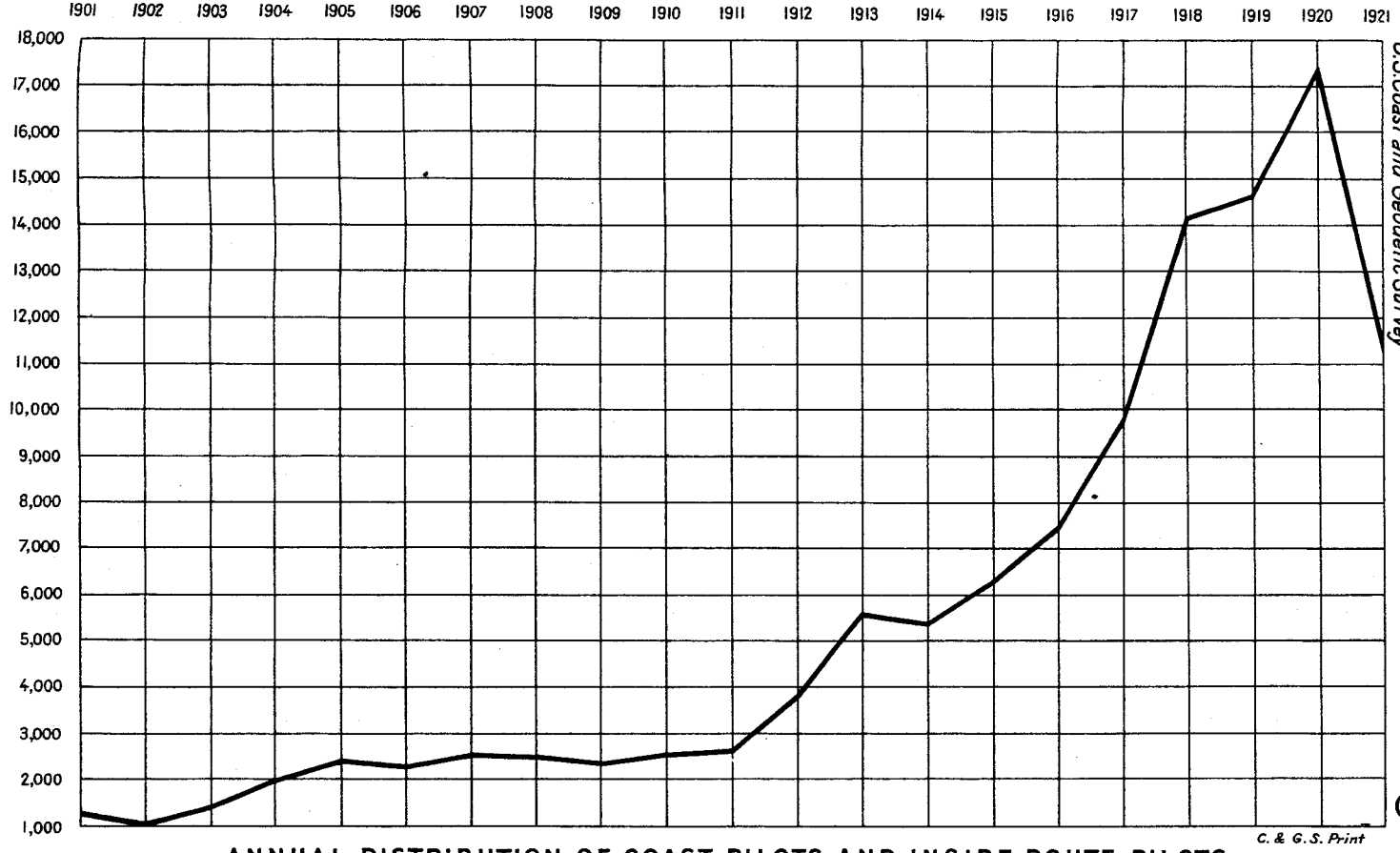
The diagram opposite graphically presents the issue from 1896 to 1921, inclusive. The largest item in the reduction of issue of charts was in the issue to the Shipping Board, which fell off from 21,707 in 1909 and 25,843 in 1920 to 6,400 in 1921.

ISSUE OF COAST PILOTS, INSIDE ROUTE PILOTS, AND TIDE TABLES.—The same influence that diminished the distribution of charts, the prevailing stagnation of the merchant marine, has also shown its effect in the distribution of coast pilots, and from a distribution of 15,261 in 1920 the issue fell off to a distribution of 8,728 in 1921. The diagram opposite presents graphically the distribution of coast pilots from 1901 to 1921, inclusive. The issue of Inside Route Pilots, instead of decreasing has increased, the issue for 1921 being 2,655 or 571 greater than for any other year. There was a slight decrease in the distribution of tide tables, though not material, the issue for 1920 being 24,887 and the issue for 1921 being 24,212.

CONSTRUCTION OF NEW CHARTS.—Although the construction of a new chart (involving the assembly of data, drafting, engraving, and printing), is not an entirely satisfactory unit of measurement of progress because the details for each new chart are not uniform, the progress in the construction of new charts during the fiscal year is very gratifying. This is due in a large measure to a program that was adopted on September 18, 1920, with the object of both expediting and increasing our production of new charts. Preceding the adoption of this program a tabulation of the cost in time and money of producing 11 new charts published during the year had been made. The most striking fact brought out by this tabulation was the length of time required to produce a new chart. The longest time required was 54 months, the shortest 15 months; the average for all charts was 27 months; for engraved charts, 35 months; and photolithographed charts, 22 months. This lapse of time was out of all proportion to the actual cost of producing the chart. Each chart required an average of seven to eight months of actual working time to produce.

This excessive lapse of time was due to the fact that preference must be given to correction of existing charts and because of these interruptions the actual time required to produce charts was increased by approximately 15 to 20 per cent. To improve this situation a definite program was drawn for the work during the fiscal year. The program called for the production of 19 new charts. The program was drawn with the end in view that each man should be kept continuously on one job until he had finished it. The success of the plan laid down in the program exceeded expectations. The program was necessarily modified for reasons beyond the control of those in administrative charge of the division, yet in spite of these modifications it was completed during the year. Although the program was necessarily somewhat in the nature of an experiment, it has demonstrated the value of the idea of giving the division as a whole a definite objective for the year's work, and in so far as possible of giving each employee in the division a definite part of that work to perform.

The following table compares the production during 1921 with other recent years during which the great increase in the demand for charts has so materially increased the work of the division. In this table Philippine Island charts are listed separately, as these charts are drawn in Manila and the work of the Washington office is confined to their printing.



ANNUAL DISTRIBUTION OF COAST PILOTS AND INSIDE ROUTE PILOTS

Produced at—	1916	1917	1918	1919	1920	1921
Washington	10	11	12	7	12	18
Manila	2	1	3	2	3	4
Total	12	12	15	9	15	22

Below is a summary of the chart work completed during the year:

Compilations of new charts	13
Compilations of reconstruction of 10 old charts in terms of compilations of new charts	7.3
Smooth drawings of new charts	9
Smooth drawings of reconstruction of 7 old charts in terms of smooth drawings of new charts	7
Drawings for extensive corrections to charts	113
Drawings for minor corrections to charts	711
Changes in aids to navigation and dangers indicated for hand corrections	2,985
New charts or proofs from new copper plates on which complete aids were plotted	72
Proofs of charts verified or on which corrected areas were indicated	1,432
New drawings from Manila prepared for publication	4

The following is a summary of the chart work in hand at the close of the year:

Compilations of new charts	7
Compilations of new charts, work suspended awaiting surveys	2
Compilations of reconstruction of 1 old chart in terms of new charts	1
Smooth drawings of new charts	3
Smooth drawings of the reconstruction of 3 old charts in terms of smooth drawings of new charts	2.4
Drawings for extensive corrections to old charts	5

The new chart production for 1921 is a 50 per cent increase over any one year and a 73 per cent increase over the average for the period on which a comparison may fairly be based. It is to be noted particularly that this result was accomplished while handling, without slighting, a greatly increased amount of correction work.

PHOTOLITHOGRAPHIC REPRODUCTION OF ENGRAVED CHARTS.—An improvement of first importance in our methods of reproducing charts from engraved copper plates has been worked out during the year. Our previous method of lithographic reproduction from copper was to pull an impression from the copper plate upon a specially prepared paper which was then laid down on the aluminum printing plate and run through the press, thus transferring the work from paper to plate. This method was defective in two respects, first, the printed chart was distorted, the distortion in some cases amounting to as much as 3 per cent; this was due to the fact that the transfer paper used was so light that in stripping it from the copper plate it was pulled out of shape. Second, the method involved a considerable duplication of correction work in the engraving and printing sections. Each time a chart was reprinted corrections were made to the printing plate by the lithographic draftsman. With a lapse of time, however, it becomes necessary to produce a new printing plate either because the existing plate has become imperfect with use, or because extensive new information has been received which can not readily be applied directly to that plate. When either of these contingencies occurs the copper plate must be corrected for all in-

formation received since it was last used in order that a new correct impression may be pulled from it for use in the transfer. Furthermore, the correction of the copper plates is a tedious and laborious process and any method which materially reduces the amount of such correction will result in a considerable saving.

By the new method the paper used in making the transfer is an unsensitized, highly glazed bromide paper. This paper is first coated on the back with a solution in water of flour, starch, glycerine, and gelatine, which is allowed to dry. In wetting the paper, as is necessary for it to pull the ink from the copper plate, this adhesive solution becomes tacky. In pulling the impression the paper is first laid on the copper plate and over it is placed a sheet of heavy blotting paper. When run through the press these two papers stick firmly together and the combined strength of the two is such that there is no distortion in pulling the paper from the plate, while the dry blotting paper prevents any subsequent change in the wet bromide paper as the latter dries.

The result is a sharp intensely black impression of the work on the copper strongly contrasted against the glazed surface of the paper furnishing an ideal subject for photolithography. From this point the process is similar to the regular photolithographic method, the one point to be noted being that much less work is required in recutting these negatives than is necessary for negatives of vellum tracings. By this method, therefore, the distortion which hitherto existed in charts produced either directly or indirectly from copper is entirely eliminated. Our charts are now, at least from the point of view of the navigator, true to scale.

The duplication in correction work will also be greatly reduced. Corrections which formerly made it necessary to bring up the copper plate can now be made on the negatives. Some corrections will still have to be made on copper, but these will occur at much more infrequent intervals where the correction is so extensive that in a photolithographic chart they would require a new drawing. Here no duplication should be involved, as such a correction would not be made in the printing office.

This method is probably the best of those in use in this office for the production of new charts for the following reasons: First, the work of the past year has demonstrated that on the average chart where the hydrography predominates and where the topography is much simplified and generalized a new chart can be engraved about as cheaply and as rapidly as a vellum tracing can be made. Second, the copper is permanent and a plate would be in good condition long after the vellum tracing is worn out. Third, corrections must still be made occasionally on either copper or vellum. On the vellum, as a rule, not more than one correction can be made in any given area, whereas by means of the electrotyping process the number of corrections in any area on the copper is unlimited. Fourth, we sometimes receive corrections so extensive that it is cheaper to make a new tracing than to attempt to correct the existing one. This, of course, means redrawing much information which is still correct on the old tracing. By means of the electrotyping process these corrections can be made on copper probably in somewhat greater time but at less cost than that of the new tracing. Fifth, the copper

plate is a valuable insurance against loss by fire or accidental damage to tracing or negative. We have to-day in our files tracings which would have to be made over if one of the negatives from them should be accidentally broken.

This method has been on trial for almost a year, and it is considered that its practicability and value have been demonstrated. Nineteen charts are now on plates produced by this process, and their number will be increased as rapidly as the facilities of the Bureau will permit. It should be noted that this method involves an increase in the work of the lithographic draftsman and in consequence that its extensive adoption will necessitate an increase in that force. It is believed, however, that such an increase can be made at the expense of the drafting and engraving sections without involving any net increase of the personnel of the division.

NEW CAMERA.—A camera for the production of photolithographic negatives is now in operation. This camera was designed and plans drawn in this Bureau along lines suggested by the Bureau of Standards and with the cooperation of that bureau. Its design includes some novel features not usually incorporated in cameras for this work.

The two essentials to good photolithographic negatives are sharpness of definition and accuracy of scale. The former is secured by properly timed exposures through a good lens. To secure the latter the drawing in the copy holder must be accurately parallel to the sensitized plate. In order to secure this condition in the new camera the depth of the box to which the plate holder is attached has been considerably increased and the box is screwed firmly to the base upon which the camera rests; focusing being accomplished by moving the front box carrying the lens. The copy holder is capable of minute adjustment by means of bolts at the ends of the beam against which it rests.

The use of this camera has materially facilitated our photolithographic production of charts. Our negatives are now exact to scale and match perfectly, whereas with the previous camera we had considerable difficulty, not only having frequently to make over negatives a second or third time, but also being compelled to make arbitrary junctions where the negatives did not join properly. Before, where one negative of a set of four or six was bad, the whole set had to be made over; now we can make over that one negative with assurance that it will fit the others.

ENGRAVING SECTION.—The work accomplished by the section during the year and that in hand at its close is as follows:

New plates for new charts finished	6
New plates for new charts in hand	5
New bassos for new editions finished	15
New bassos for new editions in hand	8
New bassos for reissues finished	13
New bassos for reissues in hand	4
New editions using printing plates for new editions finished	9
New editions using printing plates for new editions in hand	2
Extensve corrections applied to plates	195
Extensive corrections applied to plates in hand	5
Minor corrections applied to plates	186

PHOTOGRAPHIC SECTION.—The following is a comparison of the work accomplished during the fiscal year July 1, 1920, to June 30, 1921, with similar items for the four years preceding:

	1917	1918	1919	1920	1921
Glass negatives made	1,109	1,208	1,592	1,481	1,741
Velox prints made	3,413	1,761	2,430	1,345	2,685
Bromide prints made	391	489	359	322	353
Blue prints made	1,921	1,513	1,824	993	1,195
Photostat prints made	19,017	11,550	22,476	16,416	14,115
Lantern slides made	208	109	88	45	60
Matrices made	96	52	18	108	120
Redeveloped prints	197	267	.....	79	64
Prints mounted	63	118	39	214	152
Charts, maps, etc, mounted	.....	.....	.....	.....	152
Negatives developed, films	41	22	235	10	47
Negatives developed, rolls	.....	.....	.....	.....	16
Photolithographic negatives for charts	29	110	354	590	830

DIVISION OF TERRESTRIAL MAGNETISM.

The results of observations made at the Sitka and Tucson observatories during 1917 and 1918 were submitted for publication and proof of the publications was read. The reduction of the results of observations at the Porto Rico Observatory for the same period was completed and prepared for publication. The correction of the horizontal intensity results at Cheltenham, required by the fact that the magnet of the variometer was not in the prime vertical, was made and the reduction of the results was completed.

The reduction of the results of all of the observatories for 1919 was nearly completed and good progress was made with those for 1920.

The results of field observations made during 1920 were revised and published as Special Publication No. 72. Revision was made of the comparison observations at the observatories for standardization of instruments.

The earthquakes recorded during the year have been tabulated and published month by month in the Monthly Weather Review.

A new edition of Directions for Magnetic Measurements, involving considerable changes and additions, was prepared and sent to the printer just before the close of the fiscal year. To meet the continued demand for Special Publication No. 33, Distribution of the Magnetic Declination in the United States for 1915, a reprint of that publication was ordered.

An examination was made of the results of absolute observations of horizontal intensity at the different observatories to determine whether there was a systematic change of distribution coefficient with time and also to determine whether the temperature coefficient required any modification.

Comparison was made of the activity of the earth's magnetism in 1915 at the Cheltenham and Seddin magnetic observatories and the results were presented in a paper at the annual meeting of the section of terrestrial magnetism and electricity of the American Geophysical Union.

Instructions in the use of field instruments were given to J. T. Watkins, hydrographic and geodetic engineer, W. N. McFarland, computer, and Commander Rose, of the Coast Guard, in preparation for their expected assignment to field work in terrestrial magnetism, and the instruments intended for their use were tested.

Data for various special investigations were supplied to the department of terrestrial magnetism of the Carnegie Institution of Washington. A table of values of the magnetic declination at principal places in the United States was prepared for the 1922 edition of the World Almanac.

The volume of correspondence was about the same as in past years, although a considerable number of requests for magnetic data were received as a result of the issue of the digests of geodetic publications for individual States.

Compass data were supplied for 100 charts.

DIVISION OF TIDES AND CURRENTS.

The growing importance of the tidal and current work of the Survey rendered advisable the creation of the division of tides and currents out of the section of that name. This change was made on December 15, 1920. The work of this division is comprised under the following heads: Tidal observations and computations; advance prediction of tides and currents, and preparation of the annual tidal and current tables; current observations and computations; tidal and current surveys of our principal harbors; physical oceanography, and the preparation of technical publications dealing with tides, currents, and related phenomena.

Tidal observations and reductions were made at seven principal stations on the Atlantic coast, three on the Gulf coast, three on the Pacific coast, and three in Alaska.

Observations and reductions of currents were made at 10 light vessels on the Atlantic coast and 5 on the Pacific. Computations on the relation between wind and current were made for the light-vessel observations on the Pacific coast, in order to correlate wind and current for the preparation of current diagrams for the aid of the navigator in estimating the current due, both to tide and wind effects, to which his vessel is subject. The results of this work are of prime importance to shipping on that coast, and will appear as a separate current table for the year 1923, the tables for 1922 having already been issued.

The predictions of tides and currents for the 1922 tide tables were made and the manuscript submitted for printing in three separate parts: Tide Tables, Atlantic Coast; Tide Tables, Pacific Coast; and Tide Tables, United States and Foreign Ports. These publications are now available for distribution.

In connection with the publication of the tide tables for 1922, alterations were made in the presentation of the predictions, with a view to making them more easily used, and more uniform in appearance—the high and low waters, and the time and height being given in separate columns.

The following table, showing the number of copies of the tide tables issued for each year, is indicative of the usefulness of these publications:

Tide tables for year.	General tide tables.	Atlantic coast tide tables.	Pacific coast tide tables.	Total.
1915	1,776	2,291	10,989	15,056
1916	1,195	2,682	10,565	14,442
1917	1,847	3,998	13,560	19,405
1918	3,331	3,997	13,959	21,287
1919	3,945	4,465	14,952	23,362
1920	3,474	5,252	15,738	24,464
1921	3,258	4,784	14,645	22,687

The above table, however, does not show to the full the value of the Survey's tidal and current predictions to the public; for many thousands of private tide tables copied *directly* from Survey tables are annually issued all over the country. These appear as separate tide tables for different localities, and in almanacs and calendars. Some are sold and some given away in the form of advertisements, all reaching the public in useful form. In addition, the public receives the benefit of these predictions, through the medium of the daily newspapers, a great many of which publish them in their columns.

DIVISION OF ACCOUNTS.

The total disbursements from July 1, 1920, to June 30, 1921, were $1,962,998.46, which sum does not, however, represent the expenses for the fiscal year. The itemization of the expenditures under each appropriation is reported to Congress in a special report later when all accounts for the fiscal year have been received.

These expenditures were made throughout the United States, Alaska, Hawaii, Porto Rico, the Philippines, and the Virgin Islands. From 30 to 50 chiefs of party were engaged on field work at various times, being financed through advances made to them by the disbursing agent.

CHIEF CLERK.

The principal duties of this division are the care, custody, and upkeep of the buildings occupied by the Bureau; the supervision of the expenditures from the appropriation for office expenses, including the purchase of supplies for the office, for chart printing work, and to some extent for the field; the care and custody of most of the original records of the field surveys, as well as the library of printed publications kept for the use of the Bureau; the general supervision of all matters relating to the personnel work of the Bureau, including records of leaves of absence taken; the custody and accounting for the receipts for the sale of charts and publications, etc.; and the direction of the watch, engineer, electrician, labor, and messenger force of the Bureau and other employees connected with the care and protection of the buildings.

The more important accomplishments during the year have been: Planning the thorough renovation of the buildings occupied by the Bureau. This work has been partly accomplished. Forty rooms

and six halls (a total area of 54,795 square feet) have been thoroughly cleaned and painted. By the aid of an electric-driven floor-surfacing machine the floors of some very unsightly halls have been cleaned of the upper surface of dirt and grease, and old paint and the exposed clean surface of the wood has been dressed with linseed oil and shellac, so that the halls now present a very pleasing and sanitary appearance; the poorly arranged electric wiring in many rooms has been removed and replaced by indirect lighting that yields the same luminosity in every part of the rooms without casting shadows and with practically the same cost in consumption of electric current as when the inefficient glaring lights were used. Some alterations have been made in the buildings that have decidedly improved working conditions and expedited the conduct of business. Most important of these is the removal of one of two stairways where both served the same purpose in the Butler Building and using the resulting space for library stacks, thus relieving the serious congestion in the library, and by cutting two doorways making all parts of the library accessible without long detours. A contract was placed to install modern shelving in one of the rooms of the library in which are stored on wooden shelves the original field records of the Bureau, which cost probably more than $1,000,000 to produce, and which could not be replaced short of resurveys. With this modern shelving the fire hazard will be practically eliminated. Another improvement was the building of a short and inexpensive bridge joining the printing office of the chart-paper storage room and the rear Richards Building, thus permitting the chart paper to be loaded on trucks in the storage rooms and wheeled directly to the printing presses, whereas before it was necessarily carried by hand over a long detour up and down flights of stairs. Alterations that permit the more expeditious conduct of business were also made in the rooms occupied as the Director's office and in other parts of the buildings.

Legislation has been enacted authorizing the Survey to obtain heat and light from the Capitol Power Plant. The necessary installations to permit this are practically completed. It is quite certain that there will be a very considerable ultimate saving to the Government, as it is understood that the steam generated by the Capitol Power Plant is practically a by-product. Heretofore, the eight buildings occupied by the Survey have been heated by four low-pressure boilers, involving the purchase of coal, employment of firemen, and the removal of ashes, as well as the upkeep of the heating plants.

It is worthy of mention that the cost of the care, maintenance, upkeep, and operation of the buildings occupied by the Bureau has been reduced from 44 cents per square foot for the fiscal year 1920 to slightly more than 29 cents per square foot for the fiscal year 1921.

An activity during the year somewhat apart from the general routine of the duties of the office of the chief clerk has been to place the data resulting from the surveys by the Bureau more readily at the disposal of the public. The triangulation stations, magnetic stations, and bench marks resulting from surveys made by this Bureau in the interior of the country are very numerous, and in published form many large volumes are required to contain the data regarding them. For example, there are five quarto volumes containing the results for the State of Illinois, weighing 14 pounds,

containing a total of 2,370 pages and costing $3.06 to print. Formerly when a request was made for data resulting from our surveys in the State of Illinois the custom was to send some or all of these volumes to supply the information. To provide a definite guide or index to our results a small and inexpensive digest has been prepared. This digest costs about 3½ cents to print. It contains a base map of the State showing graphically where our surveys have been made and a tabular arrangement of the counties of the State, the places in the county where surveys have been made, and the publications of the Bureau containing the results. Now when an inquiry is received one of these digests is sent the correspondent, and he is enabled to find exactly what he wants without any guesswork resulting in a request for more or less costly publications. The public has appreciated these efforts. Two letters from civil engineers are quoted below:

> I think your plan of notifying the interested parties of the information which is available is very good, and I shall be glad to avail myself of it when the occasion arises.
>
> It has seemed to me in the past that some such practice which you seem to have adopted was very necessary, in view of the fact that such a large amount of information is assembled and printed, the average man being entirely unaware of its existence.

> As your letter implies, and from my own personal experience, I am led to believe that a large majority of the civil engineers of this State do not avail themselves of the great fund of engineering data contained in your publications, maps, plats, etc. I also believe that this serious oversight on the part of engineers does not result from lack of appreciation of the value of this service by the U. S. Coast and Geodetic Survey but, on account of the lack of publicity, the engineers do not know of the excellent service your Bureau is capable of rendering our profession.

By the close of the fiscal year such pamphlets had been printed and distributed for the following States: Colorado, Iowa, Illinois, Kansas, Minnesota, Missouri, Montana, and Nebraska.

In the library and archives 32 hydrographic and 30 topographic sheets, each representing new surveys made by the Bureau, were received.

Other additions to the library and archives were:

Blue prints (mostly showing results of surveys by Army engineers)	277
Maps	452
Charts	2,894
Field, office, and observatory records	3,014

During the fiscal year the expenditure from the appropriation for general expenses of the Bureau was $160,815.19.

The total number of permanent and temporary officers and employees in the office and field force, which includes the commissioned officers and all employees appointed through civil service certification, is office force, 237; field force, 156; total, 393.

These figures do not include persons engaged as rodmen, chainmen, heliotropers, etc., in the field parties, nor any enlisted men on vessels of the Bureau.

The statistics in regard to leaves of absence during the calendar year are as follows: Annual leave, 8,055 days; sick leave, 2,540 days; without-pay leave, 3,212 days; and accrued leave, 1,910 days.

While the number of employees naturally varied on account of resignations and vacancies calculated on the number actually in the

service on June 30, 1921, as a basis of computation, the average annual leave taken during the year by each employee was approximately 25 days, and sick leave 6.4 days.

The receipts from the sale of charts, publications, etc., amounted to $38,074.92.

INSTRUMENT SECTION.

The instrument section is under the supervision of the Assistant Director. This section is charged with the designing of new surveying instruments and improvements of the surveying instruments in use; the accounting for all property in the possession of the Bureau; the auditing of inventories rendered by those having possession of property of the Bureau, the packing of instruments and property to be shipped to the field; and the receipt of such property when returned from the field; and the preparation of correspondence in connection with the above activities.

Repairs were made to 1,120 instruments, apparatus, and tools during the fiscal year; 724 instruments, apparatus, tools, etc., were made in the section during the year.

PUBLICATIONS ISSUED DURING THE YEAR.

Serial No. 132. General Tide Tables for 1921. 499 pp. 1 text fig. 6 pasters. Gives tidal data for principal ports of United States and many foreign ports for year 1921, and tables by means of which tides may be calculated for other localities. Also contains current tables and diagrams for many localities and tables of sunrise and sunset and moonrise and moonset.

Serial No. 133. Results of Observations Made at United States Coast and Geodetic Survey Magnetic Observatory near Honolulu, Hawaii, 1917 and 1918. By Daniel L. Hazard. 104 pp. 10 diag. This is one of regular series of publications containing results of observations made at magnetic observatories maintained by the Coast and Geodetic Survey.

Serial No. 135. United States Coast and Geodetic Survey: Description of its Work, Methods, and Organization. Special Publication 23. Revised edition. 102 pp. 32 text fig. 3 litho.

Serial No. 136. Catalogue of Charts, Coast Pilots, and Tide Tables (Philippine Islands Excepted). July 1, 1920. 47 pp. 15 text fig. Contains corrected list of charts, coast pilots, and tide tables published by United States Coast and Geodetic Survey excepting those of the Philippine Islands. Arrangement of catalogue has been somewhat changed and simplified, and number of index maps has been reduced. These maps are an improvement in clearness and legibility on those formerly in use.

Serial No. 137. Digest of Geodetic Publications Issued by the United States Coast and Geodetic Survey Resulting from Surveys in State of Illinois. 11 pp. 1 map.

Serial No. 138. Magnetic Ranges, San Francisco Bay, Calif. Special publication 1. Revised edition. 24 pp. 18 pl. 1 litho.

Serial No. 139. Inside Route Pilot, Coast of New Jersey. Second edition, 1920. 26 pp. 3 litho. in pocket. Covers inlets and interior waters on coast of New Jersey between Sandy Hook and Cape May, and is part of Coast Pilot, Section C, which covers coast from Sandy Hook to Cape Henry, including Delaware and Chesapeake Bays.

Serial No. 143. Latitude Developments Connected with Geodesy and Cartography with Tables, Including a Table for Lambert Equal-Area meridional Projection. By Oscar S. Adams. Special publication 67. 132 pp. There are five kinds of latitude that come under consideration in application of mathematical analysis to questions of geodesy and cartography. The aim of this publication is to express differences between geodetic or astronomic latitude in series of sines of multiple arcs. This difference in each case is obtained in an expression in sines of multiple arcs of geodetic or astronomic latitude and also in series of sines of multiple arcs of other latitude in question.

Serial No. 144. Results of Observations Made at United States Coast and Geodetic Survey Magnetic Observatory at Sitka, Alaska, 1917 and 1918. By Daniel L. Hazard. 102 pp. 23 diags. One of regular series of publications containing results of observations made at magnetic observatories maintained by Coast and Geodetic Survey.

Serial No. 145. Digest of Geodetic Publications Issued by United States Coast and Geodetic Survey Resulting from Surveys in State of Colorado. 8 pp. 1 litho.

Serial No. 146. Elements of Map Projection with Applications to Map and Chart Construction. By Charles H. Deetz and Oscar S. Adams. Special Publication No. 68. 163 pp. 82 text figs. Gives a résumé of the ideas that lie at the foundation of map projection, treated from a simple and practical as well as from the theoretical point of view and gives detailed information as is necessary to clearly present the subject, in such form as to make it of interest to the nontechnical reader as well as to the cartographer.

Serial No. 147. Digest of Geodetic Publications Issued by United States Coast and Geodetic Survey Resulting from Surveys in State of Missouri. 12 pp. 1 litho. Contains references to publications of the Survey giving results of triangulation, leveling, and magnetic work in the State of Missouri, and published for benefit of engineers and others interested in this information.

Serial No. 148. Digest of Geodetic Publications Issued by United States Coast and Geodetic Survey Resulting from Surveys in State of Kansas. 11 pp. 1 litho. Contains references to publications of the Survey giving results of triangulation, leveling, and magnetic work in the State of Kansas, and published for benefit of engineers and others interested in this information.

Serial No. 149. Tide Tables, Atlantic Coast of North America, Including Data on Currents for the Year 1922. (Reprinted from the Tide Tables, United States and Foreign Ports.) 196 pp. 6 text figs. Octavo. Gives times and heights of tides for principal ports of the Atlantic Coast of the United States and Gulf of Mexico and tables by means of which tidal data may be obtained for other locations, with other information useful to mariners.

Serial No. 150. Special Publication No. 69. Modern Methods for Measuring the Intensity of Gravity. By Clarence H. Swick. 96 pp. 26 text figs. Octavo. This publication contains a brief historical outline of the methods and instruments used in determining the intensity of gravity, and a more detailed description of the precise methods and greatly improved instruments now used in such work by the United States Coast and Geodetic Survey. The illustrations show the forms of pendulum apparatus used at various periods up to the present and in some cases the details of construction.

Serial No. 152. United States Coast Pilot, Philippine Islands, Part II, Palawan, Mindanao, and Sulu Archipelago, First Edition, 363 pp. 1 text fig. Octavo. This volume covers the coasts of Palawan, Mindanao, Sulu Archipelago, and adjacent Islands and waters, and includes a short description of Borneo with the channels and islands adjacent to it based on surveys by officers of the British Navy. The descriptions of the Philippine Islands and waters are based mainly on the work of the United States Coast and Geodetic Survey. The waters of the southern part of the Sulu Sea and Sulu Archipelago and the west coast of Palawan have not yet been surveyed, and the notes relating to those waters have been compiled from various sources available.

Serial No. 154. Digest of Geodetic Publications Issued by United States Coast and Geodetic Survey Resulting from Surveys in State of Nebraska. 10 pp. 1 litho. Contains references to publications of Survey giving results of triangulation, leveling, and magnetic work in State of Nebraska, and published for benefit of engineers and others interested in this information.

Serial No. 155. Results of Observations Made at the United States Coast and Geodetic Survey Magnetic Observatory near Tucson, Ariz., 1917 and 1918. 101 pp. 23 figs. Quarto. This is one of the regular series of publications giving results of magnetic observations made at the observatories maintained for that purpose by the Coast and Geodetic Survey.

Serial No. 156. Catalogue of Charts, Coast Pilots, and Tide Tables (Philippine Islands Excepted) Published by the United States Coast and Geodetic Survey. May 1, 1921. 47 pp. 15 text figs. Quarto. This is a revised edition and lists new charts, new editions of charts, coast pilots, and tide tables published since the last issue of the catalogue.

Serial No. 158. Triangulation in Kansas. Special Publication No. 70 (Supersedes Appendix No. 3, Report for 1902). 64 pp. 6 text figs. Octavo. The primary purpose of this publication is to bring together in convenient form

for the use of engineers information in regard to all the triangulation of the Coast and Geodetic Survey in the State of Kansas, including a full report of one additional section of the ninety-eighth meridian triangulation.

Serial No. 159. Relation Between Plane Rectangular Coordinates and Geographic Positions. By Walter F. Reynolds. Special Publication No. 71. 90 pp. 2 text figs. Octavo. The control surveys over large areas the size of a State or the whole United States are necessarily made and computed by the use of geographical coordinates (latitudes and longitudes) because of the curvature of the earth. For this reason the results of triangulation in publications of the United States Coast and Geodetic Survey, the United States Geological Survey, and the United States Corps of Engineers are always given in geographic coordinates, for the triangulation in any of these publications either covers a large area or is joined to the triangulation scheme of the whole United States. When all the points of a survey are located within a relatively small area the use of plane coordinates instead of geographic coordinates is much more convenient. The object of this publication is to enable the engineer to convert geographic into plane coordinates readily and quickly or to convert plane coordinates back into geographic coordinates if desired.

Serial No. 160. Catalogue of Charts, Coast Pilots, and Tide Tables of the Philippine Islands. Published by the United States Coast and Geodetic Survey. May 1, 1921. 16 pp. 6 text figs. Quarto. This is a revised list of the charts, coast pilots, and tide tables of the Philippine Islands.

Serial No. 161. Results of Magnetic Observations Made by the United States Coast and Geodetic Survey in 1920. By Daniel L. Hazard. Special Publication No. 72. 12 pp. Octavo. This is one of the regular series of publications by the Survey of the results of magnetic observations made in the United States. The results given in this publication are for the calendar year 1920.

Serial No. 162. Precise Dead Reckoning in Offshore Soundings. By Harry A. Seran. Special Publication No. 73. 15 pp. 5 text figs. Octavo. A more precise method of dead reckoning for determining offshore positions in soundings was begun by the Coast and Geodetic Survey off the coast of Georgia, and this publication gives the results of experience in this work by several chiefs of parties and the methods at present in use by the Survey.

Annual Report of Director, 1920. 173 p. 7 pl. 56 lithos.

Notices to Mariners. Issued weekly, jointly with the United States Bureau of Lighthouses.

Philippine Islands Notices to Mariners.

Coast and Geodetic Survey Bulletin. Issued monthly.

NEW CHARTS.

222. North shore of Long Island Sound, Greenwich Point to New Rochelle, Conn. and N. Y. September, 1920. Scale, 1:20,000; dimensions, 33 by 43 inches. Completes new series of 1:20,000 scale charts of north shore of Long Island Sound and replaces charts 269, 270, and 271.

8120. Harbors in southeastern Alaska. September, 1920. Dimensions, 28 by 43 inches. Contains following plans: Ryus Bay, scale 1:10,000; and Tokeen Bay entrance, Nakat Harbor, Burnett Inlet, Port Santa Cruz, Marble Passage (southeastern part and approaches), Hunter Bay and approaches, and Rose Inlet, all on scale of 1:20,000. Intended to meet demand for charts on larger scale of above waters than have heretofore been published.

4110. Oahu, Hawaii. September, 1920. Scale 1:80,000; dimensions, 32 by 44 inches. Published to meet demands and needs of coastwise navigation around important island of Oahu. The 100-fathom curve surrounding island is included within its limits. Details in Kaneche Bay are purposely omitted.

4335. Harbors on north coast of Busuanga, P. I. September, 1920. Dimensions, 18 by 29 inches. Plans of Minuit Anchorage, Port Caltom, Minangas Bay, and Illultuk Bay, all on scale of 1:20,000 from surveys made in 1917. These are plans of best-sheltered anchorages on north coast of Busuanga.

470. Charleston Harbor, S. C. November, 1920. Scale, 1:20,000; dimensions, 34 by 42 inches. Plan: Entrance to Charleston Harbor. Scale, 1:40,000. This chart covers entire harbor from shore end of jetties to Goose Creek on Cooper River and to West Marsh Island on Ashley River. Also contains plan on scale of 1:40,000 of entrance channel out to Charleston gas and bell buoy No. 1. Replaces chart 445, and publication of chart 431 will be suspended and later canceled unless demand warrants republication.

1203. Penobscot Bay and approaches, Me. November, 1920. Scale, 1:80,000; dimensions, 32 by 42 inches. This is one of new series of charts on Mercator projection on Atlantic coast and will replace charts 104 and 105. Soundings are expressed in feet instead of feet and fathoms as on charts replaced.

4321. Bold Point to Malanao Island, Palawan, P. I. November, 1920. Scale, 1:10,000; dimensions, 31 by 44 inches. This chart gives results of surveys by United States Coast and Geodetic Survey over entire area of chart. This region has been steadily gaining in commercial importance, and chart furnishes information to mariners formerly available in blue-print form only.

5902. Yaquina Head to Columbia River, Oreg. and Wash. November, 1920. Scale, 1:20,000; dimensions, 31 by 42 inches. One of new series of charts constructed on Mercator projection to replace old 1:20,000-scale series on polyconic projection. Chart 5902 should be used instead of chart 6100 in area common to both charts, as 5902 contains later information, particularly in vicinity of river and harbor entrances. Soundings are in fathoms at mean lower low water.

4272. Tanao Pass, east coast of Luzon, P. I. January, 1921. Scale, 1:40,000; dimensions, 25 by 36 inches. Shows complete harbor information for following harbors of mining district on east coast of Luzon: Malaguit, Paracale, Gumaus, Mambulao, and Dahikan, and also includes Tanao Pass in more complete detail than given on previously published charts.

1207. Massachusetts Bay, Mass. March, 1921. Scale, 1:80,000; dimensions, 32 by 44 inches. One of new series of charts on Mercator projection and replaces chart 109 of old series. Extends from Thacher Island on north to Cape Cod on south and embraces whole of Massachusetts Bay. Depths are expressed in feet at mean low water.

1201. Quoddy Roads to Petit Manan Island, Me. April, 1921. Scale, 1:80,000; dimensions, 30 by 41 inches. One of new series of coast charts, scale 1:80,000 on Mercator projection, and replaces charts 101 and 102 of old series. Soundings are expressed in feet instead of feet and fathoms as on old charts.

4326. North Balabac Strait and vicinity, P. I. March, 1921. Scale, 1:10,000; dimensions, 32 by 43 inches. Shows intricate channels between southern end of Palawan and Balabac Islands from surveys in 1917 and includes island of Balabac with principal steamer passage eastward and southward of Cape Melville.

1248. Jupiter Inlet to Fowey Rocks, Fla. May, 1921. Scale, 1:80,000; dimensions, 33 by 49 inches. This is one of the new series of coast charts scale 1:80,000, Mercator projection. It extends from Jupiter Inlet to Fowey Rocks in two panels. The soundings are expressed in feet, and it gives the results of the recent resurvey from latitude 25° 55′ to the southern limit of the chart. This chart replaces charts 164 and 165 of the old series.

1241. Tybee Island to Doboy Sound, Ga. May, 1921. Scale, 1:80,000; dimensions, 33 by 40 inches. This is one of the new series of coast charts, scale 1:80,000, Mercator projection. It is oriented with the meridian and replaces chart 156 of the old series. The Savannah River bar and entrance are from recent surveys not previously charted. The soundings are expressed in feet instead of fathoms and feet as on chart 156.

481. Cape Henry to Thimble Shoal Light, Va. June, 1921. Scale, 1:20,000; dimensions, 29 by 43 inches. This chart was designed primarily at the request of the United States Navy for a chart on a sufficiently large scale to serve as an anchorage chart in the vicinity of Lynnhaven Roads. As it overlaps chart 400, Hampton Roads, same scale, and includes Thimble Shoal Channel, it will be of particular value to all vessels bound to or from Norfolk, Portsmouth, and Newport News.

1210. Marthas Vineyard to Block Island, including Buzzards and Narragansett Bays, Mass. and R. I. 1921. Scale, 1:80,000; dimensions, 34 by 41 inches. This is one of the new series of coast charts, scale 1:80,000, Mercator projection, and replaces charts 112 and 113 of the old series. The soundings are expressed in feet, instead of feet and fathoms as on the charts replaced.

545. Baltimore Harbor, Md. June, 1921. Scale, 1:15,000; dimensions, 30 by 40 inches. This chart was designed to meet an increasing demand for a larger scale chart of Baltimore Harbor and gives many details of interest to mariners that were impossible to chart on the smaller scale charts.

240. Salem and Lynn Harbors, Mass. June, 1921. Scale, 1:20,000; dimensions, 35 by 43 inches. This chart is essentially an extension to the southward of chart 244 so as to include Lynn Harbor and approaches and connect with chart 246, Boston Harbor. The soundings are expressed in feet at mean low water. It replaces charts 244 and 337[a].

583. Miami Harbor and approaches, Fla. June, 1921. Scale, 1:40,000; dimensions, 26 by 38 inches. This chart is issued to meet the increasing demand for a chart of Miami Harbor and approaches on a larger scale than that previously charted. It shows the results of complete resurveys. It extends from the northern end of Biscayne Bay to Fowey Rocks, embracing the inland waterway approaches to Miami as well as both the Cape Florida and the Main Channels.

NEW EDITIONS OF CHARTS.

243. Ipswich Bay to Gloucester Harbor, Mass.
1222. Chesapeake Bay entrance, Va.
1269. Lakes Pontchartrain and Maurepas, La.
4255. Manila Bay and coast of Luzon to Capones Islands, P. I.
8151. Northern part of Tlevak Strait and Ulloa Channel, Alaska.
309. East Penobscot Bay, Me.
314. Kennebec and Sheepscot Rivers, Me.
369[4]. Hudson and East Rivers, from West Sixty-seventh Street to Blackwells Island, N. Y. and N. J.
369[8]. Hudson River, Days Point to Fort Washington Point, N. Y. and N. J.
933. Harbor of St. Thomas, W. I.
950. Colon Harbor, C. A., Panama.
4707. Philippine Islands, southwestern part.
5951. Cape Sebastian to Humbug Mountain, Oreg.
5971. Coquille River entrance, Oreg.
6300. Georgia Strait and Strait of Juan de Fuca, Wash.
8216. Woewodski and Eliza Harbors—Fanshaw Bay and Cleveland Passage, Alaska.
194. Mississippi River, from the Passes to Grand Prairie, La.
273. East River—Throgs Neck to Randalls Island, N. Y.
284. Hudson River—Coxsackie to Troy, N. Y.
431. Charleston Harbor, S. C.
5984. Coos Bay, Oreg.
6460. Puget Sound, Seattle to Olympia, Wash.
428. Winyah Bay, S. C.
8235. Gastineau Channel and part of Stephens Passage, Alaska.
283. Hudson River—Poughkeepsie to Hudson, N. Y.
296. Delaware River—Philadelphia to Trenton, N. J. and Pa.
455. St. Johns River—Jacksonville to Hibernia, Fla.
950. Colon Harbor, C. Z., Panama.
1219. Cape May to Fenwick Island Light, N. J. and Del.
4218. Ragay Gulf to Tayabus Bay, Luzon Island, P. I.
4343. Puerto Princesa, east coast of Palawan, P. I.
5107. San Diego Bay, Calif.
5534. Suisun Bay, Calif.
6122. Nehalem River, Oreg.
6154. Columbia River—St. Helens to Willamette River, including Vancouver and Portland, Oreg. and Wash.
6377. Anacortes Harbor, Wash.
8525. Orca Bay and Inlet, Channel Islands to Cordova, Alaska.
298. Gardiners Bay, Long Island, N. Y.
381. Philadelphia water front, Schuylkill River, Pa.
447. St. Simons Sound, Brunswick Harbor, and Turtle River, Ga.
508. St. Johns River, Palatka to Lake George, Fla.
529. James River, Newport News to Jamestown, Va.
8200. Frederick Sound and Summer Strait, southeast Alaska.
5984. Coos Bay, Oreg.
6447. Lake Washington Ship Canal, Puget Sound to Lake Washington, Wash.
8160. Zarembo Island and approaches, Alaska.
8517. Prince William Sound, western part, Alaska.
78. Chesapeake Bay, southern part.

204. Galveston Bay, Tex.
375. Raritan River, N. J.
4106. Kaunakakai Harbor, Molokai, H. I.
4342. Halsey Harbor and Dicabaito Anchorage, Culion Island, P. I.
6003. Umpqua River entrance, Oreg.
6195. Grays Harbor, Wash.
248. Boston Inner Harbor, Mass.
340. Wellfleet Harbor, Mass.
577. Fernandina to Jacksonville, Fla.
4105. Kahului Harbor and approaches, Maui, Hawaii.
4236. Manila and Cavite Harbors, Luzon, P. I.
6151. Columbia River—entrance to Harrington Point, Oreg. and Wash.
6152. Columbia River—Harrington Point to Grims Island, Oreg. and Wash.
520. Galveston entrance, Tex.
3694. Hudson and East Rivers from West Sixty-seventh Street to Blackwells Island, N. Y. and N. J.
4415. Southwestern Panay, P. I.
5832. Humboldt Bay, Calif.
8084. Seal Cove and head of Kasaan Bay, Alaska.
184. St. Josephs and St. Andrews Bays, Fla.
246. Boston Harbor, Mass.
1211. Block Island Sound and approaches, R. I., Conn., and N. Y.
1226. Chesapeake Bay—Sandy Point to head of bay, Md.
6112. Tillamook Bay, Oreg.
8557. Knik Arm, Fire Island to Goose Creek, Cook Inlet, Alaska.
4226. Lamon Bay and Polillo Island, Luzon, P. I.
4511. Basilan Strait, P. I.
400. Hampton Roads, with continuation to Norfolk, Va.

CHAPTER II.

PROGRAM FOR CURRENT FISCAL YEAR IN THE WASHINGTON OFFICE.

DIVISION OF GEODESY.

The program of office computations for this division for 1922 by project is as follows:

(*a*) Triangulation and traverse: Memphis-Little Rock-ninety-eighth meridian; Puget Sound; North Carolina; Green Bay-Duluth, Wis.; preliminary examination of triangulation in southeastern Alaska; any special piece of work that may be requested.

(*b*) Levels: Rouses Point, eastward; Flagstaff-Lees Ferry, Ariz.; Portland-Wallula, Oreg.

(*c*) Astronomics: Azimuths, latitudes, and longitudes along the arcs of triangulation and lines of traverse given under (*a*).

(*d*) Gravity: No computations except possibly miscellaneous work for publications.

Publications: Rio Grande Triangulation; Traverse of Indiana; Traverse of Illinois; Triangulations of North Carolina; Levels in Texas; Levels in southeastern United States; Gravity; Astronomics; Instructions for Precise Leveling; Instructions for Precise Triangulation.

Measured by the unit of what an average computer can accomplish in a day and tabulated by classes of computations, there remained at the close of the fiscal year ended June 30, 1921, the following computations before the computers of the division of geodesy:

	Computer days.
(*a*) Triangulation and traverse, to finish computations	28,900
To finish publications	12,000
Total	40,900
(*b*) Leveling, computations up to date	------
To finish publications	2,500
Total	2,500
(*c*) Astronomics, to finish computations	121
To finish publications	379
Total	500
(*d*) Gravity, computations up to date	------
To finish publications	400
Total	400

This means that with our present force of 12 permanent computers (there are 6 vacancies in the 18 positions) it would take 13 years to complete the work now on hand, with no allowance made for time spent on furnishing information, research investigations, etc.

Measured by the same unit, namely, what an average computer can accomplish in a day, the new work received from the field during the fiscal year 1921, tabulated by classes, was as follows:

	Computer days.
(*a*) Triangulation and traverse	1,741
(*b*) Leveling	200
(*c*) Astronomic work	305
Total	2,246

The computations made during the fiscal year ended June 30, 1921, measured by the unit of what is accomplished by the average computer in a day amounted to 1,982 days. This was but 88 per cent of the new work received in the division during the year.

DIVISION OF HYDROGRAPHY AND TOPOGRAPHY.

The program for this division for the current fiscal year is necessarily limited to the office work incident to carrying on the office functions of this division as stated heretofore.

DIVISION OF CHARTS.

The program for 1922 calls for the production of 23 new charts and a base map of the Territory of Alaska, and the reconstruction of 10 existing charts.

DIVISION OF TERRESTRIAL MAGNETISM.

The program for the fiscal year ending June 30, 1922, for this division is as follows: Observatory results—Honolulu, 1919–20; Cheltenham, 1919–20; Sitka, 1919–20; Tucson, 1919–20; and Vieques, 1919–20. Earthquake tabulations. Field results as received. Isogonic chart of United States for 1920 and secular change tables.

Measured by the unit of what an average computer can accomplish in one day, the work before the division of terrestrial magnetism on July 1, 1912, was as follows:

	Estimated days to complete.
Observatory results:	
Cheltenham, 1919	30
Vieques, 1919	40
Tucson, 1919	60
Sitka, 1919	20
Honolulu, 1919	10
Cheltenham, 1920	70
Vieques, 1920	85
Observatory results—Continued.	
Tucson, 1920	85
Sitka, 1920	85
Honolulu, 1920	65
Five observatories, first half 1921	215
Total	765

The accomplishments during the fiscal year ended June 30, 1921, measured by the same unit were 656 computer days. The new work received in the division during the fiscal year ended June 30, 1921, amounted to 565 computer days.

DIVISION OF TIDES AND CURRENTS.

The program for this division for the year ending June 30, 1922, is as follows:

The tide tables for 1923 will be completed, scanned for the removal of errors, and sent to the printer.

The Current Tables for 1923, a new publication, will be completed during the year and sent to the printer.

The sounding records received from the hydrographic parties will be checked as received, so that no delay will be occasioned to the chart division.

Of the tidal records received, those upon which the determination of planes of reference depend will be computed immediately and the computation of the other records kept up to date as the force will allow.

The bench-mark records as received will be computed immediately for those demanding immediate attention and the others kept up to date as the force will allow.

A publication on the bench marks of the State of New York will be completed and sent to the printer early in the year.

A publication on the relation between winds and currents on the Pacific coast will be completed and sent to the printer, as will also an abridged publication of the above, written especially for the mariner.

A publication on the harmonic analysis and prediction of tides will be completed and sent to the printer during the fiscal year.

In general, the work of the division will be so arranged as to take up immediately the work upon which the publication of charts and the prosecution of field work depend; after that the energies of the division will be directed toward keeping its tabulations and computations up to date and to issue in the form of publications the large mass of material that has accumulated in this division and which is of very great value to the navigator, the engineer, the scientist, and the public generally.

DIVISION OF ACCOUNTS.

The program for this division for the current fiscal year will be the performance of the duties incident to disbursing the funds appropriated for the operation of the Bureau and the auditing of the accounts arising from these expenditures.

CHIEF CLERK.

The program for this division will be, in addition to routine duties of the division, the completion of the renovation of the buildings occupied by the Bureau, and the preparation and distribution of digests of geodetic work of the Bureau for as many States of the Union as time permits.

INSTRUMENT SECTION.

The program for this section for the current fiscal year will be to continue the repair and upkeep of technical instruments and other equipment of the Bureau, the auditing of property returns, and the correspondence incident to such work.

Part III.—IN THE FIELD.

CHAPTER I.

ACCOMPLISHMENTS IN THE FIELD DURING THE PAST FISCAL YEAR.

GEODETIC WORK.

	Length of scheme.	Area covered.
Triangulation, precise:		
Oklahoma, McAlester to ninety-eighth meridian (Little Rock–ninety-eighth meridian arc)	*Miles.* 110	*Sq. miles.* 2,100
New Mexico and Arizona, one hundred and eighth meridian to Williams, Ariz., (El Reno-Needles arc)	315	21,000
California and Oregon, California-Oregon arc	450	18,000
Washington, Tacoma to Seattle (Tacoma-Canadian arc)	25	75
Oklahoma, ninety-eighth meridian to ninety-ninth meridian (El Reno-Needles arc)	80	1,400
Alaska, Frederick Sound and Stephens Passage	45	360
Alaska, Clarence Strait	20	105
Total	1,045	43,040
Triangulation, primary:		
California and Oregon, California-Oregon arc	100	15,000
Triangulation, secondary:		
New York, Rockaway Beach speed trial course	10	70
District of Columbia, Anacostia radio compass station	3	5
Virginia, mouth of Rappahannock River	8	20
Virginia, Hampton Roads speed trial course	5	15
Virginia and Maryland, Potomac River	15	60
North Carolina, Neuse River and Pamlico Sound	15	100
North Carolina, Cape Fear River	3	5
South Carolina, Broad and Beaufort Rivers	10	20
South Carolina, St. Helena Sound	10	25
South Carolina, Calibogue Sound	10	20
Georgia, Tybee Roads	3	5
Florida, Marquesas Keys and Florida Reefs near Key West	50	190
Louisiana, Chandeleur Sound and mouth of Mississippi River	70	870
Louisiana, Mississippi delta	25	300
California, San Pedro Bay and San Francisco Bay	10	70
California, Table Bluff, Point Loma, Imperial Beach, Point Fermin, Point Hueneme, Point Arguello, Point Reyes, Bird Island, Point Montara, and Farallon Island radio compass stations	45	100
Oregon, Umpqua River	5	10
Oregon, Coos Bay and Fort Stevens radio compass stations	3	5
Washington, Grays Harbor, Smith Island, Cattle Point, New Dungeness, Slip Point, and Tatoosh Island radio compass stations	10	25
Alaska, Frederick Sound and Stephens Passage	10	10
Alaska, Shelikof Straits and Cape Ikti northeastward	20	220
Alaska, West Coast of Prince of Wales Island	35	350
Virgin Islands, St. Croix	5	20
Total	380	2,515
Precise traverse:		
Indiana, Tipton to South Bend (North Vernon-South Bend line)	110	.....
Illinois, Rockton-Vandalia line	250	.....
Wisconsin, Beloit-Racine line	50	.....
Mississippi, Pascagoula to Ovett (Pascagoula-Booneville line)	100	.....
Wisconsin, Green Bay to Mountain (Green Bay-Duluth line)	65	.....
Total	575	.....

	Length of scheme.	Area covered.
	Miles.	*Sq. miles.*
Base lines, precise:		
Oregon, Paisley base	9	.....
Oklahoma, Savanna base	4.5	.....
Total	13.5	.....
Base lines, secondary:		
North Carolina, Wilmington	.3	.....
North Carolina, Cape Fear River	.7	.....
Total	1	.....
Reconnoissance:		
Indiana, North Vernon-South Bend precise traverse line	95	.....
Illinois, Rockton-Vandalia precise traverse line	250	.....
Wisconsin, Beloit-Racine precise traverse line	50	.....
Mississippi, Pascagoula-Booneville precise traverse line	100	.....
Wisconsin, Green Bay-Duluth precise traverse line	65	.....
Total	560	.....
Precise leveling lines:		
Klamath Falls to Ontario, Oreg	388	.....
Portland, Oreg., to Auburn, Wash	177	.....
Tenaha to Gallatin, Tex	78	.....
Moira, N. Y., to Cornwall, Canada	20	.....
Rockford, Ill., to Prairie du Chien, Wis	166	.....
Rockton to Vandalia, Ill	303	.....
Portland to Astoria, Oreg	107	.....
Centralia to Grays Harbor, Wash	77	.....
Gap Ranch to Bend, Oreg	104	.....
Louisville, Ky., to Clarksville, Tenn	197	.....
Cerulean, Ky., to Nashville, Tenn	97	.....
Hinsdale, Mont., to United States and Canada boundary	45	.....
Green River, Utah, to Lees Ferry, Ariz	49	.....
Total	1,808	.....
SUMMARY.		
Precise triangulation	1,045	43,040
Primary triangulation	100	15,000
Secondary triangulation	380	2,515
Total	1,525	60,555
Precise traverse	575	.....
Precise base lines	13.5	.....
Secondary base lines	1.0	.....
Reconnoissance	560	.....
Precise leveling	1,808	.....

The progress of geodetic field operations during the period covered by this report was steady, but limited by the small appropriation.

Distinct advances were made in improving field methods in some operations. A supplement to Instructions for Precise Traverse covers many details of that very important method of furnishing horizontal control. Precise traverse will undoubtedly be used more and more in the future, both to supplement the more costly triangulation on comparatively short lines and also to furnish the secondary control for cities.

Experiments were made at various times during the year on the effect of magnetization on the period of the new invar pendulums, and at the close of the fiscal year the prospects were bright for being able to perfect simple methods and apparatus to render that effect negligible.

The publication of the new gravity manual will make the work of instructing new observers much easier in the future.

The feature which gives the greatest promise, however, and which will revolutionize the process of making observations for astronomic longitude, is the apparatus being built for the Coast and Geodetic Survey by the Bureau of Standards. It is designed to receive at any point in the United States the time signals sent out each day by radio from Annapolis and to record those signals chronographically in comparison with the same chronometer, and on the same sheet of paper employed to record the star observations by which the local time at the new station is determined. The difference of the local times of Annapolis and the new station is, of course, the difference of longitude.

This new method is exactly similar in principle to the one formerly used, except that the radio is used instead of telegraph or cable lines. The advantage of the new method over the old lies in the fact that only one observing party will be needed instead of the two formerly used, and in being independent of telegraph and cable lines. This invention is especially valuable in regions like southeast Alaska, where a number of longitude stations are needed before the triangulation can be properly adjusted and where no telegraph or cable facilities exist. It will also be very useful in connection with gravity observations at stations out of reach of telegraph lines.

HYDROGRAPHY.

The following is a statement of the vessels at the disposal of the Coast and Geodetic Survey at the beginning of the fiscal year: *Bache*, *Cosmos*, *Explorer*, *Fathomer*,[1] *Hydrographer*, *Lydonia*,[2] *Marinduque*,[1] *Natoma*,[2] *Onward*[2] (returned to Navy Department), *Pathfinder*, *Ranger*,[2] *Romblon*[1] (returned to Philippine Government), *Surveyor*, *Wenonah*,[2] *Yukon;* total, 13.

The following is a brief statement of the assignments of the vessels at the disposal of the Coast and Geodetic Survey within the fiscal year:

Bache.—On July 1 this vessel was engaged on a hydrographic survey at the entrance of Delaware Bay extending from close inshore out to the 100-fathom curve. At this depth curve the soundings developed a pronounced ravine hitherto uncharted. At the close of the season the *Bache* sailed for duty in southern waters, on October 7. On October 19 a revision of the alongshore hydrography, between Tybee Island and Port Royal Sound, was commenced and completed early in December. A number of remarkable changes were found to have occurred since the last survey. The United States Army Engineers, at their request, were furnished a copy of the Tybee Roads area, as some of the new shoals indicate the possibility of a serious encroachment on the dredged channel. In contrast with this instance of accretion is the suit of a landowner of a near-by point for damages from the Government on account of erosion along his water front which he claims was due to dredging operations. In April she resumed offshore work in the vicinity of Chesapeake Bay with a view to the extension to the northward of pre-

[1] Owned by Philippine Government and loaned to Coast and Geodetic Survey for surveying in Philippine waters.
[2] Converted yachts received by transfer from the Navy Department for surveying.

vious surveys of this class. In cooperation with the Naval Radio Compass Service a series of tests will be made which are expected to afford data for improvements in methods and apparatus valuable to both services.

Explorer.—On July 1 this vessel was engaged in combined operations in Stephens Passage, southeast Alaska. The most important feature of her work consisted of the extension of the wire-drag examination northward through Stephens Passage, Gastineau Channel, and Lynn Canal. She acts as mother ship for the wire-drag launches and takes part in the actual operation of the drag and sweep. A precise triangulation and a topographic and magnetic survey are being carried on at the same time. Field work closed on October 18, when the steamer returned to Seattle, where she remained until March 24, when she sailed for Taku to resume the same program.

Fathomer.—This vessel was employed the entire year in surveys in the Philippine Islands. On July 1 she was engaged in general surveys in Sulu Sea in the vicinity of the Cuyo and Cagayan Islands. This work was completed in October and the steamer shifted her working grounds to the southwest coast of Zamboanga Province, and continued in this area until weather conditions made further operations impracticable and she returned to Manila January 29. She was undergoing repairs until April 15. On the 18th she proceeded to her working grounds in the vicinity of the Cagayan Islands, Sulu Sea, and continued there until the close of the fiscal year.

Hydrographer.—On July 1 this vessel was investigating a reported shoal about 4 miles northwest of the Marquesas Keys, Fla., which turned out to be an uncharted coral bowlder with a depth over it of only 7.2 feet. On July 12 the offshore hydrography south of Marquesas Keys was resumed and continued until September 10. On September 14 the steamer proceeded to Boot Key Harbor, which was used as a base for the hydrographic survey between American Shoal and Sombrero Reef until the close of the season December 30. On January 8 she left Key West and after some delay, due to bad weather, arrived at Mobile, Ala., the 17th, where she remained undergoing repairs until February 21, when she proceeded to Chandeleur Sound to continue the work of the *Ranger*. Before the hydrography in the Gulf could be extended it was necessary to provide adequate control by a triangulation scheme connecting Mississippi Sound with the Delta. This was completed through Chandeleur and Breton Sounds by May 27, and the vessel arrived at Burrwood, La., to take up a hydrographic examination of the Southwest Pass of the Mississippi Delta, requested by the Army Engineers, which was in progress at the close of the fiscal year.

Lydonia.—On July 1 this vessel was engaged in combined operations on the outside coast of southeast Alaska, along the west coast of Dall Island. The steamer was engaged in offshore soundings from August 23 to the end of the season, October 23. The *Cosmos* was engaged in inshore hydrography between Cape Augustine and Meares Passage during the entire season, and the topography of the same stretch of coast was done by a detached party with launch *47*, operating from a camp. On April 2 the steamer left Seattle to take up the offshore hydrography on the northern coast of California, and this work was in progress at the close of the fiscal year.

Marinduque.—This vessel was employed the entire year in surveys in the Philippine Islands. Owing to the lack of a complement of officers, she did not take up field work until March 17, when she commenced operations in Bacoor Bay. This work was completed by May 13. On May 23 she began combined operations in the vicinity of Lagonoy Gulf and remained there during the remainder of the fiscal year.

Mikawe.—This vessel was assigned to the resurvey of the stretch of coast from Port Royal Sound to Charleston, S. C. In general, the hydrography had as its offshore limit the 3-fathom curve, and was extended into the inlets of any importance to a distance of at least a mile or to a point where the depths were unchangeable. Work was commenced on August 5 and discontinued on December 20. It was resumed in April, and an additional party with the launch *Elsie* was also assigned to cooperate with the *Mikawe* in this section.

Natoma.—From July 1 to July 13 this vessel was at San Francisco, Calif., completing miscellaneous repairs. On the latter date she left for Los Angeles Harbor to take up a general revision of the hydrography and topography. Since the last systematic survey very extensive improvements had been made, with the result that what had hitherto been little more than a convenient anchorage became a harbor with unusual facilities. Field work was completed on December 14 and the vessel returned to San Francisco to resume the revision of the hydrography and topography in that vicinity. The work included a resurvey of the bar, wire-drag investigation of shoal soundings off Fort Point and east of Angel Island, and the location of four radio compass stations. Field work was closed on May 26, and up to the close of the fiscal year the steamer was undergoing general repairs and overhauling.

Onward.—This vessel continued on the resurvey of Pamlico Sound and Neuse River until October 21. On November 26 she was returned to the Navy Department.

Pathfinder.—This vessel was employed during the entire year on surveys in the Philippine Islands. She left Manila July 26 for hydrographic surveys off the coast of Camarines Norte, east coast of Luzon. This survey includes a bank shown on former Spanish charts at the edge of deep water in the Pacific. The indications are that this bank is much smaller and deeper than reported and the survey will probably remove it from the list of dangers. This work was suspended in October before the period of northeast monsoons, and on November 1 the *Pathfinder* sailed for the west coast of Mindanao to take up combined operations. The triangulation was completed between Negros Island and Sibuguey Bay, Mindanao, and she returned to Manila January 5. From January 10 until the first part of March she was undergoing repairs, and on the completion of these she proceeded to Lagonoy Gulf, arriving there March 16, and was engaged in this section until May 16, when she proceeded to Jomalig Island. Having completed the detailed hydrographic examinations there in June, she commenced the work of deep-sea sounding, thence to Catanduanes Islands.

Ranger.—On July 1 this vessel was engaged in the offshore hydrographic survey in the Gulf of Mexico from Mobile Entrance to Chandeleur Sound. From November 14 to December 27 she was at Gulf-

port, Miss., making repairs to boilers and arranging for extensive repairs and alterations preparatory to taking up a new assignment for combined operations in Porto Rico and the Virgin Islands. From December 29, 1920, to June, 1921, she was undergoing repairs at New Orleans, La. On June 1 she proceeded to Key West, where she was joined by the launches *Mitchell* and *Marindin*, and convoyed them to San Juan, P. R., arriving July 5.

Surveyor.—On July 1, 1920, this vessel was engaged in combined operations extending from Shelikof Strait westward to Mitrofania Island, southwest Alaska. The principal part of this work was triangulation for primary control of that stretch of coast, 180 miles in length. A shortage of fuel oil rendered it necessary in midseason to change the original program to operate parties at both ends of the scheme, and to concentrate the entire complement and equipment in Shelikof Strait. The *Yukon* was used as an auxiliary during the season, which closed October 5. After stopping two days at Sitka for a special examination, the steamer proceeded to Seattle, arriving the 18th. With expectation of continued fuel-oil shortage and its high price in southwest Alaska, it was decided to postpone operations there and replace the *Lydonia* on the survey of the outside coast of Prince of Wales Island, southeast Alaska. The steamer left Seattle April 2 and on April 18 field work commenced and was in progress at the close of the fiscal year.

Wenonah.—This vessel was engaged on July 1 in carrying on combined operations in Clarence Strait. In addition to the topography and alongshore hydrography done by the launches and the hydrography out in the deeper waters of the open strait by the steamer, a section of the scheme of precise triangulation is also being done and will eventually connect with that of the *Explorer* through a short link completed in a previous season. Field work was closed in November and the *Wenonah* arrived at her home port, Seattle, on the 18th. She returned to Ketchikan April 2, and by the 18th all branches of field work were resumed.

The statements below contain the statistics regarding the class of accomplishment during the fiscal year:

SHIP AND LAUNCH HYDROGRAPHY PERFORMED DURING THE FISCAL YEAR.

	Statute square miles.
Ship hydrography:	
Delaware Bay approach	1,907.0
Chesapeake Bay approach	326.6
Savannah, Ga., entrance	123.9
Pamlico Sound, N. C	139.5
Florida Reefs	228.0
Gulf of Mexico (offshore)	1,154.0
Mississippi River approach	43.0
Los Angeles Harbor, Calif	115.1
San Francisco Bay	52.0
California (offshore)	991.1
Prince of Wales Island (outside coast)	1,788.0
Clarence Strait	553.0
Stephens Passage and Lynn Canal	16.0
Shelikoff Strait	180.0
Philippine Islands	12,378.9
Wire-drag surveys:	
Stephens Passage, southeast Alaska	394.0
Launch hydrography:	
South Carolina coast	195.0
Umpqua River entrance	8.0

Topography in connection with hydrographic work was executed as follows:

	Shore line, statute miles.	Area, square miles.
Chesapeake Bay approach	10.0	
Pamlico Sound, N. C.	25.0	
Coast of South Carolina	113.0	64.5
Savannah River entrance	49.5	
Vicinity Key West	2.0	
Los Angeles Harbor, Calif.	53.3	34.4
North coast California	17.0	
San Francisco Bay	23.2	50.0
Umpqua River entrance	2.0	3.0
Stephens Passage	138.0	388.0
Clarence Strait	569.7	63.0
Prince of Wales Island (outside coast)	569.7	63.0
Shelikof Strait	25.0	25.5
Virgin Islands	28.0	33.0
Philippine Islands	283.5	378.5

MAGNETIC WORK.

The magnetic observatories at Vieques, P. R.; Cheltenham, Md.; Tucson, Ariz.; Sitka, Alaska; and near Honolulu, Hawaii, have been in operation throughout the year and practically continuous records have been secured on the magnetographs and seismographs. The necessary absolute observations and scale value determinations have also been made.

A magnetometer which had been previously compared at Cheltenham and Tucson was compared with the magnetometers at the Honolulu and Sitka magnetic observatories, and then again at Cheltenham, thus giving an indirect comparison of the magnetometers at these four observatories. Instruments intended for field use were standardized at Cheltenham.

In April, 1921, the instruments of the yacht *Carnegie*, of the department of terrestrial magnetism of the Carnegie Institution of Washington, were compared with those at Honolulu Observatory, thus giving another determination of the relation of the latter to the international magnetic standard of that department.

In February a new Milne-Shaw seismograph was installed at the Honolulu Observatory. The greater sensitivity and more improved time-marking apparatus of this instrument will make it possible to determine the earthquake phases with much greater accuracy than was possible with the old Milne seismograph.

The time record of the seismograph at Tucson has also been greatly improved by the substitution of a make-circuit chronometer in place of the clock which came with the instrument. At the Sitka Observatory much trouble was experienced in replacing the broken jewels in the bearings of the recording arm of the E–W component of the Bosch-Omori seismograph. Steel bearings installed at the end of the year promise to give very good results. Earthquakes have been recorded as follows: Porto Rico, 25; Cheltenham, 26; Tucson, 35; Sitka, 9; and Honolulu, 68.

Extensive improvements have been made to the buildings and grounds of the Honolulu Observatory, and repairs to the office

building at Vieques were in progress at the end of the fiscal year. Local conditions in the building trades made it advisable to postpone longer the erection of a building for office and quarters at Cheltenham, but it is hoped that this most important work can be done next year.

The observer in charge of the Honolulu Observatory was a delegate to the Pan-Pacific Scientific Congress, and was able to secure the services of a former magnetic observer to take temporary charge of the observatory while he attended the meetings of the congress on the island of Hawaii.

MAGNETIC SURVEY.—Because of the inability to secure additional magnetic observers it was necessary to suspend almost entirely the field work of the magnetic survey, and as a consequence to postpone the preparation of the isogonic chart for 1920.

A magnetic observer began field work the middle of June to secure the secular change data in the northwestern part of the country needed for the preparation of that chart, and had occupied three repeat stations at the end of the fiscal year.

Declination observations were made at a number of stations in southeastern Alaska in 1920 in connection with the triangulation work, and in April, 1921, an extended series of observations was made in the vicinity of Port Snettisham, Alaska, by the party on the steamer *Explorer* for the purpose of developing a local disturbance which had been reported in the vicinity of Sentinel Point. Declination observations were made at four stations by the topographic party at work in the Virgin Islands.

Arrangements were made with the United States Coast Guard by which it will be possible to make magnetic observations on the shores of Bering Sea and the Arctic Ocean during the coming summer. After making observations at the old station at Seattle, an officer of this Bureau left that place for Nome, Alaska, on June 9, where it is expected that he will join the Coast Guard steamer *Bear* after making observations in that vicinity.

TIDE AND CURRENT OBSERVATIONS.

During the year current observations were made on the following light vessels:

Light vessel.	State.	Station.	Time employed.		
			Y.	*m.*	*d.*
Pollock Rip Slue	Massachusetts	1		11	3
Nantucket Shoals	do	1		5	2
Scotland	New York	1		3	20
Ambrose Channel	do	1		3	20
Overfalls	Delaware	1		10	9
Winter Quarter	Virginia	1			22
Diamond Shoals	North Carolina	1	1	0	0
Frying Pan Shoals	do	1	1	0	0
Charleston	South Carolina	1		2	19
Brunswick	Georgia	1	1	0	0
San Francisco	California	1	1	0	0
Blunts Reef	do	1	1	0	0
Columbia River	Oregon	1	1	0	0
Umatilla Reef	Washington	1	1	0	0
Swiftsure Bank	do	1	1	0	0
Total		15	11	1	5

Short series of current observations were made at the following localities:

Locality.	Stations.	Time employed.
		m. d.
New York Harbor and vicinity	26	2 19
Delaware Bay approaches, Del	1	2
Neuse River, N. C	1	1
Total	28	2 22

TIDAL OBSERVATIONS, PRINCIPAL STATIONS.—Automatic tide gauges were in operation throughout the year at the following stations:

1. Portland, Me.
2. Fort Hamilton, N. Y.
3. Atlantic City, N. J.
4. Philadelphia, Pa.
5. Breakwater Harbor, Del.
6. Aberdeen Proving Grounds, Md.
7. Baltimore, Md.
8. Fernandina, Fla.
9. Key West, Fla.
10. Cedar Keys, Fla.
11. Fort Morgan, Ala.
12. Galveston, Tex.
13. San Diego, Calif.
14. San Francisco, Calif.
15. Olympia, Wash.
16. Seattle, Wash.
17. Ketchikan, Alaska.
18. Kodiak, Alaska.
19. Unga, Alaska.

TIDAL OBSERVATIONS, SECONDARY STATIONS.—Tidal observations were made at the following stations during a part of the year:

1. Port Morris, N. Y.
2. Hell Gate Arch, Wards Island, N. Y.
3. Manhattan Beach, N. Y.
4. Brooklyn, First Street Pier.
5. Brooklyn, Third Street Pier.
6. New York City, Battery.
7. New York City, Willis Avenue Bridge.
8. New York City, Spuyten Duyvil.
9. Albany, N. Y.
10. Mariners Harbor, N. Y.
11. Newark, N. J.
12. Perth Amboy, N. J.
13. Oriental, N. C.
14. Edisto Island, S. C.
15. Broad River, S. C.
16. Beaufort, S. C.
17. Miami, Fla.
18. American Shoal Lighthouse, Fla.
19. Saddle Bunch Harbor, Fla.
20. Key Vaca, Fla.
21. Boca Grande Key, Fla.
22. Marquesas Key, Fla.
23. Biloxi, Miss.
24. Chandeleur Island, La.
25. San Pedro, Calif.
26. San Francisco Bay, Calif.
27. Umpqua River, Oreg.
28. Taku Harbor, Alaska.
29. Sea Otter Harbor, Alaska.
30. Craig, Alaska.
31. Menefee Anchorage, Alaska.
32. Gardners Bay, Alaska.
33. Nichols Bay, Alaska.
34. Honolulu, Hawaii.
35. Gagayan Island, P. I.
36. Diniasalang, Naro Bay, P. I.
37. Port Holland, Malusa Bay, P. I.
38. Dumaran Island, P. I.
39. Nangalao Island, P. I.
40. Cabulanan Island, P. I.
41. Tailoban Island, P. I.
42. Ragay Gulf, P. I.
43. Bisquay Island, P. I.
44. Palillo Island, P. I.
45. Cebu Island, P. I.
46. Manila Bay, P. I.
47. Mindanao Island, P. I.

Automatic tide gauges were kept in operation throughout the year at 8 stations on the Atlantic coast, 4 stations on the Gulf coast, 4 stations on the Pacific coast, and 3 in Alaska. In addition, tidal observations in connection with hydrographic surveys were made at 30 stations in the United States with an aggregate length of 5½ years, 18 stations in the Philippine Islands with an aggregate length of 3¼ years, and records received from outside sources totaled 21 stations with an aggregate length of 11¼ years.

At the principal tidal stations the relation of tide staff to bench mark was verified with spirit levels, insuring accurate data for precise level net connections and also for the detection of emergence or subsidence of coast.

To make available for engineering and other purposes definite datum planes all along the coast, and to the mariner increased accuracy of current predictions, a tidal and current party was employed in New York Harbor for about 3½ months. The work of this small party was preliminary to a contemplated intensive tidal and current survey of the port, extending over only a short period but with simultaneous observations by a number of parties over the whole area.

Current observations during the year were made on 19 light vessels on the Atlantic coast, and on 5 light vessels on the Pacific coast. In addition, short series of observations were made at 62 stations with an aggregate length of 13 months.

An improvement in connection with the observation of tides, of considerable importance, was inaugurated during the past year. This consists of a standard tide staff and backing piece which will eliminate a great deal of trouble heretofore experienced in maintaining a fixed relation between the tide curve and the zero of the tide staff. This standardized tide staff and backing piece are being established at all the principal tidal stations maintained by the Survey.

Another improvement worthy of mention here is the field automatic tide gauge, which was devised the past year and which is now being constructed in the instrument section of the Survey. This new gauge, which is portable, will aid in securing better observations for use in connection with hydrographic surveys and do away with the necessity of maintaining one or more tide observers with each party, thus securing increased accuracy at decreased expense.

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CHAPTER II

PRESENT CONDITION OF GEODETIC, HYDROGRAPHIC, MAGNETIC, AND TIDAL AND CURRENT SURVEYS.

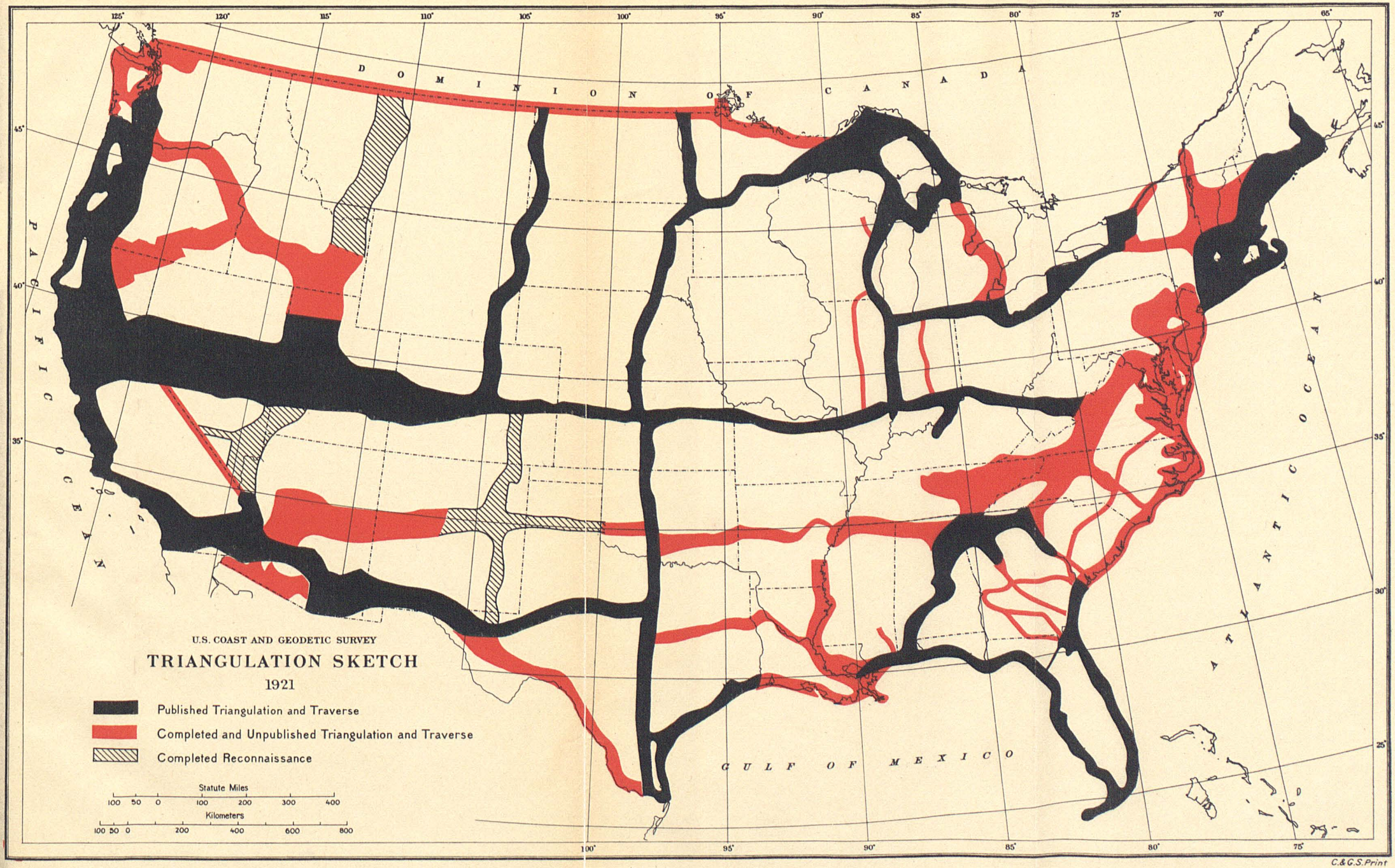
GEODETIC WORK.

One of the major operations of the Bureau is the extension of triangulation and leveling of precise and primary accuracies into the interior of the United States. All surveying and mapping of the country is, or should be, joined to these two systems of control to give proper coordination. Maps and charts are not satisfactory if discrepancies develop when two or more of them covering adjacent areas are used together. The only possible way of avoiding these discrepancies is to have all detailed and local work connected to the main scheme or control framework of precise accuracy which includes the whole country. For a graphic presentation of the present progress of triangulation see figure opposite.

Until recently the plan followed in laying out the geodetic work was to distribute the control surveys, triangulation, and precise leveling in such a manner as to have as soon as possible one or more points of precise accuracy within not more than 100 miles of any place in the United States. The Board of Surveys and Maps, after a careful consideration of the mapping situation in this country, has recently recommended that the 100 miles be decreased to 50 and that the precise control be completed at as early a date as possible. The board estimated the total cost at $4,200,000.

The need is urgent. Not only are the mapping activities of the United States Geological Survey and other Federal map-making bureaus dependent upon this precise control, but States and cities are demanding more and more insistently that this control be made available for their use. This work is a necessary preliminary to the industrial progress of the nation and must be regarded as a necessary investment rather than as running expenses.

The question of State cooperation in this work is one that should be considered. It is believed that a State should be permitted to share the cost of control surveying which is entirely within the limits of the State and which is done primarily at the request of the State to meet its own particular need. However, the greater number of arcs of precise triangulation and lines of precise leveling cross several States. Each separate piece of this control surveying must be joined at both ends to the main scheme over the whole country and so can not well be done piecemeal at wide intervals of time. It would be very difficult, one might almost say impossible, to secure the cooperation of several States in the required manner. It is, of course, out of the question


125°
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D O M I N I O N O F C A N A D A
P A C I F I C O C E A N
A T L A N T I C O C E A N
G U L F O F M E X I C O
U.S. COAST AND GEODETIC SURVEY
TRIANGULATION SKETCH
1921
Published Triangulation and Traverse
Completed and Unpublished Triangulation and Traverse
Completed Reconnaissance
Statute Miles
100 50 0 100 200 300 400
Kilometers
100 50 0 200 400 600 800

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for each State to do its own control work. The cost of organizing and equipping a geodetic survey in each State would be prohibitive to say nothing of several other almost insurmountable difficulties as, for example, the carrying of work through intervening States which were indifferent or wished to delay in making the appropriations, to a State urgently in need of control data.

Although the need for triangulation and leveling in the United States proper is very great, the condition in Alaska is even worse. The precise control work in Alaska immediately needed includes an arc of triangulation along the coast to coordinate the hydrographic charts, and triangulation and leveling from Cook Inlet into the interior toward Fairbanks, for the use of several Government organizations, especially the topographic branch of the Geological Survey, the General Land Office, and the Forest Service. This Bureau and the Geodetic Survey of Canada are at present cooperating in carrying precise triangulation from the northern boundary of the United States to a point on the Yukon River where it crosses the one hundred and forty-first meridian boundary. This will make the North American datum available for both Alaska and Canada.

One of the important lines of scientific work carried on by the Bureau is the determination of gravity. The cost of this work is very small. The results are of great value to geologists in their practical as well as theoretical work, and they have urged that the work be continued again, especially to ascertain if the gravity apparatus can be used for the detection of oil or other mineral deposits. Another important problem in gravimetric surveys is to develop an apparatus for the measurement of gravity at sea. Many investigations regarding the formation of the earth's crust and earth dynamics would be greatly advanced by accurate gravity determinations over the oceans. The cost of this work would be almost insignificant as compared with the benefits to be derived.

The subject of seismology is now being followed actively by many able investigators in this and other countries. Very recently this work has been undertaken in California by the Carnegie Institution of Washington and independently by geologists in California. This Bureau should be given an appropriation to cooperate in this work to the extent of carrying precise triangulation and leveling into the regions of seismic activity in order to detect movements of the earth both horizontally and vertically. It is very probable that there is a slow movement of the earth's crust prior to an earthquake shock and that the imminence of destructive convulsions may be predicted after proper study of the subject has been made.

Following the San Francisco earthquake of April 18, 1906, the triangulation in the area affected was revised to determine the amount and extent of the horizontal displacements in the earth's crust. Relative horizontal displacements of from 6 to 20 feet on the sides of a fault 185 miles long were disclosed by this triangulation. It also disclosed evidence of earlier movements which had affected a large area, probably at the time of the 1868 earthquake. These two great movements caused horizontal displacements in an area of more than 4,000 square miles.

In order that any preliminary gradual displacements may be detected, it is necessary that detailed precise triangulation be extended over the areas of suspected seismic activity and that the observations

at certain stations in that area be repeated at intervals. Critical strains in the earth's crust may also be evidenced by changes in the relative elevations of different portions of the terrain, so precise levels should also be run.

These precise earth measurements are a necessary preliminary to the successful study of the seismic phenomena antedating severe earthquakes. The control points established will also perform their more common function of base points for local surveys and will thus be of value in a dual capacity.

HYDROGRAPHIC WORK.

It has been found convenient to arrange this work in the form of separate projects. These projects may be divided into two classes, as follows: (1) Unchangeable areas; (2) changeable areas which will require continuing operations for an indefinite period.

In the first class, there are the offshore hydrography of the Atlantic and Pacific coasts; the wire-drag work on the Atlantic, Gulf, and Pacific coasts, including Porto Rico and southeast Alaska; the first complete survey of certain sections of southern and western Alaska, which are of immediate commercial importance. No estimate is made for the Aleutian Islands west of Unalaska, most of the area in Bering Sea or Arctic Alaska, since their commercial development seems to belong to the distant future. For the offshore work, we have planned to go seaward to a depth of 100 fathoms in the Atlantic Ocean and Gulf of Mexico and to a depth of 1,000 fathoms in the Pacific Ocean. When these ocean surveys have been accomplished in accordance with present standards, there will be no necessity for additional work inside of the 100-fathom depths on the Atlantic Ocean and Gulf of Mexico and the 1,000 fathom depths on the Pacific Ocean except in those places of comparatively shallow depths, such as Georges Bank, Nantucket Shoals, Diamond Shoals, and the shallow coastal waters which are subject to constant changes. Likewise, after the surveys of the designated sections of Alaska, the Hawaiian and Philippine waters have been completed, the only additional work that will be required in these areas will be such as may result from changes in localities of shallow depth, or where greatly increased commercial importance necessitates more detailed surveys of small bodies of water, or where changes have resulted from public works undertaken subsequent to the original survey, and work in the Bering Sea and Arctic Ocean.

The second class of work, chart revision and the resurvey of the bays and inside waters of the Atlantic and Pacific coasts of the United States, and to a lesser extent of Alaska and the insular possessions, must be carried on indefinitely, just as we are to-day resurveying waters that have been adequately surveyed several times in the past. This is due to the fact that the forces of nature are continuously cutting out and building up along the entire shore where the formation is not solid rock, and also to the fact that the industrial development of the country is continuously changing both the waterways and shore line by dredging channels, filling in, constructing piers and other works. In order that the charts may be kept up to date and be of real service to the mariner it is necessary that they be corrected from time to time to show these changes.

The oceanographic work which the Bureau should carry on can not be treated as a project on which any time limit for completion can be given. At the present time there is an urgent need for the detail of one able vessel on this work on the Atlantic coast for the exploration of the Gulf Stream is one of the problems that was laid down in the organic act creating the Coast Survey. We have done very little work of this kind in the hundred and more years of the existence of the Survey, and no work of any consequence has been done within the last 30 years.

These projects do not include all of the work that should be performed by the Bureau in the line of hydrography and topography, but it is believed that they do include all the projects that should be undertaken at this time or in the near future, the other work to be deferred until the completion of some of these projects. After the completion of any of these projects the personnel and equipment that had been employed on the project will be available for other work.

This other work includes hydrographic investigations beyond the limits of the present projects and other special investigations. It is clearly the duty of this country to perform its share of ocean investigation, and there is a large field for such investigation in the Atlantic Ocean and Gulf of Mexico, contiguous to our coast, but outside of the 100-fathom contour. There is a like need for such work in the Pacific Ocean outside of the 1,000-fathom contour, which is comparatively close to our coast. There are fishing banks seaward of the 1,000-fathom contour in the Pacific Ocean that should be investigated for the benefit of our fisheries. There is a stretch of unexplored water extending hundreds of miles west of the Hawaiian group through which our ships are required to pass. These waters are known to contain many shoals, reefs, and rocks that are a menace to navigation. The survey of these waters, together with resurveys of the shallow changeable offshore waters, would fully employ any equipment and personnel that would be released on the completion of any of the projects which require similar equipment.

WIRE DRAG, ATLANTIC AND GULF COASTS.—Area to be dragged, 5,000 square miles; 3,000 square miles of this area is on the coast of Maine, and includes much deep water. Owing to lack of appropriations, it has been impossible to do any work on this project during the last fiscal year.

ATLANTIC AND GULF COASTS.—Area of offshore work required, 166,000 square miles.

PORTO RICO AND VIRGIN ISLANDS.—Area wire-drag work required, 750 square miles, mostly in Vieques Sound.

VIRGIN ISLANDS.—General hydrographic surveys are required.

PACIFIC COAST, CALIFORNIA, WASHINGTON.—Area wire-drag work required, 1,360 square miles. No work has been done on this project owing to lack of equipment and money.

CALIFORNIA, WASHINGTON, OREGON.—Area offshore surveys, 70,500 square miles. This project is divided into the following three sections, owing to the different conditions existing in each:

San Diego to Point Conception.—Area 21,000 square miles. No work has been accomplished during this fiscal year and none is contemplated during next year.

Point Conception to Cape Blanco.—The area required to be covered is 21,000 square miles.

Cape Blanco to Puget Sound.—The area required to be covered is 28,500 square miles. No work has been accomplished during this fiscal year and none is contemplated for the next year.

SOUTHEAST ALASKA.—There are 7,000 square miles to be covered by wire drag.

DIXON ENTRANCE TO CAPE SPENCER.—On the outer coast the inshore and protected work to be covered has an area of 4,120 square miles, and the offshore work has an area of 12,000 square miles.

PACIFIC COAST OF ALASKA.—Cape Spencer to Attu Island. Incomplete hydrography area 26,250 square miles. The surveys of a large part of this are sufficient for present navigational needs. For administrative purposes it should be considered in the same class as the changeable areas on the continental coasts of the United States. Additional surveys will be made in response to a demand, and the ideal arrangement would be to assign one or more parties each year to this class of work. No work under this project is undertaken during the present, nor is any contemplated during the next, fiscal year.

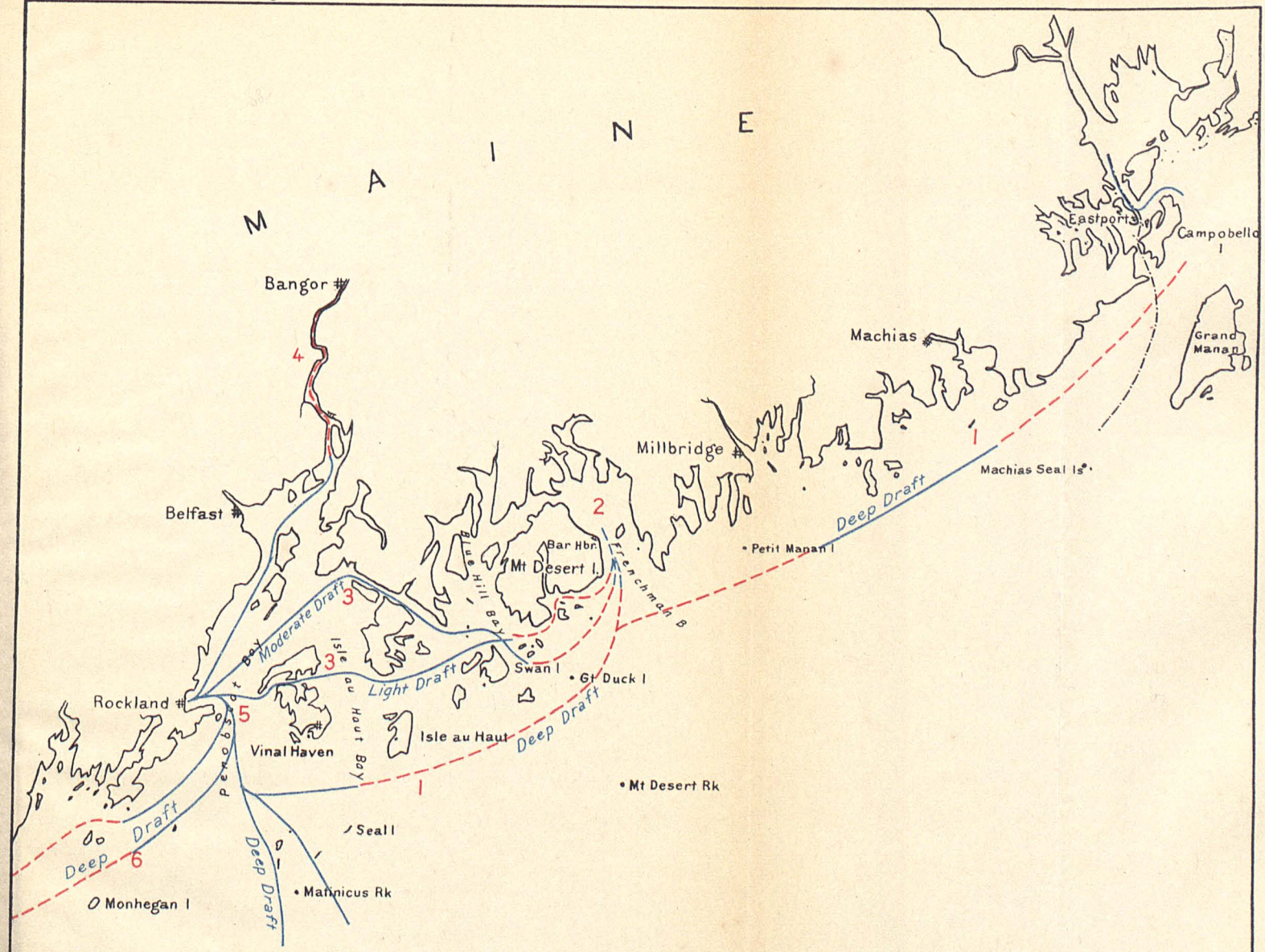
Exploratory or unsurveyed area 120,465 square miles. Of this area there are 40,000 square miles of immediate importance to navigation. This includes the stretch of coast from Prince William Sound to Unalaska Island. The party should be prepared to undertake all classes of surveys. The type of organization would be that of the *Surveyor* in 1920.

ALASKA, BERING SEA, AND ARCTIC OCEAN.—Area unsurveyed 427,345 square miles. Most of this area is of such a distance from land that its survey is of no present navigational importance. The stretch of coast on the north side of the Alaskan Peninsula and extending from Unalaska Island to the mouth of the Kuskokwim River promises to be of increasing commercial importance due to the large fishing industries and the possibility of the discovery of gold-bearing sands, the characteristics of the shores of the Kuskokwim being similar to those found at Nome. No work was accomplished on this project during the present fiscal year, nor is any contemplated during the next year.

HAWAIIAN ISLANDS.—The unsurveyed area is 10,280 square miles. Most of this area is deep water which could be done by a steamer of the *Lydonia* type. The hydrography of the bays and close along shore, as well as the topography, would be done by a detached party from the steamer living ashore and assigned a launch. This work is much needed, but owing to lack of appropriations it has been impossible to do any work on this project during this fiscal year, nor is any contemplated during the next year.

In the present and previous annual reports there are printed diagrams of the Condition of Field Operations. These diagrams are intended to show in a graphic manner where our surveys are at present adequate, or where surveys are needed, and the type of survey required to make our charts up to date and thoroughly reliable for safe navigation.

To facilitate reference to the text and to the locality, diagrams are inserted showing the important steamer courses, the courses being numbered to correspond to the paragraphs of descriptive matter.



CONDITION OF SURVEYS ALONG MAIN STEAMER ROUTES

June 30, 1921

Dragged and safe _____

Not dragged - doubtful _ _ _ _

Additional drag work required _ _ _ _

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Using these sketches as base maps, I have endeavored to show the progress that has been made in the hydrographic and topographic work, using the same sequence in numbering the courses and descriptive matter pertaining thereto.

A detailed analysis of the conditions and the progress of the work can not be given in this limited space, but there are shown on the base maps the areas covered during the past year.

1. DEEP-DRAFT ALONGSHORE COURSE FROM THE CANADIAN BOUNDARY TO THE OUTER LIMIT OF ISLE AU HAUT BAY.—The entire area that this course covers is a region of ledges and bowlders. The ledges rise abruptly from the deep water and the bowlders ordinarily lie singly or in clusters on an otherwise flat bottom, so that the navigator can not depend on the lead to avoid them. The thoroughfares affording an exit to the Bay of Fundy from Passamaquoddy Bay and St. Croix River have been wire dragged. Also an area 15 miles in length between Machias Seal Islands and Petit Manan Island. There is still remaining a large area as yet untouched by the wire drag. There are a number of towns along this course that depend on waterborne traffic for shipping out their produce and receiving their supplies. The commerce consists of lumber, fish, and fuel, and miscellaneous merchandise, constituting the supply of the smaller and larger fashionable resorts, of which the largest is Bar Harbor, Me. The exceptionally rocky coast makes it certain that a wire-drag survey will result in the discovery of many rocks that now endanger the safety of commerce over this course. (See fig. 5, opposite p. 54.)

2. FRENCHMANS BAY.—This body of water lies westward of Schoodic Peninsula and eastward of Mount Desert Island. It is the approach to the town and important summer resort of Bar Harbor, Winter Harbor, South West Harbor, Northeast Harbor, and many small villages and naval coaling stations on the north side of Eastern Bay. The bay is frequented by many passenger steamers, yachts, small craft, fishing vessels, and a few cargo vessels. This area has been dragged to a line extending westward from Schoodic Island whistle buoy, though not to depths now considered necessary. The value of the work is further impaired by the necessity of passing over not less than 14 miles of undragged, doubtful area, in order to reach the bay from the open sea. (See fig. 5, opposite p. 54.)

3. INLAND THOROUGHFARES FROM MOUNT DESERT ISLAND TO ROCKLAND.—There is a series of valuable inside passages along the Maine coast that are very narrow in places and wind between rocky ledges. Owing to the nature of the bottom they are in particular most likely to be obstructed by pinnacle rocks or the extension of narrow ridges out into the channel. The only part of these channels which has been dragged lies between Bluehill Bay and the western entrance of Penobscot Bay. The results obtained have been so startling that they clearly indicate dangers in the use of channels that have not been dragged. (See fig. 5, opposite p. 54.)

4. PENOBSCOT RIVER.—This river, emptying into the head of Penobscot Bay, forms the approach to the towns of Bucksport, Winterport, Hampden, and Brewer, and the city of Bangor, the latter two at the head of navigation, about 24 miles above Fort Point Lighthouse at the entrance. It has considerable trade in regular steamers drawing about 10 feet, and many vessels trading to Bangor draw as much as 18 feet. Practically the entire river above Bangor is used in lumber-

ing. From the mouth of the river to Bangor there will be no positive certainty of the absence of all dangers to navigation until the area has been dragged. (See fig. 5, opposite p. 54.)

5. PENOBSCOT BAY.—In Penobscot Bay every port has benefited by the practical completeness of the wire-drag work. There are, however, some of the less-important sections to be dragged, and some of the approaches from the eastward are not yet completed. The wire drag, as used by the Coast and Geodetic Survey, was developed in this region, and some of the area was not dragged to the depth now believed necessary. The size of vessels has increased rapidly, and additional work is necessary to protect this increased draft. (See fig. 5, opposite p. 54.) As it has required time to solve all the problems involved in dragging to this greater depth, it is probable that much of the deeper part of Penobscot Bay which was covered during the development of the wire-drag apparatus will later have to be dragged to a greater depth.

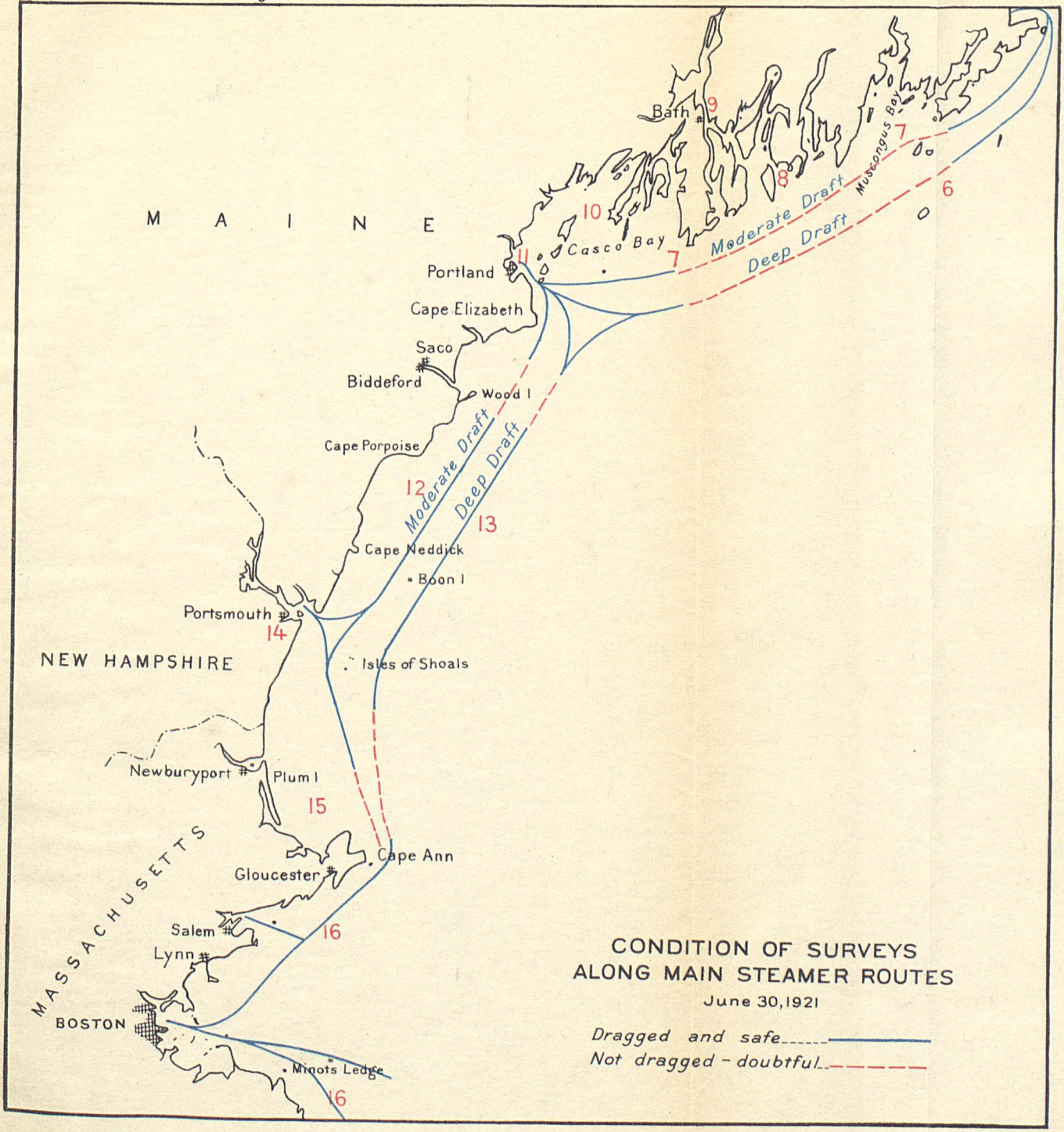
6. PENOBSCOT BAY TO CASCO BAY (DEEP DRAFT).—The coast of New England throughout its length presents practically one uniform problem to the hydrographic engineer. Surveys of varying degrees of completeness have been made of the entire area, and it is possible for navigators to select channels which are apparently safe. They would be of ample depth if it were not for the ice-worn granite rock or the large bowlders deposited during the glacial period. The lead line is not adapted to find without assistance dangers of this character. This thoroughfare presents uneven and rocky bottom between Monhegan Island and the eastern entrance to Casco Bay, which should be dragged to remove all doubt of the existence of pinnacle rocks or small ledges. (See fig. 5, opposite p. 54.)

7. PENOBSCOT BAY TO CASCO BAY (MODERATE DRAFT).—From the western entrance of Penobscot Bay to Casco Bay there has been no wire-drag work done. The inside route is constantly used by coasting steamers, but it is certain that it has within its limits many uncharted rocks, some known locally and some unknown. (See fig. 6, opposite p. 56.)

8. BOOTHBAY HARBOR.—This forms the approach to the town of Boothbay Harbor and numerous smaller summer resorts. It is frequented by many vessels and by a large number of fishing boats and pleasure craft in summer. It is one of the best anchorages on the coast of Maine, and is much used as a harbor of refuge by all classes of vessels. This area is in urgent need of a wire-drag survey. (See fig. 6, opposite p. 56.)

9. KENNEBEC RIVER.—It is the approach to the cities of Bath and Augusta, the towns of Woolworth, Richmond, and Gardiner, and numerous smaller villages and summer resorts. The river has considerable water-borne commerce, the deepest draft being about 21 feet to Bath and 14 feet to Augusta. There is urgent need for a wire-drag survey of this river. (See fig. 6, opposite p. 56.)

10. CASCO BAY.—Casco Bay and the approaches to Portland have been dragged with the result of finding numerous uncharted shoals, thereby furnishing important evidence of the need of carrying the survey to the eastward and westward to a junction with completed work. A resurvey of inner Casco Bay is badly needed, the glaciers having left a series of long, narrow, and dangerous ledges, which require closer examination. (See fig. 6, opposite p. 56.)


MAINE
NEW HAMPSHIRE
MASSACHUSETTS
Bath
Casco Bay
Muscongus Bay
Portland
Cape Elizabeth
Saco
Biddeford
Wood I
Cape Porpoise
Cape Neddick
Boon I
Portsmouth
Isles of Shoals
Newburyport
Plum I
Cape Ann
Gloucester
Salem
Lynn
BOSTON
Minots Ledge
Moderate Draft
Deep Draft
6
7
8
9
10
11
12
13
14
15
16
CONDITION OF SURVEYS
ALONG MAIN STEAMER ROUTES
June 30, 1921
Dragged and safe
Not dragged - doubtful

C. & G. S. Print

11. PORTLAND HARBOR AND APPROACHES.—These have been dragged, and all dangers to navigation are shown on the charts. (See fig. 6, opposite p. 56.)

12. PORTLAND TO PORTSMOUTH (MODERATE DRAFT).—Westward of Portland the succession of sand beaches, of which Old Orchard is the best known, might appear to indicate an absence of rocks in this region. The depth of sand above the underlying rock is not great, however, and pinnacle rocks occur outside these beaches. There is a gap in the wire-drag surveys between Cape Porpoise and Cape Elizabeth, which must be completed to make this portion safe. (See fig. 6, opposite p. 56.)

13. PORTLAND TO CAPE ANN (DEEP DRAFT).—The region from Boon Island to Isle of Shoals is very rocky, and its importance as the approach to Portsmouth is well recognized. The area has been covered by the wire drag which now forms a continuously dragged area from Cape Porpoise to within 10 miles of Cape Ann. (See fig. 6, opposite p. 56.)

14. PORTSMOUTH HARBOR.—This area has been dragged, and all dangers to navigation are known. (See fig. 6, opposite p. 56.)

15. MASSACHUSETTS COAST NORTH OF CAPE ANN.—From the New Hampshire border to Cape Ann the shores are entirely different from those to the north or south. There are high sand bluffs in places and low sandy shores in others. As a result, the depths along the shore are changeable, and, though they have been recently surveyed, they will need further attention. (See fig. 6, opposite p. 56.)

16. CAPE ANN TO CAPE COD CANAL.—A completely dragged area extends from Cape Ann to Cape Cod Canal and from the head of Buzzards Bay to Sakonnet Point, R. I. With the exception of the areas near the shores of Buzzards Bay, this important survey is complete. This work was made especially necessary by the opening of the Cape Cod Canal in 1915, the original surveys having been made while the commerce of the region was relatively unimportant. A number of shoals were found of less than the proposed canal depth. It was important not only to find those shoals of less than the proposed canal depth, but also those which might become a menace at some future date in case it should be necessary to deepen this canal to take care of the largest vessels. With this view the drag was carried at a sufficient depth to meet such requirements. Even should a depth of 40 feet be adopted for the canal, the present surveys of the approaches will be found adequate, and where less depths have been found the information will be invaluable to the engineers making the improvement. (See fig. 6, opposite p. 56.)

17. FROM BOSTON SOUTH OUTSIDE CAPE COD.—Much of the traffic between eastern New England and points west and south passes outside of Cape Cod; most of it through Nantucket and Vineyard Sounds. Off Cape Cod the surveys are not complete. In Nantucket Sound the entire route is through channels bounded by shifting sand, and requires frequent revision work. In one part of the channel most used—through Pollock Rip Slue—a shoal was formed in the last few years that has been steadily narrowing and decreasing the depth of the channel. A resurvey of parts of this route is needed every few years to insure safety to navigation. No rocks abound eastward of Cape Cod, but in the north half of Nantucket Sound and the western part of Vineyard Sound large bowlders occur

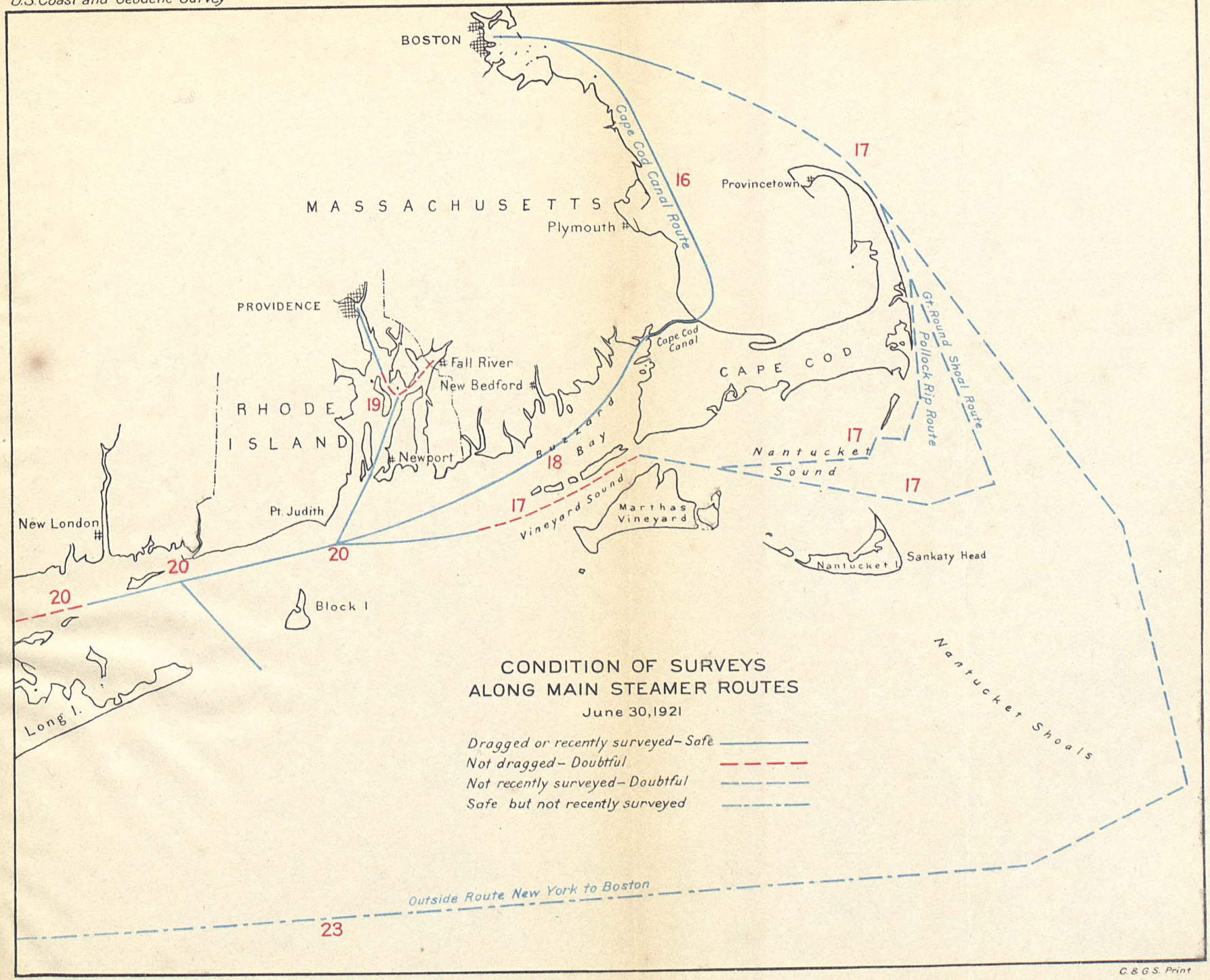
and wire-drag work is needed. At present vessels must pass over 10 miles of undragged area in following the best channel through Vineyard Sound. (See fig. 7, opposite p. 58.)

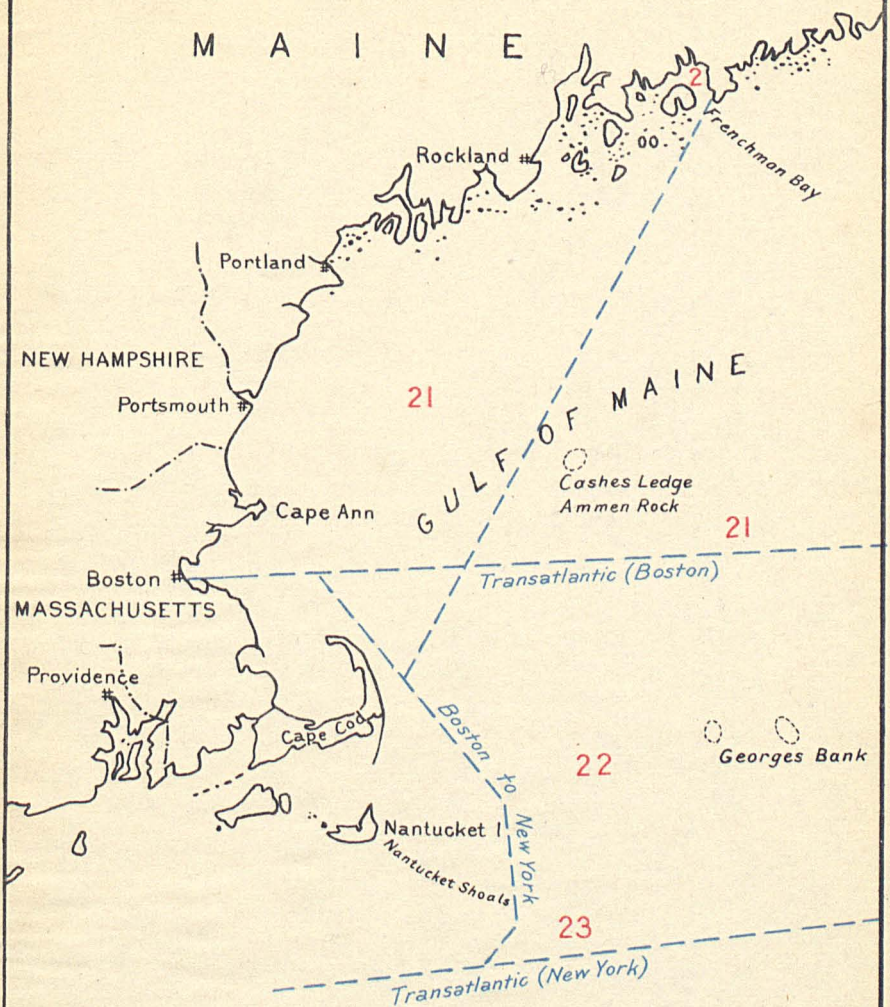
18. From Cape Cod Canal Through Buzzards Bay.—This route has been dragged out to the eastern limit of Long Island Sound. (See fig. 7, opposite p. 58.)

20. Entrance to Narragansett Bay, Block Island Sound, Fishers Island Sound, and Eastern Part of Long Island Sound.—These areas are practically completed, with the exception of the central and western parts of Long Island Sound, which remain to be dragged. (See fig. 7, opposite p. 58.)

21. Gulf of Maine.—The portion of the Gulf of Maine of which the Bureau makes surveys may be considered as lying to the westward of meridian 67° 0′ and extending to Nantucket Shoals. This entire area has been inadequately surveyed, as it was accomplished at an early date when both the appliances and the methods were far inferior to those of the present day. Not only are the soundings obtained insufficient, but many of them are not located correctly on the charts. A good example of this is the discovery several years ago that only one shoal rock exists on Cashe Ledge, where two were charted, and that Sigsbee and Ammen Rocks formerly shown four miles apart are really the same rock. These defects in the charts are serious for two reasons: The trans-Atlantic steamers approaching the ports of northern New England, especially Portland and Boston, are unable to depend on the charts of the Gulf sufficiently to locate themselves accurately by sounding. This is particularly serious during the fog of summer, which often extends far out to sea and lasts for days, and during the winter snowstorms. In addition to this, the fisheries of the Gulf of Maine are an important national asset. Not only are many important fishing banks uncharted, but the limit and depths of known banks are not correctly given. Besides, there is not at present enough information available as to the character of the bottom. The knowledge of rocky bottom may lead to the discovery of good fishing grounds. (See fig. 8, opposite p. 58.)

22. Nantucket Shoals to Georges Banks.—Extending eastward from Nantucket Sound there is an immense shoal area, consisting of sandy ridges which are shifted by the waves and currents. Nantucket Shoals extend about 50 miles offshore; then there is a deep channel followed by ridges. It is readily seen that it is important to keep the channel surveyed and to examine the adjacent shoals to detect changes; but it might readily be asked, what is the use of surveying such areas as Nantucket Shoals, which vessels are most careful to avoid? First, it is necessary to be certain that the outer limits of these shoals are clearly defined in order that they may be avoided; second, the shoals are important fishing grounds; third, more careful surveys may develop safe channels for coastwise navigation channels which are already indicated on the charts but are unsafe to use because of inadequate surveys. Due to the constant changes the existing surveys are nowhere adequate. The shoals are so numerous and the channels so intricate that a difficult problem is presented in their examination by accurate methods. The ground fishing, which has in recent years assumed large proportions, is steadily moving seaward. During the winter Nantucket Island is the


BOSTON
Cape Cod Canal Route
16
17
Provincetown
MASSACHUSETTS
Plymouth
PROVIDENCE
Fall River
New Bedford
Cape Cod Canal
CAPE COD
Gt. Round Shoal Route
Pollock Rip Route
RHODE ISLAND
19
Buzzard Bay
18
17
Nantucket Sound
17
Newport
Pt. Judith
New London
Vineyard Sound
Marthas Vineyard
20
20
20
Nantucket I.
Sankaty Head
Block I
Long I.
Nantucket Shoals
CONDITION OF SURVEYS
ALONG MAIN STEAMER ROUTES
June 30, 1921
Dragged or recently surveyed – Safe
Not dragged – Doubtful
Not recently surveyed – Doubtful
Safe but not recently surveyed
Outside Route New York to Boston
23



CONDITION OF SURVEYS ALONG MAIN STEAMER ROUTES

June 30, 1921

Solid blue - dragged or recently surveyed - Safe. _____

Broken blue - incompletely surveyed. — — —

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headquarters of this industry. Not only do the present charts lack the needed information in the search for new ground but the absence from the charts of existing shoals is a source of danger to the boats running to and from the harbor. Breakers often occur where there is ample depth for boats when the water is smooth. This is an excellent example of how a region usually avoided by commerce may be of importance to an industry which furnished part of the food supply of the nation. (See fig. 8, opposite p. 58.)

23. TRANS-ATLANTIC APPROACH TO NEW YORK.—There is scarcely any part of our coast where correct soundings are of more importance than in the approach to New York from the eastward, as all trans-Atlantic steamers bound to that port pass over this area. Many of them have to depend on soundings for safety. A fairly good survey of this area is available, but additional work should be done by modern methods in the portion out of sight of land so that the needs of the enormous traffic will be met. (See fig. 8, opposite p. 58.)

24. FROM POINT JUDITH TO NEW YORK.—It is almost unnecessary to go into particulars, except to make it clear that the central and western parts of Long Island Sound remain to be dragged. This work will be undertaken at the earliest opportunity. At present New York Harbor has but one exit to the sea for deep-draft vessels—by way of the Lower Bay and through Ambrose Channel over Sandy Hook Bar. The other exit, through Long Island Sound and Block Island Sound, is obstructed by ledges at Hell Gate, in the East River. The project to remove these and secure a depth of 40 feet is now in progress. Before it is completed, channels of this depth in the sound should be examined with the drag to make certain they are safe. This would also apply to Fort Pond and approaches, if the proposed trans-Atlantic terminal is located at that place. The project to deepen East River to 40 feet makes it necessary to be certain where the channels with such depths are located in Long Island Sound. The work done in Block Island Sound has defined the limit of such depths in the eastern approach to Long Island Sound, and it is urgent that the entire area should be completed without delay. The approaches to all the harbors on Long Island Sound should be dragged. The shoaler bays are used extensively by motor boats, and the number in operation for a given area is probably greater than anywhere else in the United States. (See fig. 9, opposite p. 60.)

25. HUDSON RIVER.—The Hudson River is a valuable waterway between New York and Albany and is a part of the canal system of the State. A few years ago a dangerous rock was found directly in the path of steamers between New York and Albany. With such a possibility all the doubtful parts of the Hudson should be dragged. (See fig. 9, opposite p. 60.)

26. NEW YORK HARBOR.—New York Harbor has had a recent survey, but as it is an area subject to change it will require a survey, at least in part, every few years. (See fig. 9, opposite p. 60.)

27. COAST OF NEW JERSEY.—Along the most of the coast of New Jersey the character of the bottom is such that the exact existing depths should be ascertained beyond all doubt, particularly as shoals dangerous to coastwise traffic have been reported from time to time. The only reliable surveys along this stretch of coast have been made in connection with searches for these reported shoals. Eastward of Cape May there are shoals that need a resurvey. A survey of this

area was in progress July 1, 1920, in the vicinity of Cape Henlopen and extended northward. The sounding lines were carried out seaward as far as the 100-fathom curve. The season closed in October. (See fig. 9, opposite p. 60.)

28. DELAWARE BAY.—Delaware Bay has as its most marked characteristic a series of narrow, fairly deep channels separated by long, narrow shoals. These shoals are subject to change. A survey is needed now, and one should be made about every 10 years in the entrance and at longer intervals in the upper bay. While dredged channels are maintained for most of the distance from the entrance of the bay to Philadelphia, vessels of moderate draft use the other channels. In view of the importance of the cities at the head of the bay and on the river, it is highly important that the needed survey of Delaware Bay be made so that a chart of the proper standard may be issued. (See fig. 10, opposite p. 60.)

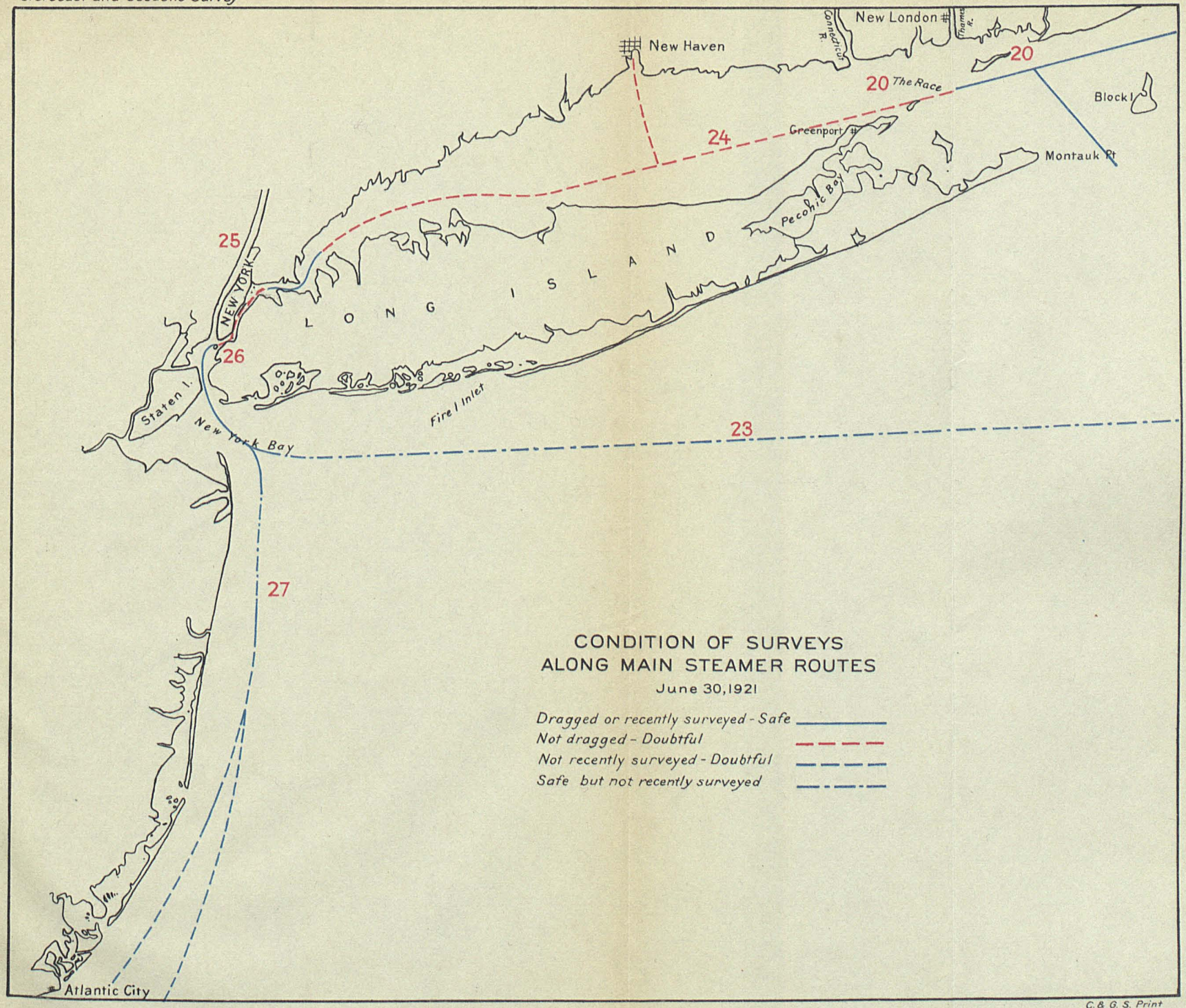
29. DELAWARE BAY ENTRANCE TO CHESAPEAKE BAY.—From Delaware Bay entrance to Chesapeake Bay there is a succession of shoals and banks. Many of these are buoyed so that moderate-draft vessels may pass inside of them. In certain regions it is of the highest importance that the survey should be correct and kept up to date. At only one place has a comprehensive survey been made, and this was the investigation of a reported shoal. Work in this section is now in progress, north of the entrance to Chesapeake Bay, and being extended northward. (See fig. 10, opposite p. 60.)

30. CHESAPEAKE BAY AND TRIBUTARIES.—These have been extensively surveyed in recent years, and a large number of tributaries will not require resurveys for many years. This is also true of the Potomac River. The parts which need resurveying are parts of the bay from Cape Charles to a point opposite Annapolis, parts of the James River, and the Rappahannock and Susquehanna Rivers. The entrance has been recently surveyed, but another survey will probably be needed in 10 years. Owing to the shifting sandy bottom, the bay is greatly in need of examination at critical localities where depths are near the draft of vessels, frequent report indicating presence of new shoals. (See fig. 10, opposite p. 60.)

31. CHESAPEAKE BAY ENTRANCE TO CAPE HATTERAS.—The diagram shows the tracks for both the light-draft and deep-draft vessels. While a resurvey is desired, the most pressing need is that the present limit of shoal areas be accurately determined. (See fig. 10, opposite p. 60.)

32. ALBEMARLE SOUND.—Albemarle Sound and its tributaries, with a few exceptions, have been resurveyed within the last few years and will not require resurveying for a long time. The uncompleted portions, including the North and Alligator Rivers, should be finished in the near future, as they form part of the project for a through 10-foot channel of the inside waterway route. The Chowan River, which is the western extension of this sound, should also be finished, and then the surveys of this region would be in a most satisfactory, up-to-date condition. (See fig. 10, opposite p. 60.)

33. CROATAN SOUND.—Croatan Sound, the connecting link between Albemarle and Pamlico Sounds, has recently been resurveyed, but the depth is so near to the draft of vessels using it that the surveys will have to be revised from time to time. Changes in the main



CONDITION OF SURVEYS ALONG MAIN STEAMER ROUTES

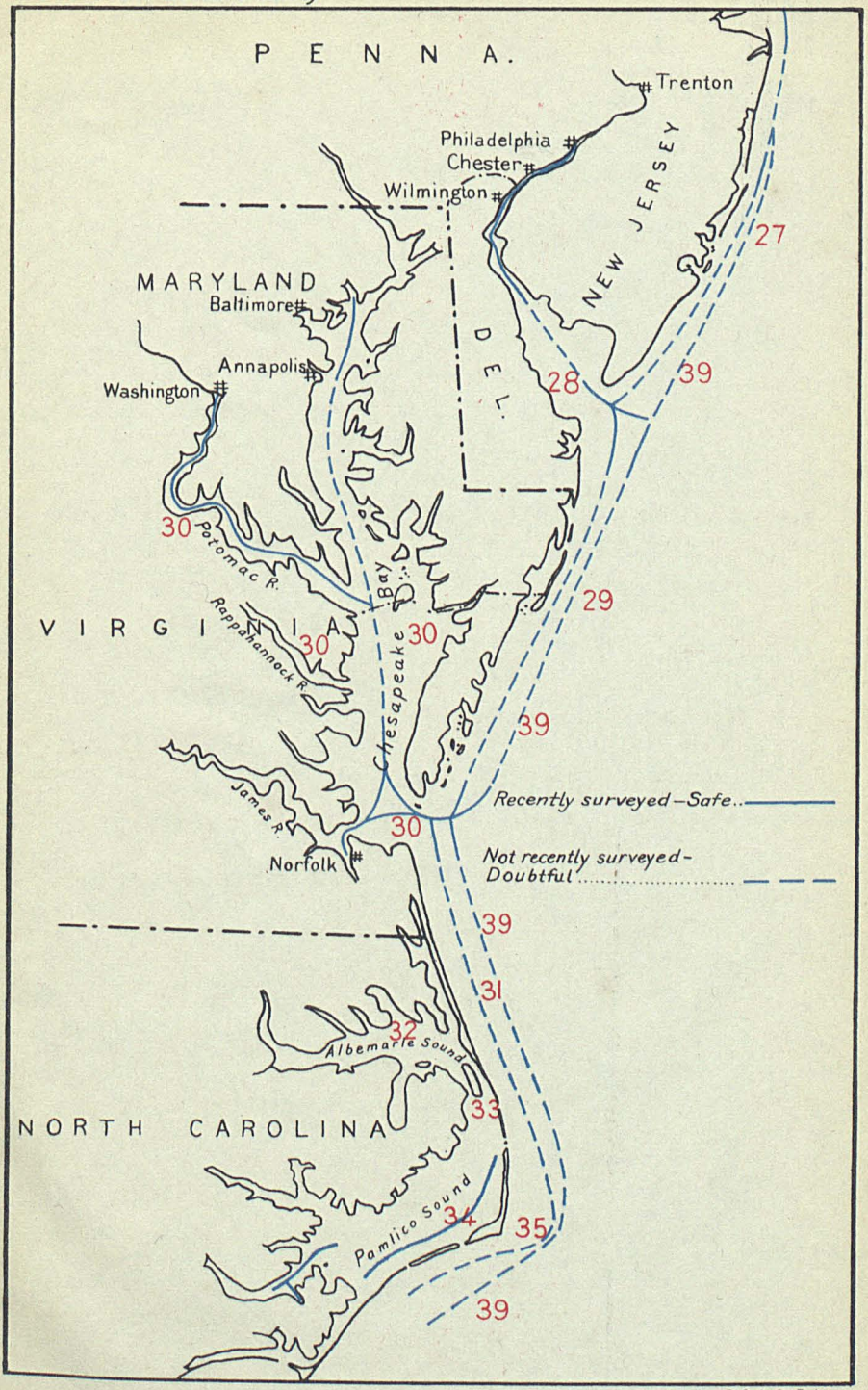
June 30, 1921

Dragged or recently surveyed - Safe

Not dragged - Doubtful

Not recently surveyed - Doubtful

Safe but not recently surveyed


PENNA.
Trenton
Philadelphia
Chester
Wilmington
NEW JERSEY
MARYLAND
Baltimore
Annapolis
Washington
DEL.
Potomac R.
Chesapeake Bay
Rappahannock R.
VIRGINIA
James R.
Norfolk
Albemarle Sound
NORTH CAROLINA
Pamlico Sound
27
28
29
30
31
32
33
34
35
39
Recently surveyed—Safe
Not recently surveyed—Doubtful

channel have occurred within the last two years. (See fig. 10, opposite p. 60.)

34. PAMLICO SOUND.—Pamlico Sound has additional importance owing to its relation to the inland waterway route. The eastern half of the sound is well surveyed, but the entire western half and the Neuse River, in addition to its local use as part of the through 10-foot channel, have not been completed; the survey was in progress up to October, 1920, when it had to be discontinued owing to the steamer proving unsuitable and too expensive to operate. (See fig. 10, opposite p. 60.)

35. DIAMOND SHOALS.—Diamond Shoals off Hatteras should be resurveyed chiefly to determine changes in their extent, and particularly to obtain a knowledge of the correct depths on the seaward side. (See fig. 10, opposite p. 60.)

36. CAPE HATTERAS TO WINYAH BAY, S. C.—Nearly the whole of this area is in need of a new survey, as those areas now charted are not in sufficient detail for modern navigation. Next to Diamond Shoals in importance to coastwise navigation are the shoals extending seaward from Cape Lookout and Cape Fear. They are subject to change and should be examined at short intervals. (See fig. 11, opposite p. 62.)

37. WINYAH BAY TO FERNANDINA, FLA.—This region has been recently surveyed, the work extending out to 100-fathom curve. The inshore limit did not include the water area inshore from the 3-fathom curve or the entrances to the harbors and inlets. Resurveys of this shoal-water area have been in progress for over a year, and the topography of the immediate coast line is being revised at the same time. The results show many changes of importance to small craft. (See fig. 11, opposite p. 62.)

38. FERNANDINA TO THE FLORIDA REEFS.—From Fernandina to the Florida Reefs the area of moderate depths continually narrows, until at Palm Beach the distance to the 100-fathom curve is very small. The completed survey referred to in paragraph 37 extends southward to a little below St. Augustine. South of St. Augustine the bottom is probably not subject to change except as noted below, and the surveys, while by no means complete, are fair. Off Cape Canaveral and outside the southern half of the Indian River there are extensive banks and ridges in urgent need of resurvey. Known depths of 11 to 16 feet a long way offshore show the need of further surveys to make certain that all the shoals are correctly charted. From Jupiter Inlet to Fowey Rocks, where the Florida Reefs begin, the deep water approaches so close to the shore that it will be a slight task to complete inshore work in connection with the offshore surveys. (See fig. 11, opposite p. 62.)

39. GENERAL, ATLANTIC, AND GULF COASTS.—An explanation of the method used in verifying the location of a vessel by sounding when objects on shore are obscured by distance or thick weather will show why accurate charts are particularly needed from New York to Palm Beach and from Key West to the Mexican Border. At fixed intervals the vessel takes soundings, which are plotted to the scale of the chart on tracing paper, and this is moved over the chart, keeping the line joining the soundings parallel to the course of the vessel until the soundings agree with those shown on the chart. If the charts are correct and based on a sufficiently modern survey, the method is one of the best known for verifying the ship's position. If,

on the other hand, the soundings are few and far apart so that the ship's soundings fall between them, and if those on the chart are wrongly placed, this method becomes much more difficult and an accidental agreement may lead the vessel into danger.

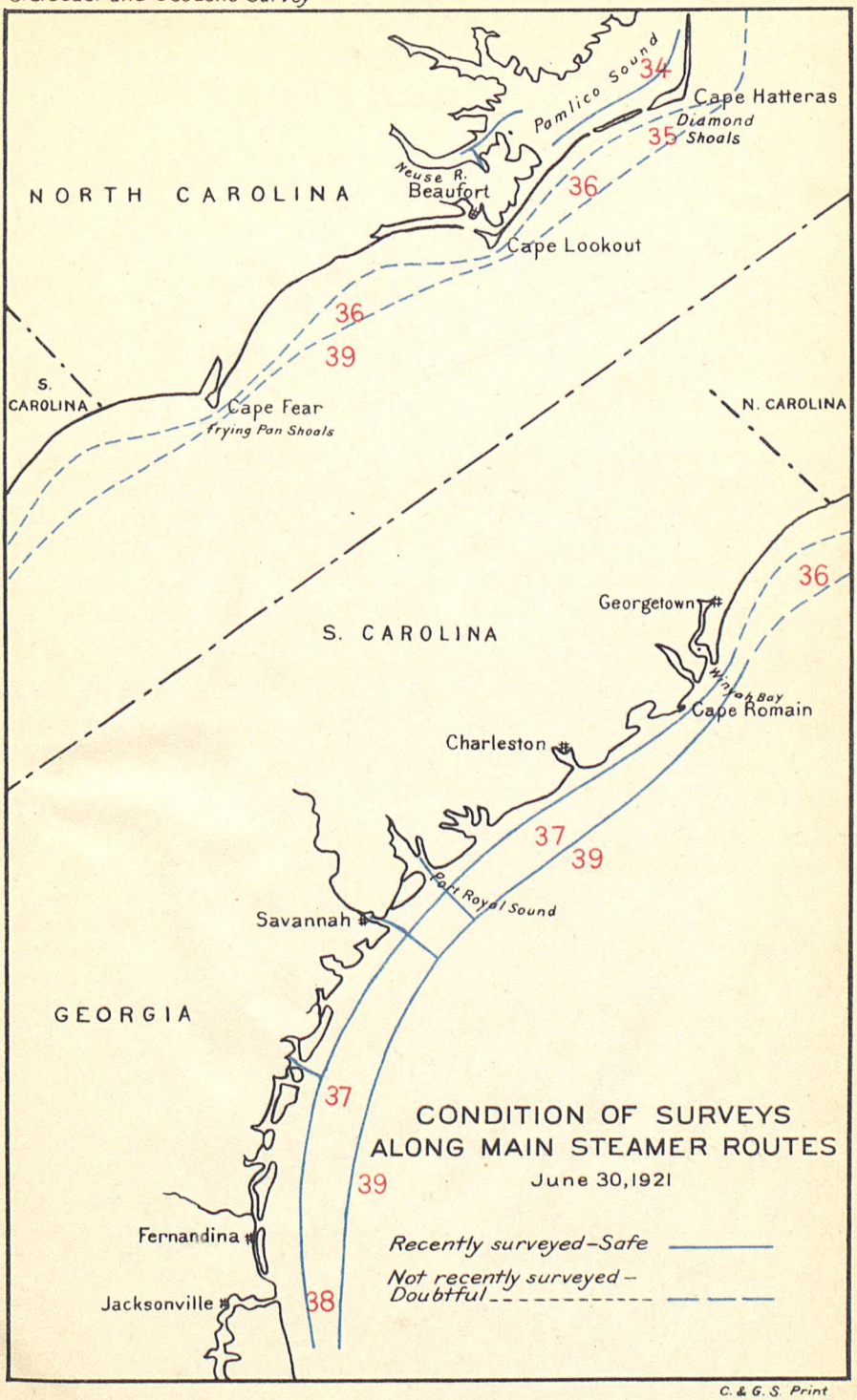
From New York to Cape Hatteras the charts, while fairly good, are by no means good enough to meet the full needs of navigation, but the work required to bring them up to date has been postponed, as the need for resurveys has been more urgent farther south. Up to a few years ago the offshore surveys from Cape Hatteras to the Florida Reefs were almost unbelievably deficient. This condition is being remedied as rapidly as possible, and between Winyah Bay, S. C., and St. Augustine, Fla., the offshore work out to the Gulf Stream is complete. It is important that this work be extended both north and south from its present limit as rapidly as possible. With adequate funds full advantage can be taken of the seasons, and by working north in the summer and south in the winter the cost of the work will be greatly reduced. (See fig. 11, opposite p. 62.)

40. INDIAN RIVER.—There have been no recent surveys of these waters. Revisionary work is needed. (See fig. 12, opposite p. 62.)

41. BISCAYNE BAY.—Recent surveys have been made of this area out to the 100-fathom curve, in the vicinity of Miami and as far south as Fowey Rocks. (See fig. 12, opposite p. 62.)

42. VICINITY OF FOWEY ROCKS LIGHT.—No recent surveys have been made. Inshore and offshore work is in progress eastward from Key West, which includes this area. The present surveys are not sufficient in detail. (See fig. 12, opposite p. 62.)

43. COAST OF FLORIDA FROM PALM BEACH AROUND TO CEDAR KEYS.—For a distance along the shore of 567 miles from Palm Beach southward around to Cedar Keys on the west coast of Florida coral reefs are found, in some places more abundant than in others. Coral reefs, whether the result of disintegration or of a building up by animal growth, are found in a great variety of forms and in vast numbers of sharp projections from the general bottom, where conditions are favorable for the growth of coral. While we are informed that an enormous number of uncharted rocks exist in this region, due to the fact that they are so numerous and that the region is so large, an effort has been made to first drag areas of the coast used by commercial and naval vessels because of both the time and cost involved. Wire-drag work is accordingly undertaken in localities where there are commerce and naval operations. To accomplish even this will require years of work. Westward-bound vessels through the Florida Straits have to force their way against the strong current of the Gulf Stream, which in places attains a velocity of 5 miles per hour. Along the northerly edge of the stream and close to the reefs the current is very weak. There is a strong temptation to keep dangerously close to the reefs and save fuel, and this is the cause of frequent accidents. Besides the danger of running into the known reefs, which are in many places bare and are of no great depth throughout their length, another danger, the extent of which is not yet known, has been discovered in a secondary reef, parallel to the main reef and about one-half mile outside of it. This secondary reef is found to approach the surface in places as a narrow ridge, with depths as little as 25 feet. Twenty-five miles of this reef have been examined, but 200 miles remain to be examined. It is impor-


NORTH CAROLINA
Pamlico Sound
34
Cape Hatteras
Diamond Shoals
35
Neuse R.
Beaufort
36
Cape Lookout
36
39
S. CAROLINA
Cape Fear
Frying Pan Shoals
N. CAROLINA
36
Georgetown
S. CAROLINA
Winyah Bay
Cape Romain
Charleston
37
39
Port Royal Sound
Savannah
GEORGIA
37
39
CONDITION OF SURVEYS
ALONG MAIN STEAMER ROUTES
June 30,1921
Recently surveyed–Safe
Not recently surveyed–
Doubtful
Fernandina
Jacksonville
38

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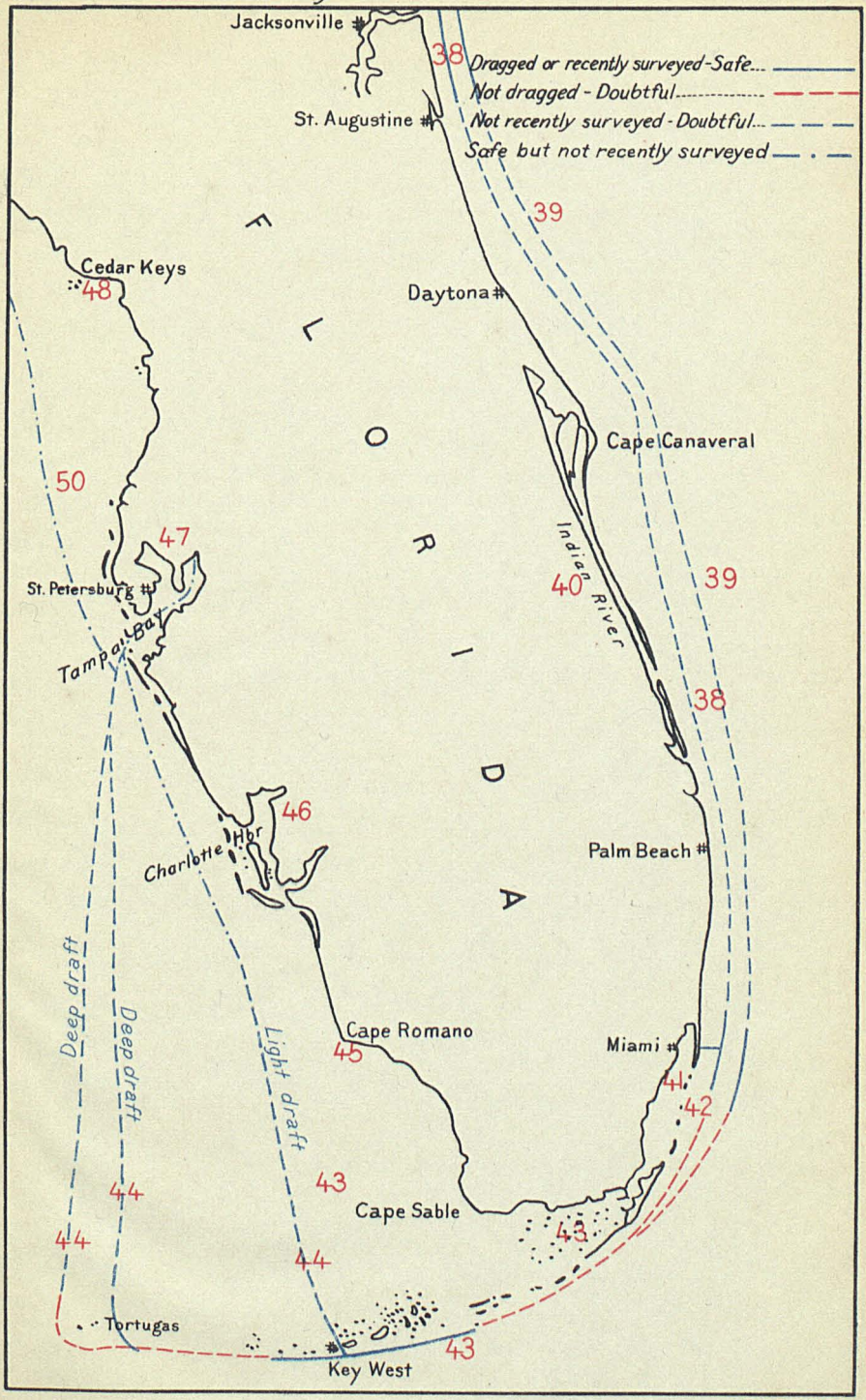

Jacksonville
St. Augustine
Dragged or recently surveyed-Safe...
Not dragged - Doubtful.....
Not recently surveyed - Doubtful...
Safe but not recently surveyed
FLORIDA
Cedar Keys
Daytona
Cape Canaveral
St. Petersburg
Tampa Bay
Indian River
Charlotte Hbr
Palm Beach
Deep draft
Deep draft
Light draft
Cape Romano
Miami
Cape Sable
Tortugas
Key West
38
39
48
50
47
40
46
45
41
42
44
43

tant to nearly all the great traffic entering the Gulf of Mexico that this examination be completed at the earliest possible moment. During the past year up to December, 1920, a vessel has been continuously employed on the surveys of the Florida reefs between the Marquesas Keys and Fowey Rocks; this includes supplementary surveys of the channels through the reefs from deep water into the inside route lying between the reefs and the mainland; also the close development of the shoal area westward of Key West and southward of the Marquesas Keys. In connection with this the work has been carried out to the 100-fathom curve for a distance of 50 miles along the reefs. (See fig. 12, opposite p. 62.)

44. Vessel Courses North from Key West.—Vessels bound for eastern gulf ports naturally wish to take the shortest route. If of light draft, they can cross the Florida Reefs at Key West. The next channel is between Rebecca Shoal and Dry Tortugas, and if this is not used, vessels must pass well to the westward of Dry Tortugas to avoid a shoal bank west of it. The Rebecca Shoal channel has been dragged and has ample depth of water. The bank west of Tortugas should be dragged, especially as vessels making land from the westward have to cross part of it. Northward of the keys from Key West to Tortugas a doubtful area should be dragged. The necessity of this is emphasized by the fact that the U. S. S. *Ellis*, while steaming northward of the Marquesas Keys recently, struck a coral head which proved to have only 7 feet over it. This coral head was directly out of a depth of 35 feet, with no indication of its existence until struck by the naval vessel, which was severely damaged. The channel between the keys and the reef known as the Hawk Channel is important for moderate-draft vessels. It will be necessary to drag the axis of the channel to insure against dangers to the vessels making use of it.

45. Cape Romano.—This area is in need of surveys. An inspection of the existing maps and charts of the State of Florida show practically a blank area for that part of the peninsula south of Lake Okechobee. There are but few areas of the United States of like size about which so little definite information can be obtained. Northward of this unknown region drainage canals are opening up the country for development. It is not unlikely the same means will be extended southward. At the present time the Bureau should prepare to meet a demand in the near future for the delineation of a broader belt of country back of the shore from Cape Sable to Punta Rosa than is now shown on our charts. Tourists and land prospectors are now exploring this intricate system of island and waterways. (See fig. 12, opposite p. 62.)

46. Charlotte Harbor.—No recent surveys have been made of this area and it should be resurveyed. (See fig. 12, opposite p. 62.)

47. Tampa Bay and Approach.—The existing surveys at present meet the needs of navigation of these waters. (See fig. 12, opposite p. 62.)

48. Cedar Keys.—No recent surveys have been made of this region. Wire-drag surveys are badly needed. (See fig. 12, opposite p. 62.)

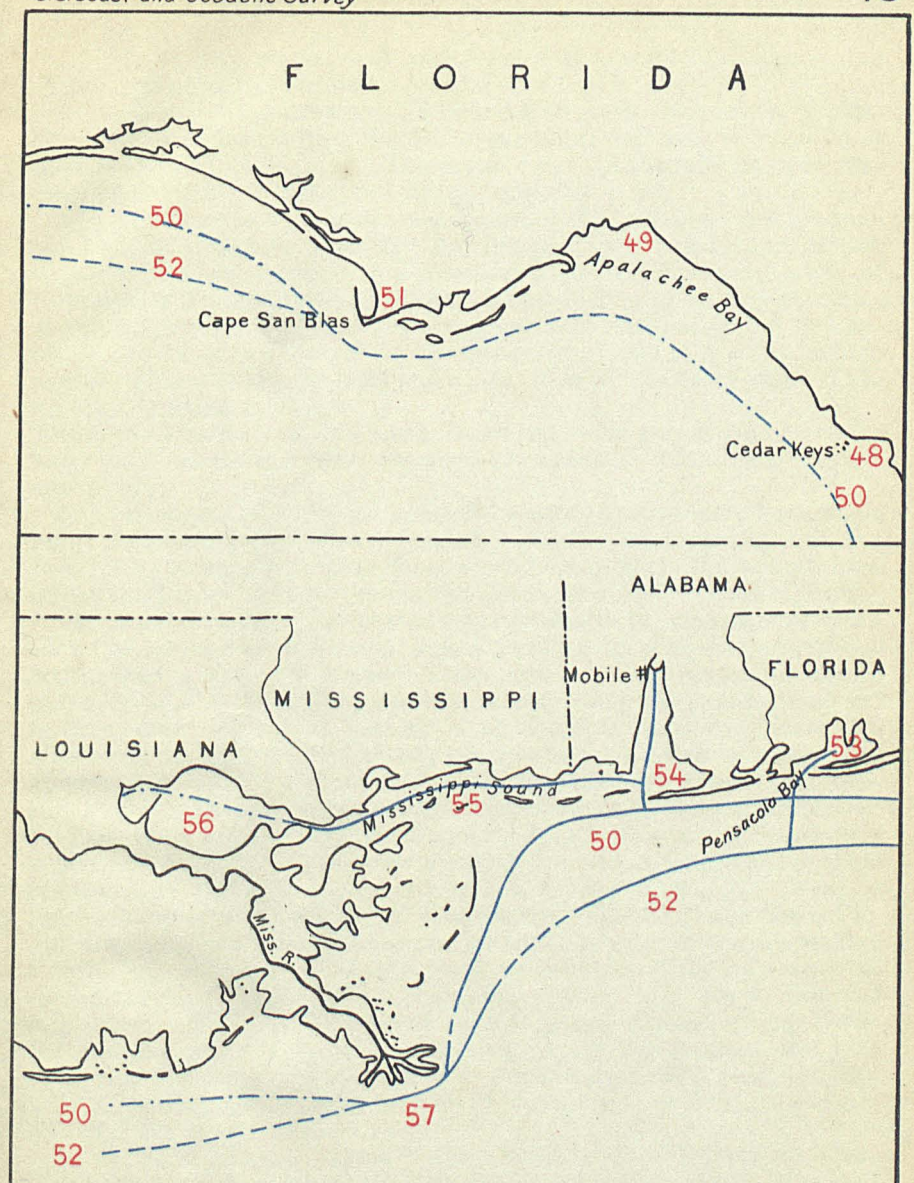
49. Apalachee Bay.—No recent surveys have been made of this region and revision work is needed. (See fig. 13, opposite p. 64.)

50. INSHORE WATERS, GULF COAST.—The chief characteristics of the west coast of Florida are the distances to which shoal water extends offshore between Cape Sable and Cape Romano and from Tampa Bay to Apalachicola and the existence of a large number of bays connected with the sea by deep channels, either natural or dredged. From Apalachee Bay to Cape San Blas the coast begins to assume a character more like the South Atlantic coast, and coral bottom is no longer found. This stretch of coast is sandy and sand shoals extend off some distance, especially in the vicinity of Cape San Blas. This region needs a resurvey, and, like other sandy portions of the coast, will need resurveying from time to time. The Florida and Alabama coasts differ somewhat, as deep water approaches close to the shore in the latter. The coast of Mississippi and Louisiana has a very large proportion of changeable area, and resurveys are needed now and will be needed from time to time in the area from Mobile Bay to the end of the offshore shoals of Vermilion Bay. The immense load of sediment carried by the Mississippi River, especially in time of flood, causes constant changes in the delta. The deposit of sediment and the action of the waves on the deposits result in rapid growth in some places and of erosion in others. Sixty miles west of the Mississippi Delta there begins an extensive shoal region which is in need of survey. The inshore region along the rest of the Louisiana coast and the Texas coast, with an important exception, has deep water fairly close to the shore. The exception is along the eastern part of the Texas coast from Sabine Pass to Galveston. Sabine Bank and Heald Bank have shoal depths at a considerable distance from the shore, and they should have a thorough resurvey. Galveston Bay also needs resurveying. (See fig. 13, opposite p. 64.)

51. ST. JOSEPHS BAY.—No recent surveys have been made of this area, and a reexamination is needed. (See fig. 13, opposite p. 64.)

52. OFFSHORE WATERS, FLORIDA REEFS TO THE MEXICAN BORDER.—Along the northern edge of the Florida Straits the soundings are insufficient, and they will have to be carried out somewhat beyond the 100-fathom curve. Along the west coast of Florida the distance out to the 100-fathom curve is about 100 miles. Over much of this area the depths are moderate and the charts are based on reconnoissance surveys only. The bottom is coral rock in many places, and projections from coral banks may come sufficiently near the surface to be a menace to navigation. Fishermen have reported several uncharted ridges, and while the somewhat incomplete surveys of the reported localities have not confirmed all the details of their reports, important differences from the charted depths have been found. The 100-fathom curve approaches fairly close to the Mississippi Delta, then swings offshore again, so that it is about 60 miles south of Sabine Pass. It then swings to the southward in a curve, which brings it within about 80 miles offshore at the Mexican border. This whole offshore area is badly in need of a thorough resurvey. There is no other part of the work in offshore water so likely to be productive in furnishing important changes in existing charted depths. (See fig. 13, opposite p. 64.)

53. PENSACOLA BAY.—Surveys have recently been completed in the entrance to the bay; the entire bay requires reexamination. (See fig. 13, opposite p. 64.)



CONDITION OF SURVEYS ALONG MAIN STEAMER ROUTES

June 30, 1921

Recently surveyed - Safe.....

Not recently surveyed - Doubtful.....

Safe but not recently surveyed.....

54. MOBILE BAY.—A resurvey of this bay has been completed. (See fig. 13, opposite p. 64.)

55. MISSISSIPPI SOUND.—A resurvey of this sound has been completed. (See fig. 13, opposite p. 64.)

56. LAKE PONCHARTRAIN.—In connection with the surveys in Mobile Bay and Mississippi Sound, a recent survey has been made at the eastern end of the lake. The greater part of the lake has not been examined for 20 years. (See fig. 13, opposite p. 64.)

57. APPROACHES TO MISSISSIPPI PASSES.—The offshore work which has been in progress westward for the past two years from Mobile entrance has been carried to a junction with recent surveys north of Chandeleur Islands, and has been interrupted temporarily to make, at the request of the Army Engineers, an examination of the approach to Southwest Pass of the Mississippi out to the 50-fathom curve. This was nearly complete at the close of the fiscal year. (See fig. 13, opposite p. 64.)

58. VERMILION BAY AND COTE BLANCHE.—No recent surveys have been made of these areas. Surveys are needed. (See fig. 14, opposite p. 66.)

59. APPROACH TO SABINE PASS.—No recent surveys have been made here; revisionary surveys are needed. (See fig. 14, opposite p. 66.)

60. The surveys of Porto Rico were begun when the island came under the jurisdiction of the United States as a result of the Spanish-American War. By 1910 the surveys of the bays, channels, and inshore waters were completed and a number of deep-sea soundings were taken around the island. There are, however, extending to the eastward and westward of the island and along the south coast extensive areas where the bottom is of coral formation. There are also reefs along the north coast, but as they are close to shore, and must be avoided by vessels, it is only important to know their location and limits. The areas on the east, south, and west are different in that there is traffic between the reef and over areas where the depth is little greater than the draft of the vessel, and the probable existence of uncharted projections is a source of danger. Vieques Sound, between Culebra and Vieques Island, east of Porto Rico, Virgin Passage, and the approaches to the harbors of the American Virgin Islands are in need of wire-drag surveys. The only work of this character that has been accomplished here is in the vicinity of Mayaguez. This work resulted in the abandonment of one channel and the rebuoying of another. A surveying steamer and two launches, specially constructed for wire-drag work, arrived July 5, 1921, at San Juan and commenced operations in Vieques Sound. (See fig. 15, opposite p. 66.)

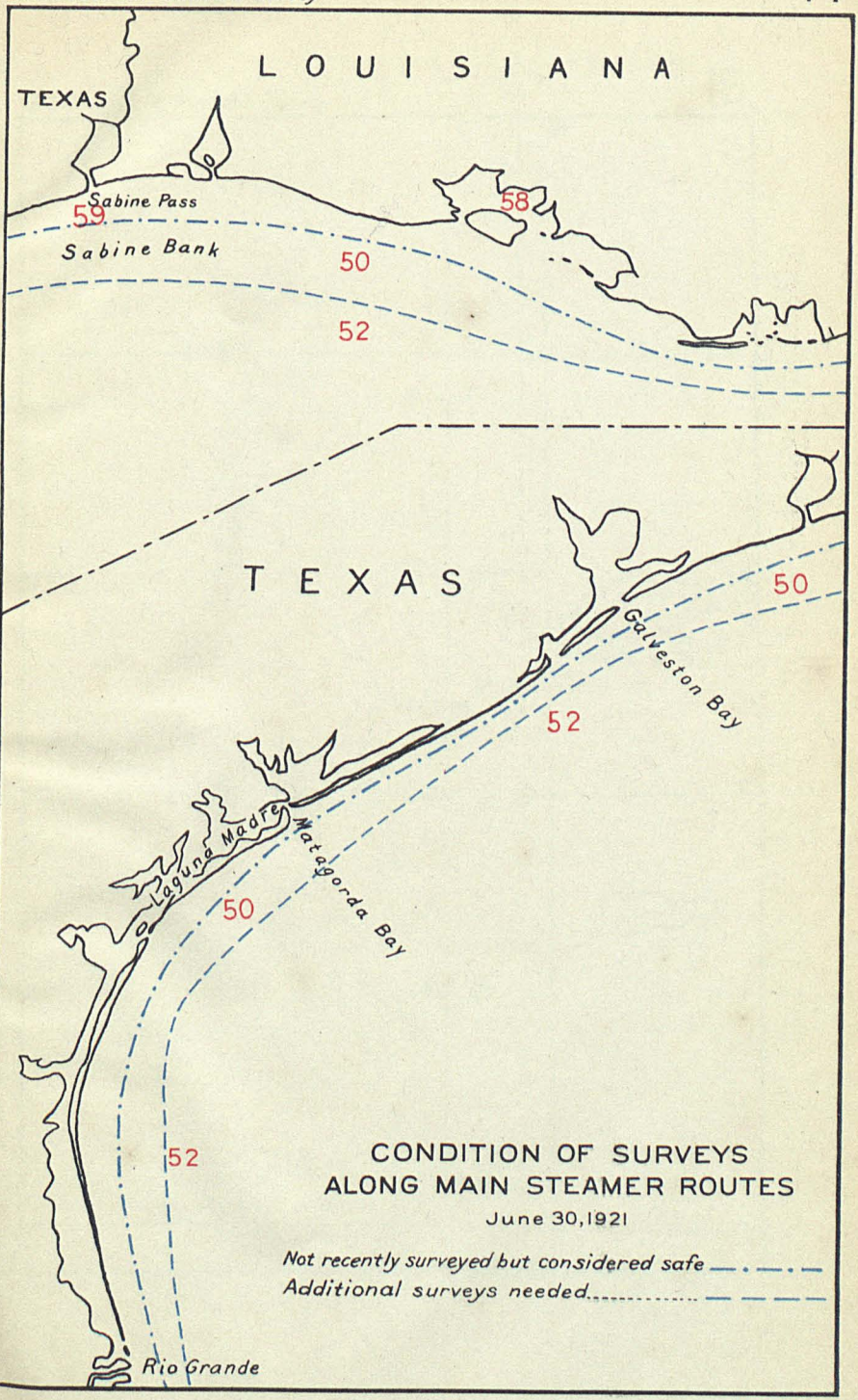
61. VIRGIN ISLANDS.—The Virgin Islands were purchased from Denmark, and the United States took possession in 1917. The surveys that have been made are by the British and Danish Governments. At the present time the available hydrographic data regarding these surveys are being examined with a view of determining whether they are sufficient for the needs of our naval and commercial vessels. It is certain that the coral formation in the waters touching these islands requires extensive wire-drag surveys before accurate charts can be issued. Topographic surveys of these islands were

requested by the Navy Department. The triangulation was extended eastward from Porto Rico for the control of the topography. St. Thomas and St. John have been completed and St. Croix was completed last June. In connection with the wire-drag surveys of Porto Rican waters, there will be a hydrographic examination of the water area surrounding the Virgin Islands to supplement the British and Danish surveys.

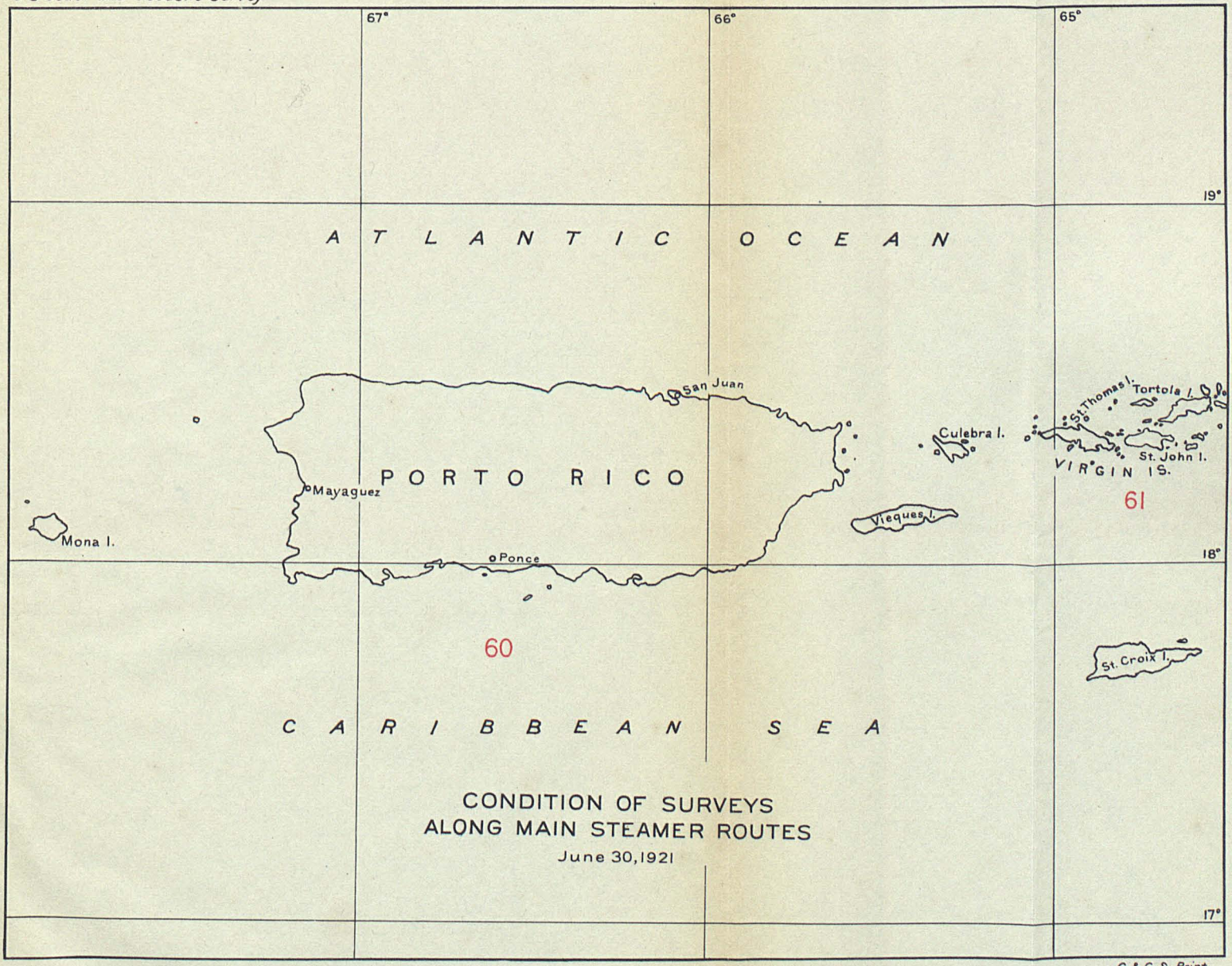
62. PANAMA CANAL.—The Atlantic approach to the Panama Canal has been surveyed since work started on the canal construction. Limon Bay is, however, a region where pinnacle rocks occur. All the anchorages should be dragged, and the work should be carried a short distance outside. The Pacific approach to the canal has had a recent survey and has been dragged. (See fig. 16, opposite p. 66.)

63. PACIFIC COAST OF THE UNITED STATES.—The western coast of the United States is very different from the eastern. Generally mountainous, with comparatively few harbors or inside waterways, and with comparatively deep water close to the shore, it presents little resemblance to the low shores and wide continental shelf of the Atlantic. The purpose of the survey is, then, to meet the needs of vessels approaching from seaward and coasting vessels which keep to a few comparatively narrow tracks, to insure up-to-date charts of the various harbors, to make soundings offshore, and to develop fishing banks that are known to exist. The weather is an important factor in increasing the importance of the charts of this coast. From Los Angeles Harbor northward fog is very common in the summer time, and in the winter gales accompanied by thick weather are of frequent occurrence. On the coast and in the vicinity of San Francisco thick weather is prevalent for perhaps 25 per cent of the time. Under such conditions the navigator must rely entirely upon his chart, and it is essential that detail surveys be made to the 100-fathom curve, which is beyond the limit of soundings taken by merchant vessels. Along the shore of southern California much work was done up to 1895, and some of the surveys then made may be accepted as final. In the vicinity of the outer islands surveys extended only a little way from the shore, and the deep waters between and outside of them are unsurveyed. The few soundings taken show irregular bottom, and breakers have been reported in places where the chart shows 600 fathoms. These waters, therefore, should be surveyed out to the 1,000-fathom depth. The Oregon coast is practically unsurveyed.

A limited amount of work was done years ago south of Cape Blanco and in the vicinity of the Columbia River, but this was not more than a reconnoissance and does not extend out far enough to be of practical value to navigators. Elsewhere no surveys have ever been undertaken until recently. Even in such an important locality as Cape Blanco, which must be rounded by all vessels plying between the Columbia River and San Francisco, there are no soundings to serve as a guide in thick weather, and vessels have been lost wholly on account of this lack of surveys. On the coast of Oregon there are eight important harbors on which the Government and private interests have expended approximately $40,250,000 in improvements designed to facilitate navigation. One of these is the Columbia River, the gateway to one of the most important transportation centers of


LOUISIANA
TEXAS
Sabine Pass
59
Sabine Bank
50
52
58
TEXAS
50
Galveston Bay
52
Laguna Madre
Matagorda Bay
50
52
Rio Grande
CONDITION OF SURVEYS
ALONG MAIN STEAMER ROUTES
June 30, 1921
Not recently surveyed but considered safe
Additional surveys needed

C&G.S. Print



CONDITION OF SURVEYS
ALONG MAIN STEAMER ROUTES
June 30, 1921

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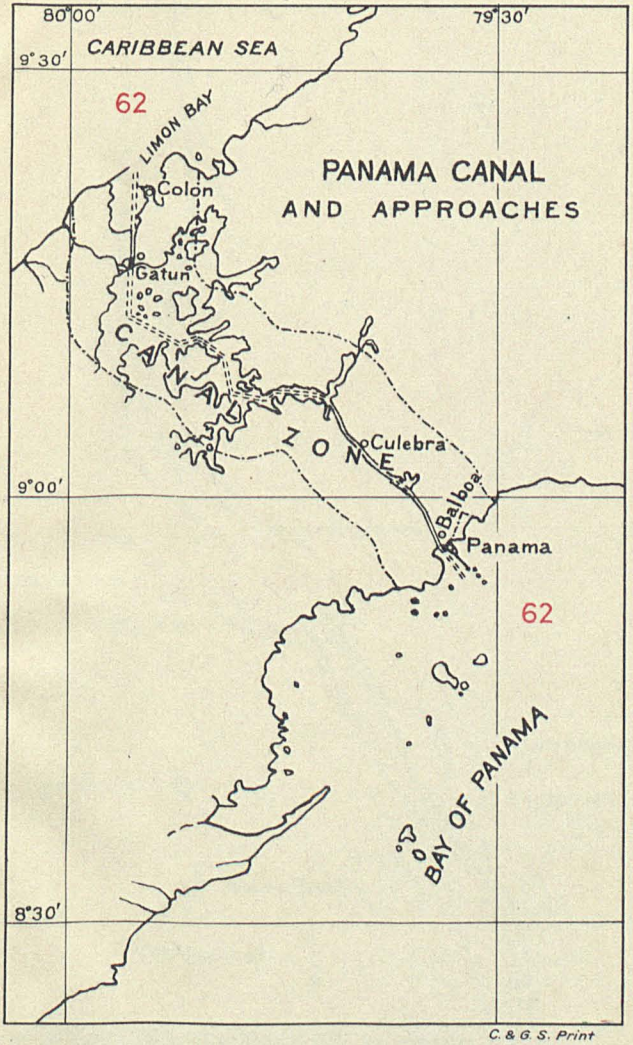
U.S. Coast and Geodetic Survey



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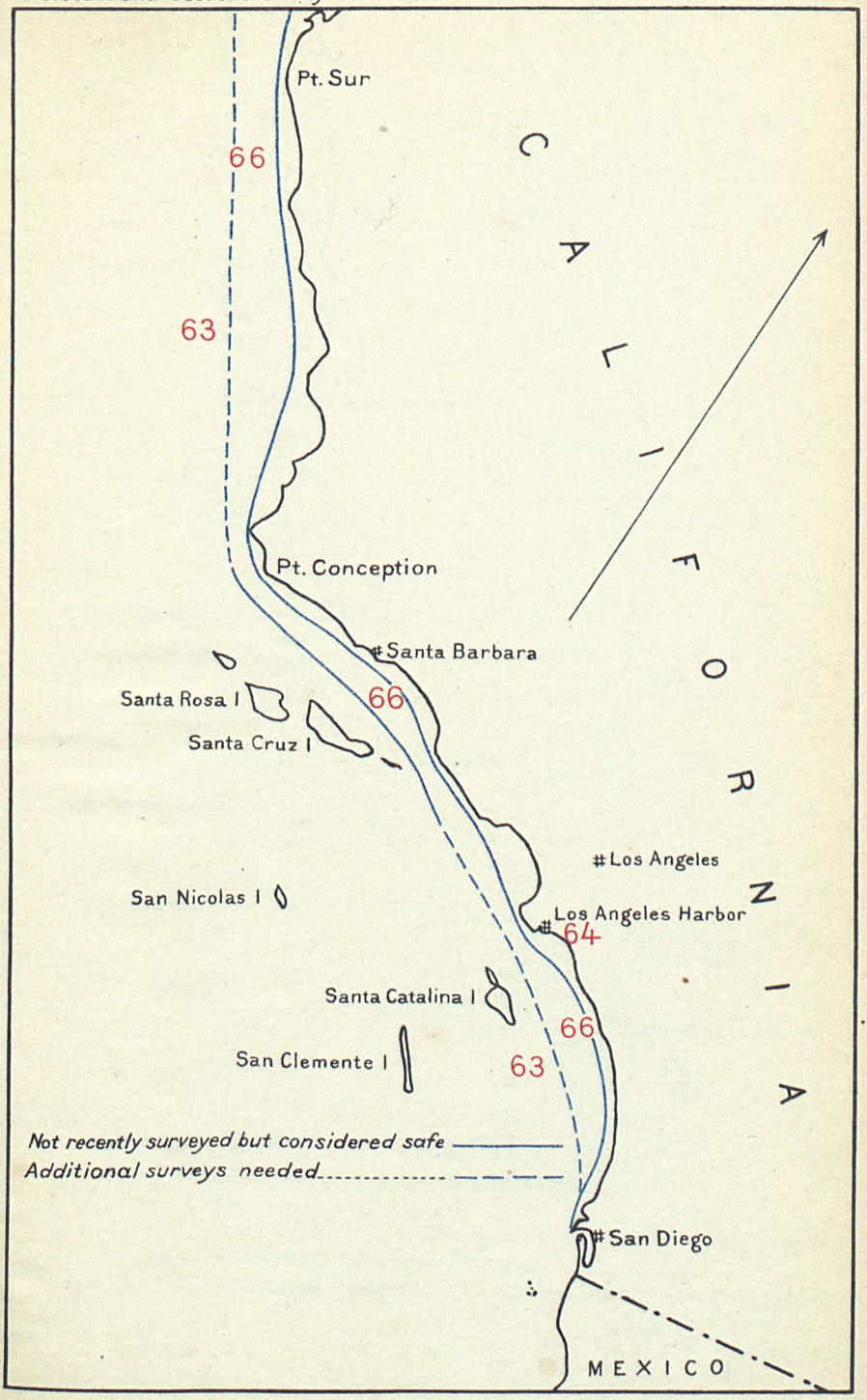
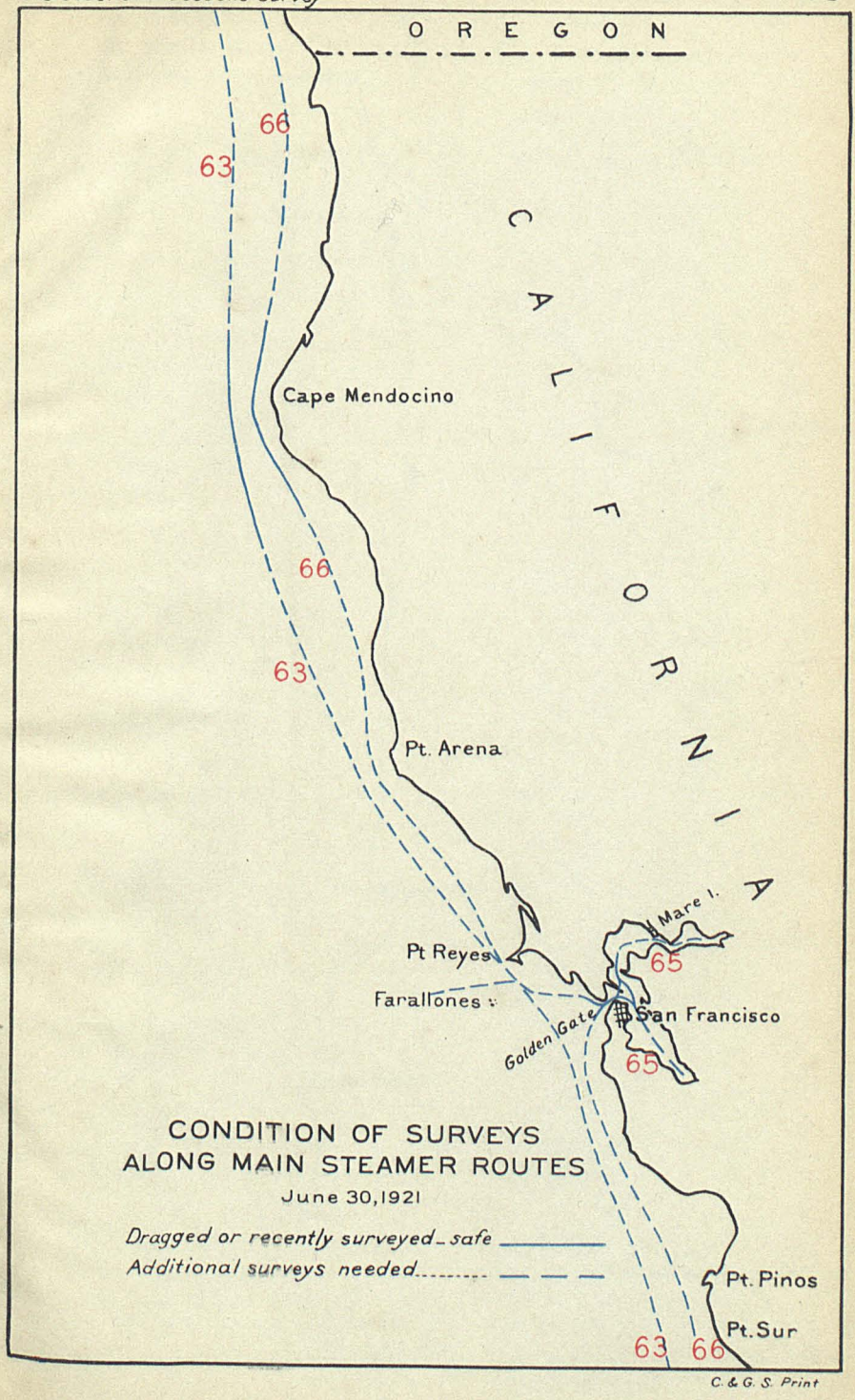
CONDITION OF SURVEYS
ALONG MAIN STEAMER ROUTES

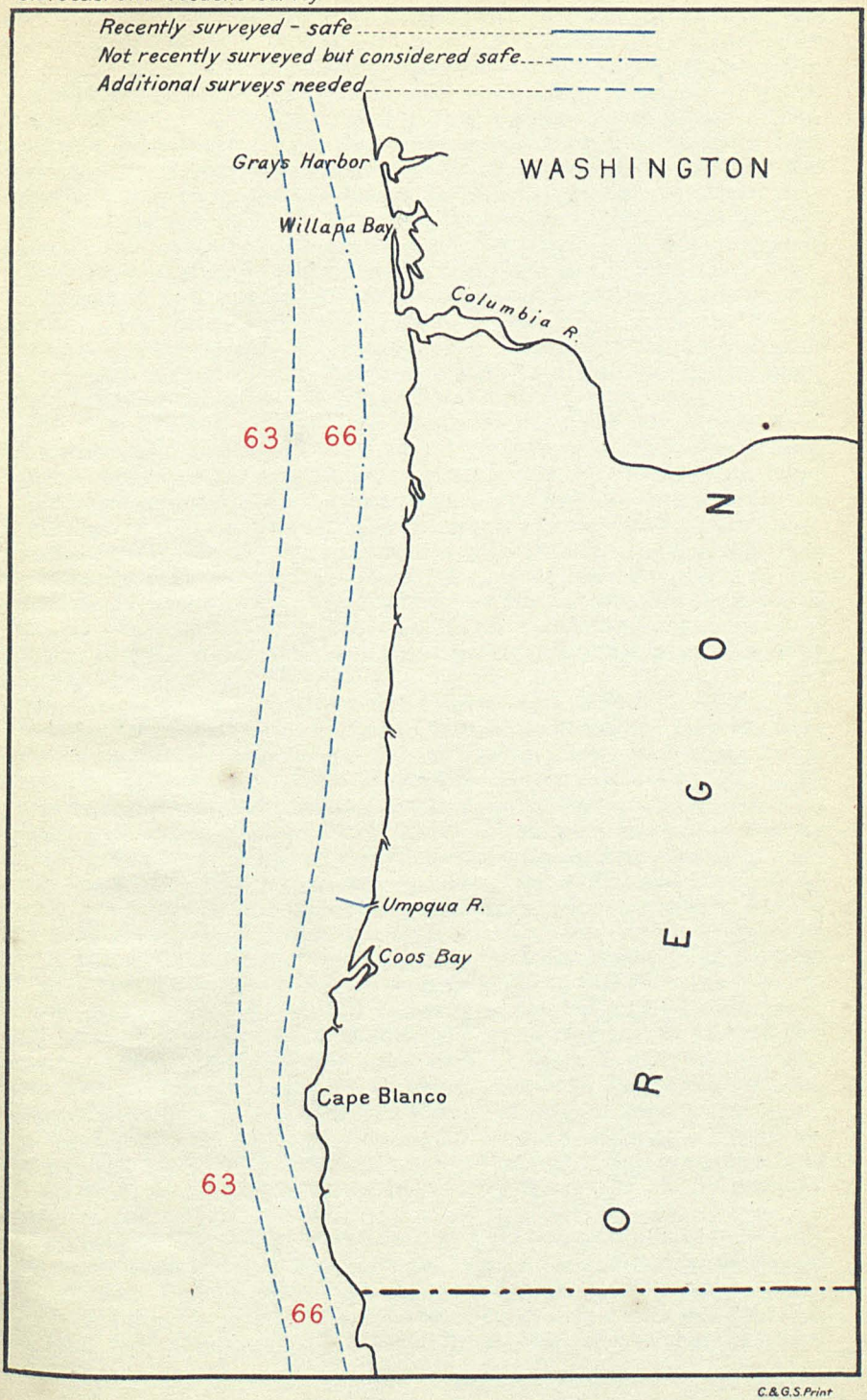
June 30, 1921


Pt. Sur
66
63
CALIFORNIA
Pt. Conception
Santa Barbara
Santa Rosa I
66
Santa Cruz I
Los Angeles
San Nicolas I
Los Angeles Harbor
64
Santa Catalina I
66
San Clemente I
63
Not recently surveyed but considered safe
Additional surveys needed
San Diego
MEXICO

C.&G.S. Print


OREGON
66
63
CALIFORNIA
Cape Mendocino
66
63
Pt. Arena
Mare I.
Pt Reyes
65
Farallones
Golden Gate
San Francisco
65
CONDITION OF SURVEYS
ALONG MAIN STEAMER ROUTES
June 30,1921
Dragged or recently surveyed_safe
Additional surveys needed
Pt. Pinos
Pt. Sur
63
66

C. & G. S. Print


Recently surveyed - safe
Not recently surveyed but considered safe
Additional surveys needed
Grays Harbor
WASHINGTON
Willapa Bay
Columbia R.
63
66
O R E G O N
Umpqua R.
Coos Bay
Cape Blanco
63
66

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the Pacific coast. Yet, in spite of the immense expenditures for improvements, there is not a single one of these harbors the approaches to which have been adequately surveyed. The approaches to the Columbia River have been sounded for a short distance offshore, but even in this area the soundings are too far apart to more than indicate, in a general way, the depth which may be expected. This partial survey extends southward along the coast to include the approaches to two other harbors. The approaches to the remaining five, on which $3,826,000 have been expended in improvement, are entirely unsurveyed. The entire Washington coast stands in urgent need of a first survey, except in the approach to the Straits of Juan de Fuca and in the straits themselves, where the present work is adequate. (See fig. 14, opposite p. 66.)

64. Los Angeles Harbor.—Los Angeles Harbor should be dragged. A revision survey of Los Angeles Harbor and approach was completed during the first half of the fiscal year.

65. San Francisco Bay.—San Francisco Bay is of varied character of bottom and needed surveys vary to correspond. The immediate approaches are complete except in the vicinity of Farallones. Here additional sounding is needed, and an investigation should be made with the wire drag to verify the existence of other rocks than those charted. Wire-drag work has been carried through the Golden Gate and inside, both northward and southward of San Francisco to the limit of the rocky area. The resurvey of the bar outside the Golden Gate has been completed. Surveys in the southern part of the bay have also been completed and the revision of San Pablo Bay will shortly be taken up.

66. Alongshore Waters of the Pacific Coast States.—From the western end of the Santa Barbara Channel to Monterey Bay the surveys, as a rule, extend only to the 50-fathom curve, which lies but a short distance offshore. The surveys should be extended seaward to include the usual track of coastwise vessels, which lies an average distance of about 10 miles from shore. From San Francisco Bay to Point Arena a widely spaced system of sounding lines has been carried out to the 100-fathom curve. Here an additional amount of work, about equal to that already accomplished, is necessary before the survey can be considered complete. Between Point Arena and Cape Mendocino the surveys extend a uniform distance of 6 miles from shore, reaching depths varying from 50 to 600 fathoms. Additional detailed surveys should be made in the vicinity of each cape, and between them the work should be carried seaward to beyond the steamer track. The offshore surveys have been in progress for the past two years, extending from Point Arena to the northward of Cape Mendocino. A party with a chartered launch made a survey of the Umpqua River bar. The necessity for such surveys is shown by the location of the hitherto uncharted submarine valley north of Cape Mendocino, which was a factor in causing the wreck of the steamer *Bear*.

From Cape Mendocino northward to the Oregon boundary the limited surveys existing made many years ago are entirely inadequate. A complete survey should be made at the earliest possible date. There are no adequate surveys of the inshore area along the State of Oregon. Of the water off the northern part of the Pacific coast

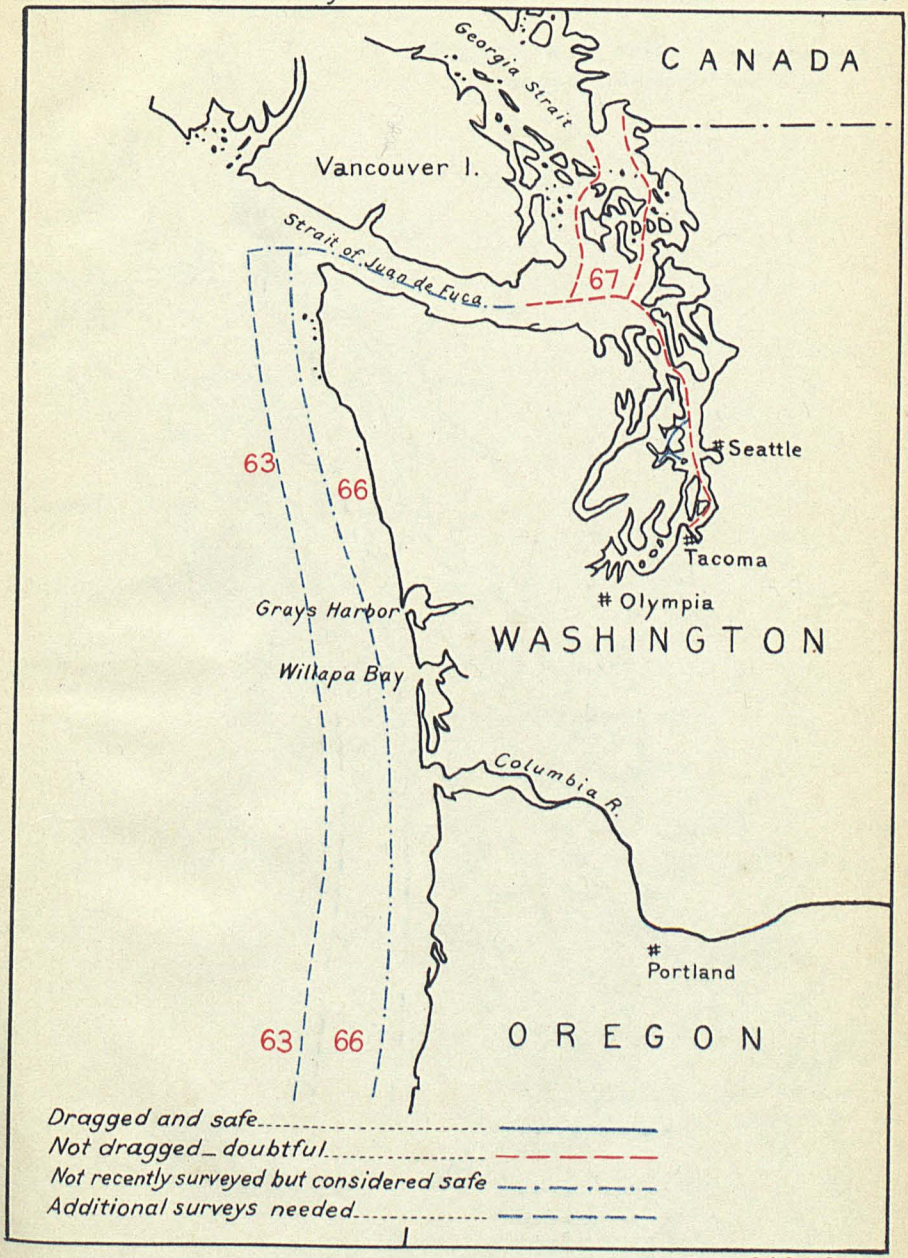
little is known, except that the Bureau of Fisheries, acting on the information obtained from fishermen, has located certain banks. These banks should be surveyed to determine their depth and extent, and it is believed that a general survey carried out to the 1,000-fathom curve will result in the discovery of other banks of great value. (See fig. 14, opposite p. 66.)

67. INTERIOR WATERS OF THE STATE OF WASHINGTON.—The interior waters of the State of Washington represent the point of change from a practically straight coast line to the broken formation of the coast of British Columbia and southeastern Alaska. There are many channels of importance leading to Seattle, Tacoma, Everett, Bellingham, and Olympia, and connecting with the inside passage to southeastern Alaska. All these waters should be dragged wherever there is the slightest doubt as to the presence of dangers to navigation. (See fig. 20, opposite p. 68.)

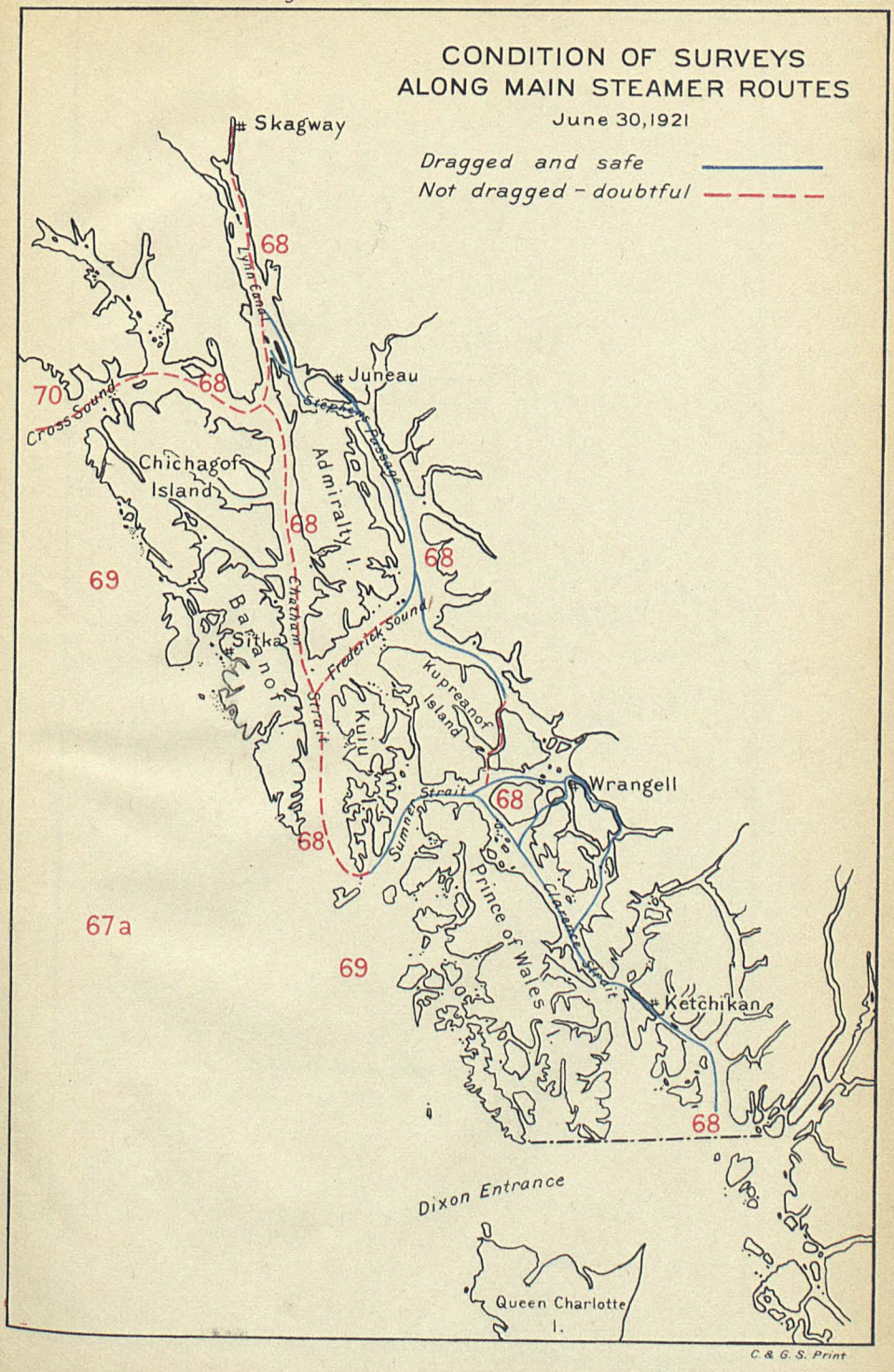
68. STEAMER ROUTES, SOUTHEASTERN ALASKA.—In southeastern Alaska the first and most obvious need is to complete the wire-drag work. Most of these waters have been sounded, so that only dragging is necessary to complete the survey. This drag work should be taken up in the order of its importance, beginning with the main steamer route through the region and then taking up the various tributary waters leading to areas of commercial importance. For some years past parties have been actively engaged in dragging the main steamer routes, and this work is now about 70 per cent complete. One of these parties has completed Stephens Passage northward from Frederick Sound, as well as Gastineau Channel to Juneau, and is now engaged in Lynn Canal.

69. THE OUTSIDE COAST WATERS OF THE ISLANDS BORDERING ON THE OPEN PACIFIC.—These and their connecting channels are largely unsurveyed and should be navigated with great caution. A navigator seeing the chart on which the shore line is sketched—no soundings, several rocks and shoal banks, notes as to rocks and breakers reported, and a statement on the chart to the effect that the area is unsurveyed—is, to say the least, unable to proceed with confidence, and this situation is by no means unusual. The same pressing need of such regions is a complete hydrographic survey, followed later in places by wire-drag work. The rapidly increasing commercial importance of this region and the exceptionally dangerous character of the waters through which traffic must pass render surveys in the near future imperative. Work on the outer coast is now in progress northward from Dixon Entrance. Surveys were also in progress in Clarence Strait and Dixon Entrance. (See fig. 21, opposite p. 68.)

70. CROSS SOUND TO PRINCE WILLIAM SOUND.—From Cross Sound, the northernmost channel from the inside waters to the sea, to Prince William Sound, the coast has few features of present or prospective importance. There is, however, urgent need for surveys to insure the safety of vessels approaching and passing this coast. In this region the charts are very defective in the manner of showing soundings and prominent coastal mountain peaks and headlands that would enable the navigator to obtain his position on approaching from seaward. The only important break on this coast, Yukutat Bay, has some canneries, and additional surveys are needed here on this account. (See fig. 21, opposite p. 68.)


CANADA
Georgia Strait
Vancouver I.
Strait of Juan de Fuca
67
63
66
Seattle
Tacoma
Olympia
Gray's Harbor
WASHINGTON
Willapa Bay
Columbia R.
Portland
63
66
OREGON
Dragged and safe
Not dragged_doubtful
Not recently surveyed but considered safe
Additional surveys needed

C. & G. S. Print


CONDITION OF SURVEYS
ALONG MAIN STEAMER ROUTES
June 30, 1921
Dragged and safe
Not dragged - doubtful
Skagway
Juneau
Lynn Canal
Stephens Passage
Cross Sound
Chichagof Island
Admiralty I.
Baranof I.
Sitka
Chatham Strait
Frederick Sound
Kupreanof Island
Kuiu I.
Sumner Strait
Wrangell
Clarence Strait
Prince of Wales I.
Ketchikan
Dixon Entrance
Queen Charlotte I.
68
70
69
67a
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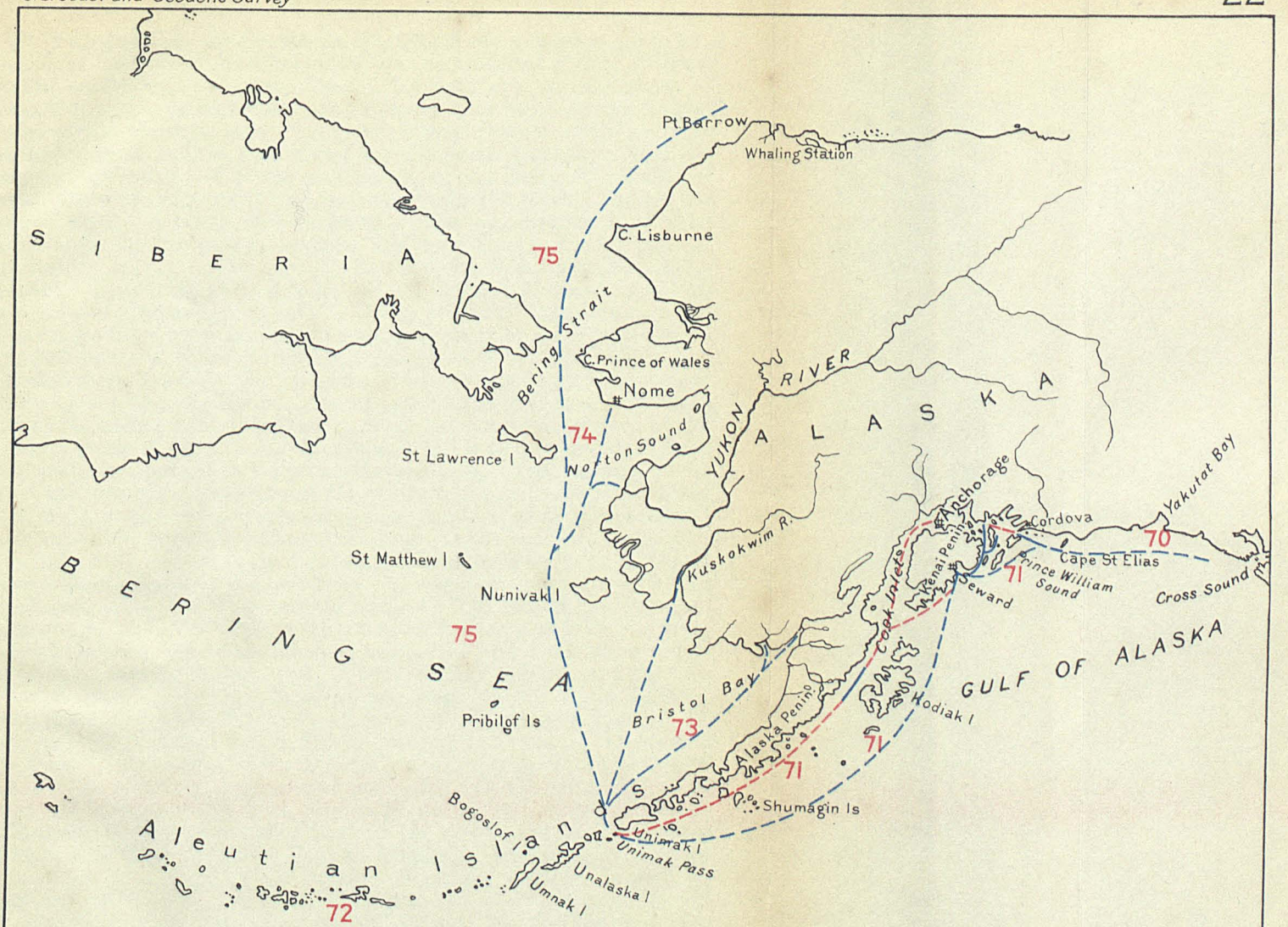

This locality visited by Coast Guard Cutters and Whalers.

CONDITION OF SURVEYS ALONG MAIN STEAMER ROUTES

June 30, 1921

Dragged or recently surveyed - Safe ———

Not dragged - Doubtful – – – –

Not recently surveyed - Doubtful — — — —

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71. PRINCE WILLIAM SOUND TO UNIMAK PASS.—A very important section of the Alaska coast extends from the waters of Prince William Sound westward to Unimak Pass. Not only are the industries of present importance, but there are extensive mineral resources largely undeveloped through lack of cheaper transportation. The point to be emphasized is that this is not an old, settled country, with its needs in the matter of transportation fixed, but it is still capable of great future development, and in considering the needed surveys its future must be taken into account. The approaches to Prince William Sound have been surveyed, and no resurveys for the present are needed except in the vicinity of Cape St. Elias and Middleton Island. Wire-drag work will be needed in both of these localities, as reefs and pinnacle rocks exist. Prince William Sound needs additional soundings over most of its area, and many of its branches need original surveys. Cordova is the terminus of the Copper River and Northwestern Railway, which gives access to the important copper mines on the Copper River. The approaches to Cordova have been surveyed, except for wire-drag surveys needed to insure complete safety. Seward, on Resurrection Bay, is the terminus of the Alaska Railroad now being built by the Government. The surveys of its approach are completed except for wire-drag work. It is probable that much of the trade originating along the line of the Government railway will be transshipped at Anchorage, at the head of Cook Inlet. Not only will this make it necessary for many vessels to navigate these waters, but there are now very large salmon canneries all along its shores, as well as considerable mining. The present surveys are inadequate, and wire-drag work is needed over much of its area. Kodiak Island, with a number of canneries and with some cattle grazing, is largely unsurveyed. From Kodiak Island westward to Unimak Pass surveys are now in progress; only a comparatively small part has been surveyed at present. While the amount of present traffic is small it is sufficient to need protection. At present the Coast Guard vessels and the freight and passenger vessels run grave risks in using the protected natural channel leading along the coast inside the island. This is a particularly bad stretch of coast, with many reefs and islands. Only in the vicinity of the Shumagin Islands and from Unimak Pass to Unalaska Island have surveys been made, and they are inadequate. It is not now practicable to drag the entire area, but it is important that the immediate needs of navigation, even though of limited amount, be met by dragging a selected channel to insure the safety of vessels from Shelikof Strait to Unimak Pass. Unimak Pass is the almost universally used channel into Bering Sea. It has been surveyed, but it is probable that part of it should be dragged or at least further soundings be taken. Surveys were in progress from Shelikof Strait westward to Metrofania Island during the season of 1920. The operations were hampered by a shortage of fuel oil, and with the expectation of a continuance of this shortage and the high price of the oil during the season of 1921, it was decided to postpone surveys in this section until another year. (See fig. 22, opposite p. 68.)

72. ALEUTIAN ISLANDS.—The Aleutian Islands have comparatively little traffic and are without survey. It is necessary that this region be patrolled by Coast Guard vessels. The loss of one of the vessels

of this service a few years ago was wholly due to the lack of adequate surveys. (See fig. 22, opposite p. 68.)

73. Bristol Bay.—A large part of the salmon shipped from Alaska comes from Bristol Bay. This is without surveys except in Nushagak Bay and Kuskokwim Bay and River. Both of these have recent surveys, but, as the bottom is subject to change on account of the large rivers, future additional surveys will be needed. As an example of what surveys mean in a new region, the discovery of an entrance to the Kuskokwim River suitable for moderate-draft vessels opened up an immense area for grazing, and also in places for general agriculture. (See fig. 22, opposite p. 68.)

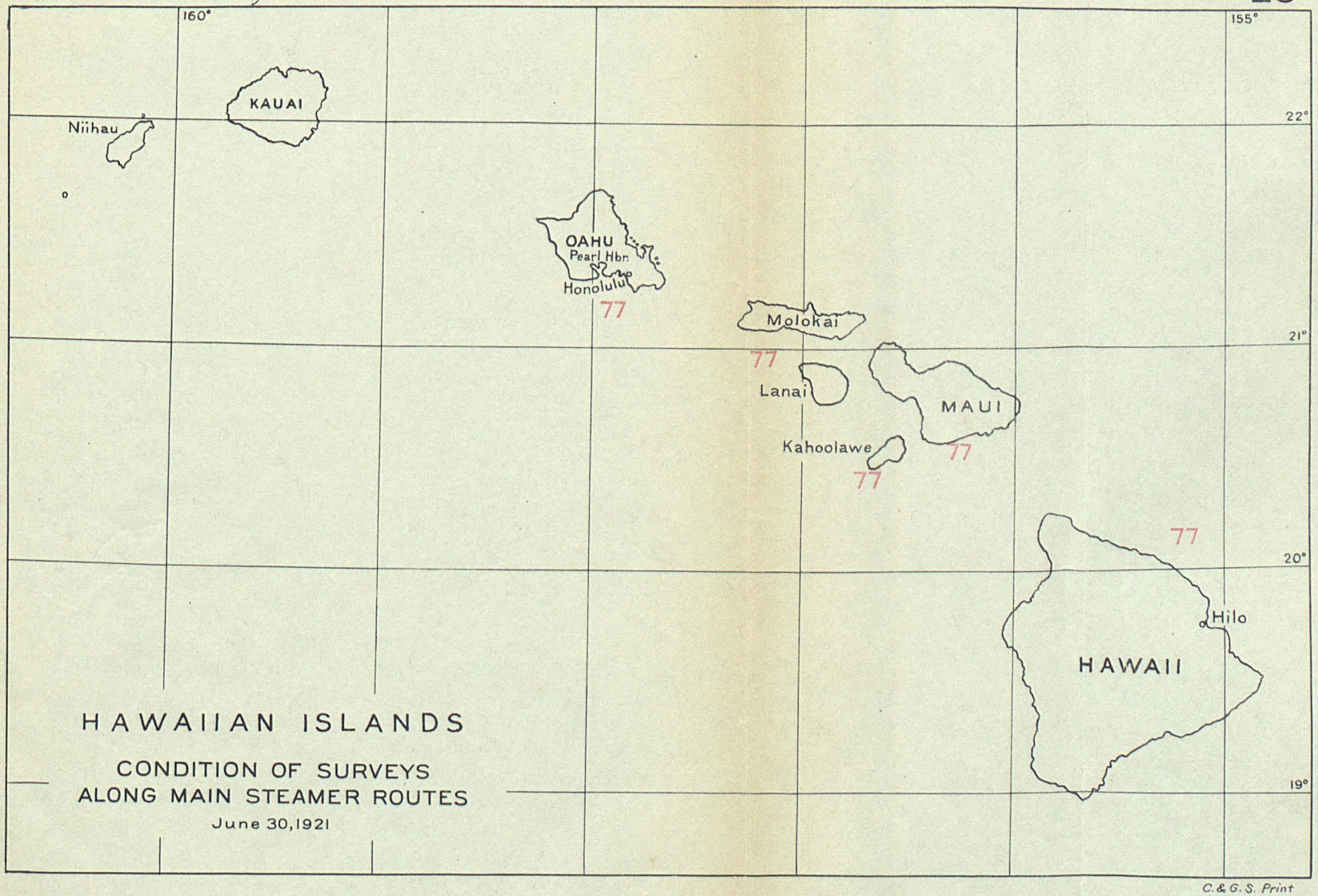
74. Norton Sound.—The importance of Norton Sound is due to the gold mining on its northern shores and as being the outlet of the Yukon Delta on the southern shore. In all of Norton Sound additional surveys are needed. It is curious that in this sound, which according to all available information is of quite level, sandy, or muddy bottom, Besboro Island rises very abruptly to a height of 1,012 feet. With such an occurrence it is not absolutely certain that no pinnacle rocks exist. (See fig. 22, opposite p. 68.)

75. Bering Sea and Arctic Ocean.—Except in the vicinity of Pribilof Islands, there are no other existing surveys in Bering Sea or to the north which can be considered of value. (See fig. 22, opposite p. 68.)

76. Guam.—The present chart of the Island of Guam is compiled from Spanish and British charts and some harbor surveys by the United States Navy. No attempt at a comprehensive survey has been made. A complete survey should be made, not only including the harbors, but the surrounding waters, carrying the work out to a depth that will be certain to include all dangers. In these waters shoals rise abruptly from great depths, and the absence of soundings on the charts does not imply safety, but simply absence of surveys.

77. Hawaiian Islands.—There are only two good harbors on all the Hawaiian Islands, and both of these are on Oahu Island. All of the islands except Hawaii have coral reefs around at least part of them. In the vicinity of Oahu, Maui, Kahoolawe, and the south coast of Molokai the surveys are fairly complete. In the vicinity of Hawaii the surveys are very inadequate except in the only harbor, Hilo Bay. The west coast of Lanai and the vicinity of the two westernmost islands, Jauai and Niihau, are practically unsurveyed. The various channels between the islands from Taui to Oahu are fairly well surveyed. The others are practically without surveys. (See fig. 23, opposite p. 70.)

78. Philippine Islands.—The Philippine Islands are composed of not less than 3,000 islands and islets covering an area of approximately 150,000 square miles, and about the same as that of the five New England States and the State of New York combined. The total length of the general coast line, measured on small-scale charts using 3-mile spaces of dividers and omitting islands and bays less than 3 miles long, is approximately 10,850 miles, or about the same as that for the entire Atlantic coast of the United States, including the islands. The unsurveyed hydrography covers a large area on account of the necessity of extending this work, in some localities, for many miles offshore, and on account of the very extensive area of the Sulu Sea. The unsurveyed regions are as follows: The northeast



HAWAIIAN ISLANDS

CONDITION OF SURVEYS ALONG MAIN STEAMER ROUTES

June 30, 1921

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coast of Luzon from Polillo Island northward to Aparri; the region off the north coast of Luzon, including the Babyan Islands, Balintang Channel, the Natan Islands, and Bashi Channel; the entire west coast of the island of Palawan; the south coast of Mindanao, from Pola Point to Malita, in Davao Gulf; the Sulu Archipelago and the Sulu Sea from the Tubbathaha Reefs south to the limit of our possessions off the coast of Borneo. (See fig. 24, opposite p. 72.)

79. NORTHEAST COAST OF LUZON.—This entire unsurveyed region, from Polillo Island on the south to Aparri on the north, is of little commercial importance, and being quite free from dangers to navigation, the execution of the work is being delayed until more important localities are completed. Little reliable information relating to this region is available, but a number of good anchorages have been reported. Among these are the inner harbor of Port San Vincente, Dilasac Bay, Casiguran Sound, and Dingalan Bay. The first and third mentioned are excellent typhoon harbors. The work must, however, be done during the season of frequent typhoons, it being impossible to approach the coast at any other time of the year on account of the heavy sea caused by the northeast monsoon. (See fig. 24, opposite p. 72.)

80. OFF NORTH COAST OF LUZON.—A survey should be made of the islands and the waters to the northward of Luzon as far as Bashi Channel, as, in accordance with the numerous reports, there is considerable uncertainty in regard to the true location of the islands and the rocks that are dangerous to navigation in the locality. As it is in the region visited by frequent typhoons, the work should be undertaken during the period when the typhoons are less frequent. (See fig. 24, opposite p. 72.)

81. WEST AND EAST COAST OF PALAWAN.—The coast line of the island of Palawan is very irregular, indented with deep bays forming some of the finest harbors in the archipelago. The whole region about the island and extending southward to Balabac Island, Banguey Island, to Cagayan Sulu, and off the north coast of Borneo consists of coral reefs, many small islets, and innumerable hidden dangers to navigation. To the westward of Palawan, reefs and dangers extend to over 100 miles offshore. The hydrographic survey of this region involves an immense amount of labor. A preliminary survey for the location of channels through the reefs and entrances to harbors will first be necessary, after which these localities must be swept with the wire drag. (See fig. 24, opposite p. 72.)

82. WEST COAST OF MINDANAO.—This island is of little commercial importance due to the absence of harbors and having a rugged mountainous country adjacent to the coast which is not adapted to the growth of any of the staple products. The usual steamer tracks do not approach the shore within 4 or 5 miles, a sufficient distance to avoid all dangers. For these reasons the surveys now in progress have been postponed for more important localities.

83. SOUTH COAST OF MINDANAO.—This stretch of about 160 miles, from Pola Point to Malita in Davao Gulf, is similar in many respects to the west coast. In general, it is bold and steep, with numerous outlying reefs, which, however, do not extend a great distance from shore. The triangulation for furnishing the controlling positions for the hydrography and topography presents a difficult problem.

the shore line being invisible from the peaks and ridges but a short distance back.

84. SULU ARCHIPELAGO.—This region, about 75 miles wide, extending in a southwesterly direction from Zamboanga, on the southern coast of Mindanao, to the coast of Borneo, a distance of about 180 miles, has scattered over it about 300 islands and islets and numerous hidden dangers to navigation. Surveys in this area are now in progress. It requires a survey of the most careful and intricate character, and much of the locality must be swept with the wire drag after the present hydrographic survey is made. The formation is coral and dangerous to navigation, as rocks are frequently found in localities where they are least expected to exist. The currents in the region are very strong. The physical conditions are such that excellent control to coördinate the work with that along the coast of Mindanao can be obtained. (See fig. 24, opposite p. 72.)

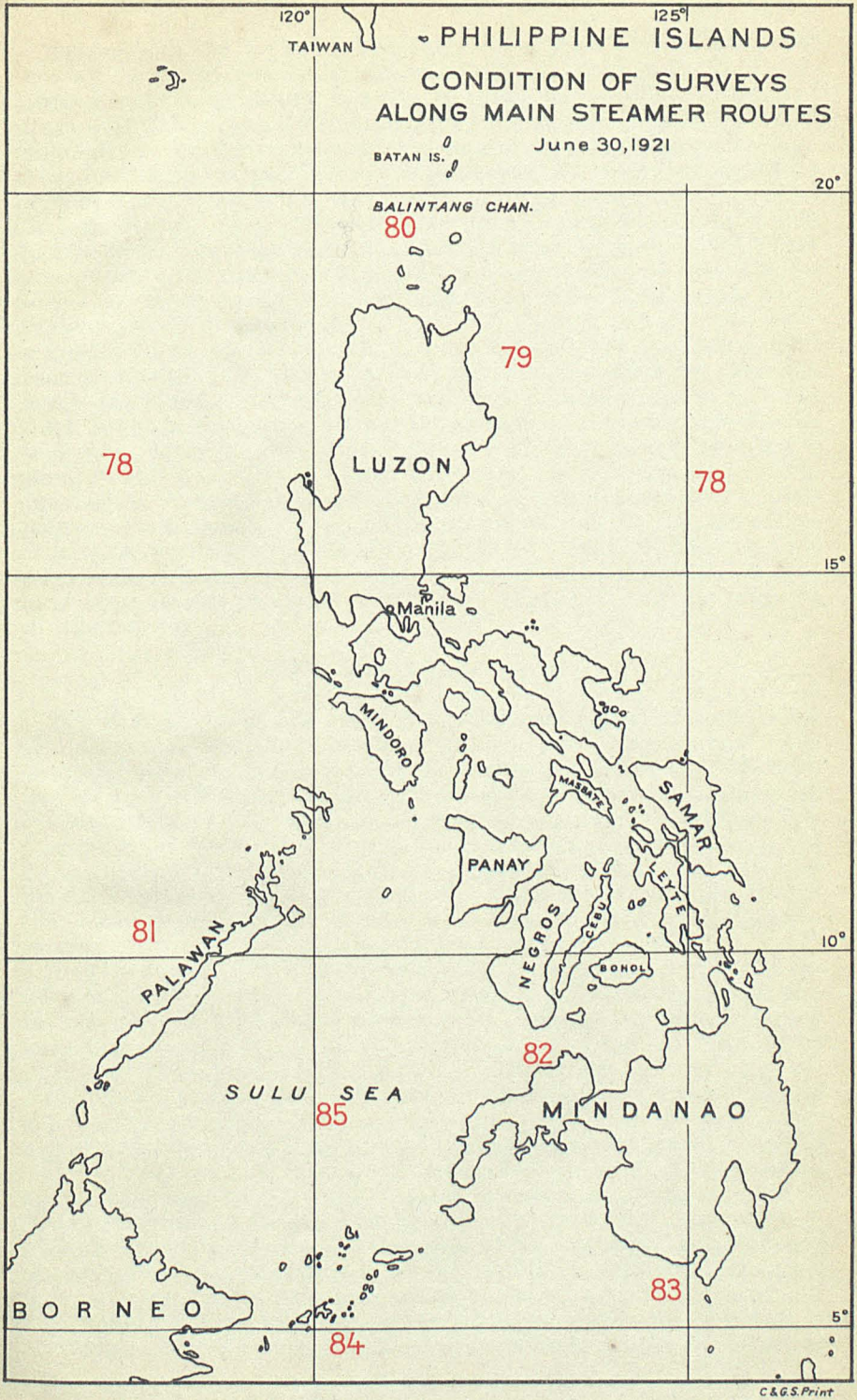
85. SULU SEA.—The northern end, as far south as the Tubbataha Reefs, except certain small area, has been surveyed with a fair degree of accuracy, but owing to the coral formations, where hidden dangers frequently exist, wire-drag sweeping will be necessary in selected passages. A large part of the region to the south of the Tubbataha Reefs remains unsurveyed except for a reconnoissance with approximate locations by navigational methods. A survey of this area is now in progress. Numerous rocks and reefs dangerous to navigation are scattered throughout the sea, but certain well-defined passages have been examined with sufficient accuracy to make navigation through them reasonably safe. (See fig. 24, opposite p. 72.)

MAGNETIC WORK.

OBSERVATORIES.—The five observatories now in operation are not adequate for an extensive and detailed magnetic survey of the United States and outlying territories. This was clearly evident during the last few years in our efforts to secure sufficiently accurate data to reconstruct the secular change lines on the new isogonic chart for 1915. The lack of personnel for field work was partly responsible for this, but even if the usual number of observers had been in the field, the results of the recent unusual change in the secular variation would not have been so readily apparent or so precise as would have been the case had a magnetic observatory been in operation somewhere in the northwestern part of the United States.

In the outlying territories still greater areas are without adequate facilities for registering the magnetic variations. Especially important are the Canal Zone and the region of Guam which lie directly in the path of two most important trade routes.

FIELD WORK.—In planning the field work for a magnetic survey of the United States it was decided to establish one station at every county seat, and the work has been carried on with this end in view. At present there are about 175 county seats to be occupied. Observations have been made at slightly over 7,000 land stations in the United States and outlying territories. Reestablishing stations that have been destroyed and occupying stations in newly incorporated counties is work of a continuous nature.


120°
125°
TAIWAN
PHILIPPINE ISLANDS
CONDITION OF SURVEYS
ALONG MAIN STEAMER ROUTES
June 30,1921
BATAN IS.
20°
BALINTANG CHAN.
80
79
78
LUZON
78
15°
Manila
MINDORO
MARBATE
SAMAR
PANAY
LEYTE
81
PALAWAN
NEGROS
CEBU
10°
BOHOL
82
SULU SEA
85
MINDANAO
BORNEO
83
84
5°

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Throughout the United States there are a great number of localities which are magnetically disturbed and which require additional observations at auxiliary stations in order to be able to represent them even fairly accurately on our isogonic charts. From the viewpoint of the practical engineer it is as important to know the magnetic declination at points 1 or 2 miles apart in a disturbed region as it is to know it at points 50 miles apart in a region that is undisturbed. Special observations to determine the extent of locally disturbed areas have been made at about 156 places in the United States and outlying territories. A glance at the isogonic chart will show that there is still a great amount of work to be done before these regions are all investigated.

Observations for secular change during the past few years have been so few that the 1920 edition of our isogonic chart has been delayed until additional data are received. Another phase of field work is the investigation of secular change in regions of local disturbance. Only a very limited amount of data is available for a study of this problem. A systematic survey for this data is a matter for future consideration and may involve more labor than anticipated. Another subject for future consideration, no less important than those mentioned above, is the magnetic survey of the coast line. At present this is lacking in detail because most of the available data have been obtained only as opportunity offered during the progress of other work.

TIDAL AND CURRENT WORK.

The first stage of the tidal work for the coasts of continental United States may now be considered as completed, so that very accurate and extensive tide tables are being furnished the American navigator. Although the harmonic analysis, which is made use of in the prediction of tides, has not yet reached a state of perfection, further study of the method may be made from the observations at the representative principal tidal stations maintained for other purposes by the Bureau at the larger ports along the coasts, and the annual tide tables issued by the Survey have been brought to a standard ranking well with the published tables of any other nation.

More detailed tidal and current work in connection with the development of the principal harbors of the United States is required for the purpose of furnishing necessary data to engineers charged with this development, both for commercial and military and naval purposes. The port of New York is greatly in need of such systematic and detailed tidal and current surveys, both for the use of the mariner in furnishing him more accurate predictions for the berthing of large vessels in that part of the harbor where strong currents make it hazardous, and at times impossible, to berth a large vessel except very near to the times of slack water, and also for the use of Federal engineers charged with the efficient and economical expenditure of large sums in the development of this harbor. A beginning has been made so far as funds would permit, by securing from time to time current and tidal observations scattered over the harbor; but the problem complicated by the harbor being made up of a bay, a tidal river, and two straits connecting independent tidal bodies made

necessary *simultaneous* observations over the area before conclusive and accurate results can possibly be reached.

Such systematic tidal and current surveys have not been made in any of the harbors of the United States and should be carried out in the order of the commercial and military importance of the different ports, beginning with New York.

In the matter of currents it can not be said that even the preliminary work has been completed. Observations are not only necessary in the different harbors, but along the coasts, so that current tables for the use of the mariner may be built up.

At present the Survey is making predictions of times of slack water at only five places on the Atlantic coast and four places on the Pacific. These predictions are of tidal currents only and even less has been done toward the predictions of currents due to winds.

The Survey has made use of every available means for securing observations for the study of current conditions along the coasts. It has secured the cooperation of the Lighthouse Service and mariners in securing information on currents. What is now needed are short series of current observations made by a Survey vessel at designated vital points between light vessels which will link together the observations made at these light vessels.

The methods used by the Survey in the observation and reduction of currents are such that from the same set of observations the wind currents and the tidal are deduced.

Under physical oceanography, comprising miscellaneous oceanographic observations and computations for the purpose of furnishing information relative to densities, temperatures, ocean currents, and related matters to navigators, engineers, and scientists, very little has been done and much is required to bring our state of knowledge and amount of information to that of other even less important nations. At our door is the Gulf Stream, a study of which is one of the most important items in oceanography which should be continued by the Survey. Considerable work of a reconnoissance nature was done a number of years ago by the Coast and Geodetic Survey in this important field, but lack of funds has not permitted further work.

At present observations of densities and temperatures are being secured at four of the principal tidal stations maintained by the Survey. These will be extended during the current fiscal year to cover all principal stations.

In the matter of tidal bench marks it is evident that the goal to be aimed at is the establishment of one or more bench marks at each important place on the Atlantic, Pacific, and Gulf coasts of the United States. The most economical method, however, to accomplish this is in connection with hydrographic surveys and it is this system that the Bureau is following.

At a number of points the Survey has for many years been establishing bench marks along the coasts based on long series of tidal observations at its principal tidal stations, and the time has come when these stations, many of which have been discontinued, should be visited and new bench marks established where old ones have been destroyed. The only work being done along this line is that at stations which are at present in operation, and there remain all old

stations yet to be leveled and new marks established. This important work should not be delayed longer, for these bench marks protect, in many cases, long series of tidal observations costing many thousands of dollars and the duplication of which would require not only many thousands more but many years.

To the present time new bench marks have been established and old ones releveled only in connection with other survey work, and while this makes for economy and will be continued there is also great need for a special tidal bench-mark party for reestablishing of bench marks at stations that have been discontinued. At any one station this work will be necessary only every 5 to 10 years.

CHAPTER III.

PROGRAM FOR CURRENT FISCAL YEAR IN THE FIELD.

GEODETIC WORK.

The precise traverse started in Wisconsin during the fiscal year 1921 will be completed to Duluth, Minn., where a connection will be made with the triangulation of the United States Lake Survey. This traverse in Wisconsin will then be extended southward and westward from Ladysmith to La Crosse, on the Mississippi River. This is a line of traverse which will eventually be extended across the southern part of Minnesota and in the northeastern part of South Dakota, where it will connect with the ninety-eighth meridian precise triangulation.

Precise leveling will be begun in the spring of 1922 following the line of precise traverse from Green Bay to Duluth.

Triangulation will be extended in Oklahoma, Texas, and New Mexico to complete an arc which will extend from the vicinity of El Reno, Okla., to Williams, Ariz. Triangulation will be begun on the arc which will extend from the vicinity of Pecos, Tex., northward into Colorado. This line will run through eastern New Mexico.

Precise leveling will be run in the State of Oregon from Portland, Oreg., to Wallula, Wash. This line will connect two of the main lines of precise levels of the country. Another line in Oregon will be run from Bend to Prineville.

Precise leveling will be run from the vicinity of Green River, Utah, to Halls Crossing, thence down the canon of the Colorado River to Lees Ferry, and from that place southward to Flagstaff, Ariz.

A reconnoissance will be made in Montana and Idaho for the selection of precise-triangulation stations along the boundary between the United States and Canada.

There will also be made a reconnoissance in northern Minnesota for the purpose of selecting precise-triangulation stations for an arc along the international boundary.

Precise leveling will be begun in Montana and Minnesota in the spring of 1922 along the Canadian boundary following the reconnoissance which will be made during the summer of 1921.

The triangulation along the boundary is part of a general scheme which is being undertaken by the Coast and Geodetic Survey and the Geodetic Survey of Canada, looking toward the completion of an arc of precise triangulation from Lake Superior to the Pacific coast.

In the winter of 1921–22 precise traverse will be run in the State of Mississippi, extending the line that was begun in the winter of 1920–21.

Precise leveling will be done in New York to revise the leveling which had been previously carried on in that State and to make a connection between certain pieces of existing work.

In the spring of 1922 a line of precise leveling will be begun near the Canadian border, in northern New Hampshire. This line is a part of a line of leveling which will extend from northern New Hampshire to Portland, Me., and thence along the coast, touching at Boston, Providence, and other places, to New York City.

The determination of the intensity of gravity and of the astronomic latitude will be made at a number of stations in the States of Alabama, Mississippi, Louisiana, and Texas.

The precise triangulation of Puget Sound will be completed during the fiscal year 1922. Precise triangulation will be continued in southeastern Alaska to the northward of Dixon Entrance.

The work in Puget Sound and in southeastern Alaska is part of a general scheme which is being executed by the Coast and Geodetic Survey and the Geodetic Survey of Canada, working in cooperation. It is being proposed to extend the precise-triangulation system of the United States from the vicinity of Puget Sound, northward along the coast to White Pass, just above Skagway. From that point the Geodetic Survey of Canada will extend precise triangulation down the Yukon River to the crossing of that river by the one hundred and forty-first meridian, which is the boundary between Alaska and Canada. When this work has been completed, geographic positions on the North American, or final, datum, will be available for northwestern Canada and for Alaska. This will be of great value to those engaged in surveying, mapping, and charting within the areas mentioned.

Practically all of the work outlined above, to be done during the fiscal year 1922, has been requested by some competent authority or it is working toward a plan for the completion of the precise control of the country.

HYDROGRAPHIC AND TOPOGRAPHIC WORK.

ATLANTIC COAST.—*Offshore hydrography.*—The steamer *Bache* will continue operations between the entrances to Chesapeake Bay and Delaware Bay, extending the hydrography seaward to the 100-fathom depth.

The steamer *Hydrographer* will continue offshore hydrography to the 100-fathom depth off the Mississippi River Delta, eastward to a junction with the offshore work accomplished by the steamer *Ranger* during the past fiscal year.

Wire-drag work.—One and if possible two wire-drag parties will continue wire-drag work off the Maine and Rhode Island coasts in continuation of the work abandoned in the fiscal year 1920.

Inshore hydrography and topography.—Two parties with the launches *Mikawe* and *Elsie* will continue inshore hydrography and topographic revision along the South Atlantic coast from North Carolina to Florida.

PORTO RICO AND VIRGIN ISLANDS.—*Wire drag and hydrography.*—The steamer *Ranger*, with wire-drag launches, will continue dragging the navigable waters between Porto Rico and the Virgin Islands, and will make a close hydrographic survey of the harbors and ap-

proaches of the Virgin Islands. All topography has been completed in these localities and only such additional triangulation will be done as may be required for the determination of signals for use of hydrographic parties.

PACIFIC COAST.—*Offshore hydrography.*—The steamer *Lydonia* will continue offshore hydrography seaward to a depth of 1,000 fathoms off the California coast in the vicinities of Cape Mendocino and Cape Blanco, and, if possible, on the southern California coast.

Inshore hydrography.—The steamer *Natoma* will endeavor to complete the survey of San Francisco Bay and tributaries. Hydrography and topography will be undertaken in Puget Sound and tributaries during the winter, if personnel and equipment are available.

SOUTHEASTERN ALASKA.—*Offshore hydrography.*—The steamer *Surveyor* will continue on the offshore hydrography and original topography and hydrography upon which she was engaged during the past fiscal year. It is contemplated that this work will be continued without interruption to Cross Sound, as much work as possible being accomplished each year.

Wire drag, inside hydrography, and topography.—The steamer *Explorer* will continue wire-drag operations, primary triangulation, hydrography, and topography northward to the head of Lynn Canal and thence down Chatham Strait and through Icy Strait and Cross Sound to the Pacific, thus completing the main steamer thoroughfare through southeastern Alaska. Primary triangulation will be carried by this party only as far as the head of Lynn Canal.

It is planned to equip the steamer *Wenonah* for wire-drag operations and have this vessel assist the *Explorer* in the work outlined above. On completion of the main steamer route through southeastern Alaska, both vessels will then engage upon dragging the less-frequented steamer routes in southeastern Alaska, taking up the various passages and waterways in the order of their importance.

Primary triangulation.—During the past fiscal year the Bureau has, for the first time, undertaken primary triangulation as an element of combined operations from full-powered vessels. This work has been performed so successfully that it is planned to carry out as much as possible of the primary control of southeastern Alaska in this way. There are, however, some places where primary triangulation can not be economically performed from these vessels, and in those places, of which the Dry Strait is one, the primary triangulation will be performed from launches. It is planned to have one such launch party in southeastern Alaska during the fiscal year.

PHILIPPINE ISLANDS.—*Triangulation, hydrography, and topography.*—Three vessels, the *Pathfinder*, *Fathomer*, and *Marinduque*, will operate during the fiscal year in continuation of the projects on which they are now engaged. This work will be largely offshore hydrography in the open-water areas between the islands and principally in the southern part of the archipelago.

WESTERN ALASKA.—*Triangulation, hydrography, and topography.*—If practicable to do so, the steamer *Yukon* will be put in commission during the second half of the fiscal year, and will be employed on triangulation, topography, and hydrography in Shelikof Straits.

MAGNETIC WORK.

OBSERVATORIES.—The observatories at Cheltenham, Md., Vieques, P. R., Tucson, Ariz., Sitka, Alaska, and Honolulu, Hawaii, will be kept in operation as heretofore. It is expected that work will be begun on the new office at Cheltenham in the spring of 1922.

FIELD WORK.—Two parties will be placed in the field in the United States. Secular change data will be obtained at about 50 stations in Northwestern and Southern States. It was not planned to occupy any new localities on account of the urgent need for secular change data. It is expected that two or more parties will be placed in the field in the spring in time to occupy about 50 or more new stations and repeat stations. This is now possible on account of the increase in personnel.

TIDAL AND CURRENT WORK.

In order to utilize fully the series of systematic current observations made on the different light vessels on the Pacific coast during the past two years in the building up of satisfactory and useful current tables for the use of the coastwise mariner, short series of current observations should be made along the sailing lines between these light-vessel stations for the purpose of linking together the current conditions along the whole coast. During the present fiscal year it is proposed to make a beginning of this work along a part of the Pacific coast by utilizing one of the Survey vessels for about two months between survey seasons. While this addition to the regular program of tidal and current work will necessitate a curtailment of other very important normal activities, it is thought that the vital information obtainable should not be longer kept from the mariner to assist him in keeping his vessel from the rocks along a coast where the current conditions are most complicated.

Principal tidal stations, representative of the tidal conditions along their different stretches of coast, will be continued at the following places:

Portland, Me.
Boston, Mass.
Delaware Breakwater, Del.
Baltimore, Md.
Fernandina, Fla.
Key West, Fla.
Cedar Keys, Fla.
Galveston, Tex.
San Diego, Calif.
San Francisco, Calif.
Seattle, Wash.
Ketchikan, Alaska.

The tidal station established at Anacortes, Wash., during the past fiscal year for the purpose of defining a mean sea-level datum for connecting the Canadian and American precise leveling will be continued during the current fiscal year.

For purposes of this Bureau and for use of the Weather Bureau in its hurricane warning work an automatic tide-gauge station will be established at Charleston, S. C. After this station has been in operation for a year the tidal station at Fernandina, Fla., will be discontinued, so that this will entail practically no added expense.

The principal tidal station at Philadelphia, which was discontinued during the past fiscal year for repairs to the dock on which it is located, will be reestablished during the current fiscal year.

In order to carry out the field work on currents at intermediate stations on the Pacific coast as previously outlined, it has been found necessary to curtail somewhat the current work on the light vessels on both coasts. On the Atlantic coast observations will be continued only on Nantucket Shoals and Diamond Shoals Light Vessels for the full year and at Charleston light vessel for a few months, until a short series of observations are made in the immediate entrance to Charleston Harbor, so that predictions for this port may be included in the new current tables which will be issued for the year 1923. On the Pacific coast current observations will be discontinued temporarily at all light vessels except Blunts Reef. Observations on all these vessels on the Pacific coast, however, will be again taken up when the Survey vessel begins observations at intermediate points along the coast.

In order to maintain a fixed zero of staff, a most essential matter in securing a long series of tidal observations, tide staffs of standard design with special backing piece, cap, and stop have been designed during the past year and installation made at three of the principal stations. It is a part of the program of tidal and current work for the current year to install these standard staffs at all principal stations maintained by the Survey.

Datum planes for the use of the engineer and the mariner, based on tidal definition, are the only ones which lend themselves to coordination of surveys widely distributed and brought together. The Survey has for many years by means of its principal and subsidiary tidal stations established bench marks and is furnishing to engineers in all parts of the country descriptions and elevation of such bench marks based on mean sea level. Since an accurate determination of mean sea level can be obtained only from a comparatively long series of tidal observations, the value of such bench marks and the importance of their preservation is very evident. A large number of important bench marks determined by long series of observations at stations which have been discontinued are in danger of being lost. While the present modest appropriation will not permit of maintaining a level party to visit all stations and save all such bench marks from destruction, it is planned to visit and level as many as possible during the current fiscal year, beginning with the most important ones.

Because of the destruction by fire of the principal tidal station at Fort Hamilton, N. Y., the Survey is not at present maintaining a station in New York Harbor. However, through cooperation with the United States Army Engineers, who are operating a number of gauges in this region, tidal information for this important harbor is being secured and kept up to date. Arrangements have been made with the Engineers to take over one of their stations upon their discontinuing tidal work here.

Part IV.—DETAILED STATEMENT OF FIELD WORK.

HYDROGRAPHIC AND TOPOGRAPHIC WORK, ATLANTIC COAST.

MASSACHUSETTS.

[W. C. HODGKINS.]

The work of the field station consisted largely in supplying information in regard to charts and other nautical matters to the yachting and general maritime public; also in supplying charts and publications to the several sales agents as necessary to enable them to meet extraordinary public demands upon their stocks. A fairly large number of such publications was also disposed of by direct sale to the public, some seeming to prefer to deal directly with the Bureau when aware of the establishment of the field station.

In addition to the strictly maritime information furnished as stated, many inquiries in regard to other activities of the Survey, and also of other Government bureaus, were received and answered as fully as the available information would permit.

Frequent calls from the Army, Navy, Coast Guard, and other public services for copies of our charts and publications have been honored so far as possible.

From time to time, and from various sources, information has been collected for the correction or improvement of the charts of this inspection district and, when deemed of sufficient importance, this has been communicated to the office at Washington.

The special incident of the year has been the establishment of a new tidal station at South Boston. That station, situated on Commonwealth Pier No. 5 by the courtesy of the Massachusetts Department of Public Works, is supplied with an automatic gauge, of the customary Coast Survey pattern, and has a specially designed float tube of steel provided with a conical base of cast iron, through a small aperture in the apex of which the sea water finds entrance to the tube.

Preliminary steps toward the establishment of the tide station were taken in the winter months, but it was not until May 3, 1921, that the gauge was put in operation. Since that date, it has functioned without interruption or serious mishap.

Lines of spirit levels were run from the gauge to bench marks of the city of Boston and of the Navy Department in other parts of South Boston in order to have permanent marks of reference for the tide planes.

The clerk attached to the field station, since the establishment of the new tide station has acted as tide observer and has also observed the density of the sea water at the station.

MAINE, MASSACHUSETTS, NEW YORK, AND PENNSYLVANIA.

[H. A. MARMER.]

Between April 22 and May 6 an inspection was made of the tide stations at Portland, Me., Boston and New Bedford, Mass., New York City, N. Y., and Philadelphia, Pa.

From New Bedford Pollock Rip Slue Light Vessel was visited and an inspection made of the instruments and methods used in current observations.

NEW YORK.

[ISAAC WINSTON.]

An officer of the Survey has continued on duty as inspector in charge of the New York field station. The duties of inspector include those of a chart agent

for the publications of the Survey and agent for the sale of publications of the Bureau of Lighthouses. During the year 3,685 charts were sold; 776 charts were furnished for official use of the Army, Navy, Shipping Board, United States district attorney, and other officials; 2,588 calls were made in person, by letter, and by telephone for charts and publications and for information.

An inspection was made of the motor launch *Elsie III*, in company of the officer in charge of the section of vessels and equipment, and repairs were arranged for and made under the direction of the inspector until the arrival of the chief of party and the transfer to him of the launch and equipment on July 27.

Tide and current observations were continued in New York Harbor during the season, and every possible assistance was rendered in installing a self-registering tide gauge at Port Newark, N. J., and a tide observer was furnished for the tide gauge in the Harlem River for a short time.

Proposed locations of tide gauges by the U. S. Engineers in the East and Harlem Rivers were reported to the office, and an inspection of certain locations was made in company with the representative of the section of tides and currents.

Permission was secured from contractors operating dredges in the East River to make current observations from their floating plants.

An uncharted rock in Kill Van Kull was reported and request was made to have its position determined.

Three chart agencies in New York City were inspected, and inventories were made of their charts and publications.

Minor repairs were made to the tide station at Fort Hamilton, and a new tide gauge was installed in December. The total destruction of the station by fire was reported a few days later. A visit was made to the office of the U. S. Engineers at Albany, N. Y., in order to secure data for correcting the charts of the Hudson River. A sketch of the triangulation of the upper part of the Hudson River and the coordinates of the station were also secured and forwarded.

Fifteen piers under construction by the city in the narrows on the Staten Island shore were located on the chart.

The times and heights of the tides at pier "A" and the barge office for the period September, 1920, were tabulated for comparison. A tabulation showing the location of the stations for tide observations made by the city from 1885 to date was prepared giving dates of occupation to indicate the tidal records available for discussion. The summation of the hourly heights of the tides at San Francisco, Calif., for 1905 was partly completed.

The clerk of the field station was detailed to assist the officer in charge of the Coast and Geodetic Survey exhibit at the National Motor Boat Show held in New York, December 10–18, to install and care for the exhibit, and the inspector attended on several evenings to aid in furnishing information. Everything possible was done to make the exhibit a success. The field station was removed from 428 to room 503 in the customhouse. An officer of the Survey, in addition to the inspector, was on duty at the field station, except when absent on leave, until the end of December.

Tide-gauge readings from the records of the U. S. Engineers' office were copied, and tide curves were plotted from the U. S. Engineers' records of gauge readings at nine stations in New York Harbor and transmitted to the office at Washington. Data for the correction of charts were compiled and furnished. Material and instruments for the vessels of the Survey were inspected and forwarded. Apparatus for observing currents was placed on the Harbor Channel and Stickland Lightships. Times of tides at Governors Island, Sandy Hook, and Hell Gate Ferry, Astoria, were compiled and furnished for publication. An investigation was made and consultation held with the chief of the division of tides and currents with a view to planning simultaneous observations of currents at a number of stations in New York Harbor in cooperation with the U .S. Engineers. The Assistant Secretary of Commerce inspected the station on May 19. The Director of the Coast and Geodetic Survey inspected the station on June 8.

[G. T. RUDE.]

On October 7, 1920, an officer proceeded to New York City and conferred with the inspector at the New York field station with regard to the tidal and current survey of New York Harbor and the work of the city engineers in regard to the engineers' tide gauges at the two ends of Harlem River. Afterwards a confer-

ence was had with the chief of the Coast and Geodetic Survey party engaged in tidal and current surveys in New York Harbor.

It was found that the pipe necessary for the establishment of the tide gauges in Harlem River by the U. S. Engineers had not been received. Consequently the chief of the Coast and Geodetic Survey party was furnished with two Coast and Geodetic Survey automatic tide gauges and instructed to proceed with the survey in Newark Bay, thus allowing more time for the completion of the engineers' tide gauges in the Harlem River. The Coast and Geodetic Survey party was inspected on October 12, the records examined and found to be in good condition. While it was impossible owing to congestion of traffic in the East River to locate all current stations in mid-channel exactly as contemplated in the instructions for this work, this has been done as far as possible under the circumstances. It is commendable that this work has been carried on in a locality such as the East River and Hell Gate without an accident or damage to the equipment.

On completion of the above work, the inspecting officer proceeded to Boston, Mass., and conferred with the inspector of the field station at that place, with the U. S. Engineer Office and the city engineers in regard to the establishment of a principal tidal station at that port, and also in regard to any tidal or current observations in progress or completed. In regard to the matter of a favorable location for a principal tide station, it was found that the State engineers had been operating at intervals an automatic tide gauge of their own design on Commonwealth Pier No. 5, but that the operation of the gauge had been discontinued. This station could be secured for the purpose of installing a Coast and Geodetic Survey automatic gauge.

Automatic tide gauges have been run at times by the city engineers, metropolitan State engineers, and Federal engineers at Moon Island, Deer Island, Charles River Dam, and at the navy yard. No current observations have been made.

The officer of the Coast and Geodetic Survey returned to Washington, October 15, and resumed his duties as chief of the section of tides and currents.

[R. J. AULD.]

SUMMARY OF RESULTS—Physical hydrography: 26 current stations occupied; 8 tidal stations established.

The work of making a tide and current survey of New York Harbor and Newark Bay in continuation of the survey begun in 1919, was taken up in accordance with orders dated July 21, 1920. The chief of party arrived in New York on July 28, and arrangements were made with the inspector of the New York field station for completing repairs to the launch *Elsie III*, and from that date until August 19, 1920, repairs to launch and organizing the field party were in progress. A field officer assigned to the party reported on August 18. On the following day a trial run was made with the launch. Before beginning the work of the current survey, search was made for a reported rock in Kill Van Kull.

By the end of August 2 current stations were occupied in East River. A subparty was placed on board the drill boat of the New Jersey Shipbuilding & Dredging Co. operating off Twenty-third Street. Only a partial record was obtained by this party, due to the fact that the drill boat had to be moved a considerable distance with the aid of tugs. Various difficulties were encountered by this party, as equipment had to be shipped from one end of the boat to the other at each change in direction of the current. The remainder of the party on the launch *Elsie* occupied a station in the channel on the west side of Blackwells Island simultaneously with the party on the drill boat. The combined party, however, proved too small to observe two stations at once, as all members had to actually stand a continuous watch for the whole period of 25 hours. The dangers of the work made this a too great physical and nervous strain. It was later found possible to make observations from the launch at all places where dredges were operating in the East River. After the two initial stations were occupied in the East River the base of operations was transferred to the part of Long Island Sound between Execution Rocks Light and Throgs Neck. Tide staffs were established at New Rochelle, Execution Rocks Light, and Elm Point near Little Neck Bay. Excellent weather conditions favored the work at the stations near Execution Rocks Light, Manhasset Bay, Little Neck Bay, and between Throgs Neck and Willets Point.

No unusual conditions were encountered at these stations, and the party gained experience for the more hazardous stations in the East River.

Work in the East River might be considered as beginning with the station between Rikers Island and Barretto Point. A drill boat of the New Jersey Shipbuilding & Dredging Co. was engaged in blasting a ledge of rock in the center of the channel. Advantage of their position was taken by anchoring the launch about 500 feet to eastward of them in the axis of the channel. From this point—that is, between Rikers Island and Hunts Pond—to the Battery the traffic in the East River is very strictly regulated by the War Department through regulations issued by the Corps of Engineers. Violations by tug masters were reported by inspectors on the dredges and drill boats and resulted in fines and loss of licenses, so that traffic exercised due care and caution in the vicinity of dredges, dynamite boats, and the launches of the Corps of Engineers. In order to inform passing craft as to the nature of the work, a large sign was carried on either side of the launch. These signs were approximately 4 by 8 feet, made of white oilcloth bearing the caption "U. S. Coast Survey" in black letters about 8 inches in height; beneath were the words "At Anchor" in red letters about 14 inches in height and a warning "Keep Clear" in black letters about 8 inches in height at the bottom. The special Coast Survey day signals and night lights were also carried. The light at night, however, proved to be confusing to traffic, especially the larger and faster boats. The green lights could not be separated the maximum distance, and doubtless at a distance were mistaken for one light. Fortunately, the launch was equipped with an excellent whistle, which when operated with 80 to 100 pounds of air pressure could be distinctly heard at a distance of a mile or more. When a vessel seemed in doubt of the launch's movements four blasts of the whistle served as a warning. This signal was regularly used by all the floating craft, such as dredges, drill boats, pontoons, etc., and was well understood by tug masters and pilots to mean to either slow down or use caution in passing. In the lower East River, where traffic was too dense to be continually on the lookout, use of the Coast Survey signals was dispensed with entirely, and two red balls by day and two red lanterns at night were used. Thereafter very little trouble was experienced with passing craft. Only in Newark Bay, where the tug masters stubbornly chose to dispute the right of dredges, etc., to restrict the channel, was any serious difficulty encountered.

Stations in the East River were occupied as follows: Throgs Neck, Barretto Point, Lawrence Point, Bronx Kill, west end of Hell Gate, between Blackwells Island Light and Hallets Point, west side of Blackwells Island, east side of Blackwells Island, off Twenty-third Street, New York; off Brooklyn Navy Yard; under Brooklyn Bridge; north end Buttermilk Channel; between Governors Island and the Battery, and in Newtown Creek.

Following the completion of observations in the East River on October 15, 1920, a day was spent making some repairs to the tide station at Fort Hamilton, under the direction of the inspector of the New York field station. On October 18, 1920, the party proceeded to Newark Bay, and pending the arrival of an automatic tide gauge from the office was engaged in establishing a plain staff at Greenville, between Jersey City and Bayonne. Permission was obtained from the Submarine Boat Corporation to use a house and well at the end of their dock, where a tide gauge loaned by the Coast Survey had formerly been established. The party returned to New York, secured a tide gauge, and with the assistance of the inspector the gauge was put in operation on October 20, 1920. The services of a field engineer for the Submarine Boat Corporation were secured to look after the gauge and note the staff readings on the marigram. Frequent inspections of the gauge were made by the current party. Beside the tide stations noted above, an automatic tide gauge was maintained by the Army Engineers at Shooters Island; plain staffs were also read at Lincoln Highway Bridge, over Passaic River, and at Elizabethport during periods of observations near those points.

The following stations were occupied in Newark Bay and tributaries: Entrance to Arthur Kill, below Central Railroad of New Jersey Bridge at Bayonne; above the Pennsylvania Railroad bridge; near the junction of the Passaic and Hackensack Rivers, and at points in the Hackensack and Passaic Rivers near the bridges carrying the Lincoln Highway or Plank Road over those streams. No unusual conditions prevailed in Newark Bay, the current in the main being fair with the channel. In the rivers a difference in the time of change was noted between surface and subsurface currents. Traffic in Newark Bay is mainly the movement of freight in barges. Some difficulty was ex-

perienced in avoiding traffic at the station above the Pennsylvania Railroad, and one tow which fouled the anchor line necessitated cutting the line to clear.

Upon completion of work in Newark Bay instructions were received to take up the work in Harlem River, occupying the stations from Spuyten Duyvil to the southward. The week of November 8–13 was used to establish automatic tide gauges and do the necessary leveling at Spuyten Duyvil and Willis Avenue Bridge. Little or no difficulty was experienced with traffic at any of the stations. At Broadway Bridge all towns and most small boats use the southern channel on account of its being a clear fairway. But little difference could be noted in the current in either channel. The piers for High Bridge constrict the channel to such an extent that dangerous velocities are generated at that point. Traffic uses the center opening in the middle of the river, while observations were made under the western opening. It is believed that there is but little difference in the velocities through these openings. The above station was the last station occupied, being finished on November 24, 1920. As it was necessary to close work on or about December 1 in order to bring the *Elsie III* south to Baltimore, the rest of the month was spent in painting and overhauling the launch and in dismantling the tide stations. The party was disbanded with the exception of two officers.

The party during the above season was aided materially by the experience and methods of the current party during the season of 1919. The inspector of New York field station was of the greatest assistance, with advice, in procuring information from the Army Engineers and in communicating with the Washington office.

On December 1, 1920, the launch *Elsie III* left New York. The inspector accompanied the party to Fort Hamilton, where a new automatic gauge was installed in place of the one then in use some years. The party proceeded to Tompkinsville, thence to Elizabeth, N. J., where a supply of gasoline was taken aboard. The party arrived in Philadelphia on December 4, 1920. A stop was made here over Sunday, continuing the journey the next day, and arriving in Baltimore on December 8, at which place orders were received to continue to Lewisetta, Va., and there turn the launch and equipment over to H. B. Campbell. At Baltimore an officer was detached from the party. The launch arrived at Lewisetta on December 10, 1920, and the transfer was made, after which the chief of party proceeded to Washington, D. C.

PENNSYLVANIA AND NEW JERSEY.

[L. A. COLE.]

Under instructions dated January 4, 1921, an inspection was made of the tide station on the Wilson Line Pier at Philadelphia, and arrangements were made for running levels between the tide gauge and bench marks upon receipt of instruments. It had been intended to discontinue the tide station at Philadelphia, but this intention was reconsidered, and the observer was directed not to dismantle it but to carry out instructions in regard to Atlantic City.

Upon arrival at Atlantic City on January 14 the rainy weather prevented work on that day. Levels were run on January 15 and 17, and the gauge was dismantled on the 16th. The observer then returned to Philadelphia and on January 21 completed the necessary leveling, returning to duty at the Washington office on January 22.

DELAWARE.

[H. A. SERAN, Commanding Steamer *Bache*.]

SUMMARY OF RESULTS.—Magnetic work: Ship swung for compass deviation at one station at sea. Hydrography: 1,907 square miles of area covered, 2,101 miles run while sounding, 4,070 positions determined (double angles), 20,720 soundings made, 2 tidal stations established (including one sea station), 119 current stations occupied, 2 hydrographic sheets finished, 1 : 40,000 and 1 : 120,000.

On July 1, 1920, the steamer *Bache* was engaged in offshore and inshore hydrography off the coast of Delaware from a junction with recently completed work northward to the entrance of New York Harbor and southward to latitude 38° 28½′. The instructions in regard to the sounding lines directed that they to be run at intervals of one-fourth mile out to the 10-fathom curve and crossed by lines spaced 2 miles apart. Beyond the 10-fathom curve the lines were to be spaced one-half mile apart to the limit of visibility of the buoys.

Beyond the limit of visibility of the buoys the lines were to be run to the 100-fathom curve, spaced 2 miles apart to and 4 miles apart beyond the 25-fathom curve. The usual procedure customary for the control of the offshore lines was to be followed.

By the close of the season the inshore hydrography was finished from latitude 38° 28½′ to 38° 50′. The sounding lines on this work were run east and west. Offshore hydrography within the same limits was finished. The offshore lines run about southeast and northwest.

The inshore hydrography between the latitudes 38° 34′ and 38° 44′ had been done by the party of the *Isis* in 1919. There were three areas within this work which had to have additional development. This development was made, and the only important discovery was a 30-foot sounding on the ridge running northeast and southwest in latitude 38° 41½′ and longitude 74° 45½′. The doubtful 30-foot sounding about 2 miles southeast of Indian River Inlet could not be verified. Careful sounding in this vicinity gave no depth less than 43 feet, and it is assumed that the 30-foot sounding was an error on the part of the leadsman. The spots close to shore between Indian River Inlet and Bethany Beach on which 18-foot soundings are shown on the present chart were carefully developed. No shoaler water was found.

Particular attention was paid to the uneven bottom a couple of miles offshore and extending from the vicinity of Signal Cotton Patch to the southern limits of the work. All the shoals in this area are shown on the present charts, although they have moved a little from their former positions. The work in one place was carried a little below the southern limits as instructed in order to finish the development of the shoal about 2 miles east of the Fenwick Island Life Saving Station.

Several lines were run in the vicinity of the wreck, position doubtful, about 4 miles north of Fenwick Island Light Vessel. While sounding in this vicinity the submarine sentry was towed at a depth of 10 fathoms. There is a long shoal in this vicinity which may have been caused by the wreck, but this seems rather doubtful as it is so large.

The bottom is very uneven along the lines of the survey buoys. A great deal of development work was done, especially at the northern end of these.

Hen and Chickens Shoal just off the point of Cape Henlopen was developed with the launch. The shoalest sounding obtained while making this development was 9 feet. The present chart shows three-fourths fathom on this shoal but probably it has been washed away, and the least depth is as obtained by this survey. In addition to the regularly plotted lines a number of lines were run without plotting, sounding in the breakers, etc. Nothing was found.

Several channel lines were run in the deep channel in the immediate vicinity of the approach to the bay, about 5 miles east of Cape Henlopen. There are 20 to 25 fathoms in this channel and the sounding was done with the trolley rig. The channel is about 8 miles long and extends southeast from the Overfalls Light Vessel.

The instructions of May 26 specified that McCrie's Shoal and Five Fathom Bank were to be developed on the same projection. In order that no holes would be left in the work a small triangular space was sounded at the junction of the three hydrographic sheets, 3079 which is the previous work, 4093 the present sheet, and the next sheet to the northward. This triangular space is just west of McCrie's Shoal.

At the 100-fathom curve quite a pronounced ravine was found. This ravine is in longitude 73° 55′ and extends north from latitude 38° 05′ to 38° 15′. This ravine was crossed with three lines, and a fourth line was run just north of it to mark its limits.

Instructions dated June 23 directed an inspection of the current apparatus in use on board the Overfalls Light Vessel. This inspection was made on July 20, and a report was forwarded to the office on July 31. The current observations are receiving close attention aboard this vessel, and to all appearances they are doing good work. About the end of September the master of this light vessel secured material for making a new current line from the *Bache*.

Paragraph 13 of instructions of May 26 directed that the necessary buoys for this work be constructed by the party rather than to borrow the navigational buoys from the Lighthouse Service as had been done in the past. After a study of the various types of buoys it was decided to adopt a buoy with three barrels for buoyancy. This work was turned over to one of the officers to work out the plans and build the buoys. They proved very successful after a few minor changes, which experience showed were necessary. A special report

on the construction and handling of these buoys was forwarded to the office on August 13. Owing to these buoys being directly in the fairway and not being lighted, several were lost in the course of the season by ships running them down.

These buoys can be handled by the ship, and no time is lost waiting for the lighthouse tender to plant or shift them.

Their total cost of construction is less than the amount charged us by the Lighthouse Service for depreciation on their buoys and the use of the tender in placing or shifting them.

Their construction by the field party renders the Coast Survey independent of the other bureaus.

The officers and men get valuable seamanship information in handling them.

The disadvantages in their use are that they can not be made as strong as the navigational type of buoy and probably can not be made strong enough to stand a whole gale.

There is a great deal of wear and tear on the ground tackle of the ship in handling them, and there is considerable danger of serious accident to personnel in handling them.

They can only be handled in smooth weather, and this is the best working weather for offshore hydrography, hence the field work suffers.

A set of instructions giving full information for the running of precise dead-reckoning lines and the final plotting of the soundings was prepared, to be used by the officers of the ship. A copy of these instructions was forwarded to the office August 14.

Instructions were issued under date of August 18 to make a series of tests of the newly devised sounding tubes. These tests were to be made in the vicinity of the finished hydrography in order to have a check on the soundings from the actual contours of the bottom as determined in the usual manner. Two lines from the 15-fathom curve to the 100-fathom curve were run in making these tests. One line was run with the ship running at full speed between soundings and stopping to take vertical soundings every 5 miles, the other line was run with the ship running at 6 knots an hour and sounding while under way. These latter soundings were spaced about 2½ miles apart and so arranged that every other one was taken in about the same location as the corresponding vertical sounding on the other line. These tests proved very satisfactory. A complete report of these tests was forwarded to the office on September 18.

Paragraph 11 of instructions of May 26 directed that if possible 50 consecutive hours of tidal observations be made on Five Fathom Bank with the apparatus especially designed for this purpose in the office. Weather conditions were very unfavorable for this work until the latter part of September when a couple of days of calm and smooth weather allowed the apparatus to be installed and the observations made. A special report of this work, describing the installation of the apparatus and the results of the observations, was made and forwarded to the office on October 13.

By the end of September the hydrographic work had been completed from the southern limits of the work to McCrie's Shoal. Arrangements were made for the closing of field work in the vicinity of Lewes and then proceeding to Beaufort, S. C., to cooperate with the party of the *Mikawe* in the inshore work in the vicinity of Port Royal Sound. Instructions directing this change of base were issued under date of October 5. The vessel sailed from Lewes the afternoon of October 7 and arrived at Beaufort, S. C., the afternoon of October 10. After conference with the assistant chief, division of hydrography and topography, and the commanding officer of the *Mikawe*, the vessel proceeded to Savannah, Ga., the morning of October 11.

NEW JERSEY.

[H. A. SERAN, Commanding Steamer *Bache*.]

The instructions issued to this party under date of May 26, 1920, contained the following: "At Five Fathom Bank tidal observations are desired over a period of 50 consecutive hours during good weather for use in securing these observations, a staff and float will be forwarded with description and illustration of the apparatus and suggestions for installation."

Apparatus used.—A 2-inch galvanized pipe, 33 feet long, in sections 6 feet, 12 feet, 12 feet, and 3 feet, respectively, was moored so it stood upright, in 27 feet of water. The 6-foot bottom section was cast in an 800-pound block of concrete,

reinforced with wire rope, loops of which were run out on opposite sides for fastenings for the lowering lines. A tide staff 1 by 1 inch by 10 feet, graduated to feet and two-tenths, was set in a cylindrical float of wood 1½ inches in diameter. This float and staff operated inside the pipe, the top of the staff extending out through a square hole cut in the cap over the top of the pipe. Staff was read at the top of the pipe. Four concrete anchors 2 by 2 by 2 feet, weighing between 1,100 and 1,200 pounds each, and No. 6 galvanized wire were used in mooring the pipe. The anchors were a little too light, they lose about 500 pounds when immersed in water, and any future work should use anchors weighing or having at least 1,000 pounds effective holding power. The anchors were placed about 100 feet from the bottom of the pipe just below the cap and four small sheaves, one for each guy wire, were secured to this flange by wire loops. (Shackles could not be used in securing these on account of the leads of the guys and the small amount of material in the flange.) The guys were led through these sheaves and set taut with a fence wire stretcher purchase, securing each guy back on itself when set up. There was a small amount of vibration at the top of the pipe, which made the apparatus more trustworthy as this prevented the float from adhering to the sides of the pipe. It was noted that when the staff was pulled up above or forced below its flotation level, it took some time for it to resume its normal position. A one-fourth inch hole was drilled near the bottom of the lower 12-foot section. This was about 7 or 8 feet above the bottom of the ocean and high enough to eliminate any chance of its becoming clogged with sand.

The installing of this apparatus with the equipment of the *Bache* was rather a difficult piece of work, and a number of mistakes were made. It was finally installed by anchoring a whaleboat with the stern in the immediate vicinity of the desired location for the staff. The pipe and block were swung under the launch, the block being about amidships and the pipe extending aft past the stern of the launch. A line to hold the end of the pipe was brought from the end of the pipe to the stern of the launch and made fast. Lowering lines were made fast to the wire loops on the sides of the concrete block. The launch ran alongside the whaleboat, one set of lowering lines were passed to the whaleboat and secured, the other set of lowering lines were slacked away from the launch until those on the whaleboat had the strain; the block was then directly under the stern of the whaleboat. It was lowered away from the whaleboat. The line from the end of the pipe was held, and as the block was lowered the end of the pipe naturally came up out of the water and into position. The pipe could be held upright from the anchored whaleboat, while the anchors were run to position and the guy wires, which were free when the anchors were let go, brought to the pipe and made fast, setting taut as previously described.

The pipe and staff were placed in position about 2.30 p. m., September 28. The staff did not work correctly for two hours. The cause of this was probably that the float was becoming water-logged or rather watersoaked during this time until it had absorbed all it would take. This occupied about 3 hours. About 6 or 7 o'clock the tides as shown by the staff were regular, and excellent observations were obtained. Hourly observations were continued until 9 a. m., September 30, when the increasing wind and sea and rapidly falling barometer made it imperative for the *Bache* to run for Lewes. In all, three excellent highs and three excellent lows were obtained. The range is practically the same as at Lewes, Del., time about 1 hour earlier.

Currents were observed simultaneously with the tides. These currents are plotted on the sheet of polar coordinate paper accompanying this report. It is noted that slack currents occur at about the time of low water, and that an average current, setting 30 degrees true with strength of 0.5 knots, obtains at high water.

The pipe and staff were installed about one-fourth mile 25° true from Buoy 2 TS marking the southern end of Five Fathom Bank, approximately in latitude 38° 51′ and longitude 74° 38′.

VIRGINIA AND MARYLAND.

[H. B. CAMPBELL.]

SUMMARY OF RESULTS.—Triangulation: 62.6 square miles of area covered; three signal poles erected; nine stations in main scheme occupied by horizontal measures; 16 geographic positions determined.

Between November 19, 1920, and January 17, 1921, the supplemental trangulation was done at the mouth of the Rappahannock River, including the establish-

ment of an additional station for the purpose of strengthening the scheme already completed by the State Bureau of Fisheries of Virginia. All angles were reobserved, and the eccentricity of Station Boss was determined. This work was completed by November 30.

Following this work five stations which had been erected by the Navy at the mouth of the Potomac River and four range buoys and five target buoys were located by triangulation. A connection was also made between the triangulation in Chesapeake Bay with that in the Potomac River. Unfavorable weather condition delayed the completion of this work until January 11, 1921.

The observations in both localities were made with the 7-inch repeating theodolite, and the work was planned to conform to the requirements of tertiary triangulation. On the Potomac signal lights were used in part of the work. A motor sailer was used for transporting the party from Norfolk to the working grounds and in the execution of the work until December 14, when the *Elsie III* was used exclusively until the completion of the work. On the completion of the triangulation called for the observer proceeded to Hampton, Va., with the two launches and laid them up for the winter in accordance with instructions.

VIRGINIA.

[H. A. SERAN, Commanding Steamer *Bache*.]

SUMMARY OF RESULTS.—Topography: 10.5 miles of detailed shore line surveyed; 1 topographic sheet finished, scale 1:40,000. Hydrography: 326.6 square miles of area covered; 938 miles run while sounding; 2,624 positions determined, double angles; 16,205 soundings made; 2 tidal stations established; 31 current stations occupied; scale of hydrographic sheet 1:40,000 and 1:120,000.

Instructions issued February 8, 1921, provided for a continuation of the resurvey from northward to the approaches to Chesapeake Bay. This resurvey had been begun in 1919, but had been suspended during 1920.

The details are similar to those of previous years. Survey buoys were to be placed inshore and fixed-position hydrography carried from the shore to the limit of visibility of the buoys. The offshore work was to extend from the limits of the visibility of the buoys to the 100,000 curve.

As the signals in this vicinity had been destroyed it was necessary to rebuild the 100-foot signals on Mink Hill between Cape Henry, Virginia Beach, and at Ship Shoal Inlet and to rebuild the 40-foot signals on Smith Island between Cape Charles Lighthouse and Ship Shoal Inlet before hydrography could be started. In order to have these signals built by the time the ship was ready to begin operations, a subparty was organized to work on shore. Between March 21 and April 18, two 100-foot signals mentioned above and three 40-foot signals on Smith Island were built. A tide staff was established at Fisherman's Island and an automatic gauge erected at Assateague Harbor on April 5.

Before doing any hydrography the compasses were adjusted and the ship swung for deviations. The logs were tested and their factors computed.

Hydrographic work was begun on April 13 and was in progress at the close of the year. At that time the hydrography had been finished between latitudes 37° 00′ and 37° 08′ and between longitude 75° 15′ and 76° 00′. Some spots needed a little development in this area. In addition to this, one line was run to the 100,000-fathom curve and extended to the 1,000-fathom curve to test the new sounding machine. This offshore line was along latitude 36° 36′. The sounding line was placed as follows: One-quarter mile apart, crossed by lines 2 miles apart, between the shore and the 10-fathom curve; one-half mile apart from the 10-fathom curve to the limit of visibility on the buoys; 1 mile apart from the limit of visibility on the buoys to the edge of the inshore sheet; and 4 miles apart from the limit of the inshore sheet to the 100-fathom curve. The hydrography was all done from the ship except the development of Nautilus Shoal. This small amount of work was done with a launch party. Considerable development is being done, especially in the area between Cape Charles Light Vessel and Fisherman's Island. The bottom in that vicinity is quite irregular and broken.

In order to locate the signals on Smith Island, a plane-table traverse was run between Cape Charles Old Tower and the ship at Ship Shoal Inlet. All the signals were tied to this traverse.

The signal-building party was engaged in building signals between Ship Shoal Inlet and Hod Island Lighthouse from June 13 to June 30, 1921. During this time one tall hydrographic signal 100 feet high was built on Cobb

Island near the Coast Guard station, and two intermediate signals, one at the north point of Cobb Island and the other at the south point of Wreck Island. These signals are to be located in position, and an attempt will be made to recover some of the old triangulation in the vicinity.

NORTH CAROLINA.

[J. H. HAWLEY, Commanding Steamer *Onward*.]

SUMMARY OF RESULTS.—Triangulation: 102 square miles of area covered, 5 observing tripods and scaffolds built, average height 32 feet, 8 stations in main scheme occupied for horizontal measures, 1 station in supplemental scheme occupied for horizontal measures, 11 geographic positions determined. Leveling: 2 permanent tidal bench marks established, 1 mile of levels run. Topography: 25 miles of shore line of rivers run, 1 topographic sheet finished. Hydrography: 139.5 square miles of area sounded, 851 miles run while sounding, 3,882 positions determined (double angles), 31,244 soundings made, 3 tidal stations established, 1 current station occupied, 5 hydrographic sheets finished, scales 1:5,000, 1:10,000, and 1:20,000.

The steamer *Onward* arrived in the Neuse River, N. C., from Savannah, Ga., on March 22, 1920, and on March 26 began combined surveys of Neuse River and Pamlico Sound in accordance with instructions. The *Onward* was at Elizabeth City, N. C., from July 1 to 16, 1920, undergoing emergency repairs. During this period the officers and crew of the vessel were engaged in office work on sheets and records and in miscellaneous ship work. Repairs were completed on the 16th, and on the 17th the vessel left Elizabeth City to return to the working grounds. On the evening of the 17th, in the vicinity of Brant Island Shoal Lighthouse, the vessel became disabled by boiler trouble and on the 18th was towed to Oriental, N. C.

From July 19 to 22, the ship was at Oriental while repairs to her boiler were being made by the ship's force. She left Oriental on the 22d and proceeded to New Bern for coal. On July 23 she returned to the working grounds and resumed field work.

From July 23 to October 21 combined surveys were carried on in Neuse River and Pamlico Sound. Until the latter part of September the progress of the work was very slow, due to unfavorable weather. The work was also interfered with during the entire period covered by this report by the shortage of officers and the weakness of the vessel. Details of the work accomplished after July 23 are given below.

Triangulation station Maw on Maw Point, established in 1913, was recovered and re-marked, and station Brant I. III was recovered. The latter station was found out in the water, and a new station, Brant I. IV, was established on the island and located by measured angle and distance from the old station. To carry the triangulation eastward into Pamlico Sound, new stations were established at Point of Marsh, North Swan Island, and on the point on the east side of the entrance to Cedar Island Bay, these stations being located from the line Maw-Brant I. IV. Brant I. Slue Beacon and Cedar Island Beacon were also located during the course of this work. A 20-foot signal was erected over station Maw, and 32-foot scaffolds with 16-foot instrument tripods were erected over the other stations in the main scheme.

The position of Neuse River Lighthouse, which was included in this scheme, was found to differ from the position obtained earlier in the season from the triangulation in Neuse River, and the two schemes were then connected by observing the lines Broad Creek Beacon-Maw and Mid 2-Point 2, the entire work being recomputed as a continuous scheme starting with the line Cockle 2-Gum Thicket in the Neuse River as a base.

The beacon at the entrance to Oriental Harbor was also occupied in order to determine its geographic position.

Revision of shore line was continued in Neuse River and Pamlico Sound. On the north shore of the river the shore-line revision of Maw Point was made, and on the south shore of the river and sound the work was extended from Rattan Bay eastward to Newstump Point in Cedar Island Bay.

In accordance with instructions dated July 14, 1920, a shore-line revision of South River was made, control stations for topography and hydrography being established by plane-table triangulation extending from the mouth of the river to Eastmans Creek.

The inshore hydrography in the Neuse River was completed eastward of Brown Creek on the south bank and eastward from and including Broad Creek on the north bank. After this work was completed the survey of the western end of Pamlico Sound was taken up. Joining the work at the mouth

of the Neuse River this work was extended eastward to overlap the limit of previous work extending from Brant Island Shoal Lighthouse to Camp Point. To the northward the work was extended up to the southern limit of Brant Island Shoal west of the slue beacon and across the shoal to the eastward of the beacon.

The survey of Adams Creek and Oriental Harbor was completed and a hydrographic survey was made of South River in accordance with instructions dated July 14, 1920.

The automatic tide gauge established at Oriental on March 29 was continued in operation until the end of the season, and observations were also continued at Neuse River Lighthouse until the end of the season. Additional level lines were run between the gauge and bench marks at Oriental before the gauge was discontinued.

Tide gauges were established at Brant Island Shoal Lighthouse and Harbor Island Bar Lighthouse on September 1 and 16, respectively, and continued in operation until the end of the season. A gauge was also established in Coffee Creek, and observations were obtained during the course of the hydrographic work in South River.

A current station at the mouth of the Neuse River was occupied for 25 consecutive hours.

Field work was discontinued on October 21, 1920, in accordance with instructions dated October 15, 1920, and on October 22 the vessel left Oriental for Norfolk, Va., arriving on the afternoon of the 24th.

From October 25 to November 22 the ship was at Norfolk. Officers and crew were engaged in work on the records and sheets, in packing and listing equipment, preparing inventories, and in miscellaneous work in preparation for the return of the vessel to the custody of the Navy Department.

On November 23 the ship left Norfolk and proceeded to the Naval Operating Base, Hampton Roads, Va., and on November 26, 1920, was returned to the Navy.

[R. J. AULD.]

On March 31, 1921, instructions were issued for measuring a base line on the Cape Fear River, N. C., and to connect with the existing triangulation.

As this work was to be done by the party transferring two wire-drag launches, but little delay was occasioned in the work. The launches arrived at Southport, N. C., on April 24. A preliminary reconnoissance was made on the following day, and several stations were recovered. The necessary materials and supplies were obtained from Wilmington on April 26.

It was decided to measure the base along the Carolina Beach Railway in order to avoid a considerable amount of clearing, and to take advantage of the supporting surface of the rail.

A line was measured starting from station Join established as a connection in a traverse from Myrtle Sound to Cape Fear River. The base which was approximately 1 kilometer in length lacked the strength of figure in the connection with the existing triangulation which had been called for in the instructions.

The expense of choosing and preparing a more favorable site was not felt to be warranted under the conditions under which the work was done.

The base site was prepared, signals were erected, horizontal angles measured and leveled during the period from April 26 to May 4, 1921.

The old stations recovered were in excellent condition and fully described in such manner as to be readily recoverable in the future.

SOUTH CAROLINA.

[H. A. SERAN, Commanding Steamer *Bache*.]

SUMMARY OF RESULTS.—Triangulation: 20 square miles of area covered; 6 signal poles erected; 14 stations in supplemental scheme occupied for horizontal measures; 20 geographic positions determined. Topography: 49.5 miles of detailed shore line run; 20.4 miles of detailed shore line of rivers surveyed; 17.3 miles of shore line of creeks surveyed; 13.7 miles of roads surveyed; 2 topographic sheets finished, scale 1:20,000. Hydrography: 123.9 miles of area covered; 700.9 miles run while sounding; 2,511 positions determined (double angles); 25,921 soundings made; 2 tidal stations established; 2 hydrographic sheets finished, scale 1:20,000.

After closing work in the vicinity of the Delaware Capes, the steamer *Bache* took up a hydrographic survey of the area between the inshore limits of the offshore hydrography previously done and the shore line, from Tybee Creek on

Tybee Island to Port Royal Sound and including Calibogue Sound, making connection at Port Royal with the hydrography of 1916. The instructions also provided for a topographic survey, primarily a plane-table traverse, for the location of the necessary hydrographic signals, of the same area including the contiguous islands.

The *Bache* arrived at Savannah on the evening of October 11. Until October 18 the party was in Savannah engaged in making field projections and gathering data for the field work. Actual field work was begun on October 19 with a signal-building party. From that date until December 4 the work was in progress as weather permitted. On the latter date the work as called for in instructions of October 15 was completed and the party moved to St. Helena Sound.

For the hydrography of Tybee Roads enough natural objects, consisting principally of lighthouse range towers, were standing, and no additional signals were necessary.

The Army Engineers had a scheme of triangulation, including a measured base, covering Tybee Island. This scheme was connected with the triangulation of Tybee Roads, and a quadrilateral and their signals (40-foot towers) were used both in the hydrographic and topographic work.

A tertiary scheme of triangulation, consisting of 3 quadrilaterals and a final triangle, for location of hydrographic and topographic signals only, was extended up Calibogue Sound from the three points—Tybee Island Lighthouse, Bloody Point Front Range, and Do.

The survey of the outer coast of Hilton Head Island was controlled by the position of Do at the southwestern end and the position of Hilton at the northeastern end, with Hilton Head Front Range and Deer as intermediate checks.

The topographic survey was made on two sheets: One covering the outer coast of Hilton Head Island from Braddock Point in Calibogue Sound to the small creek about 2 miles north of Hilton Head, the other covering the remaining territory as called for in the instructions of October 15, 1920, from Skull Creek, at the head of Calibogue Sound, to Tybee Creek, Tybee Island, the southern limit of the work.

The survey of the outer coast of Hilton Head Island on sheet No. 1 was all plane-table traverse. On sheet No. 2 practically all methods of topographic surveying were used, including sextant locations of the greater part of the shore line on the sheet. The survey of the shore line of South Channel, Savannah River, from the east end of Cockspur Island to the western limits of the sheet, was made by the hydrographic party.

The instructions of October 15, 1920, called for a resurvey of the southeastern coast only of Turtle Island. This island has changed so much since the previous survey as shown on the present charts that it was necessary to rerun the entire island with the exception of the northern shore before a satisfactory connection could be made.

Few changes were found in the shore line in the balance of the region. Hilton Head Island has been washed in some degree, and the shore line has moved inland from its position on the present charts, as has the eastern shore of Daufauskie Island. Hague Point on Daufauskie Island has been eroded more than any other point.

Along the marshy shores at the head of Calibogue Sound, there is a network of canals and indentations. This shore line is covered at high water, and the shore line shown on the sheet is a generalization only of the outer edge of the grass line. This applies particularly to the area between May River and Skull Creek. To really survey this section would require more time than its importance or need would warrant.

All the hydrography was small-boat work and was done on two sheets corresponding to the topographic sheets.

In accordance with the instructions lines were run at quarter-mile intervals, with such additional lines as were necessary to develop the shoals and channels.

The results of the hydrographic survey were startling in the changes found. Tybee Roads has changed so from the conditions as given on the present charts that new charts will undoubtedly be necessary. The most recent survey of the dredged channel from the end of the jetties, Savannah River, to the sea buoy at the entrance was obtained from the Army Engineers at Savannah and is submitted with the records.

At the north end of Tybee Island a shoal with 1 foot at the outer end has extended about 1 mile to the eastward. The northern side of this shoal approaches the southern edge of the dredged channel very closely. It is thought

that this shoal will tend to build to the northward rather than extend itself to the eastward and that unless checked it will encroach on the dredged channel. Only time will tell whether this is correct. Incidentally, Chart No. 440 shows 15 feet of water over the outer end of this shoal.

About 1 mile to the southward of this shoal, a large V-shaped shoal with its apex about 1½ miles offshore commences. This shoal is shown on the present charts much smaller than it actually is. Between these two shoals there is a stretch of fairly deep water, 7 and 8 feet right up to shore. This is interesting in that at the present time a landowner at this point has brought suit against the Government for damages to this property, washing away, which he claims has been caused by the dredging of the channel.

Another remarkable change is at the southwest corner of Hilton Head Island. The present charts show little or no water between the island and the shoals immediately south. The present survey has developed a narrow channel with 13 feet from Calibogue Sound to the sea following closely the shore line.

The two shoals immediately south of Braddock Point are much larger in extent, while the shoal immediately east of the bell buoy (Bell Buoy No. 2 on Chart No. 440) is much smaller than the present charts show.

A line of soundings was run from the mouth of Lazaretto Creek to the cut-off connecting this creek and Tybee Creek, through this cut-off and down Tybee Creek to its mouth. Fixed positions were carried throughout this line at all changes of direction. This line gives a valuable check on the positions of these creeks and also hydrographic information in regard to Tybee Creek. The present charts show no soundings in this creek.

The hydrography off Hilton Head Island shows great changes from that shown on the present Chart No. 571. Gaskin Bank is much smaller in extent and has moved to the westward. Joiner's Bank, off Hilton Head, retains its general outline so far as that portion of it which bares at low water is concerned, otherwise it also has been reduced.

An excellent connection was made with the 1916 hydrography of Port Royal Sound although there seems to be a little more water at the inshore ends of the offshore lines than the previous survey showed.

The self-reading tide gauge of the U. S. Engineers on the wharf at the north end of Tybee Island was used for this work. The staff of this gauge is set with its zero at mean low water—16.71 feet below Bench Mark No. 8. This setting was checked by levels before any observations were made. The self-reading device on the gauge reads constantly 0.2 feet lower than the staff, and all observations have been corrected by adding this amount to them. This correction was determined by a number of simultaneous readings on both the staff and the self-reading gauge.

A tide observer was detailed from the ship, and through the courtesy of Col. Hiner, Coast Artillery Corps, commanding officer, Fort Screven, he was subsisted at that post.

A tide staff was secured to Jenkins Float Post Light, at the head of Calibogue Sound, and daylight observations made on two days. These observations checked the information given in the Tide Tables for May River Range as compared with Tybee Island 1.1, time about 1 hour later. In accordance with instructions of November 22, 1920, the soundings in Calibogue Sound were reduced using the Tybee Island gauge directly.

Half-hourly observations were made from 9 a. m., November 22, until 5 p. m., November 25, for simultaneous observations with the automatic gauge established by the party at work north of Port Royal Sound. It subsequently developed that during this period the automatic gauge was out of order, and the Tybee Island observations went for naught. Fortunately the U. S. Engineers maintain two automatic gauges in the immediate vicinity of the Tybee Island gauge, one at the end of the jetties and the other just off Fort Pulaski in the Savannah River just below the quarantine station, and the necessary information can be obtained from that source to make the comparison.

Particular mention is made of the cooperation of the U. S. Engineer Office in Savannah. This survey was one in which they were vitally interested, and they rendered every aid called for. Permission having been given by the Director, they were allowed to make a copy of the boat sheet of Tybee Roads. This boat sheet showed the soundings reduced according to the predicted tides as given in the Tide Tables.

Through the courtesy of Capt. O. J. Bond, Coast Artillery Corps, post quartermaster at Fort Screven, and formerly a field officer in the Coast and Geodetic Survey, gasoline was secured for the launches several times when the supply became exhausted.

Savannah, Ga., was used as a base for this work, the ship running there for supplies every week end. This port makes an excellent base, although docking facilities are rather limited and some difficulty is experienced in getting permission to lie at a dock on the Savannah side of the river.

Under date of November 20, 1920, supplemental instructions covering the hydrography immediately south of the entrance to St. Helena Sound and north of the finished work of the party of the *Mikawe* were issued. This work was to be taken up when the survey as called for by the instructions of October 15, 1920, had been completed.

The *Bache* left Savannah the morning of December 7 and arrived in St. Helena Sound the same afternoon. The boat sheet for this work had been prepared by the party of the *Mikawe*, and hydrography was started the next morning. After two partial days' work the circulating pump of the launch engine broke down, and the ship proceeded to Charleston, S. C., for a new one, securing the same at the navy yard. The vessel returned to the working grounds on December 13, and during that week weather conditions were so unfavorable that only one partial day's work could be done. The vessel was forced to run to Charleston for shelter on December 16. The office was advised by telegraph, and a telegram dated December 21 was received directing the commanding officer to close work and proceed with the *Bache* to the Coast Guard depot, Baltimore, Md., for repairs.

But little work was done under the supplemental instructions of November 20, 1920, and that little was done under such unfavorable weather and sea conditions that it is recommended the entire area be resurveyed. There is about a week's work in this vicinity, with favorable weather, and signals built.

Upon the receipt of the telegram directing the movement of the vessel to Baltimore, the boiler was cleaned. After coaling the ship on December 27, the *Bache* left Charleston at 4.30 p. m. and arrived at the Coast Guard station, Baltimore, Md., at 11 a. m. December 30, 1920.

Exceedingly disagreeable weather was experienced between Charleston and Cape Hatteras. Head gales and heavy seas reduced the speed considerably.

The experiment of carrying steam on the donkey boiler and connecting it with the main boiler was tried on this trip. It was quite a success, and the vessel was able to carry 125 pounds of steam practically the entire trip even with inexperienced firemen.

In accordance with instructions from the office, dated January 4, 1921, the *Bache* was delivered to the Coast Guard authorities at their depot, Baltimore, Md., for repairs on January 5, 1921.

[R. F. LUCE, in Charge of Launch *Mikawe*.]

SUMMARY OF RESULTS.—Triangulation: 25 square miles of area covered; 11 signals erected; 4 stations occupied for horizontal measures; 5 geographic positions determined. Topography: 32 square miles of area surveyed; 48 miles of shore line surveyed; 35 miles of creeks and sloughs surveyed. Hydrography: 95 square miles of area covered; 544 miles run while sounding; 2,862 positions determined (double angles); 12,299 soundings made; 18 signals built for hydrography; 4 tide stations occupied.

From August 5 to December 20, 1920, the party with the launch *Mikawe* was engaged in surveys on the coast of South Carolina between Port Royal Sound and Charleston.

The triangulation done was only incidental to the hydrography and topography in order to provide control. In general the triangulation stations visited were found to be in very good condition, only two stations searched for were not recovered, both having been destroyed by the washing of the shores on which they were located.

In order to provide control for the work in the vicinity of the entrance to the south of Edisto River some triangulation was necessary. Old triangulation stations Hunt, Ott, and Hunting Island Lighthouse were used to get locations for new stations South, Fish, and Ed. The new stations were marked in the regulation manner.

The topography done consisted in the mapping of the shore line and contiguous territory (to about a mile in from shore on the average), including creeks, inlets, sloughs, low-water line where possible, and shoals offshore, along the coast from Port Royal Sound to Framptons Inlet, including the shore line in the lower part of St. Helena Sound.

In general, locations were obtained in the usual manner from triangulation stations recovered or established. The work was done by means of a planetable and telemeter rods, except for a small area in the South Edisto River, and on

outlying shoals, which was done by means of sextant angles on signals. The distances between the triangulation stations were never great, and the traverse lines, being short, always closed well within the allowable limit.

The hydrography done in the period covered by this report covered the following areas: Beginning with the junction of the work of the steamer *Hydrographer* at the entrance to Port Royal Sound and extending along the coast to Framptons Inlet, with the exception of a small area at the entrance to St. Helena Sound, to make a junction with the work of the steamer *Endeavor*, the offshore limit being a junction with the work of the steamer *Isis* at about the 3-fathom curve and extending in to the shore. In general the hydrography was extended in to the inlets of any importance to a distance of at least a mile, or to a point where the depths were unchangeable.

The spacing of the sounding lines called for in the instructions was closely followed, and consisted in running a system of parallel lines normal to the general trend of the shore line at a maximum distance of a quarter of a mile apart, narrowing to 100 to 200 meters apart at important points.

In channels, channel lines were run, crossed by lines running from one side of the channel to the other. Developments were made carefully whenever the soundings taken indicated the necessity for it. In general soundings were taken by means of the hand lead from the *Mikawe* or from the motor sailing launch while under way at a speed from 4½ to 5 knots at thirty-second intervals.

Off the straight beach between intervals the bottom was found to be very even and close spacing of the lines was unnecessary. Near the inlet, however, the bottom was lumpy and irregular and differed very considerably from the charted soundings, so a close spacing of the lines was very necessary. In general, inside the inlets the soundings agreed very well with the charted soundings. There were a number of shoals offshore and others extending a considerable distance out from the shore which were bare at low water, and a special effort was made to get the low-water line on all these, the method used being to walk around the edges of the shoals at or near mean low water, as shown by the tidal predictions, and to locate them by sextant positions taken at frequent intervals.

In order to obtain tidal corrections for the reduction of soundings taken, tidal observations were made at four points on the working grounds.

Throughout the season, readings of the staff gauge at Fort Fremont, Beaufort River, were taken at half-hour intervals from 7 a. m. to 5 p. m. by a careful observer.

This staff was connected by means of simultaneous observations with a staff at Station Creek, where several months of tidal observations had been taken a few years previously.

For about two months in the latter part of the season tidal observations were made at Peters Point, St. Pierre Creek, Edisto Island, at first by means of a staff and later, when an automatic gauge was received, by means of that gauge. This station was also connected with the Fort Fremont staff by means of simultaneous observations.

In order to get tidal corrections for the work in the vicinity of Fripps Sound a staff was established at the inlet, connected with the stations at Peters Point and Fort Fremont by means of simultaneous observations, and readings were taken while work was in progress from the *Mikawe*. One of the bench marks at Station Creek was recovered, and that, together with two initial marks, was connected with the staff by means of levels.

Three bench marks were established at Fort Fremont, three at Fripps Inlet, and five at Peters Point, all connected with each staff by means of carefully run lines of levels. At Fort Fremont and at Peters Point levels were run both at the beginning and at the end of the season, in order to give a check on results and to guard against errors which might be noticed by the possible settlement of the staff during the season.

The charts of the area covered by the work of the *Mikawe* were based on surveys of many years ago, and it is considered quite possible that considerable changes might be found by the present surveys; and this was found to be the case, especially in regard to the hydrography. In several cases radical changes were found to have taken place in the bottom, 8 and 9 foot channels were found where the chart showed shoals bare at low water, 18 feet of water was found where the chart showed breakers, shoals were found which had shifted several hundred meters, and many other similar changes were found.

The difficulties were not restricted to the hydrography. It was found that the shore line had changed most radically in many places. Along the outer shore of Pritchard Inlet and Island the shore line had been cut away by 300 meters; the northern point of Skull Inlet had built out and changed radically; at the mouth of the South Edisto River, Pine Island had built at several hundred meters; Bay Point, Edisto Island, had built out into what the present chart shows as the center of the river channel; Edisto Island, at the town of Edingsville, had cut away so that the town no longer exists; as a matter of fact, an inlet is now found at the point where the center of the town is shown at present.

The differences between the old charted depths and the new soundings are so considerable, and the new surveys show such changes in the shore line, that the continuance of the work to embrace all similar areas is desirable.

Along the coast of South Carolina and Georgia the country back for several miles from the shore is generally very marshy and boggy and cut up by innumerable creeks and sloughs, some of the creeks being a part of the coastal inland waterways. This condition makes the mapping of the area in the usual manner by means of a planetable exceedingly difficult and expensive. The best method of mapping this country without great expenditure of time and money is by means of airplane photography, by which method accurate surveys can be made at a comparatively low cost and in a small fraction of the time required by any other method.

[R. F. LUCE, in Charge of Launch *Mikawe*.]

SUMMARY OF RESULTS.—Triangulation, tertiary: 3.2 square miles of area covered; 5 signals erected; 4 stations occupied for horizontal measures. Topography: 29.5 square miles of area surveyed; 40.7 miles of detailed shore line surveyed; 42.7 miles of roads surveyed. Hydrography: 37.1 square miles of area covered; 301.7 miles run while sounding; 1,640 positions determined (double angles); 7,357 soundings made; 3 tidal stations established; 2.4 miles of levels run; 11 bench marks established; one current station occupied.

From April 19, 1921, to the close of the fiscal year the party on the launch *Mikawe* was engaged in revision of surveys on the coast of South Carolina from Charleston southward.

By May 26 the topography and hydrography in Beaufort River and the area off the entrance to St. Helena Sound had been completed. During June the party was engaged in combined operations in the area between Charleston and Framptons Inlet.

[F. S. BORDEN, in Charge of Launch *Elsie III*.]

SUMMARY OF RESULTS.—Triangulation: 17.5 square miles of area covered; 5 signal poles erected; 5 observing tripods built; 6 stations in main scheme occupied for horizontal measures; 1 station in supplemental scheme occupied by horizontal measures; 11 geographic positions determined. Topography: 3 square miles of area surveyed; 24.3 miles of general coast line surveyed. Hydrography: 62.9 square miles of area covered; 367.2 miles run while sounding; 1,294 positions determined (double angles); 6 permanent bench marks established; 2 hydrographic sheets finished, scale 1:20,000.

The necessary repair work to fit the launch *Elsie III* for the season's work was completed at Hampton, Va., on March 29, 1921, and on April 1 the party left Norfolk, Va., for the working ground. The party was delayed at Beaufort, N. C., for one week while awaiting favorable weather for the outside run to Charleston. On April 12 the party arrived at Charleston and after consultation with the chief of the cooperating party in regard to the division of the field work proceeded to the working ground in the vicinity of Beaufort, S. C., and began work on April 14.

The field work accomplished by the *Elsie III* included the following: A scheme of triangulation covering the area to be surveyed in Broad and Beaufort Rivers was completed; the hydrography of Broad River was extended from the south end of Daw Island to a line three-fourths of a mile north of Archers Creek.

In St. Helena Sound signals were rebuilt, and the hydrography of the area off Huntington Island not covered in 1920 was completed.

In the region from Charleston, S. C., to Price Inlet, the topography of the outer coasts and inlets was 75 per cent completed, and the hydrography from the shore line to a junction with the offshore hydrography was 75 per cent completed by the end of June.

Several of the objects determined in the triangulation of Broad and Beaufort Rivers were recorded as of value for publication as landmarks on the new chart of this area.

The hydrography of Broad River consisted of a system of sounding lines normal to shore lines, run approximately 200 meters apart and crossed by a sufficient number of lines to check the soundings. Very few changes were found in the Broad River surveys, but Archers Creek was found to have shoaled considerably. On account of the strong currents in Broad Creek a drag was used for the greater part of the work. Practically all of the signals used were triangulation stations. For the reduction of soundings tides were observed on a sta ffat the west end of Archers Creek. The reference plane for this station was established by simultaneous observations with a staff at Parris Island Naval Station.

The hydrography of the shoals off St. Helena Sound comprised the area not completed in 1920 by the steamer *Bache* and the launch *Mikawe*. It adjoins the work of the steamer *Isis* to the eastward and southward, the steamer *Bache* to the westward, and the steamer *Endeavor* to the northward. This work was done under very unfavorable weather conditions, and for this reason it was not possible to run any regular system of sounding lines, being largely over a very shoal area and with the sea breaking a greater part of the time in 9 to 10 feet of water, sounding had to be done largely at high tide and the lines run normal or nearly so to the swell.

The depth of water on the shoals remained about the same as shown on the present chart, but the shoal had removed considerably to the southward.

Tide observations for reduction of soundings were made during the course of the work at Peters Point, St. Pierre Creek; the reference plane for this station had been established by the launch *Mikawe* in 1920. All sounding in this area was done from the *Elsie III*.

The sheet covering the area from Charleston to Price Inlet is the first of a series extending from Charleston to Winyah Bay. Work on this sheet was begun June 1 in the vicinity of Winyah Inlet. A sufficient number of signals were located in this vicinity for the survey of this inlet, and the hydrography and topography were carried to the westward, the hydrography being done when the weather permitted and the topography when it was not possible to sound. Control for this work was obtained from two recovered triangulation stations in the vicinity of Capers Inlet. Considerable change was found in the coast line. The short lines on the southwest end of Dewees and the south end of Capers Island have been cut back for more than a quarter of a mile. An island has built up east of Dewees Island, completely filling up the Capers Inlet channel, which at one time passed close inshore along the south of Dewees Island. The bars of both Dewees Inlet and Capers Inlet have shifted considerably, but the amount of water over them remained about the same. Rattlesnake Shoal has deepened so that it now has a depth of at least 10 feet on it. The changes in the shore line and the depths of water are confined to the areas where sea action is felt and do not extend far into the inlets.

The greater part of the sounding in this area was done with the *Elsie III*. The work in the inlets and the shoals at their entrances was done with the motor sailer. For the reduction of soundings a tide staff was established at Dewees Inlet.

Triangulation data for the area along the coast between Charleston and Cape Romain are meager. The greater part of the data furnished the party were based on the triangulation executed in 1857. The greater part of the stations have been lost. The stations which are on the outer coast which are not a part of the main scheme have been washed away or buried beneath the shifting sands. The main scheme crosses the marshes back of the trees which fringe the shore. Six of the 16 main-scheme stations between Charleston and Cape Romain have been recovered in recent years and have been re-marked in a permanent manner. Eight of the main-scheme stations have not been recovered since first established, although searched for on several occasions. One station recovered in 1917 was lost owing to the wearing away of the bluff on which it stood. The party on the *Elsie* only executed enough triangulation to control this survey. This consisted largely in bringing down to the coast at the inlets points from the main scheme.

The inside passage in this vicinity is only a short distance back from the coast, and it has been possible in connection with the topographic work to locate many of the beacon ranges, etc., used as aids to navigation to the inside passage. This station will be a valuable control point if this area is photographed.

ALABAMA, MISSISSIPPI, AND LOUISIANA.

[J. H. PETERS, Commanding Steamer *Ranger*.]

SUMMARY OF RESULTS.—Triangulation: Three observing tripods built, height, 45 feet each; 3 observing scaffolds built, height, 36 feet each. Hydrography: 359 square miles of area covered; 2,758.3 miles run while sounding; 3,993 positions determined (double angles); 2,182 soundings made; 1 tidal station established; 12 tall hydrographic signals built, each 100 feet in height; 14 current stations occupied; 2 hydrographic sheets finished, scale 1: 80,000.

On July 1, 1920, the party on the steamer *Ranger* was engaged in offshore hydrography in the Gulf of Mexico, continuing the work mentioned in the last annual report. Work was suspended from August 4 to 12 in order that the vessel might undergo repairs at Pascagoula, Miss.

On August 12 offshore hydrography was resumed, and signals were built in order to carry the triangulation down Chandeleur Sound.

From November 14 to December 27 the vessel was at Gulfport, Miss., repairing boilers.

On December 27 the vessel proceeded to New Orleans and was taken to the naval station for repairs, which were in progress at the close of December.

The result of the work for the season of 1920 was a very close hydrographic resurvey of the Gulf coast from Mobile entrance to Chandeleur Sound.

Current and tidal observations were carried along simultaneously with the hydrography.

Triangulation signals and observing platforms were built at points in Chandeleur Sound to carry the scheme of triangulation along the coast for the control of the hydrography.

FLORIDA.

[F. B. T. SIEMS, Commanding Steamer *Hydrographer*.]

SUMMARY OF RESULTS.—Triangulation: 189 square miles of area covered; 6 signal poles erected; 5 water signals in 14 to 21 feet of water; 3 observing tripods built, heights, 35 and 40 feet; 2 observing scaffolds built, height, 30 feet; 9 stations in main scheme occupied for horizontal measures; 6 stations in supplemental scheme occupied for horizontal measures; 15 geographic positions determined. Leveling: 6 permanent bench marks established; 2 secondary bench marks established; 0.8 mile of levels run. Topography: 2 miles of detailed shore line surveyed; 1 topographic sheet partly finished, scale 1: 5,000. Hydrography: 128 square miles of area covered; 1,286.6 miles run while sounding; 7,687 positions determined (double angles); 38,712 soundings made; 2 tide stations established; 5 hydrographic sheets finished, scales 1: 5,000, 1: 15,000, 1: 20,000, and 1: 40,000.

At the beginning of July, 1920, signal building and triangulation were in progress preparatory to the hydrographic survey of the locality of the shoal about 4 miles northwestward of Marquesas Keys, Fla., reported by the U. S. destroyer *Ellis*. An area of 2½ square miles was covered by sounding lines, spaced 100 meters or less apart. Except for a coral shoal of a small extent, this area was found to have a general uniform sloping depth of about 5 to 7 fathoms. During the further investigation of the shoal area mentioned a coral bowlder was sighted and found to have a depth of 7.2 feet at mean low water.

On July 12 the inshore hydrography started from Marquesas Keys and the inshore hydrography south of Boca Grande Channel were resumed where left uncompleted by the party on the steamer *Hydrographer* at the time of the September, 1919, hurricane. For the control of the hydrography it was necessary to rebuild two tower signals about 45 feet in height and erect three water signals in 12, 16, and 18 feet of water, respectively. The inshore hydrography was executed on a scale of 1: 15,000, making it necessary to use these fixed signals located by triangulation in order to attain the desired accuracy in locating closely spaced sounding lines. Several uncharted coral shoals were found to exist between Cosgrove and Coalbin Rock, also several uncharted shoal soundings were obtained between Coalbin Rock and Vestal Shoal. The *Hydrographer* was used for all of the hydrography. When seeing and other conditions were unfavorable, the ship was maneuvered to pass over the shoalest appearing parts of the coral patches, and thus endeavor was made to obtain the shoal soundings. This will account for the number of shoals discovered which in the ordinary methods of hydrography would probably have escaped attention. Weather conditions were generally favorable for field work in the vicinity of Marquesas Keys, but long spells of easterly trade winds accompanied by hazy atmosphere hampered the progress of the work at times.

Tides were observed at Marquesas Keys and later at Boca Grande Key, where a tidal station was established and a plane of reference obtained by simultaneous observations with the Bay station at Key West.

The fixed water signal as used by this party consists of a wooden tripod frame and center pole built ashore and towed by the ship to the shoal where erected. Three iron pipes of sufficient length are attached at the base of the tripod legs, the tops meeting and fastened at the center pole. The weight of the pipes causes the structure to rest on the bottom on two of its legs, while end of center pole is held above the water surface. By attaching sufficient weights at the end of third leg, which also projects above water, the signal is readily erected by lifting the center pole. It is then firmly secured in place by allowing weights attached to wire loops around the pipe to slide to the base of the signal. The water signals were destroyed after they had served their purpose. The wire lashings between the three pipes and center pole were cut, the wooden frame was attached to a stout line from the ship and towed over the bottom until the pipes and weights let go, and the wooden frame then floated to the surface.

Field work was closed in the vicinity of Marquesas Keys on September 19, thus completing the work required under instructions dated December 28, 1918.

After taking aboard considerable material for signal building and making minor engine-room repairs at Key West, Fla., the *Hydrographer* took up field work between American Shoal and Sombrero Keys, along the Florida Reefs and Florida Straits. On September 14 the vessel proceeded to Boot Key Harbor to investigate the practicability of using this place as a base for survey operations. It was found to afford excellent refuge in case of a hurricane. During the end of the season while operations were carried on in this locality the ship obtained fresh water, ice, and provisions every other week-end, thus avoiding the long run to Key West, except for coal. On two occasions the vessel harbored at Boot Key during hurricane weather.

Little field work was accomplished during the latter half of September for the reason that several tropical disturbances confined the party to signal-building operations in the vicinity of Boot Key Harbor.

During October the signal building and triangulation between American Shoal and Sombrero Reef were accomplished. With the use of two water signals described in this report in 14 and 21 feet of water, respectively, it was possible to extend a coastal scheme of triangulation from American Shoal Lighthouse to Sombrero Reef Lighthouse. One of the water signals was occupied with theodolite, and apparently good observations were obtained. This triangulation was necessary for the reason that at this part of the coast the triangulation of the Florida Keys was carried along the inland portions of the Keys.

On November 3 the offshore hydrography in the Florida Straits was resumed eastward of American Shoal Lighthouse and carried to Sombrero Reef by the end of the season, December 30. Likewise the inshore hydrography along the edge of the reefs was executed during this period. The Coast Survey sounding tubes were used with hand-sounding machine for sounding in depths from 20 to 100 fathoms, and in depths less than 20 fathoms the hand lead was used. Tides for the reduction of soundings were observed at American Shoal Lighthouse.

Strong easterly trade winds retarded the progress of the work considerably while engaged in the triangulation and offshore hydrography between American Shoal and Sombrero Reef. Also there were only two officers engaged in this work, which prevented efficient progress.

A revision survey of Boot Key Harbor Channel and approach was made. This place was used by the Florida East Coast Railway as a construction camp during the overseas extension of the railway. A channel dredged by the Florida East Coast Railway has now a controlling depth of 7½ feet, which provides an entrance to the landlocked harbor for the greater number of vessels using Hawk Channel. It is practically the only good harbor between Key West and Miami. A tidal station was established at Boot Key, and tidal datum was obtained by simultaneous observations with the base station at Key West.

The *Hydrographer* based her operations from Key West, Fla., obtaining coal, water, and supplies from the United States naval station. The Lighthouse Service furnished docking space for the vessel while at Key West. The services thus obtained were of considerable assistance to the party.

During December the automatic tide gauge at Key West was inspected, and a new time striking clock was installed. The relation between staff and bench marks was obtained by levels during August.

The Coast Survey sounding tubes were tested on September 23 and 24 in accordance with instructions from the Director dated September 2, 1920.

ALABAMA AND LOUISIANA.

[F. B. T. SIEMS, Commanding Steamer *Hydrographer.*]

SUMMARY OF RESULTS.—Triangulation: 867 square miles of area covered; 9 signal poles erected; 12 observing tripods erected, total height 380 feet; 12 observing scaffolds built, total height 534 feet; 21 stations in main scheme occupied for horizontal measures; 4 stations in supplemental scheme occupied for horizontal measures; 80 geographic positions determined. Hydrography: 43 square miles of area covered; 210.1 miles run while sounding; 1,126 positions determined (double angles); 4,753 soundings made; 2 tide stations established; 27 bottom specimens preserved; scale of hydrographic sheet 1:40,000.

The Steamer *Hydrographer* closed field work in the locality of the Florida reefs and made preparations for the passage from Key West, Fla., to Mobile, Ala., for repairs. On January 8, 1921, the vessel left Key West and did not arrive at Mobile until January 17, 1921, delays having been occasioned by stormy weather. After securing proposals for repairs to the *Hydrographer*, the ship was delivered to the successful bidder on January 26. General annual repairs and overhauling were accomplished, and the same were completed on February 18. The *Hydrographer* then proceeded to Gulfport, Miss., on February 21, arriving the same day, to take up the triangulation from Mississippi Sound to the Mississippi Delta, required under the Director's instructions dated January 19, 1921.

The party was engaged on the tertiary triangulation in Chandeleur Sound and Breton Sound during the months of March, April, and May. The scheme is based on the line Biloxi Lighthouse to Ship Island Lighthouse, and was carried to the line Sable Point to Battledore Island. In addition to the main scheme three stations were determined on the west shore of Chandeleur Sound, and four hydrographic signals were located by triangulation on the barrier islands at the east side of the sounds. Four of the main-scheme triangulation signals were erected in 12 to 13 feet of water, and two of these were occupied by theodolite. The description and manner of erecting water signals for triangulation were furnished in a report entitled "Special Report on Water Signals Used for Triangulation and Hydrography."

Good figures were thus made possible by the use of the water signals, and the lengths of the lines were considerably shorter than would otherwise have been the case if land stations only had been used on both shores of the sound. The need of short lines was necessary in order to make economic progress in observing during the months of March and April, as the seeing conditions then are generally very unsatisfactory on the Gulf coast.

Even with shorter lines the continual hazy weather delayed observations along the first or northern half of the scheme, also on days when the atmosphere was clear a bank of mist about 4 to 10 feet in height hovered about the water surface during the day and night and eventually necessitated increasing the height of the signal in addition to that required to overcome curvature, to have signals show above the mist bank. Rapid progress was made on the second or southern half of the triangulation scheme, the signals were built high enough to overcome the difficulty experienced before, and also there were several days of clear seeing about the time observations were in progress. Delays were also occasioned by frequent strong winds throughout the greater part of the season. Two of the signals had to be rebuilt on account of the shifting nature of some of the islands; they were subsequently erected in unchangeable shoal water.

Considerable erosion of the shore line was noted in Chandeleur Sound, as examples: Errol Island has disappeared except that small parts of it are awash, Barrel Key on the west shore of Chandeleur Sound has washed away entirely; also the islands off Door Point no longer exist.

The completion of the triangulation to the mouths of the Mississippi Delta was postponed pending the completion of the hydrographic investigation of the waters off Southwest Pass for the needs of the United States Army Engineers. The latter work was begun on June 7 and was in progress at the close of the fiscal year. Signals for hydrography were determined by triangulation, survey buoys were constructed and planted in place for fixed position work to the 50-fathom curve. The inshore hydrography from the 3-fathom to the 20-fathom curve was completed from latitude 29° 00′ on the west side of the Southwest Pass to longitude 89° 19′ on the east side of the pass. The chartered launch *Carl F*, obtained April 23, assisted in the work outlined above. The lease was terminated on June 30, 1921.

LOUISIANA.

[E. B. LATHAM.]

The operations of the New Orleans field station have been continued as usual during the year.

On October 1 the office of the field station was removed from the Godchaux Building to quarters obtained in the customhouse, in room 314.

Some additional equipment has been obtained for more conveniently storing and filing charts, Coast Pilots, and tide tables.

In August the inspector was detailed to the field for the purpose of verifying an angle in the Louisiana traverse in the vicinity of Mansura. A special report on this duty was submitted.

The three sales agencies of the Bureau in New Orleans were inspected and reported on.

Cooperation has been maintained with the division and district U. S. Engineer officer in New Orleans.

Charts and other information have been furnished to Federal, State, and commercial organizations as requested.

HYDROGRAPHIC AND TOPOGRAPHIC WORK, PACIFIC COAST.

CALIFORNIA.

[F. G. ENGLE, Commanding Steamer *Natoma*.]

SUMMARY OF RESULTS.—Triangulation: 72 square miles of area covered; 5 signal poles erected; 5 stations in main scheme occupied for horizontal measures; 30 topographic positions determined. Topography: 34.4 square miles of area surveyed; 53.3 miles of coast line surveyed; 30.6 miles of shore line of creeks surveyed; 64.2 miles of roads surveyed; 80.4 miles of railroad surveyed; 2 topographic sheets finished, scale 1:10,000. Hydrography: 115.1 square miles of area covered; 847.3 miles run while sounding; 18,136 soundings made; 2 tide stations established; 1 current station occupied; 2 hydrographic sheets finished, scales 1:10,000 and 1:20,000.

Under instructions issued May 12, 1920, field work on the survey of Los Angeles Harbor and San Pedro Bay was commenced on July 19. The *Natoma* arrived at San Pedro from San Francisco on July 15, and preparations were made for beginning field work. The 24-foot motor sailing launch which had been shipped to San Pedro was obtained and prepared for hydrography. A topographic sheet on the scale 1:10,000 was made to cover the area of San Pedro, Wilmington, and Terminal Island. Boat sheets were prepared, one on the scale of 1:10,000 for the harbor survey and another on the same scale for the area eastward of the harbor extending to Long Beach, and the old soundings from bromide of hydrographic sheet No. 1418 were transferred to the latter sheet. On July 19 the work on the erection of an automatic tide gauge in the outer harbor was commenced, and this was finished on the 21st. This gauge was maintained until November 30; five bench marks were established and connected by levels with the gauge.

Prominent artificial objects in the vicinity of San Pedro and Long Beach were cut in from the recovered stations on July 21, 22, and 23, and field work on the topographic sheet of San Pedro was begun on July 22 and continued without interruption thereafter. On July 30 signal building for the hydrography of San Pedro Bay eastward of Long Beach was begun; 5 stations were established; tall hydrographic signals of the tripod design, using whitewashed boards and cloth, were erected over these stations, and symmetrical diamond targets placed on the center poles and carefully centered were used for locating them by triangulation. Station Reservoir 2 is on the same hill as original station Reservoir, no description of which is available. The primary station Los Bolsas which was on the same site is apparently destroyed by the construction of the reservoir. No attempt was made to recover any of the old tertiary stations. On August 7 a boat sheet on a scale of 1:20,000 was made for the hydrography east of Long Beach and outside of the breakwater for work out to the 20-fathom curve. Soundings from the old hydrographic sheet 1418 were transferred as the instructions called for splitting old sounding lines and for comparison with old work. On August 12–14 two officers were at work on the topographic sheet of San Pedro. Launch hydrography of the inner and outer harbors was begun August 16 and continued until August 30. On August 17 a topographic projection for Long Beach was made, and observations for locating

the new triangulation stations were begun August 16. The new stations, together with prominent artificial objects between Long Beach and Huntington Beach, were cut in from stations Breakwater, Deadman's Island, and Los Cerritos.

While launch hydrography and topography in the vicinity of San Pedro were in progress the trolley sounding apparatus and electric-driven hauling reel were constructed by the ship's force for work on the 1:20,000 sheet outside of the 12-fathom curve. A platform for the leadsman was built for use with the trolley and placed aft of the port side.

The greater part of the launch hydrography in the outer harbor was completed by the end of August, and work was begun with the ship on the 1:10,000 sheet and the 1:20,000 sheet. Clear weather was utilized for this work on the offshore side of the 1:20,000 sheet as signals were distinct, and in hazy weather the work on the 1:10,000 sheet was done. A staff gauge was established at Long Beach on September 28 for reduction of soundings on the eastern end of sheet. Topography was begun early in September on the Long Beach sheet, the San Pedro sheet having been completed, and by the end of the month the Long Beach sheet also was completed. During September and October ship hydrography was prosecuted. Work was prevented by foggy weather on eight days in September and four days in October, and on account of lack of men on three days in September and three days in October. The work on the two hydrographic sheets was completed by the end of October, and office work on reduction of soundings and inking topographic sheets, tabulating tide roll, and plotting soundings on the boat sheets was continued until September 8. From December 8 to 15 field work found necessary to complete sheets was done, and two signals at Long Beach and Reservoir 2 were moved at the request of the property owners. Current observations were made near Weldt Rock, from the vessel at anchor, on November 15, 16, and 17. No appreciable current was observed at this station. It was found impracticable to obtain current observations at the other two stations indicated in the instructions as anchorage in the channels is prohibited. The currents in the channel appear to flood and ebb with rise and fall of tide and never to exceed 1 knot.

Field work at San Pedro was completed on December 14, and on December 16 the vessel sailed for San Francisco in accordance with orders dated November 16, 1920, arriving on December 17. Field work on the continuation of revision of hydrography and topography of San Francisco Bay was commenced on completion of the office work on records of the San Pedro work on January 11. The work of the past season included also a resurvey of the bar, wire-drag investigations of shoal soundings off Fort Point and east of Angel Island, and the location of the four radio-compass stations in the vicinity of San Francisco, namely, Bird Island, Montara Point, Farralon Islands, and Point Reyes. The work is described in descriptive reports and the season's report for the period January 11–May 26, 1921.

In accordance with instructions dated April 28, field work was brought to a close on May 26 on completion of assigned work in and around San Francisco Bay, and the vessel was moored in China Basin for overhauling.

[FREMONT MORSE.]

The work of the San Francisco field station has been continued along the usual lines. Besides the routine work of the station the sales agencies of the Coast and Geodetic Survey in San Francisco were inspected, and the charts and publications on hand were listed.

Recommendations were made as to details of resurveys by the steamer *Natoma* in the vicinity of San Francisco Bay.

Progress was made on a graphic index of tracings on file with the field station.

Information was obtained from the office of the engineer in charge of the Oakland Harbor improvements concerning the depth of water in the Albers and the Southern Pacific Basin.

A copy of the latest map of the San Francisco water front was obtained from the chief engineer of the State harbor commission. This map shows changes that have occurred since its publication. It was checked up in the field by the inspector personally and some further changes indicated. The positions of wharves near Fort Point were obtained from the constructing quartermaster, U. S. Army.

[E. H. PAGENHART, Commanding Steamer *Lydonia*.]

SUMMARY OF RESULTS.—Leveling: 3 permanent bench marks established; 1 mile of levels run. Topography: 17 miles of traverse run to locate signals; scale of topographic sheets 1: 20,000. Hydrography: 991.1 square miles of area covered; 1,179.4 miles run while sounding; 2,989 positions determined (double angles); 6,778 soundings made; 2 tide stations established; 3 current stations occupied; scale of hydrographic sheets 1: 20,000, 1: 40,000, and 1: 120,000.

In compliance with instructions dated March 23, 1921, the *Lydonia* left Seattle for the locality of work April 2 and arrived off the Humboldt Bar during the night of April 4. The bar was rough and the ship ran to Shelter Cove, where field work was begun the next day by the erection of a tide staff. Two days later an automatic gauge was placed in operation at North Jetty at Humboldt Bay and the hydrography was begun. The work was in progress at the end of the fiscal year.

Additional split lines were run between the 40 and 100 fathom curve over the area from Chris Rocks to Shelter Cove. This gives a spacing of one-half-mile lines.

Additional lines were run to Tolo Bank wherever the original surveys showed widely spaced soundings or where there were indications of shoaler spots.

Similar development work was resumed in the vicinity of Punta Gorda and had extended to Cape Mendocino by the end of June.

Offshore lines were run to the 1,000-fathom curve which extends well off the coast at Punta Gorda. Much of this work was done on dead reckoning, as the weather was generally foggy and no fixes and but few sights could be obtained.

By June 30 the inshore and offshore work was completed to Cape Mendocino.

OREGON.

[O. W. SWAINSON.]

SUMMARY OF RESULTS.—Triangulation: 9 square miles of area covered; 21 signal poles erected; 13 stations in main scheme occupied for horizontal measures; 26 stations occupied for vertical measures; 21 geographic positions determined. Leveling: 6 permanent bench marks established; 1 mile of levels run. Topography: 1¾ square miles of area surveyed; 2 miles of double shore line surveyed; 13 miles of rivers surveyed; 2 topographic sheets finished, scale 1: 10,000. Hydrography: 7 square miles of area covered; 354 miles run while sounding; 3,218 positions determined (double angles); 1,271 soundings made; 1 tide station established; 1 current station occupied; 2 hydrographic sheets finished, scale 1: 10,000.

The survey of the Umpqua River, Oreg., and bar lying off the entrance, was begun May 23, 1920. Progress to June 30 is detailed in the last annual report of the Director.

The original instructions called for a close development of the bar and the river's mouth and an inspection of the river as far up as the railroad bridge to see if a resurvey of that portion was necessary. The examination showed that a resurvey as far as the railroad bridge was advisable, and the office was so notified, and the party was instructed to continue work as far up the river as to include the water front of Reedsport. Two hired launches were used in the execution of this work.

When the survey was begun, it was expected that two triangulation stations easy of access and near the mouth of the river could be recovered. This, however, was not the case, as none of the old stations could be found, and it was necessary to start the scheme from the line Burn to Brushy Hill 2. Station Burn was on a brush-covered hill which necessitated the building of a 15-foot scaffold and three days' clearing to open up lines of sight. Three of the U. S. Army Engineers stations established in 1916 were recovered and incorporated in the Coast and Geodetic Survey work. These were North Base, Winchester, and Cornwall. When it became necessary to carry the triangulation up the river, some of these stations on the sand hills had been undermined and blown down, and the stations could not be recovered. It was necessary to establish a new station and to reoccupy two of the other stations.

A fairly strong scheme of tertiary triangulation extended up to the bridge.

The stations were marked as permanently as possible. In many cases it was impossible to put in reference marks.

The topography consisted in running in the shore line where there was any change from the original survey, consequently the outer beach was run for about a mile on either side of the river. The north shore line of the river was run as far as Barretts Light and from Three Mile Light to the railroad bridge. The south shore of the river was run as far as the eastern point of Winchester

Bay. From there to the Big Point the shore line was bold and rocky and had therefore not changed. The shore line of all the small islands or flats was determined. The shore line of all the small islands or flats was run. Bone Island was located, and the water front at Reedsport.

No contours were run except on the sand hills in the vicinity of the Coast Guard station, Army Hill, and the large sand hill off the middle grounds. Two sheets on the scale of 1:10,000 were used. One plane-table sheet on the scale of 1:20,000 was used to locate signals for the preliminary survey to check the existing chart and determine if a complete survey was needed. Where the shore line was not run it was carefully checked with the old survey.

Sounding on the bar was in progress on July 1, and from that time until July 16 a constant watch was kept on the sea and weather, and whenever possible a few hours' sounding on the bar were put in. The Coast Guard station lookout kept the party informed regarding the sea.

The first three weeks of July brought favorable weather. The only chance for a smooth sea was when a decided change took place in the direction of the wind, but during this time the fog was apt to be worse. Consequently the party always remained in constant readiness to go out onto the bar whenever the conditions were favorable. One hour before high tide on July 16 the sea became smooth and the fog lifted. The party was on hand with the launch, and they immediately began sounding out the bar. The sea was smooth for about 2½ hours, just long enough for the party to cover the north spit.

The channel through the bar was sounded over more thoroughly than usual, because as it had but recently been washed out about 10 feet it was feared that the sand might have washed away, leaving a pinnacle rock with but very little indication of its existence.

A very decided change from the old chart was discovered in the depth of the channel through the bar and in the mouth of the river.

The soundings in the critical places were reduced, the tide reducers being obtained from the predicted tides, and the soundings were recorded on the boat sheet for a careful study.

Two boat sheets on the scale of 1:10,000 were used to cover the entire area from the whistling buoy off the bar to the eastern end of the water front of Reedsport. A few lines of preliminary soundings were taken on a 1:20,000 scale sheet to check the accuracy of the chart. The last sounding was taken on August 30.

On arrival at Gardiner an automatic tide gauge was established at the jetty, and a record was obtained beginning May 24 and ending August 30. A tide staff was erected at the Gardiner Mill Co.'s wharf and a series of one-half hourly readings were made beginning August 6 at 10 a. m. and continued until 7 p. m. the next day. This gave 33 hours of simultaneous readings with the automatic gauge. Thereafter the hydrographic party took a reading on the staff before going to work and upon returning. Otherwise no tidal observations were made on this staff while the party was sounding.

Permanent bench marks were established and connected with the tide staffs at the jetty and at Gardiner.

On July 16 the launch was made fast to the black can buoy at the inner entrance of the channel through the bar, and current observations were begun. The pole and log line method with a stop watch was used, and observations were continued for 25 hours. A maximum velocity of 3.5 knots was obtained.

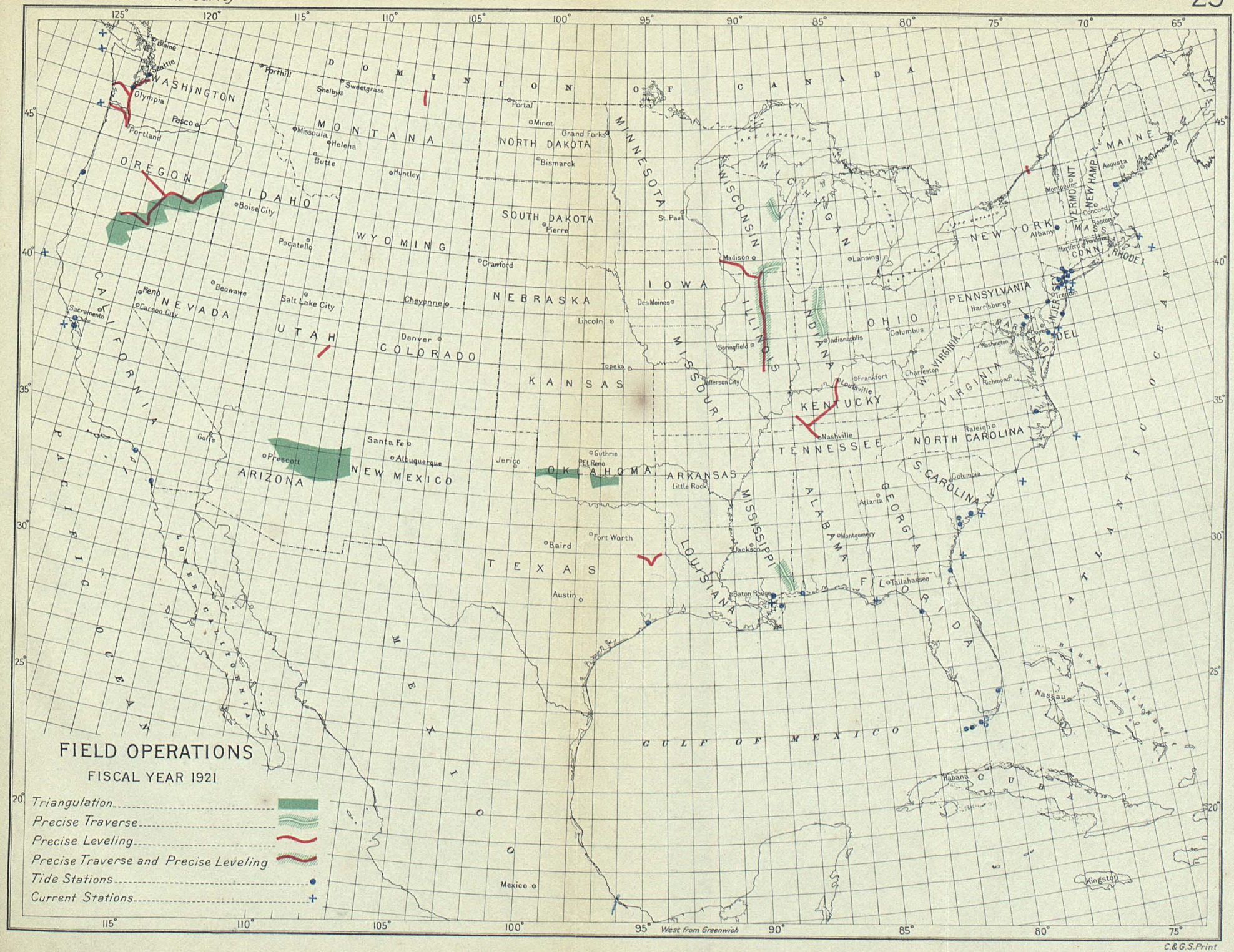
A survey was made on the beach on either side of the river and at the mouth of the river for indications of rock. None were found other than the rocks near the boathouse on the south side, Ork Reef, and at Winchester Point. All specimens of bottom obtained were sand. The bottom of the whole river as far as surveyed was sand or mud.

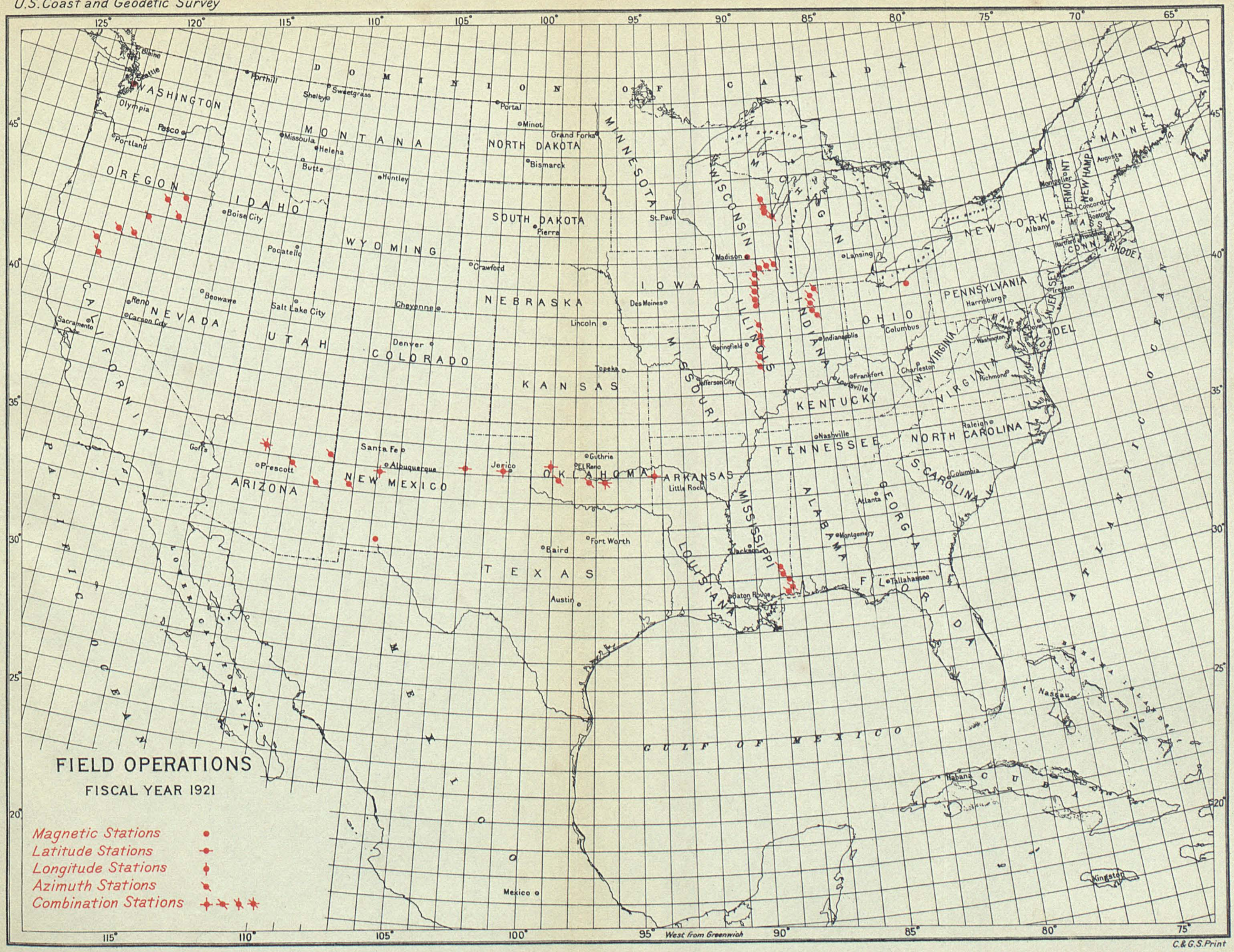
On September 2 the work in the Umpqua River was completed and the party disbanded except for one man. On September 7 the two officers and this one man went to Coos Bay and there marked the true meridian passing through the naval radio compass station. A separate report was made on this work under date of September 18.

SEATTLE, WASH.

[J. E. McGRATH, July 1, 1920, to Jan. 15, 1921; R. B. DERICKSON, Jan. 15, 1921, to June 30, 1921.]

An officer of the Survey continued on duty as inspector in charge of the field station at Seattle, Wash., and continued the usual details of work.


FIELD OPERATIONS
FISCAL YEAR 1921
Triangulation
Precise Traverse
Precise Leveling
Precise Traverse and Precise Leveling
Tide Stations
Current Stations
DOMINION OF CANADA
WASHINGTON
OREGON
CALIFORNIA
IDAHO
NEVADA
MONTANA
WYOMING
UTAH
COLORADO
ARIZONA
NEW MEXICO
NORTH DAKOTA
SOUTH DAKOTA
NEBRASKA
KANSAS
OKLAHOMA
TEXAS
MINNESOTA
IOWA
MISSOURI
ARKANSAS
LOUISIANA
WISCONSIN
ILLINOIS
MICHIGAN
INDIANA
OHIO
KENTUCKY
TENNESSEE
MISSISSIPPI
ALABAMA
GEORGIA
FLORIDA
S. CAROLINA
NORTH CAROLINA
VIRGINIA
W. VIRGINIA
PENNSYLVANIA
NEW YORK
MAINE
VERMONT
NEW HAMP.
MASS.
CONN.
RHODE I.
NEW JERSEY
DEL.
MD.
Seattle
Olympia
Portland
Spokane
Pasco
Missoula
Helena
Butte
Huntley
Shelby
Sweetgrass
Portal
Minot
Grand Forks
Bismarck
Pierre
Boise City
Pocatello
Crawford
Cheyenne
Denver
Beowawe
Reno
Carson City
Salt Lake City
Sacramento
Goffs
Prescott
Santa Fe
Albuquerque
Jerico
Guthrie
El Reno
Topeka
Lincoln
Des Moines
St. Paul
Madison
Lansing
Springfield
Jefferson City
Little Rock
Fort Worth
Baird
Austin
Jackson
Baton Rouge
Nashville
Louisville
Frankfort
Indianapolis
Columbus
Charleston
Harrisburg
Washington
Dover
Trenton
Albany
Montpelier
Concord
Boston
Augusta
Providence
Hartford
Raleigh
Columbia
Atlanta
Montgomery
Tallahassee
Nassau
Habana
Kingston
Mexico
PACIFIC OCEAN
GULF OF MEXICO
ATLANTIC OCEAN
BAHAMA ISLANDS
CUBA
LOWER CALIFORNIA
MEXICO
125°
120°
115°
110°
105°
100°
95°
90°
85°
80°
75°
70°
65°
45°
40°
35°
30°
25°
20°
West from Greenwich


FIELD OPERATIONS
FISCAL YEAR 1921
Magnetic Stations
Latitude Stations
Longitude Stations
Azimuth Stations
Combination Stations
DOMINION OF CANADA
WASHINGTON
OREGON
CALIFORNIA
NEVADA
IDAHO
MONTANA
WYOMING
UTAH
COLORADO
ARIZONA
NEW MEXICO
NORTH DAKOTA
SOUTH DAKOTA
NEBRASKA
KANSAS
OKLAHOMA
TEXAS
MINNESOTA
IOWA
MISSOURI
ARKANSAS
LOUISIANA
WISCONSIN
ILLINOIS
MICHIGAN
INDIANA
OHIO
KENTUCKY
TENNESSEE
MISSISSIPPI
ALABAMA
GEORGIA
FLORIDA
S. CAROLINA
NORTH CAROLINA
VIRGINIA
W. VIRGINIA
PENNSYLVANIA
NEW YORK
VERMONT
NEW HAMP.
MAINE
MASS.
CONN.
RHODE I.
N. JERSEY
MARYLAND
DEL.
PACIFIC OCEAN
ATLANTIC OCEAN
GULF OF MEXICO
MEXICO
CUBA
LOWER CALIFORNIA
Seattle
Olympia
Pasco
Portland
Porthill
Sweetgrass
Shelby
Missoula
Helena
Butte
Huntley
Boise City
Pocatello
Beowawe
Reno
Carson City
Sacramento
Salt Lake City
Cheyenne
Denver
Goffs
Prescott
Santa Fe
Albuquerque
Jerico
Portal
Minot
Grand Forks
Bismarck
Pierre
Crawford
Lincoln
Topeka
Guthrie
El Reno
Fort Worth
Baird
Austin
Mexico
St. Paul
Des Moines
Madison
Springfield
Jefferson City
Little Rock
Jackson
Baton Rouge
Lansing
Indianapolis
Columbus
Frankfort
Louisville
Nashville
Charleston
Richmond
Raleigh
Columbia
Atlanta
Montgomery
Tallahassee
Albany
Montpelier
Concord
Boston
Augusta
Harrisburg
Trenton
Washington
Dover
Nassau
Habana
Kingston
West from Greenwich
C.&G.S.Print

The principal duties which are required of the inspector at this station are: The maintenance of a stock of charts and nautical publications for reference, distribution to the Government officers, and sale, and also the inspection of the principal chart agencies in the district; supplying light vessels, which incidentally to their regular work are engaged in making current observations for the Survey, with materials and appliances required in that work; charge of the property belonging to the Coast and Geodetic Survey stored at Seattle; receiving and forwarding mail and instruments to vessels and field parties of the Survey engaged in field work in Alaska or having their home station at Seattle; keeping on hand supplies of stationery in order to meet requisitions from land and hydrographic parties; supplying requisitions for information from the general public pertaining to the tides, geographic positions, magnetic declination, elevations, depths, changes in aids to navigation, and other information affecting the maritime interests; supplying the office at Washington with the most recent information affecting the charts and tide tables; supervising the operation of tide stations at Seattle and Olympia, Wash., and at Ketchikan, Alaska.

Advance notices to mariners are published immediately upon receipt of important information affecting the charts.

On January 15, 1921, the charge of the field station at Seattle was transferred to another officer of the Survey.

On January 15, 1921, the administrative responsibility and activities of the field station were increased by having assigned to it the general supervision over the hydrographic and topographic parties working within the district, or based at Seattle, except as limited by the regulations, to the end that the greatest possible assistance may be given to such parties, keeping in touch with the parties working in Alaska and advising the Washington office regarding such changes in the working operations as it is believed should be made from time to time.

GEODETIC WORK.

NORTH CAROLINA.

[R. J. AULD.]

Between April 26 and May 4, 1921, a base line, approximately 1 kilometer in length, was measured along the Carolina Beach Railway for the purpose of strengthening the triangulation along the Cape Fear River. The base is located near the point where the coast triangulation from the north connects with the Cape Fear River triangulation.

[GEORGE D. COWIE.]

Between June 6 and June 14, 1921, the length Sand 2 to Redmond, a line of the Cape Fear River triangulation just south of Wilmington, was measured as a base for the purpose of strengthening that triangulation. Several stations in Wilmington were recovered, with a view to checking the connection at Wilmington between the Cape Fear River triangulation and the precise-traverse line from Wilmington to Sanford.

MISSISSIPPI.

[J. S. BILBY.]

SUMMARY OF RESULTS.—Precise traverse: 100 miles of traverse run; 120 main stations occupied for horizontal measures; 23 supplemental stations occupied for horizontal measures. Azimuth: 10 stations occupied for determination of azimuth.

Work was begun on a precise traverse in the State of Mississippi in the vicinity of Pascagoula in January, 1921. A base line was measured on the Louisville & Nashville Railway track to the westward of Pascagoula. The base stations were connected by triangulation with two old triangulation stations on Mississippi Sound. The traverse started from East Base and was extended eastward to Pascagoula, thence northward on the Pascagoula-Moss Point concrete highway about 2½ miles to the Alabama & Mississippi Railway track, thence northward on this railway to Evanston, thence on the Gulf, Mobile & Northern Railway by way of Beaumont and Richton to Ovett. Field work was closed on March 10.

The means of transportation for the field party consisted of two ¾ ton trucks, one ½-ton truck, and three hand-driven velocipede cars. The hand velocipede

cars were used in connection with the motor trucks to transport men and material to intermediate points between road crossings which it was not practicable to reach with the motor truck. They were hauled from place to place on the motor truck and were available at all times when needed. The observing party used one of these velocipede cars instead of the motor truck for moves between stations. It was found that the move from station to station could be made with the velocipede car in less time than was required by motor truck. Velocipede cars were also used in connection with the motor truck by the party building stands, marking stations, and doing reconnoissance and by the party staking curves, running wye levels, and observing. Had motor trucks only been used it would have required four trucks, and at many places it would have been necessary for the men to pack the material and instruments to points that could not be reached with the truck; therefore, the velocipede cars reduced the time, labor, and expense of the work.

The railway over which the traverse was measured and the nature of the country were unfavorable to rapid progress.

LOUISIANA.

[E. B. LATHAM.]

On September 10, 1920, the inspector of the field station at New Orleans left for Mansura, La., to verify certain angles in a traverse line in that vicinity.

A party was organized and field work begun on September 11, signals were erected on the 11th and 13th, and observations at Station Omar were completed on the latter date. The inspector returned to New Orleans on the 14th and resumed his duties at the New Orleans field station.

CALIFORNIA AND OREGON.

[E. W. EICKELBERG.]

SUMMARY OF RESULTS.—Base line: 1 precise, 14.26 kilometers in length. Precise and primary triangulation: 32,250 square miles of area covered (17,250 square miles precise, 15,000 square miles primary); length of scheme, 500 miles; 43 observing tripods and scaffolds built; 31 stations in main scheme occupied for horizontal measures; 4 stations in supplemental scheme occupied for horizontal measures; 37 stations occupied for vertical measures; 69 geographic positions determined; 69 elevations determined trigonometrically. Leveling: 18.1 miles of leveling run. Azimuth: 7 stations occupied for observations of azimuth.

This arc of precise triangulation extends in a northeasterly direction from northern California to eastern Oregon. It starts from the line Bolivar-Bally of the California-Washington arc of precise triangulation and ends on the line Dry-Squaw of the Utah-Washington arc of precise triangulation. (See Special Publications Nos. 13 and 74.) The California end of the arc is in high mountains, while much of the remainder of the arc is across a high, arid plateau broken by ridges and peaks and very sparsely inhabited. As an indication of the height of the stations it is noted that the party was still resorting to melted snow for a water supply on July 4, while occupying Mount Grizzly.

Field work began in northern California on June 12, 1920, and was in progress at the beginning of the fiscal year. There were two observers on the work, namely, the chief of party and E. O. Heaton, junior hydrographic and geodetic engineer. During the first part of the season the latter occupied the primary stations, while the former occupied the precise stations. Later both observers shared in the precise work. Due to inability to obtain men, the party started work with only three light keepers, the remainder of the stations being tended by truck drivers and employees of the U. S. Forest Service. This cooperation by the Forest Service aided very materially.

The work was considerably hindered by dust storms, by smoke from numerous and extensive forest fires, by an unusual amount of rain, and by inability to obtain careful, reliable, and resourceful light keepers and hands.

Six automobile trucks were used for transportation, one of these being used exclusively in the marking of stations and in the building of stands. On the first four stations the length of pack averaged over 10 miles. Animals were used for packing to these stations, but on the remainder of the arc back packing was resorted to on account of the saving in time. The moves between stations averaged about 100 miles and usually required a whole day, as the roads were rough and the trucks could average only about 10 miles an hour.

The observing was completed at station Squaw in a foot of snow on October 22, 1920. The average closure of the 69 triangles of the arc is 0.86″.

WASHINGTON.

[E. W. EICKELBERG.]

SUMMARY OF RESULTS.—Reconnoissance: Length of scheme 10 miles; 40 square miles of area covered; 12 lines of intervisibility determined; 5 points selected for scheme. Triangulation: Length of scheme, 25 miles; 75 square miles of area covered; 6 signal poles erected; 20 observing stands and scaffolds built; 19 stations in main scheme occupied for horizontal measures; 3 stations in supplemental scheme occupied for horizontal measures; 35 geographic positions determined.

Between April 21 and June 30, 1921, observations were made along the arc of precise triangulation which will extend along Puget Sound from the northern end of the California-Washington arc in the vicinity of Tacoma to the forty-ninth parallel. This is a part of the general scheme of precise triangulation which will carry the North American datum to Alaska. At the end of the fiscal year all the work between Tacoma and Seattle had been done except the occupation of eight stations in the vicinity of Tacoma. A launch was used for transporting the party on this work.

ILLINOIS.

[EARL O. HEATON.]

Check measurements with a 300-foot tape were made over two sections of the precise traverse in the vicinity of Burlington, Ill. The work was done between February 19 and 28, 1921. Two errors were located in the original measurement.

ILLINOIS AND WISCONSIN.

[J. S. BILBY.]

SUMMARY OF RESULTS.—Precise traverse: Reconnoissance and signal building, 320 miles; observing, 320 miles; taping and traverse completed, 85 miles; 190 principal stations occupied for horizontal measures. Azimuth: 18 stations occupied for determination of azimuth.

About August 15, 1920, work was started at the northern end of a line of precise traverse, requested by the U. S. Geological Survey, extending north and south through the central part of Illinois. It was anticipated at first that a connection could be made at the north end with precise triangulation done by the State of Wisconsin. The old stations could not be recovered, however, and it was necessary to measure a traverse line eastward through the southern part of Wisconsin to connect with the precise triangulation of the Lake Survey along the west shore of Lake Michigan. The southern end of the Illinois traverse connected with the thirty-ninth parallel precise triangulation.

The northern end of the Illinois traverse was quite difficult, due to numerous curves. After 85 miles had been completed the taping party was put in charge of C. L. Garner for the remainder of the work.

Motor trucks were used for transportation. The work was completed the latter part of October.

[CLEM L. GARNER.]

SUMMARY OF RESULTS.—Precise traverse: 220 miles of traverse measurements completed; 75 stations in supplemental scheme occupied for horizontal measures.

Mr. Garner took charge of the precise-traverse party operating in Illinois on September 13, 1920, when the work had been carried to a point just north of La Salle. From here the line of traverse extends south along the Illinois Central Railroad to the vicinity of Vandalia, where it connects up with the arc of precise triangulation along the thirty-ninth parallel. The reconnoissance, signal building, and principal angle measures on this section were made by another party.

The railroad track along this section of traverse is very favorable for this kind of work and good progress was made in spite of a shortage of hands.

After the completion of this line the party proceeded to Beloit, Wis., and measured a line of traverse from there to Racine, Wis. This was for the purpose of connecting the northern end of the Illinois traverse with the precise triangulation of the Great Lakes. The chief of party had previously made a

reconnoissance and ascertained that a traverse line would be much more economical than triangulation for this connection.

On both of the projects above automobile trucks were used exclusively for transporting the party. This proved a very satisfactory arrangement as the railroads were paralleled by highways, which in many cases were adjacent to the track, and there were very few stations where the trucks could not be driven within a short distance.

On the Wisconsin line the grade corrections were obtained by the use of a track level, thus obviating the necessity for precise levels. The accuracy of this method was tested and found to be satisfactory.

The work of the season was closed on November 20, 1920.

WISCONSIN.

[C. L. GARNER.]

SUMMARY OF RESULTS.—Precise traverse: 64 miles of line completed; 56 principal stations occupied for horizontal measures; 30 supplemental stations occupied for horizontal measures. Precise triangulation: 100 square miles of area covered; 5 stations in main scheme occupied for horizontal measures. Azimuth: 4 stations occupied for determination of azimuth.

About June 1, 1921, work was started at Green Bay, Wis., on the line of precise traverse which will extend to the western end of Lake Superior. Enough precise triangulation was done at Green Bay to connect the traverse with the old precise triangulation of the U. S. Lake Survey. This work is being done at the request of the U. S. Geological Survey to furnish precise control for mapping operations in northeastern Wisconsin.

The plan followed was to have the entire party work as close together as possible, usually from the same base. The building party was kept just far enough ahead not to delay the other operations. In this way the office work and correspondence were much reduced, and the computations were more easily made since all the records were available at any time.

Automobile trucks were used for transportation.

INDIANA.

[J. S. BILEY.]

SUMMARY OF RESULTS.—Precise traverse: Reconnoissance and signal building, 105 miles; observing, 120 miles; taping and traverse completed, 145 miles; 92 principal stations occupied for horizontal measures. Azimuth: 7 stations occupied for determination of azimuth.

At the beginning of the fiscal year 1921 work was in progress on the line of precise traverse extending north and south through the center of the State of Indiana, connecting with the thirty-ninth parallel precise triangulation at the southern end and with the precise triangulation of the Lake Survey at the northern end. This work was done at the request of the U. S. Geological Survey.

About 20 miles were traversed over improved roads in the neighborhood of Indianapolis. The remainder of the line was along railroads as usual. No especial difficulties were encountered on the work except in getting through the large cities where the numerous curves, railroad yards, and traffic over the streets made the work slow and hard. Motor trucks were used for transportation.

The reconnoissance, building, and observing were completed on August 9, and the taping two days later.

OKLAHOMA.

[EARL O. HEATON.]

SUMMARY OF RESULTS.—Precise triangulation: 1,400 square miles of area covered; 10 stations in the main scheme occupied for horizontal measures; 10 geographic positions determined; 10 elevations determined trigonometrically. Azimuth: 2 stations occupied for determination of azimuth.

Between May 25 and June 30, 1921, precise triangulation was executed to the westward of the ninety-eighth meridian triangulation near Chickasha, Okla. This is the eastern end of the arc which extends to Needles, Calif.

The conditions for observing were good most of the time on this work, but transportation was difficult due to excessive rainfall and the nature of the soil.

[RAY L. SCHOPPE.]

SUMMARY OF RESULTS.—Base line, precise: 4.7 miles in length. Triangulation, precise: 2,125 square miles of area covered; 16 stations in main scheme occupied for horizontal measures; 4 stations in supplemental scheme occupied for horizontal measures; 16 stations occupied for vertical measures; 32 geographic positions determined; 16 elevations determined trigonometrically. Leveling: 9.4 miles of levels run along base line. Azimuth: 2 stations occupied for determination of azimuth.

On September 4 the party engaged in precise triangulation at Williams, Ariz., was transferred to Mr. Schoppe. The party and outfit were then taken in five automobile trucks to Allen, Okla. There triangulation was begun where the work had been left in 1919 and extended westward to a connection with the ninety-eighth meridian triangulation. The old towers were found in bad condition, as only such repairs had been made to them as were possible without rebuilding. They were too insecure to use for observing in any but the most favorable weather. Poor closures were obtained at station Turkey, when an attempt was made to use the 60-foot tripod in a wind. The observations were repeated later under better conditions with satisfactory results.

The work was started on October 5, 1920. One Laplace azimuth was observed at station Allen, and one primary azimuth at station Rosedale. Vertical angles were measured at all stations.

Considerable delay was caused by the lack of bridges on the South Canadian River and also by muddy roads. The local soil formation is such as to make travel by truck practically impossible in wet weather. Trial was made under all conditions, and it was found that excessive breakage of various truck parts resulted from trying to get through the mud. On November 9 all four trucks were laid up for repairs due to this cause.

Connection with the ninety-eighth meridian precise triangulation was made at stations Purcell, Table Hill, and Arbuckle Mountain, and the horizontal measures of the season were completed on November 30, 1920.

On December 1 the party was assembled and started for Savanna, Okla., where a base line was measured. The base extended along a tangent of the Missouri, Kansas & Texas Railway for a distance of 6,500 meters, and over stakes for the remaining 1,000 meters at the southern end. All measures were completed on December 13 and the party was disbanded on December 16, 1920.

OKLAHOMA AND TEXAS.

[DAN W. TAYLOR.]

In September, 1920, a party was organized for the purpose of building and repairing triangulation signals on the western end of the arc of precise triangulation, which will extend from El Reno, Okla., to Needles, Calif.

The signals had been built several years, as the observations were delayed on account of the war. Although the necessary repairs were rather extensive, only three new signals had to be built. The chief of party was assisted by a truck driver and one hand. The party was disbanded early in November.

This work was resumed with a somewhat larger party on May 10, 1921, and on June 30 was completed as far as Clarendon, Tex.

NEW MEXICO AND ARIZONA.

[CLEM L. GARNER.]

SUMMARY OF RESULTS.—Precise triangulation: 21,300 square miles of area covered; 2 observing tripods and scaffolds built; 14 stations in main scheme occupied for horizontal measures; 3 stations in supplemental scheme occupied for horizontal measures; 14 stations occupied for vertical measures; 36 geographic positions determined; 25 elevations determined trigonometrically. Azimuth: 4 stations occupied for observation of azimuth.

On July 1, 1920, a party was engaged in precise triangulation in Arizona and New Mexico. This work is a link in the arc of precise control which eventually will extend across the continent from the vicinity of Huntsville, Ala., to the Texas-California triangulation just south of Prescott, Ariz., and which will follow in the general direction the line defined by the cities of Memphis, Little Rock, Albuquerque, and Williams. The section of the line covered during the season is from the vicinity of Albuquerque, N. Mex., to Williams, Ariz. The observations on this section were finished on August 26, 1920.

The work done during the period up to June 30, 1920, is given in the previous annual report. The observations were made by two observers, the chief of the party and R. L. Schoppe, hydrographic and geodetic engineer, working on opposite sides of the scheme.

Much difficulty was experienced in obtaining suitable labor for the work in the field, as triangulation in a mountainous country requires much exposure and isolation as well as very hard physical labor, and is not attractive to the men.

Heavy rainfall was experienced from June until August. For a period of nearly six weeks it was practically impossible to observe on heliotropes for vertical angles, and often due to storms observations at night were impossible. As a general thing, however, the weather was much clearer at night than during the day, and the vertical observations were finished then by pointing on the lights.

With one exception the equipment was practically the same as that used by various parties engaged in similar work during recent years. The exception was the exclusive use of electric lamps.

Transportation was largely by truck. The camp equipment necessarily was reduced to a minimum in order to avoid overloading the trucks, and even then the trucks were frequently overloaded on account of the extra supplies and material for emergency repairs, which had to be carried in such isolated places.

There were 67 lines in the main scheme, and the average length of line is 56.8 statute miles. The average width of the scheme is 66 miles, and the length is 408 miles. The longest line is 152.8 statute miles, and the second longest line is 146 miles. These, it is believed, are the longest lines over which complete observations for the figures involved have ever been made. Fortunately, these did not cause any delays in the observations except at station Ords. At the two other stations involved, the long lines were finished the first night. Most of the long lines hinged on the station Frisco, and that station was finished during the first night of observations. The success of the observations over these long lines is largely due to the efficiency of the electric signal lamps.

Connections with precise levels were made at Holbrook and Williams, Ariz., and at Los Lunas, N. Mex.

Two observers were used on this work, and no other arrangement would have been successful on this part of this particular arc of triangulation. On a stretch of over 200 miles on the south side of the scheme there is no railroad and not a single road over which trucks could be driven from one side of the scheme to the other. If the work had been undertaken by only one observer, some of the moves from station to station would have required drives of 400 miles or more.

The chief of party visited the office of the Forest Service at Albuquerque during the early part of the season. The officials there were very anxious to secure points of control in their various forest reserves.

NEW YORK.

[H. G. AVERS.]

SUMMARY OF RESULTS.—Precise leveling: 20 miles of levels run; 9 permanent bench marks established.

Between August 3 and 17, 1920, a line of precise levels was run from Moira, N. Y., to Cornwall, Ontario, as part of the scheme to connect the precise level nets of the United States and Canada at various places along the boundary.

The route followed the New York Central Railroad.

TEXAS, ILLINOIS, AND WISCONSIN.

[O. W. FERGUSON.]

SUMMARY OF RESULTS.—Precise leveling: (1) Texas, 78 miles of levels run, 31 permanent bench marks established; (2) Illinois and Wisconsin, 122 miles of levels run, 49 permanent bench marks established.

(1) From July 3 to August 14, 1920, a line of precise levels was run from Tenaha to Gallatin, Tex., to complete the unfinished portion of the line from Hillsboro, Tex., to Naples, La.

The route followed the Houston, East & West Texas Railroad to Nacogdoches, a distance of 38 miles; thence the Texas & New Orleans Railroad to Gallatin, a distance of 40 miles.

(2) Between August 24 and November 4, 1920, work on a line of precise levels from Rockford, Ill., to Prairie du Chien, Wis., was completed as far as a point 6 miles east of Fennimore, Wis. At this point the ill health of the chief of party necessitated turning over the work to F. W. Hough for completion.

The route followed the Chicago & North Western Railroad from Rockford to Freeport, Ill., a distance of 32 miles; thence the Illinois Central Railroad to Dodgeville, Wis., a distance of 65 miles; thence the Chicago & North Western Railroad to a point 6 miles east of Fennimore, Wis., a distance of 25 miles.

OREGON.

[C. M. DURGIN.]

SUMMARY OF RESULTS.—Precise leveling: 492 miles of levels run, 196 permanent bench marks established.

Beginning July 1, 1920, the line of levels running eastward across the State of Oregon from Klamath Falls to Ontario, with a spur line from Gap Ranch to Bend, was continued from a point 55 miles east of Klamath Falls and completed on November 15, 1920, at Bend, Oreg.

From Klamath Falls to Crane the route was along highways and passed through Olene, Dairy, Yainax, Beatty, Bly, Lakeview, Valley Falls, Alkali Lake, Butte, Egli, Gap Ranch, Riley, Burns, Lawen, and Saddle Butte. From Crane to Ontario the route was along the Oregon Short Line Railroad, a distance of 125 miles. The route from Gap Ranch to Bend was along the highways and passed through Hampton and Millican.

A double observing party was used, the subparty being in charge of F. W. Hough.

Transportation was by means of three automobile trucks, except on the railroad between Crane and Ontario, where motor-velocipede cars were used.

This leveling follows very closely the triangulation across the State. At several places bench marks were so placed that the triangulation party which followed could easily connect them with the triangulation scheme in order to control the trigonometric leveling.

OREGON AND WASHINGTON.

[J. D. CRICHTON.]

SUMMARY OF RESULTS.—Precise leveling: 494.2 miles of levels run, 297 permanent bench marks established.

On July 1, 1920, work was in progress on a line of precise levels from Weed, Calif., to Auburn, Wash., the line having reached Portland, Oreg.

The main line of the levels followed the Southern Pacific Railroad from Weed, Calif., to Portland, Oreg., and the Northern Pacific Railroad from Portland, Oreg., to Auburn, Wash., with the exception of 9 miles of single-track branch line between St. Clair and Olympia, Wash., and 7½ miles of single track owned by the Oregon-Washington Railroad and Navigation Co. between Olympia and Chambers Prairie, Wash.

Spur lines of levels were run from Portland to Fort Stevens, Oreg., and from Centralia to Westport, Wash.

From Portland to Fort Stevens, Oreg., the line followed the route of the Spokane, Portland & Seattle Railroad. At Fort Stevens three U. S. Engineer bench marks, and at Astoria, Oreg., one U. S. Engineer bench mark were recovered.

From Centralia to Westport, Wash., the line followed the route of the Gate and Grays Harbor branch of the Northern Pacific Railroad to Bay City, Wash.; thence overland to Westport, a distance of about 8 miles. At Westport two tidal bench marks were recovered.

Six tidal bench marks were connected with at Olympia, four at Steilacoom, and one at Tacoma, Wash. Two other tidal bench marks at Tacoma were found to be inaccessible on account of construction work, and two others were over 100 feet above the track and hence required a great deal of time to tie in. No tidal bench marks at Dupont, Wash., were recovered, although a thorough search for them was made.

At Auburn, Wash., the end of the line, connection was made with two bench marks of the Seattle, Wash., to Pocatello, Idaho, precise level line.

Motor-velocipede cars were used throughout the season. On several sections of the work where the traffic was unusually heavy, and also where the route followed the Columbia River, the use of the cars was extremely hazardous.

When using motor cars on leveling work it has been the practice heretofore to mount the tripod of the instrument on a car of the side-drive pattern. This method of mounting has not proved entirely satisfactory as the side-drive car has given more or less trouble in not keeping to the rails, thus subjecting the instrument to severe shocks. The instrument mounted in this manner was directly over the center of the track, and the line of sight passed close to the recorder who was seated in the second car. The possible effect on the line of sight of the proximity of the recorder and the second car was balanced by shifting the relative positions of the cars.

For some time a center-drive type of car has been in use, and its greater serviceability prompted the observer to design a mounting for the instrument on this type of car and to give it a trial on 275 kilometers of the line.

In mounting the instrument on a center-drive car, an ordinary tripod was used with the legs cut to the proper length. Two of the legs were bolted to the car, one at each end near the side. The third leg of the tripod was swung underneath the head and fastened to the side stringer of the frame of the car. The tripod head was steadied by an extra brace to the platform in the center of the car, and the entire mounting was inclined in such a way that the observer could stand in line with the end of the railroad ties while looking through the instrument.

While using this form of mounting, the rerunning of the party was not reduced appreciably, but the residuals of the sections (B–F) showed no systematic tendency to increase.

MONTANA.

[J. D. CRICHTON.]

SUMMARY OF RESULTS.—Precise leveling: 45.3 miles of levels run, 17 bench marks established.

This line of precise levels started from standard bench marks along the Great Northern Railway at Hinsdale, Mont., and followed the roads northward to monument No. 486 on the United States and Canada boundary, near the one hundred and seventh meridian. The field work was begun on May 19, 1921, and ended on June 18, 1921.

The Geodetic Survey of Canada is extending a line of precise levels southward to the boundary at monument No. 486. These two lines form a part of the scheme to connect the precise level nets of the United States and of Canada at various places along the boundary.

UTAH.

[F. W. HOUGH.]

SUMMARY OF RESULTS.—Precise leveling: 49 miles of levels run, 20 permanent bench marks established.

On June 5, 1921, work was begun on a line of precise levels to extend from Green River, Utah, southward to Halls Crossing, thence along the Colorado River to Lees Ferry, Ariz. At the end of the fiscal year the work had progressed to a point 49 miles south of Green River.

This work was undertaken at the request of the U. S. Geological Survey, and it will furnish the vertical control for extensive topographic operations which are now being carried on in that locality.

WISCONSIN AND ILLINOIS.

[F. W. HOUGH.]

SUMMARY OF RESULTS.—Precise leveling: Wisconsin, 44 miles of levels run, 23 permanent bench marks established; Illinois, 19 miles of levels run and 10 permanent bench marks established.

From November 5 to November 26, 1920, the line of precise levels from Rockford, Ill., to Prairie du Chien, Wis., was completed from a point 6 miles east of Fennimore, Wis.

The route followed the Chicago & North Western Railroad to the Wisconsin River near Woodman, a distance of 22 miles; thence along the Chicago, Milwaukee & St. Paul Railroad to Prairie du Chien, Wis., a distance of 22 miles.

Upon the completion of the line the party ran check levels for a distance of 20 miles between Freeport, Ill., and Martintown, Wis., where an error was known to exist.

Between December 5 and 22, 1920, the Rockton-Sandoval line was connected by spur lines with previously established bench marks at Monroe Center, La Salle, and Oglesby, Ill. The main line of levels was then extended 8 miles along the Illinois Central Railroad from Sandoval to Centralia, Ill. A spur line was run from Sandoval to Odin, Ill., a distance of 4 miles along the Baltimore & Ohio Railroad.

Considerable difficulty was experienced in locating old bench marks in the vicinity of Centralia upon which to close the work. The old marks were placed about the year 1880, and since that time the culverts and buildings upon which the marks were established have been destroyed or remodeled.

ILLINOIS.

[C. A. EGNER.]

SUMMARY OF RESULTS.—Precise leveling: 284 miles of levels run, 256 permanent bench marks established.

Beginning September 17 and completing the work December 22, 1920, a line of precise levels was run from Rockton southward through the State of Illinois to a point 2 miles north of Sandoval.

The route was along the Chicago, Milwaukee & St. Paul Railroad from Rockton to Rockford; thence along the Chicago, Burlington & Quincy Railroad to Rochelle; again along the Chicago, Milwaukee & St. Paul Railroad to Mendota, and the remainder of the distance to a point 2 miles north of Sandoval along the Illinois Central Railroad.

This line of levels provided elevations for the traverse work along the same route.

KENTUCKY AND TENNESSEE.

[C. M. DURGIN, F. W. HOUGH, C. H. OBER, F. E. JOEKEL.]

SUMMARY OF RESULTS.—Precise leveling: 289 miles of levels run, 135 permanent bench marks established.

Beginning about the middle of April work was started on two lines of precise levels in Kentucky and Tennessee.

One line started from bench marks of the U. S. Engineers at Louisville, Ky., followed the Illinois Central Railroad through West Point to Elizabethtown, Ky., a distance of 54 miles; thence along the Louisville & Nashville Railroad through Bowling Green, Ky., to Clarksville, Tenn., a distance of 134 miles.

The other line started from bench marks of the U. S. Geological Survey at Cerulean, Ky., followed the Illinois Central Railroad to Hopkinsville, Ky., a distance of 16 miles; thence along the Tennessee Central Railroad through Clarksville, Tenn., to Nashville, Tenn., a distance of 85 miles.

Connections were made with bench marks of the U. S. Geological Survey at West Point, Glasgow, Oakland, and Bowling Green, Ky., and at Nashville, Tenn.

KENTUCKY AND NEW YORK.

[C. H. OBER.]

SUMMARY OF RESULTS.—Precise leveling: 64 miles of levels run, 37 permanent bench marks established.

In June, 1921, the party took the field in Kentucky to run a line of leveling beginning at Russellville. This work was continued to Bowling Green, Ky., where work was closed on June 25.

A main party and a subparty were employed in this work, each party having five men with an officer in charge.

The subparty working south and west from Louisville, and the main party working northeast from Clarksville, effected a junction at Bowling Green on June 25.

The Kentucky party was disbanded and a new party organized in Bowling Green for precise leveling work in the State of New York. The motor truck and party left Bowling Green on June 26 and were on their way to Buffalo, N. Y., on June 28. The chief of party proceeded to Buffalo by rail, arriving there on June 28, and was for the rest of the month engaged in reconnoissance and preparation for field work.

ARKANSAS, OKLAHOMA, TEXAS, NEW MEXICO, ARIZONA, AND CALIFORNIA.

[W. B. FAIRFIELD and G. D. COWIE.]

SUMMARY OF RESULTS.—Latitude and longitude: 7 precise latitude stations established; 9 differences of longitude (telegraphic) determined.

During the period between August 16 and December 31, 1920, differences of longitude were determined between the following stations: Little Rock, Ark.; Hartford, Ark.; Allen, Okla.; Pond Creek, Okla.; Dill, Okla.; Conway, Tex.; Glen Rio, N. Mex.; Los Lunas, N. Mex.; Williams, Ariz.; and Needles, Calif.

Latitude was determined at Hartford, Ark.; Allen, Okla.; Dill, Okla.; Conway, Tex.; Glen Rio, N. Mex.; Los Lunas, N. Mex.; and Williams, Ariz.

At the beginning of the season, the longitude station at Little Rock, Ark., was connected with the main scheme of triangulation in that vicinity.

Field operations closed for the season on January 4, 1921.

The Western Union Telegraph Co. as usual rendered assistance in the use of their lines and in making the necessary connections.

DISTRICT OF COLUMBIA.

[E. W. EICKELBERG.]

Tests were made of the flexure of a portable aluminum stand resting on a concrete floor, when the stand is used for gravity observations.

The stand is the one used by the Survey for the zenith telescope for latitude observations. It consists essentially of a triangular-shaped head and three legs with extensions made mostly of aluminum for lightness. It is held together by means of cross diagonals which are drawn up by means of turnbuckles.

The usual method of observing flexure was followed.

The results showed a flexure correction of 27 in the seventh place of the period of the pendulum. This is rather large as compared with the average value of 12, obtained when the case is mounted on the brick pier of the pendulum room of the Coast and Geodetic Survey building, but probably not too large to permit of the stand being used.

EXPERIMENTAL WORK IN ASTRONOMY AND GRAVITY.

[G. D. COWIE.]

During the latter part of the fiscal year 1921 considerable experimental work was done at the Washington office on new auxiliary apparatus to be used on longitude work and in the determination of gravity. A new wireless receiving set that will record wireless time signals on a chronograph has recently been devised by the Bureau of Standards, and Mr. Cowie was occupied in making tests and designing and collecting certain necessary auxiliary apparatus. He was also engaged in making magnetic tests of the new invar pendulums to be used for gravity determinations.

MAGNETIC WORK.

MARYLAND (CHELTENHAM MAGNETIC OBSERVATORY).

[GEORGE HARTNELL.]

The work of the Cheltenham Magnetic Observatory has been continued throughout the year without material interruption. The variation instruments

have required very little adjustment and the absolute instruments have given satisfactory results.

The seismograph has performed satisfactorily during the year and 26 earthquakes were recorded.

Magnetometers Nos. 40, 19, and 38, earth inductor No. 22, and dip circles Nos. 36 and 56 have been compared with the standard instruments of the observatory.

A new wireless receiving set purchased in June has been tested and found very satisfactory.

ARIZONA (TUCSON MAGNETIC OBSERVATORY).

[S. A. DEEL, July 1–Aug. 26, 1920. WM. H. CULLUM, Aug. 27, 1920–June 30, 1921.]

The observatory work was continued without interruption throughout the year. The variometers of the magnetograph required considerable adjustment, and much trouble was experienced in getting a satisfactory rate of the driving clock of the recording apparatus.

Absolute observations were made once a week, scale value determinations at least once a month, and meteorologic observations daily.

The seismograph has been in continuous operation and 35 earthquakes were recorded. The use of a make-circuit chronometer for marking time on the seismograms has proved very satisfactory.

The chronometers were kept rated by means of weekly comparisons in Tucson with telegraphic time signals from Mare Island.

Necessary repairs were made to the observatory buildings.

OHIO, ILLINOIS, WISCONSIN.

[WM. WALTER MERRYMON.]

STATIONS OCCUPIED.—Ohio, Cleveland; Illinois, Urbana; Wisconsin, Madison.

All of the stations were repeat stations reoccupied for the determination of the secular change. At Cleveland the station was re-marked so that it will now be available for a long time.

The nature of the work, and information about it and the Coast and Geodetic Survey and the furnishing of magnetic data by the Survey, was communicated to a number of surveyors and engineers and other persons interested at each place.

NEW MEXICO.

[S. A. DEEL.]

STATION OCCUPIED.—State College.

At the request of Prof. J. W. Jourdan, of the Department of Civil and Irrigation Engineering of the College of Agriculture and Mechanic Arts, a meridian line was established and complete magnetic observations made at the above station.

WASHINGTON AND ALASKA.

[J. T. WATKINS.]

In accordance with an arrangement made with the Coast Guard to secure magnetic observations on the shores of Bering Sea an dthe Arctic Ocean, the above officer left Washington, D. C., for Nome, Alaska, on May 21. While awaiting a steamer at Seattle, Wash., he made complete magnetic observations at the old station in Seward Park. He reached Nome on June 18 and made observations at that place before the end of the fiscal year. He then joined the Coast Guard steamer *Bear* and will as far as possible make observations at the places at which she stops during the summer.

ALASKA.

[F. H. HARDY, Commanding Steamer *Surveyor*.]

SUMMARY OF RESULTS.—Reconnoissance: 464 square miles of area covered, length of scheme 22 miles; 9 lines of intervisibility determined; 3 points selected for scheme. Triangulation: 217 square miles of area covered; 24 signal poles erected; 14 stations in main scheme occupied by horizontal measures; 3 stations in supplemental scheme occupied by horizontal measures; 9 stations occupied by vertical measures; 63 geographic positions determined. Magnetic work: 3 land stations occupied for magnetic declination; one station at sea occupied, at which ship was completely swung. Topography: 25¼ square miles of area surveyed; 25 miles of general coast line surveyed; scales of hydrographic sheets 1:10,000 and 1:5,000. Hydrography: 180 square miles of area covered; 131.1 miles run while sounding; 631 positions determined (double angles); 816 soundings made; one tide station established; three hydrographic sheets finished, scale 1:100,00, 1:20,000, and 1:10,000.

On July 1, 1920, the steamer *Surveyor* was at work on the coast of southwestern Alaska. It was planned to keep as many parties in the field as the complement and surveying equipment on board would allow, and before reaching the working grounds to put out four observing parties in Shelikof Straits, to complete the large figure in the triangulation which had been begun during the previous season. Owing to the severity of the weather and the quantity of snow it was impracticable to establish these parties upon arrival on the working ground, and the whole party was taken to King Cove, where the work of putting the steamer *Yukon* in condition was taken up. The attached parties were established in Shelikof Straits upon the first trip of the vessel for a supply of oil on May 12 and 13.

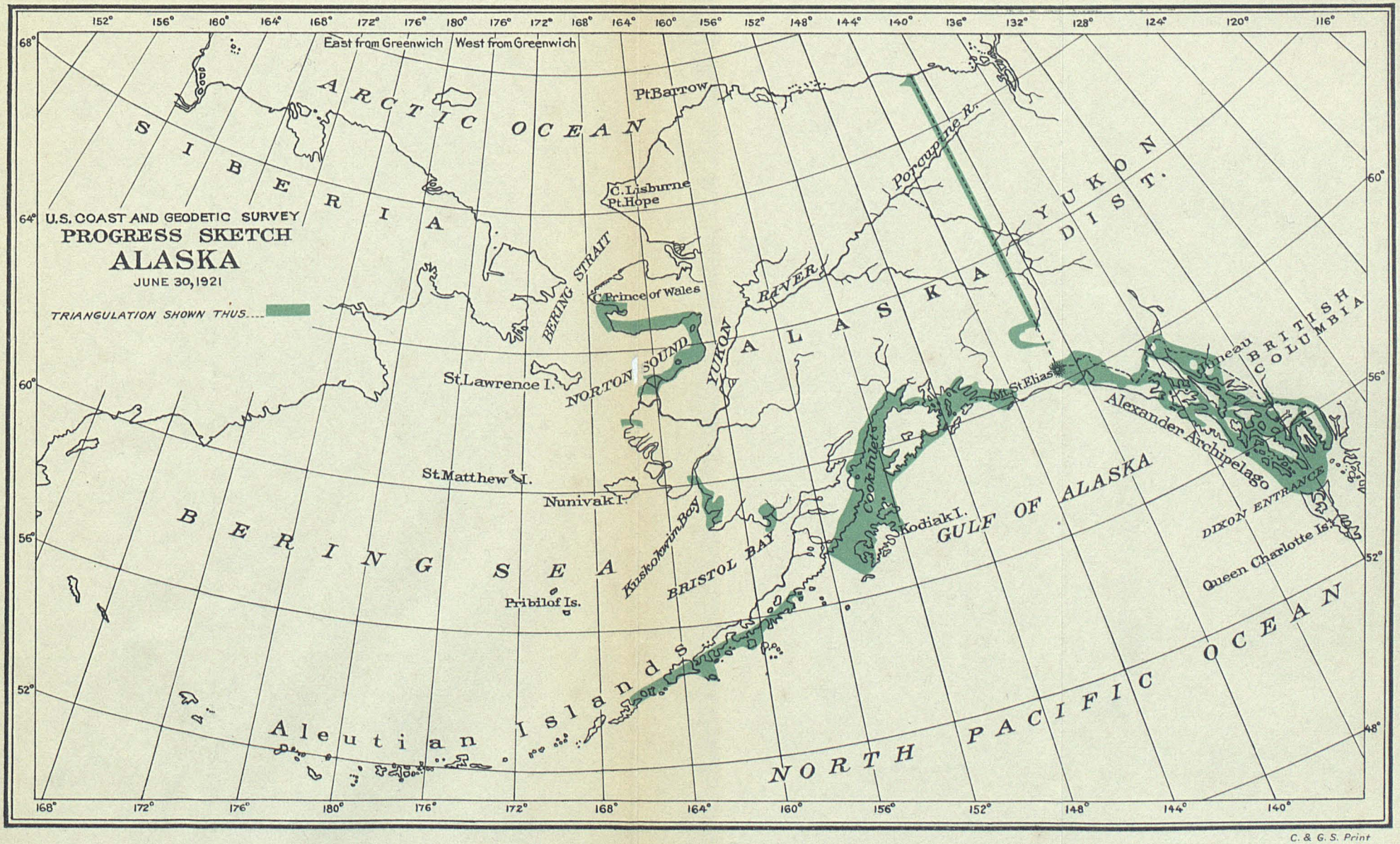
The principal and most important part of the work required was the connection of the triangulation in the vicinity of Shelikof Straits with that in the vicinity of Mitrofonia. As the extension of the western part of this work necessitated reconnoissance, the work could be carried on quite as readily and more economically by leaving the portion from Cape Ikti to Castle Bay to a party on the launch *Yukon*, and utilizing the remaining officers and instruments in extending the work from Shelikof Straits to the westward, where mountain peaks had already been determined and the ship could be used in hydrographic work while triangulation was in progress.

Having determined a line on Cape Unalishagvek for extending the triangulation to the westward, it had been planned to concentrate the latter force of the party on work in the vicinity of Chignik Bay. However, the unforeseen shortage of oil necessitated the cutting out of as much running as possible, and this fact in connection with the receipt of telegraphic instructions to forecast and gather information in regard to Kialagvik Bay (Wide Bay) made it desirable to concentrate all the efforts of the party on the extension of the triangulation from Shelikof Straits to the westward.

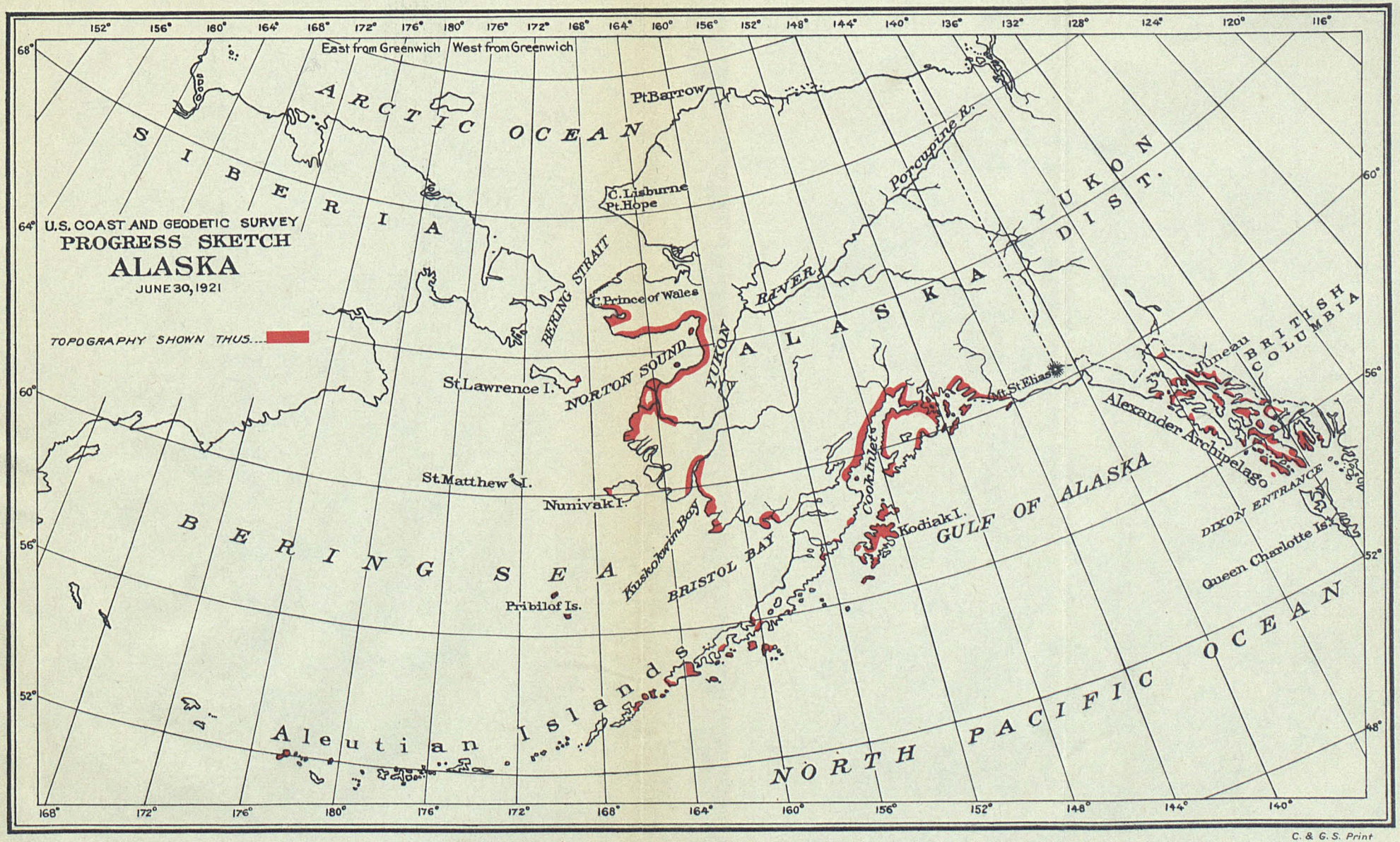
During the season the existence of a rock was reported in the vicinity of Lighthouse Rocks; one trip was made to the location reported, but no evidence of the danger was found. During the whole season every opportunity was taken to make observations.

The triangulation was divided into two parts, that extending from the work of the previous year in the vicinity of Cape Ikti to the eastward and the other from the line Kekurnoi-Ridge in Shelikof Straits to the westward. Commencing with the line Village to Copper determined during the previous year, triangulation was extended by a quadrilateral to the line Goat-Slope, then by the triangles Goat-Slope-Ship and Goat-Village-Ship to Ship-Goat from Ship-Goat to Fool-Kits by the four-sided central point (Pudding) figure with both diagonals observed. From the line Fool-Kits it had been planned to determine the line Kumliun-Atkulik by a four-sided central pointed figure with Nak as the central point and the diagonal Kits-Kumliun observed. Although several attempts were made to observe the line Kits-Kumliun it was found impossible to get a determination of the line from either station owing to the clouds which covered Kumliun when Kits was occupied. A double determination of the line Kumliun-Atkulik can be determined by the observing done, but the figures are not strong enough to use this determination in carrying the work to the eastward. To extend this work to the eastward from the line Kumliun to Atkulik it was planned to establish and determine stations on the highest point on Sutwik Island with a central point on the little island south of Cape Kumliun if the strength of figures necessitated the establishment of such a point. From the line Atkulik to Sutwik, points on the Semidi Islands can be determined.

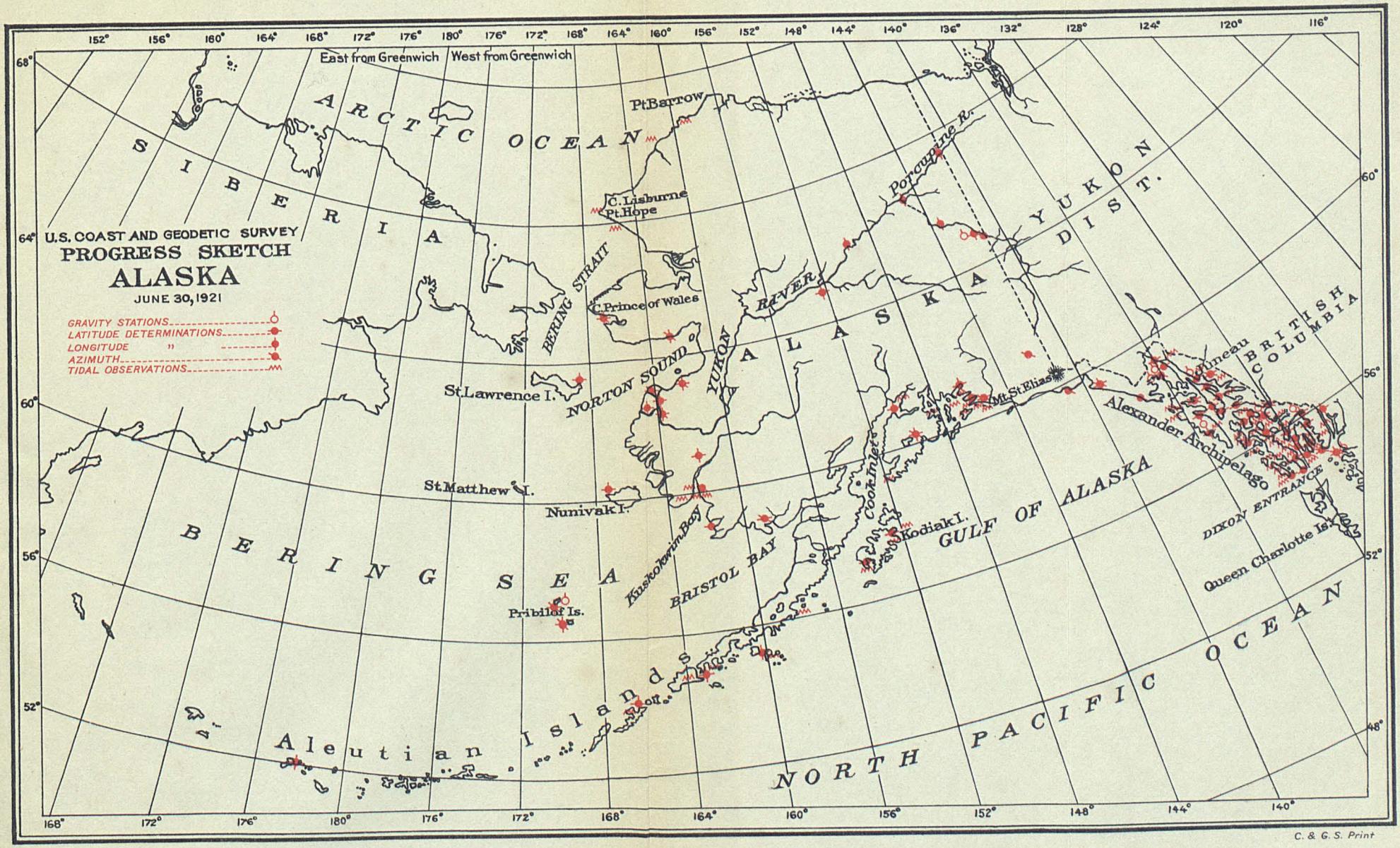
The work in Shelikof Straits was extended from the line Kekurnoi-Ridge, determined in 1919, to the line Kekurnoi-Top by a simple quadrilateral. From


U.S. COAST AND GEODETIC SURVEY
PROGRESS SKETCH
ALASKA
JUNE 30, 1921
TRIANGULATION SHOWN THUS....
East from Greenwich
West from Greenwich
ARCTIC OCEAN
SIBERIA
Pt Barrow
C. Lisburne
Pt. Hope
Porcupine R.
YUKON DIST.
BERING STRAIT
C. Prince of Wales
YUKON RIVER
ALASKA
BRITISH COLUMBIA
Juneau
St. Lawrence I.
NORTON SOUND
Mt. St. Elias
Alexander Archipelago
St. Matthew I.
Nunivak I.
Kuskokwim Bay
BERING SEA
BRISTOL BAY
Cook Inlet
Kodiak I.
GULF OF ALASKA
DIXON ENTRANCE
Queen Charlotte Is.
Pribilof Is.
Aleutian Islands
NORTH PACIFIC OCEAN

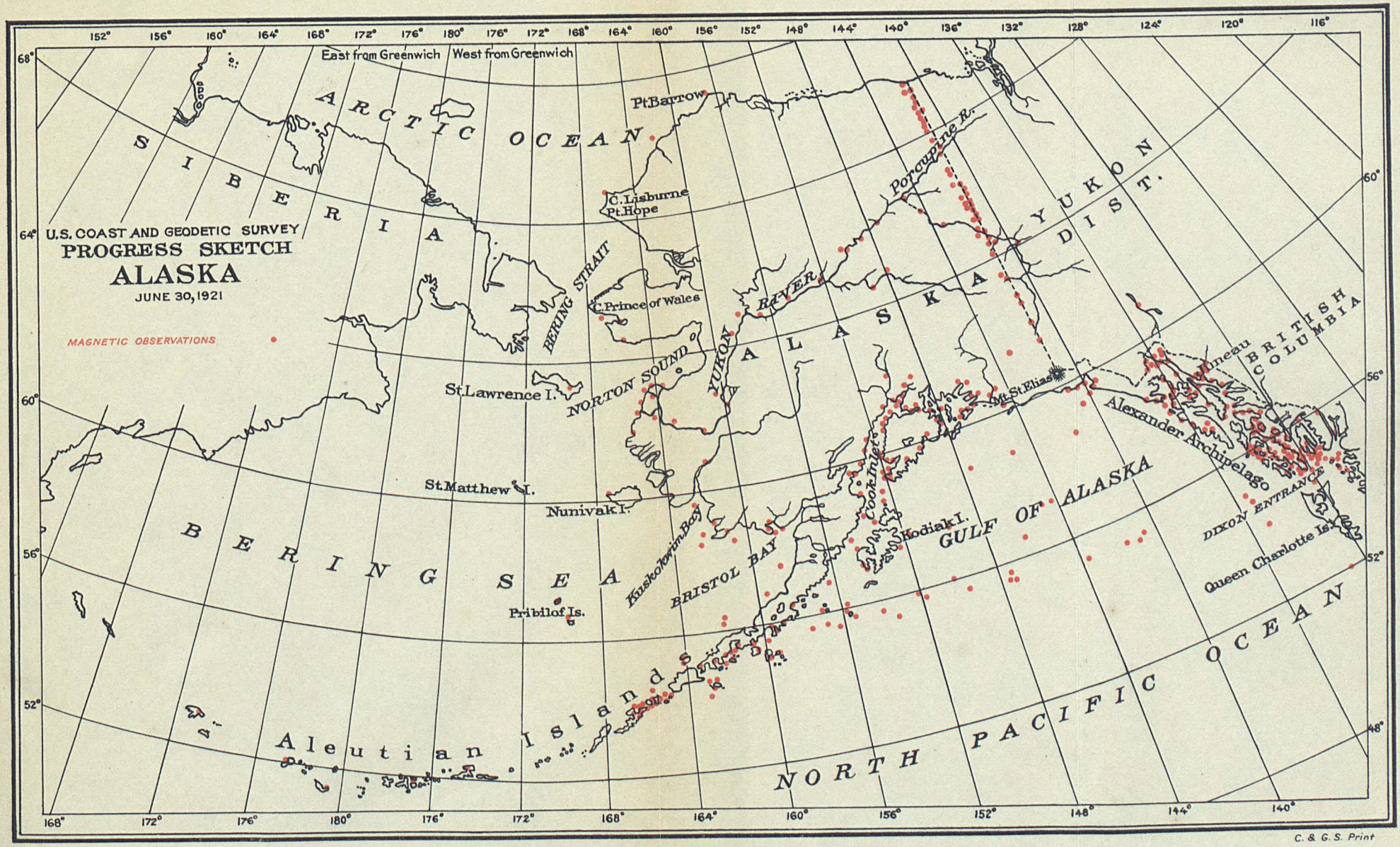
C. & G. S. Print


U.S. COAST AND GEODETIC SURVEY
PROGRESS SKETCH
ALASKA
JUNE 30, 1921
TOPOGRAPHY SHOWN THUS.
East from Greenwich
West from Greenwich
ARCTIC OCEAN
SIBERIA
Pt. Barrow
C. Lisburne
Pt. Hope
Porcupine R.
YUKON DIST.
BERING STRAIT
C. Prince of Wales
YUKON RIVER
ALASKA
BRITISH COLUMBIA
Juneau
NORTON SOUND
St. Lawrence I.
Mt. St. Elias
Alexander Archipelago
St. Matthew I.
Nunivak I.
Kuskokwim Bay
BRISTOL BAY
Cook Inlet
Kodiak I.
GULF OF ALASKA
DIXON ENTRANCE
Queen Charlotte Is.
BERING SEA
Pribilof Is.
Aleutian Islands
NORTH PACIFIC OCEAN
152° 156° 160° 164° 168° 172° 176° 180° 176° 172° 168° 164° 160° 156° 152° 148° 144° 140° 136° 132° 128° 124° 120° 116°
68° 64° 60° 56° 52° 60° 56° 52° 48°
168° 172° 176° 180° 176° 172° 168° 164° 160° 156° 152° 148° 144° 140°

C. & G. S. Print


U.S. COAST AND GEODETIC SURVEY
PROGRESS SKETCH
ALASKA
JUNE 30, 1921
GRAVITY STATIONS
LATITUDE DETERMINATIONS
LONGITUDE "
AZIMUTH
TIDAL OBSERVATIONS
East from Greenwich
West from Greenwich
ARCTIC OCEAN
SIBERIA
Pt.Barrow
C. Lisburne
Pt.Hope
C.Prince of Wales
BERING STRAIT
YUKON
DIST.
Porcupine R.
YUKON RIVER
ALASKA
BRITISH COLUMBIA
Juneau
Mt.St.Elias
Alexander Archipelago
DIXON ENTRANCE
Queen Charlotte Is.
St.Lawrence I.
NORTON SOUND
St.Matthew I.
Nunivak I.
Kuskokwim Bay
BRISTOL BAY
Cook Inlet
Kodiak I.
GULF OF ALASKA
BERING SEA
Pribilof Is.
Aleutian Islands
NORTH PACIFIC OCEAN
152° 156° 160° 164° 168° 172° 176° 180° 176° 172° 168° 164° 160° 156° 152° 148° 144° 140° 136° 132° 128° 124° 120° 116°
68° 64° 60° 56° 52°
168° 172° 176° 180° 176° 172° 168° 164° 160° 156° 152° 148° 144° 140°
60° 56° 52° 48°

C. & G. S. Print


U.S. COAST AND GEODETIC SURVEY
PROGRESS SKETCH
ALASKA
JUNE 30, 1921
MAGNETIC OBSERVATIONS
East from Greenwich
West from Greenwich
ARCTIC OCEAN
SIBERIA
Pt Barrow
C. Lisburne
Pt Hope
BERING STRAIT
C. Prince of Wales
Porcupine R.
YUKON DIST.
YUKON RIVER
ALASKA
BRITISH COLUMBIA
St Lawrence I.
NORTON SOUND
Mt St Elias
Juneau
Alexander Archipelago
St Matthew I.
Nunivak I.
BERING SEA
Kuskokwim Bay
BRISTOL BAY
Cook Inlet
Kodiak I.
GULF OF ALASKA
DIXON ENTRANCE
Queen Charlotte Is.
Pribilof Is.
Aleutian Islands
NORTH PACIFIC OCEAN
C. & G. S. Print

the line Kekurnoi-Top the line Cold-Shag was determined by the quadrilateral Kekurnoi-Shag-Top-Cold. From the line Cold-Shag the line Kenatak-Igvak was determined by a four-sided central-pointed figure, the central point being at Jure, and the diagonal Shag-Kanatak observed. The line Igvak-Becharof was determined by a simple triangle, Becharof being concluded. A check on the line Igvak-Bacharof which will be used in extending this work to the westward can be obtained by utilizing Una, 1919, on Cape Unalishagvak, or probably by the establishment of a new station on a peak back from Kialagvik Bay. To establish this station it would be necessary to climb approximately 2,500 feet and go back from the coast for a distance of 4 or 5 miles.

It would be possible to measure a base on the sand spit between Chignik Lagoon and Chignik Bay. The length of such a base would be approximately 2 miles, and it could be connected with the main scheme with good figures. Although no reconnoissance was done it may be possible to establish a base site from the southern part of Kialagvik Bay.

Halibut Cove on Kodiak Island offers an ideal place for the measurement of the base, and the base could be connected with the line Ridge-Ikolik of the main scheme. However, the line Ridge-Ikolik affords a weak connection in the main scheme for continuance to the westward.

The area of Shelikof Straits from Cape Yuak south to Cape Ikolik not previously done was completed during this year. The tide gauges at Kodiak and Baralof Bay were repaired and the former dismantled at the end of the season and brought to Seattle. During weather when it was impossible to work with the vessel a survey was made of the south portion of Halibut Cove. This was done for two reasons, first to take advantage of the time and second to give the surveying launch a thorough trial under a new engineer before putting parties out to work in the exposed waters of Cold and Portage Bays.

The weather during the season was extremely unfavorable for the prosecution of the triangulation.

During the season Coast Pilot notes were collected covering the locality in the vicinity of Chignik and thence up the Alaska Peninsula to Cold Bay. These Coast Pilot notes, together with those incorporated in a descriptive report accompanying hydrographic sheets, furnished information for the whole area of the work assigned to the survey.

[T. J. MAHER, Commanding Steamer *Surveyor*.]

SUMMARY OF RESULTS.—Triangulation: 340 square miles of area covered; 10 signal poles erected; 38 observing tripods built, heights from 16 to 20 feet; 11 stations in main scheme occupied for horizontal measures; 8 stations occupied for vertical measures; 43 geographic positions determined. Leveling: 3 permanent bench marks established; one-half mile of levels run. Magnetic work: Ship swung at 2 sea stations at sea. Topography: 33 square miles of area surveyed; 52.7 miles of detailed shore line surveyed; scale of topographic sheets 1:10,000 and 1:20,000. Hydrography: 1,306.1 square miles of area covered; 2,259.6 miles run while sounding; 3,645 positions determined (double angles); 3,715 soundings made; 2 tidal stations established; 5 current stations established; scale of hydrographic sheets 1:10,000, 1:20,000, 1:120,000.

The work assigned to the steamer *Surveyor* for the season of 1921 included the ship hydrography west of Forrester, Baker, and Noyes Islands from the western limit to complete work to the 1,000-fathom curve; triangulation sufficient to give control for the topographic survey of Baker and Noyes Islands, the scheme being laid out, if possible, with a view to strengthening the two loops of small figures which join Iphigenia and Bucareli Bays; a topographic survey of Baker, Noyes, San Pedro, and Noname Islands; the rectification of errors in the topographic survey of Meares Passage, and inshore launch hydrography along the coasts and in the bays and inlets to connect with the ship hydrography; magnetic observations sufficient to determine the variation and any local irregularities.

The vessel arrived at the working grounds in Alaska at Santa Cruz Bay, Suemez Island, April 16, 1921.

The statistics of work done up to June 30 are given above.

The soundings were up and down with the vessel stopped, using the Miller-Dake and Sigsbee sounding machine with stranded wire, 30-pound lead, and also detachable sounding shot. No tube or hand-lead soundings were made. The depth varied from 60 to 1,000 fathoms. Eleven stations were occupied in the triangulation and 27 stations in supplemental scheme covering an area of 340 square miles. The supplemental scheme is within the limits of the main scheme.

Launch hydrography was done in vicinity of Steamboat Bay, Noyes Island.

In the topography 52.7 miles of shore line were run and 33 square miles covered. Survey of the west coasts of Baker and Noyes Islands was in progress at the close of the year.

Two ship swings were made for deviation of compass.

From the 8th to the 15th of April the vessel was at Metlakatla, Alaska, and the party was engaged in laying boat ways, putting in the water launch 47 and installing in it machinery, boiler, tanks, and equipment. The wheelhouse on the *Cosmos* was rebuilt.

On April 18 reconnoissance for triangulation was started. By the close of the fiscal year this had been completed, all stations equipped, and the two objects in view attained, namely: Control for the topographic survey of Noyes and Baker Islands and strengthening the loops from Iphigenia to Bucareli Bay. The closures were rather large. Ship hydrography was in progress continuously. The work being offshore, anchorages were not available, so the practice was to stay at sea from Monday morning to Saturday afternoon each week. It was necessary to establish sea watches, eight hours constituting the time of duty for each watch. This procedure reduced the number of men and officers available for detached parties, but permitted almost continuous ship hydrography.

The topography at first progressed slowly. The work is along exposed coasts and of such character that only experienced topographers can execute it satisfactorily. In connection with the supplemental scheme of triangulation topographic work was done along the west coast of Baker Island, and a traverse was run along the coast of Noyes Island. Some current observations were made, but before the vessel can be used for systematic observations of currents in localities where deep water is found suitable arrangements will have to be made for anchoring in deep water.

Two ship swings were made primarily for the adjustment of the compasses, but the observations may be used for the determination of the variation. Several small pieces of work south of Noyes Island remained to be done at the close of the fiscal year to fill in deficiencies of the chart and develop reported shoals, the survey of entrances to some of the harbors, and the location of errors in the topographic survey where the sheets did not make a satisfactory connection.

[T. J. MAHER, Commanding Steamer *Wenonah*.]

SUMMARY OF RESULTS.—Triangulation: 16 square miles of area covered; 24 stations occupied for horizontal measures. Topography: 16 square miles of area surveyed; 19 miles of detailed shore line run. Leveling: 2 miles of levels run. Magnetic work: 3 shore stations occupied for magnetic declination; 2 stations occupied for deviation of compass. Hydrography: 280 square miles of area covered; 1,147.9 miles run while sounding; 9,382 soundings made; 5,430 positions determined (double angles). Wire-drag work: 16.3 square miles of area covered; 2,082 soundings made.

In March, 1920, the steamer *Wenonah* was directed to proceed to southeastern Alaska and take up the hydrographic and topographic survey of Clarence Strait from a junction with previously completed work in the vicinity of Point Nunez and West Devil Rock to a junction with Vallanar and Grindell Island.

Assigned to the steamer *Wenonah* for this work were steam launches *Delta* and *No. 117* and motor launch *No. 38*. The ship's boat equipment consisted of one whaleboat, two dories, two dinghies, and one motor dory. A wire-drag outfit was obtained from the warehouse in Seattle, which was part of the old outfit left by the party on the steamer *Explorer*, and proved altogether unsuitable for the work. No spare parts or extra equipment were furnished. On June 30 the party sailed for Nichols Bay. On June 2 the ship with launch *No. 38* in tow, started for Alaska. On Sunday, June 6, the vessel anchored off Ketchikan. On the 7th coal was taken on board, and the vessel proceeded to Metlakatla and began work on the boathouse there. From that time to the end of the month the entire party was engaged in repairing the launches and installing boilers and engines on them.

On June 30 the party sailed for Nichols Bay, from which place on July 1 the wire-drag survey of the waters between Cape Chacon and Nunez Rock was begun. Points located by former survey intended to be used for control were not recovered, and plane-table triangulation was started, but discrepancies were found in the original survey which resulted in some confusion. It was then decided that points should be located by triangulation. A scheme of triangulation was completed which furnished the locations of points more accurately than the plane-table determinations, but with a less degree of accuracy than tertiary triangulation. Three triangulation stations furnished the control. The two bases started from one station which was not visible from the other

two stations; the two last mentioned were intervisible, but so located as to furnish an azimuth only. The scheme was carried through in two ways which checked, so that no error exists which would in any way affect the hydrography. The triangulation was done only for the purpose of checking the location of points. The scheme was carried up the southwest channel of Nichols Bay, as the hydrographic party reported discrepancies there.

The work completed during the season included a wire-drag survey from Cape Chacon, 5 nautical miles westward and south of Nunez Rock; the revision of 19 miles of topography from a point 5 nautical miles westward from Cape Chacon around the cape and 1 mile to the northward, including Nichols Bay; a close hydrographic survey from Cape Chacon to a point 5 nautical miles to the westward, south of Nunez Rock, including the bank on which the rock was located; a close hydrographic survey of Nichols Bay, wire dragging the northern channel to Nichols Bay; the establishment of a tide staff in the bay and the maintenance of another at the entrance for comparative readings; a close inshore hydrographic development from Cape Chacon to Gardner Bay; ship hydrography from the latitude of Nunez Rock to 1 mile south of West Devil Rock, thence to a point 1 nautical mile east of West Devil Rock and north to the latitude of Gardner Bay; the maintenance of the tide staff in Gardner Bay; the recovery of 8 triangulation stations, the erection of signals, and the occupation of 24 stations; the permanent marking of 108 hydrographic stations, the establishment of 9 tidal bench marks, redescribing and releveling tidal bench marks at Ketchikan and Metlakatla; shifting the automatic tide gauge from the north to the south end of Ketchikan, and the installation of a new float box; the inspection of the chart agency at Ketchikan, and interview with the chart agent at Prince Rupert, British Columbia; three sets of magnetic observations and two ship's swings; a revision of the topography of Ketchikan begun and half completed.

During July the weather was unusually good, though toward the end of the month it was not possible to start work until noon each day on account of the fog. A tide staff was erected in the first bight at the head of Southwest Channel in Nichols Bay, on which observations were made day and night. Wire-drag work was continued throughout the month. A 300-foot drag was used, set to 72 feet so as to give an effective depth at 45 feet. Owing to the strong currents and the fact that the launches lack power, difficulty was experienced in handling the drag, and it was difficult to continue the drag lanes of uniform width. Topography and triangulation were carried on by the chief of party at the same time. Owing to the removal of the lighthouse wharf at Ketchikan it was necessary to move the automatic tide gauge to a dock at the southerly end of the town and to install another float box. Water levels were used in placing the new staff at the same elevation as the old. It was temporarily connected by leveling with a near-by bench mark. The Lighthouse Department built the gauge house which is a very satisfactory structure.

Work was continued during August with some delay on account of the difficulty of getting supplies of coal. Triangulation, topography, launch hydrography, tide observing, wire-drag work, and leveling were done. From the cape to 5 miles to the westward and from the south end of Prince of Wales Island and along Nichols Rock the area had been dragged except close inshore. In order to cover possible gaps in this work a detailed hydrographic survey was begun with a development possibly closer than anywhere else in Alaska, which was necessary as vessels going around the cape use this area exclusively.

During September field work was continued from Nichols Bay. Further delay was experienced in getting supplies of coal. From the 1st to the 14th of the month no field work was done. This delay prevented the completion of the ship and launch hydrography of Clarence Strait.

During August a hydrographic survey was made of Nichols Bay. At times when it was not practicable to work outside, a short drag was run down the channel to the bay outside the area, but the bay was completely dragged.

During October ship and launch work was carried on from Gardner Bay. Good progress was made, but weather was unfavorable. A little additional work was done off the rocks at the north end of Gardner Bay. Shoal soundings were obtained in the channel off the south entrance, and a shoal sounding off the rocks on the north side of the south entrance. Among fishermen this bay has the reputation of being the best anchorage along the coast. It is well protected from the sea. A close survey was made of Mallard Bay, at the head of which the topographic party found a mine where considerable development work had been done. Although the survey along the coast was not completed the ap-

proaches to the mine were connected with surveyed waters around West Devil Rock, and shoal soundings were obtained which might indicate uncharted dangers, but a close development was not made. A junction was made west of Duke Island with launch work done during preceding years. A tide staff was maintained in Gardner Bay.

On November 5 the ship convoyed the launches to Metlakatla, arriving there on the same day. From November 4 to the 10th the party was engaged in laying up the launches, cleaning, painting, stowing away small boats, and making a general inventory. On the 13th the ship sailed for Seattle, arriving on the 16th.

[J. H. HAWLEY, Commanding Steamer *Wenonah*.]

SUMMARY OF RESULTS.—*Triangulation*: 105 square miles of area covered; 26 signal poles erected; 11 instrument stands built; 2 observing scaffolds built, height, 64 feet; 6 stations in main scheme occupied for horizontal measures; 5 stations in supplemental scheme occupied for horizontal measures; 8 geographic positions determined. Leveling: 11 permanent tidal bench marks established. Magnetic work: One land station occupied for magnetic variation; ship swung at one station at sea. Topography: 83 square miles of area surveyed; 132 miles of detailed shore line surveyed; 3 topographic sheets finished, scale 1:20,000. Hydrography: 273 square miles of area covered; 890 miles run while sounding; 4,110 positions determined (double angles); 9,568 soundings made; 4 tide stations established; 3 hydrographic sheets finished, scale 1:50,000 and 1:20,000.

In March, 1921, the *Wenonah* was at Seattle undergoing repairs, obtaining supplies, and making general preparations for field work. On March 29 the vessel left Seattle and proceeded to Ketchikan, Alaska, arriving on April 2. From this date until April 17 the ship was at Ketchikan and Metlakatla engaged in launching and outfitting the launches that had been stored at Metlakatla at the end of the previous season. On April 18, the *Wenonah* left Ketchikan with the three launches in tow, proceeded to Moira Sound, and in the afternoon began the combined surveys in Clarence Strait, which were continued until the end of the fiscal year.

The party engaged in triangulation was at work until May 23 recovering and re-marking the stations established in 1912 that were used in the present primary scheme. Eleven of these stations were recovered, at each of which an instrument stand was installed. Scaffolds about 30 feet in height were erected at stations Duncan and Wedge to provide a line of sight between these stations.

Observations for the primary triangulation were begun on May 24 and continued until the end of the fiscal year. The observations were commenced at the line Skin-Gravina and the work carried south from this line. At the end of June observations had been completed at five stations of the main scheme. The observations were made during the day, and the triangulation closures were well within the required limit.

Some tertiary work was done in recovering and re-marking nine supplemental stations of the 1912 scheme and observations were made for the location of eight additional stations for the control of the topography and hydrography.

Topographic work was begun on April 21 in Moira Sound. The topography was completed from Black Point around to Niblack Anchorage and from opposite Black Point around to Scott Point, including Ingraham Bay. A topographic traverse was then run from Scott Point southward to Gardner Bay to locate signals for inshore hydrography. After this was completed work was started at Adams Point and extended northward to Chasina Anchorage, including Port Johnson.

The inshore hydrography on the west side of Clarence Strait was completed from the limit of the previous work at the entrance to Mallard Bay northward of the Wedge Islands, including the survey at Gardner Bay, Ingraham Bay, the entrance to Moira Sound as far west as Black Point and Port Johnson.

The ship hydrography was begun at the north limit of the previous work opposite Kendrick Bay and extended northward to the entrance of Chasina Anchorage.

An automatic tide gauge was installed at the entrance to Moira Sound on April 23 and continued in operation until the end of the year. Observations at supplemental staff gauges were obtained during the course of the inshore hydrography at Hidden Bay, Gardner Bay, and Port Johnson.

Observations for magnetic variation were obtained at three stations of the primary triangulation scheme.

[N. H. HECK, Commanding Steamer *Explorer*.]

SUMMARY OF RESULTS.—Reconnoissance for primary triangulation: Length of scheme, 6 miles; 42 square miles of area covered; 8 lines of intervisibility determined; 2 points located for scheme. Triangulation (tertiary): 50 square miles of area covered; 6 signal poles erected; 7 stations in main scheme occupied for horizontal measures; 17 stations in supplemental scheme occupied for horizontal measures; 32 geographic positions determined. Leveling: 12 permanent bench marks established; 5 miles of levels run. Magnetic work: 6 land stations occupied for magnetic declination. Topography: 250 square miles of area surveyed; 71 miles of general coast line surveyed; 10 topographic sheets finished, scales 1:40,000 and 1:20,000. Hydrography: (Wire drag) 298 square miles of area dragged; 389 miles run while dragging; 7,143 angles measured; 141 soundings made; 4 tidal stations established; 2 current stations occupied; 3 hydrographic sheets finished, scale 1:40,000.

On July 1, 1920, the steamer *Explorer* with launches *Helianthus* and *Scandinavia*, was engaged in combined operations in southeast Alaska, paying particular attention to the wire-drag work. All classes of work were in progress at the beginning of the year.

The main scheme of triangulation was completed by the middle of August.

Supplemental triangulation was carrieid on to locate additional stations in sufficient numbers to meet the prescribed standards of the Alaska work. All stations were marked and described, and reference marks were established at each station occupied. All of the triangulation was completed before leaving the field, and additional observations were made where necessary.

The reconnoissance was practically completed during the previous fiscal year, but the scheme contained a very short line at Point League. The scheme was revised, but the requisite signals were not constructed, and this work was left until the permanent triangulation party was ready to occupy them.

Observations for the magnetic declination were made at all main-scheme stations.

The topographic work was carried on by one party through the season, and by an additional party for about half the season. Progress was somewhat retarded by the breaking down of the engine on one of the launches, making it necessary to use a pulling boat for transporting the party.

In spite of this handicap, the topography was in advance of the other work by the end of the season, and had it not been for circumstances connected with the drag work the entire area assigned could have been finished. Both shore lines and form lines for an average distance of 3 miles back from the shore from each side of the channel were completed from the southern limits of the work to and including Grand Island. Several unfinished stretches of shore line left at the end of the season 1917 were completed this year. Each of these stretches required more time than it would have if finished at that time, as it was necessary to carry a traverse from some distance to establish new stations for the control of the work. The shore line was typical of the Alaska coast: rocky shores with stretches of sand beach, occasional almost impassable cliffs, in some cases the shore being fringed with off-lying rocks and kelp beds.

Automatic tide gauge observations were continued through the season until October 11 at Taku Harbor Cannery. The bench marks established were connected by leveling with a bench mark established in 1888.

Tide staffs were placed in the localities designated by instructions, excepting one, and in one additional locality, and enough observations were made at each to determine the staff readings of the plane of reference. Observations were made and bench marks established at Cleveland Passage, Hobart Bay, Pybus Bay, Gambier Bay, Windham Bay, and Holkham Bay entrance (cove just west of Woodspit). The staff in Hobart Bay was necessary for the control of work near this anchorage.

The staff in Gambier Bay was established on Good Island near the anchorage in regular use; this was connected by simultaneous observations with the staff established at the cannery wharf, and referred to previous bench marks. The reading on staff of mean low water, deduced from this comparison, is almost exactly that deduced by comparison of the series at Good Island with the automatic tide gauge record at Taku Harbor.

Preliminary examinations of the results and comparative curves indicate that Taku Harbor is a satisfactory location for the automatic gauge, as the other curves are very similar except for the known difference in height of the tide. It may be noted that in no case were the currents observed to meet as far south as the entrance to Taku Harbor, and in general the meeting place was northerly at Point Arden as indicated on the chart. Current observations were begun in the middle of September. Observations were obtained at two stations, which though in or near the channels were selected chiefly because of the moderate

depth of water. The results were just sufficient to emphasize the lack of knowledge of the currents of this region. The observations made at the first station are useful, but tend to give a wrong impression both of the strength and the confused character of the currents, as this point is probably less affected by the currents in and out of the numerous bays than any other that could have been selected.

The observations were made by the *Explorer* anchored with the kedge and wire cable in depths up to 80 fathoms. She had no facilities for anchoring in greater depths, and the anchor was too small to hold her in a strong wind.

A moderate amount of sounding work was done with the lead line, but more is required. No power boat was available to carry the line of sounding behind the drag.

Some hydrography was done to locate the more obvious defects in the charts of the bays and harbors. This work was incomplete because of poor locations and insufficient time to make the proper development, but the results were of importance.

Various notes were made of facts of interest discovered during the season that affected the existing Coast Pilot. The localities were taken up in the same order as in the Coast Pilot.

At the beginning of the fiscal year wire-drag work was in progress, but under a great handicap because of lack of apparatus and material. The way to get a solution of this problem was just being realized, and all this was worked out during the present season. The resulting changes have revolutionized Alaska wire-drag methods to such an extent that in deep-water work the old methods could not be returned to even if desired. The methods developed on the Atlantic coast have proved to be not well suited to Alaska because the drag moves too slowly. Experience shows that no assumption in regard to the direction of the currents will work out, and in such a region as Stephens Passage the drag which can proceed regardless of currents is the only practicable device.

The total output of the season's work and the maximum daily output are not the true measure of what can be accomplished, as the work was handicapped by lack of material throughout the season, and at the end it was doubtful whether the supply of wire and drums would hold out. The real accomplishment of the season was the working out of an idea which had the double merit of greatly decreasing the maintenance of the work and increasing the output in a given time. The daily output under the conditions met with in May and June could with the methods finally adopted have been more than doubled.

For convenience the apparatus developed will be called the sweep to distinguish it from the drag; the purpose of the sweep being to rapidly cover deep areas, and of the drag to cover all doubtful and shoal areas.

The fundamental features of the sweep are: Very quick setting out and taking up, which lengthens the working day (this quick setting out keeps the drag in position so that no area is lost by drifting as formerly); nonimportance of currents except those of considerable strength (in no case was the sweep stopped by the currents, though the drag was several times brought to a dead stop and had to be taken up), a possibility of rounding up all shoal area with the sweep at high speed, leaving comparatively small areas for the slow-moving drag; quick taking up makes bad weather of less importance, and it is possible to continue longer under unfavorable conditions. It is possible to use the vessel economically with this drag on account of the increased output.

It has been stated that the drag is equally well suited for finding shoals and determining whether an apparently open sea is clear of all obstructions, and for finding all obstructions that may exist in a given area. For the first use the drag has been superseded by the sweep. For the second purpose the drag is best equipped, but time is gained by closing in on the shoals with the sweep. It would appear to be desirable to modify the drag for use in Alaska so that it would have more speed.

Construction.—The sweep consists of a bottom wire made up of units of 100 feet or of any greater length which can be obtained without kinking of the wire because of swivels being unable to take out the twist. The need for stronger swivels was indicated by not infrequent shearing off of the heads. Weak fittings can not be tolerated in a drag whose possible output is 25 square miles per day. Uprights are 100-foot sections of bottom wire with swivels on each end, small weights are used solely to keep the uprights from becoming twisted around the bottom wire, and these are unnecessary if the uprights are shackled directly to the ground wire and allowed to slide to a position against

one or other of the sockets at the end of a section. The weight of the wire does all the holding down necessary.

No metal floats or any other floats are used.

Bottom wire.—Three-sixteenths-inch wire was used during the last season as it was the only wire available. Indications are that one-fourth-inch wire of the same type should be used for at least half the sweep when towed by the *Explorer*. Three-sixteenths-inch wire is more suitable to a launch because of its less resistance.

Method of attaching sockets is as described though crimping the ends is found unnecessary. Links are not used. All connections are made for uprights and towlines by passing a shackle over a swivel instead of putting the pin through the eye as formerly. Shackles so used should pass freely but should not be too large. Sockets for the quarter-inch wire should be drop-forged and not the heavy cast sockets on the market.

Large and small weights.—The large weights require no change though, owing to the method of attachment just described, the staple at the lower end is no longer necessary as all attachments are made at the upper end. The rod should be heavier than heretofore as these not infrequently bend or break. The small weight may be as described; the detail is not important, and it is frequently entirely omitted.

Large and small buoys.—Only one type of buoy has been used during the season. This is the standard 55 gallon drum with a rounded wooden bottom strapped to the drum. To the center of the bottom a 10-foot section of wire is shackled, but the lower end is attached so that the total length of upright will be 110 feet. For quarter-inch wire the standard 110-gallon drums will be required. These drums have the greater advantage in that they are designed with greater care and are made of the best material obtainable. It is proposed, however, to improve them by adopting a simple device so that they can be filled with compressed air and so prevented from crushing when submerged.

Towline arrangement.—This is an important development, and present methods could be profitably adopted for general use. The towline, except for the upper bridle, is simply a continuation of the drag wire. The upright and upper bridle, also section of ground wire, are carried on separate reel. The inner end of the upper bridle has a snap hook on the wire just forward of the fittings at the junction joints.

Length of sweep.—Preferably 15,000 feet for two launches with six 2,500-foot sections. Greater length may be used, and with the vessel and two launches 25,000 feet is entirely possible. Note that 15,000 feet is used without regard to ordinary currents as the normal speed is about 3 miles per hour.

List of parts.—The following list gives the amount and cost of equipment necessary for a 15,000-foot sweep with no spare parts. Cost has continued to increase since this estimate was made. Under the conditions of an Alaskan season there should be a 200 per cent surplus of wire and fittings and 40 per cent surplus in buoys.

Quantity.	Articles.	Cost.	
		Unit.	Total.
[1] 17,000	Wire, for sweep, uprights, and towline	$0.04	$680.00
2	Large weights	15.00	30.00
7	Gasoline drums, with rounded bottoms	15.00	105.00
350	Sockets	.40	140.00
175	Drop-forged swivels	.20	35.00
2	No. 5 snaphooks	.60	1.20
25	$\frac{5}{16}$-inch shackles	.25	6.25
	Total		997.45

[1] Feet.

NOTE.—This total is against $2,500 for the drag figured at much lower unit prices.

In the drag work a depth of 85 feet at mean low water was required.

The average speed of the sweep when there is no current is for a 15,000-foot drag about 3 miles per hour, and about 15 minutes is required for setting it out. The drag can not make more than 1¼ miles per hour under the most favorable conditions.

Field work was discontinued on October 7. The *Explorer* left Juneau October 18, and arrived at Seattle October 23.

During the season, whenever practicable, information was gathered for use in the correction of the Alaska Coast Pilot.

[N. H. HECK, Commanding Steamer *Explorer*.]

SUMMARY OF RESULTS.—Reconnoissance: Length of scheme, 20 miles; 49 square miles of area covered; 54 lines of intervisibility determined, 34 selected for scheme. Triangulation; 369 square miles of area covered; 24 signal poles erected; 22 observing tripods and scaffolds built, heights—20 tripods, 5 feet, 2 scaffolds, 35 feet; 43 stations in main scheme occupied for horizontal measures; 91 geographic positions determined. Leveling: One permanent bench mark established; 1 mile of levels run. Magnetic work: 37 land stations occupied for magnetic declination; 110 sea stations occupied for magnetic declination; 2 sea stations at which ship was completely swung. Topography: 138 square miles of area surveyed; 67 miles of general coast line surveyed; 5 miles of road surveyed; 2 topographic sheets finished, scales 1:10,000 and 1:20,000. Hydrography: 96 square miles of area dragged; 16 miles of area covered by soundings; 262 miles run while dragging; 67 miles run while sounding; 5,352 positions determined (double angles) in dragging; 649 positions determined (double angles) in sounding; 31 soundings made in dragging; 745 soundings made in sounding work; 6 tide stations occupied; 4 hydrographic sheets nearly completed, scales, one on scale 1:20,000 and three on 1:40,000.

From March 24 to June 30, 1921, the steamer *Explorer* was engaged in continuing work begun in the previous season in extending an arc of primary triangulation from a base in Dixons Entrance, through Clarence Strait, east of Marmion and Nulikoff Islands through Frederick Sound, Stevens Passage, Gastineau Channel, and Lynn Canal to the headwaters of the Yukon, to which it was intended that all of the triangulation in southeastern Alaska should ultimately be connected and adjusted.

Besides the triangulation the wire-drag work was to be carried through all of the principal channels.

It was intended that a spur of tertiary triangulation should be carried up Gastineau Channel for the control of the topography and hydrography.

The instructions contemplated the development of the inshore hydrography of Gastineau Channel, including the revision of the hydrography between Juneau and Salmon Creek; and the completion of the dragging of Lynn Canal from the work done in 1917 to Skagway.

The topography of Gastineau Channel was to be executed as far as Salmon Creek and the work extended to the head of Lynn Canal.

In 1920 the gap in the triangulation of 1917, a distance of about 45 miles, was filled in by tertiary triangulation by the party on the steamer *Explorer*, so that the main-scheme reconnoissance necessary to prepare the scheme for primary work was completed. Two bases had been measured in 1917 at considerable distances from the localities at which the parties discontinued work. The scheme for 1921 was accordingly almost a duplication of the previous year's tertiary work. Only a few stations were moved to insure better marking or improved conditions for setting up the instrument and tent. One station was shifted to reduce observations necessary to reach the base site. After careful study of the previous work and of the possible places for measuring bases, it was found that two bases would be necessary. Excellent sites were found for both bases, and these were the only sites practicable. There are frequent stretches of sand beaches, but with very few exceptions they are cut off at short intervals by cliffs reaching to the low-water line. The base nets were given careful study, and they have been included in the work.

At the close of the year all but 3 of the 22 main-scheme stations were completed, and satisfactory closures had been obtained. A few stations with very short lines had to be reoccupied. Nearly all of the work except on some of the longer lines was done by daylight—that is, early morning or late afternoon—using targets which under the conditions appeared to eliminate phase in a satisfactory manner.

Tertiary triangulation was done for the control of the hydrography and topography in Gastineau Channel. A scheme of continuous quadrilaterals was worked out. This work was practically finished during the preliminary period of preparation for the drag work. Special effort was made to recover and locate any Land Office monuments, Geological Survey stations, etc., that could be recovered. At the close of the year only two stations remained to be observed. The triangulation done was continuous with that of the previous year's work. At the end of the year work was completed to Point Young on the south side of Stevens Passage, and form-line work was finished on both sides of the channel

to this point. On the north side work was continuous with that of the party operating here in 1917. The work includes form lines not finished by this party. The work in Gastineau Channel was practically completed. This was supplemented by information received from various sources—Land Office maps, Geological Survey maps, work of city engineers, mining companies, etc.—to avoid duplication and at the same time to produce a chart corrected to the present date.

The magnetic work done includes the special survey of the area of local attraction of Port Snettisham, both land and water observations. The former were done by compass declinometer and the latter with the ship's compass after careful determination of deviation. The phenomena of this region as developed proved of exceptional interest. A vessel proceeding at the speed of the *Explorer* past Sentinel Point will get a sudden very rapid shift of the compass through 55°. This work required primary plane-table triangulation.

Elsewhere as many stations as practicable were occupied with the compass declinometer to detect the existence of local attraction. This work was not carried very far, owing to the lack of an available boat and officers.

In the hydrographic work the sweep was used practically as it was developed in the previous season. The amount of sweep work remaining from the last season's work was comparatively small. However, it was found that much of the shoal-water work with general depths of over 20 fathoms could be covered with the sweep if the bottom were not too rocky, and this was done to a degree previously believed impossible. No area that can be covered with the sweep in the general region of Juneau remains to be done.

The sweep has been used successfully under very adverse conditions. On one occasion off Port Snettisham the sweep was towed through violent tide rips with a head tide, the rips being such that the worst places had to be avoided by the tender for its safety, yet the progress of the sweep was not retarded. A number of shoals were found with the sweep and developed with the drag. The customary length of the sweep was 12,000 feet. This is now set out with the launches practically at full speed. Improvements in methods and apparatus have made this possible.

Sweep work is now fully standardized. The open waters of Alaska present no further problem but simply the application of routine methods. No records of area were made during this period, as all of the work was completed before beginning the new locality. Preparations were completed for work on a large scale in Lynn Canal.

The progress in wire-drag work represents the great advance made by this party in two seasons in Alaska. The drag developed on the Atlantic coast was a highly efficient apparatus and probably had reached its maximum possible development under prewar conditions. New ideas suggested by war experience, and in a no less degree improved materials resulting from investigations made by wire companies during the war, have placed this work on a new basis. The weakest feature of all drag work had been its inability to contend with currents. With fair currents the drag had been wonderfully successful, and great results had been obtained in Alaska as well as on the Atlantic coast. With the substitution of the sweep for the drag in all deep-water work, it became important that the drag should be specially fitted to get more results in its own field. At the same time the shoal areas have always been characterized by stronger currents than the deep waters adjacent.

The problem may now be considered solved. No claim is made that the drag work can be done successfully against all currents, but any ordinary conditions cause no difficulty now. Drags are towed at any desired speed without danger or damage to gear, and progress can be made whenever desired.

The drag work of this season was exceptional in quantity for Alaska, in fact comparable with any work on the Atlantic coast except that greater results have been obtained in a given time than ever before. The alongshore area left unfinished last year has been found to include a very considerable number of uncharted rocks, quite a few of them at dangerous depths.

The improved behavior of the drag is due to new apparatus devised for the use of this party, and it is probable that the new methods and apparatus will have to be adopted in all drag work to stop the loss of time heretofore unavoidable. This applies to wire-drag work in any locality. The sweep and the drag are now frequently used on the same day, no area that can be covered by the sweep being done by the drag. It is now easy to do any required work with the drag, as there is no difficulty in shifting the depth through wide ranges.

The drag work resulted in finding 18 rocks with a less depth than charted, which is quite comparable with a similar amount of work done anywhere.

The progress in wire-drag work has been notably increased by the new practice of obtaining soundings in advance in all doubtful areas. These soundings are often obtained just in advance of the drag work, the soundings being obtained on the same day and plotted before the drag reaches the area affected. This adds immensely to the value of the drag work.

The drag depth is frequently tested to make sure that the higher speed does not introduce uncertainty in depth.

The time of setting out the drag is greatly reduced and also the time required to change the depth. In a recent case a 4,500-foot drag was lowered throughout its length, 4 feet in 14 minutes. This means that assuming that 6 minutes is spent in maneuvering at each buoy only an average of 48 seconds is required to stop at each buoy and change the depth. The lowering is so fast that the weights can not sink as far as the wire is pulled off the buoy, and it is necessary for the tender to move the buoy so that the wire will run out. The possibility of quickly changing the drag depth makes it practicable to go close to known shoals before changing the depth, and to lower the drag more quickly at passing; this adds much to the value and economy of the work. Taking the soundings in connection with the drag work is practically a new feature which was developed during the season, although soundings have been taken in the past for the control of drag work. The conditions in Alaska are different from those elsewhere. In fact the charts are of little value for control of drag depth, especially along the shore. The new practice of making a survey along the shore and in the vicinity of shoals in advance of the drag work represents a marked advance, and by this means valuable information is obtained in regard to a heretofore unknown area in drag work, that lying between the work of the drag and the topography of the shore.

This is made possible by the three-man hydrographic launch. By the methods developed it is very easy to do this work without unnecessary expense and with no delay to other work.

Another development is the elimination of the cotton lead line in connection with drag work. The lead line now used is of the same wire as the uprights and is very flexible. Its small diameter makes it possible to keep it vertical in the slow current. It is not as hard on the hands as might be expected. Graduations are painted at 1-foot intervals. This eliminates all uncertainty in regard to depth and does away with the uncertainty of entering old-line corrections in the records.

The soundings are placed as in ordinary hydrography. Their purpose is to find the width of the shoal reef along the shore or the general extent of a shoal. This is done by a single line of soundings along the shore if the shelf is narrow. If it is broad, zigzag lines are run in order to get the curves more rapidly, and later one or more lines parallel to the shore are run. Positions are taken at every sounding, the launch being stopped for each sounding.

Automatic tide gauge observations were taken at Taku Harbor during the progress of the work. Staff readings were obtained in the vicinity of work distant from the automatic gauge as during the past season. Bench marks were connected with gauges by lines of leveling.

Several areas, suitable landing fields for airplanes, were examined. The only difficulty was in finding fields in the vicinity of towns. The emergency fields more or less accessible to other lines of connection are easily found.

[E. H. PAGENHART, Commanding Steamer *Lydonia*.]

SUMMARY OF RESULTS.—Triangulation: 10 signal poles erected; 10 stations in main scheme occupied for horizontal measures; 11 geographic positions determined. Leveling: 3 permanent bench marks established; 4 miles of levels run. Topography: 30 square miles of area surveyed; 517 miles of detailed shore line surveyed; 2 topographic sheets finished, scale 1:20,000. Hydrography: 483 square miles of area covered; 5,262 positions determined (double angles); 7,054 soundings made; 1 tidal station established; 3 hydrographic sheets finished, scales 1:20,000 and 1:120,000.

On July 1, 1920, field work was in progress by the steamer *Lydonia* on the west coast of Dall Island, southeast Alaska.

The short season available for work made it desirable to confine operations to one area and to complete as far as possible all work within that area. For this reason the triangulation connecting Bucareli Bay with Noyes Island was not undertaken. An effort was made to complete the topography and hydrography along the coast of Dall Island.

The unfinished work within the area in which the party was working included the hydrography of Sakie Bay; investigation of several shoal soundings along the shore of Dall Island; further development on south coast of Suemez Island; and continuation of the shore line on Dall Island from station Last northward to a satisfactory junction with previous work.

The ship was engaged on offshore soundings from August 23 to the end of the season.

The *Cosmos* was engaged on inshore hydrography between Cape Augustine and Meares Passage during the entire season, except for 10 days spent on triangulation. The topography from Cape Augustine to station Last at the entrance to Meares Passage was done by a subparty with the launch 47 operating from a camp.

At Craig an automatic tide gauge was left in operation throughout the season. A very good record was obtained covering four months.

At Sea Otter Harbor an automatic gauge was kept in operation by the hydrographic party for tidal reductions. The tidal record obtained from this station was unsatisfactory, and the record was only used for simultaneous observations with the Craig station and for a comparison of hourly heights.

A comparison of the hourly heights of tides between Sea Otter Harbor and Craig station, covering five different periods, totaling 24 days between July 29 and October 7, shows the greatest discrepancy to be plus or minus 1 foot with an average plus or minus four-tenths of a foot. Because of this small difference in height the Craig data were used for all tidal reductions entered in the sounding record. The Sea Otter record was not used at all.

Sea Otter Harbor on Dall Island was used throughout the season as a base for the detached parties, and a season's supply of coal and provisions was stored here.

Ketchikan was the base for the ship, as there was no place closer to the working grounds where coal could be landed.

Early in the season no suitable docks were available for storing coal. After August 1, a dock at Waterfall was available, but transportation then was too uncertain. One trip was made to Prince Rupert, British Columbia, for coal; at all other times Ketchikan was able to supply it.

The weather during the season was fair. The parties working along the shore encountered much more fog and rain than did the ship working offshore. Weather conditions are extremely local, and there is no way of judging the weather other than by being on the immediate working grounds.

On August 30, the locality was hit by a sudden and severe southeaster. At the first indication of bad weather the ship, sounding to the southward of Baker Island, ran to Cape Felix, a two hours' run, hoping to be able to pick up a whaleboat party which had been landed there that morning. On reaching Cape Felix, the vessel steamed about for an hour watching for the whaleboat party which it was thought might have put out from shore before the storm. Seeing nothing, the ship remained in Port Santa Cruz during the night; and next morning steamed back to Cape Felix and found the party safe on shore, although the boat was broken up on the beach.

Sounding tubes were used in this work with good results.

[J. S. BILBY.]

Under instructions dated April 20, 1921, this officer left Washington, April 22, for Ketchikan, Alaska, to construct launch ways and a boathouse at that place for the use of the vessels of the Survey.

Owing to delays in transportation the party was unable to leave Seattle until May 15, arriving at Ketchikan on the 18th.

On May 19, with the cooperation of the superintendent of lighthouses at Ketchikan, a site for the ways was selected in the most favorable place available on land covered by a license held by the Pure Food Fish Co., of Ketchikan. Satisfactory arrangements were made with this company to remove any of their property that might interfere with the construction of the ways so that work might start immediately.

The work of clearing the ground, which was heavily timbered, was begun May 21, and by June 2 the ground was cleared, stumps grubbed out, part of the lumber and material on the ground, and work on the foundation begun. By June 30 the building was inclosed, the building of ways well advanced, and all the necessary material on the ground for completing the work.

SITKA MAGNETIC OBSERVATORY.

[F. P. ULRICH.]

The work of the Sitka magnetic observatory has been carried out without material interruption throughout the year. The magnetograph has been kept in continuous operation. The D and H variometers worked very satisfactorily and required little adjustment. At the end of the year, the H variometer was taken apart in order to secure a freer movement of the collar which holds the deflection bar. Considerable trouble was experienced with changing scale value of the Z variometer, and it was cleaned and adjusted on June 30.

At least one component of the seismograph was in operation throughout the year, but only nine earthquakes were recorded. Much trouble was experienced with the bearings of the recording arm of the E–W component, so that the instrument was either out of commission or not giving satisfactory record for the greater part of the year. New steel cup bearings were inserted on June 28, which are apparently very satisfactory.

Absolute observations were made once a week and scale value determinations at least once a month. Comparison observations were made with magnetometer No. 40, which had previously been compared at Cheltenham, Tucson, and Honolulu. The chronometers were kept rated by means of time signals from the local office of the U. S. Signal Corps. Various repairs were made to the buildings, and the clearing of the observatory grounds was completed

HAWAIIAN ISLANDS.

HONOLULU MAGNETIC OBSERVATORY.

[H. E. MCCOMB.]

The work of the Honolulu magnetic observatory was carried out without interruption throughout the year except as noted below. The magnetograph was kept in continuous operation and required little adjusting. The usual scale-value and base-line determinations were made. The installation of a small wireless receiving set early in 1921 made it possible to get the time signals sent out daily from Pearl Harbor and dispense with solar observations with sextant and artificial horizon.

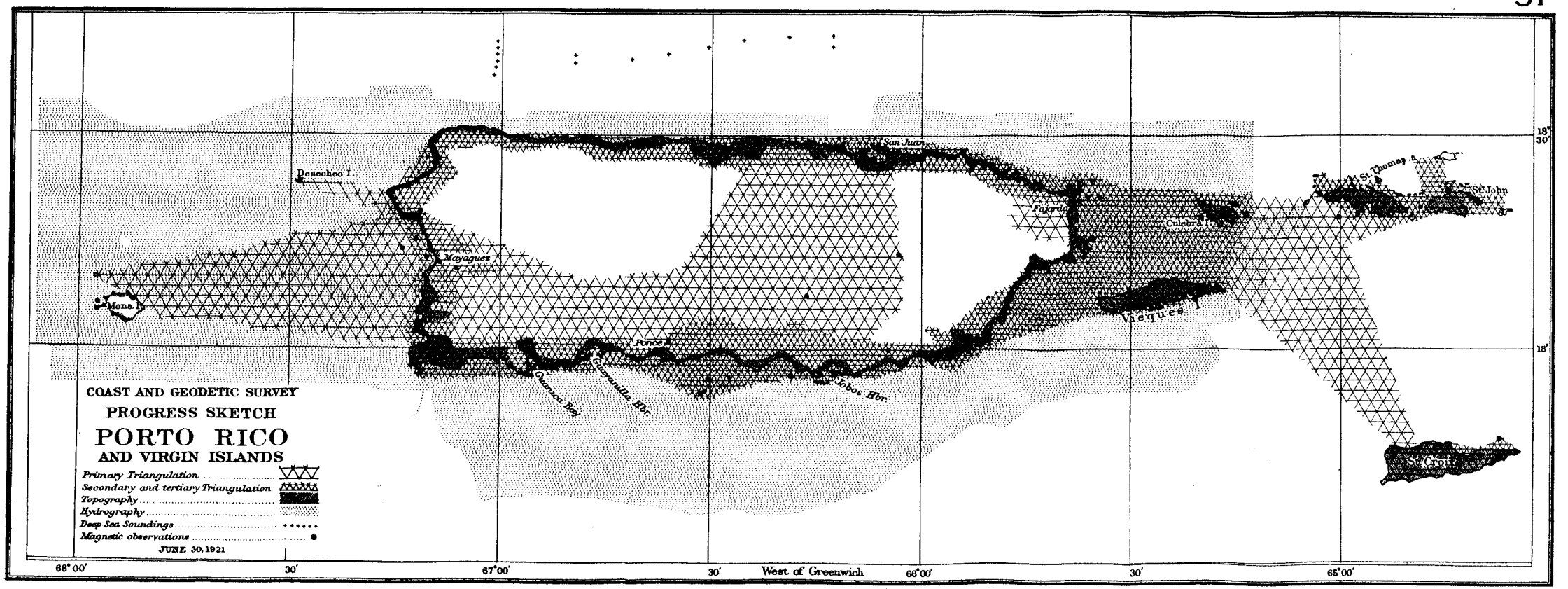
The old Milne seismograph was dismounted on January 27, and work was begun at once on the construction of piers for the new Milne-Shaw seismograph. The work was delayed somewhat by the breaking of the pump, so that water for mixing the concrete had to be taken from the well in buckets. The new instrument was mounted on February 19, and the continuous record begun on the 27th. Except for this period of a month a seismograph was in operation throughout the year, and 88 earthquakes were recorded.

In April, 1921, a party from the yacht *Carnegie*, of the department of terrestrial magnetism of the Carnegie Institution of Washington, made an extended series of observations at the observatory for comparing their instruments with those at the observatory. Simultaneous observations were made, using an auxiliary station near the absolute building, with interchange of station in the middle of each series of observations.

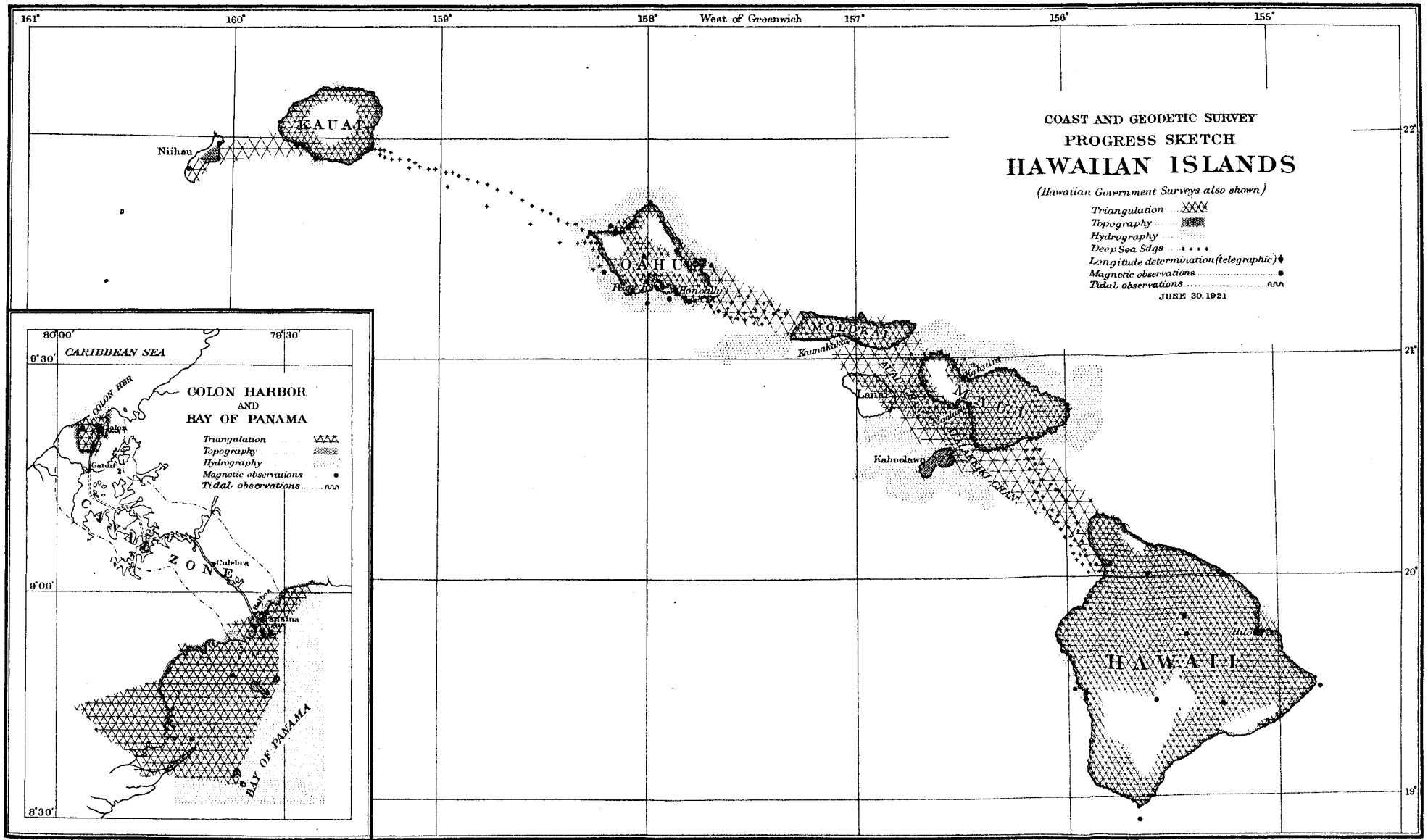
During August, 1920, the chiefs of the divisions of geodesy and terrestrial magnetism visited Honolulu as delegates to the Pan-Pacific Scientific Congress and while on this duty inspected the magnetic observatory. The observer was a local delegate to this congress and was able to attend the meetings on the island of Hawaii through the kindness of a former magnetic observer now resident in Oahu who was willing to take temporary charge of the observatory.

The buildings were painted outside, a new dark room was fitted up in the building used also for a garage, a vestibule was added to the seismograph house, many minor repairs and alterations were made to the observers' quarters, and the inside was painted.

A siphon lamp filler was made for use with the magnetograph lamp and proved to be a great convenience and timesaver. Drawings for a new magnetograph reading glass were prepared and submitted to the office, and scales of this style are now in use at all of the observatories.


COAST AND GEODETIC SURVEY
PROGRESS SKETCH
PORTO RICO
AND VIRGIN ISLANDS
Primary Triangulation
Secondary and tertiary Triangulation
Topography
Hydrography
Deep Sea Soundings
Magnetic observations
JUNE 30, 1921
Desecheo I.
Mona I.
Mayaguez
San Juan
Fajardo
Culebra I.
Vieques I.
St. Thomas
St. John
St. Croix
Ponce
Guanica Bay
Guayanilla Hbr.
Jobos Hbr.
18° 30'
18°
68° 00'
30'
67° 00'
30'
West of Greenwich
66° 00'
30'
65° 00'

C.& G.S. Print


COAST AND GEODETIC SURVEY
PROGRESS SKETCH
HAWAIIAN ISLANDS
(Hawaiian Government Surveys also shown)
Triangulation
Topography
Hydrography
Deep Sea Sdgs
Longitude determination (telegraphic)
Magnetic observations
Tidal observations
JUNE 30, 1921
West of Greenwich
161°
160°
159°
158°
157°
156°
155°
22°
21°
20°
19°
KAUAI
Niihau
OAHU
Honolulu
MOLOKAI
Kaunakakai
Lanai
MAUI
Kahoolawe
HAWAII
Hilo
CARIBBEAN SEA
COLON HARBOR
AND
BAY OF PANAMA
Triangulation
Topography
Hydrography
Magnetic observations
Tidal observations
COLON HBR
Colon
Gatun
CANAL ZONE
Culebra
Balboa
Panama
BAY OF PANAMA
80°00'
79°30'
9°30'
9°00'
8°30'

C & G.S. Print

PHILIPPINE ISLANDS.

[H. C. DENSON, Director of Coast Surveys.]

During the first half of the fiscal year 1921 the quantity of surveying results and of chart construction accomplished by the Manila field station was much below the normal, due to the greatly depleted numbers in both field and office force assigned to this station.

Only two vessels were engaged in surveying work during this period, as it was impracticable to furnish the necessary complement of officers for additional vessels.

The office work was seriously handicapped by the insufficiency of technical help, which caused additional work to be placed on those already laboring under multiplied duties.

The field work accomplished includes the following:

West coast of Mindanao—Dapitan to Caldera Bay. The triangulation of this stretch of coast line was completed, and the work of topography and inshore hydrography had progressed to the extent that only a short time would be required to complete it.

Cuyo West Pass.—The detailed survey of the waters of Cuyo West Pass that had been in progress for the past three years was completed October 2.

East coast of Luzon Island.—A careful investigation was made of the waters off the north coast of the Camarines, which shows that the reported extensive 3 fathoms bank 36 miles off this coast does not exist. The result of this investigation will furnish the navigator of deep-draft vessels all desired information for the safe approach to the port of Hondagua, the east coast terminal of the Manila Railway Co.

The principal routes of commerce in the archipelago have been surveyed; the greater part of the remaining work to be done is distantly located from a base of supplies and coaling station.

Although the surveying operations planned for the year 1921 will be carried on with the present existing conveniences, economy will require that a coaling station be established on the west coast of Palawan and at Aparri, north coast of Luzon, before the surveys in these localities are attempted.

On August 31 a severe typhoon passed over Manila and did considerable damage to the working equipment of the Survey.

The steamer *Marinduque*, which was moored at Engineer Island, having just completed extensive repairs, was fouled by a vessel that had been blown adrift by the storm and sustained considerable damage. One whaleboat, property of the United States Government, on the steamer *Romblon*, was destroyed.

The Manila tide station, located on one of the Government piers, was completely demolished. Preliminary steps toward building a new station to be located on the new concrete pier, in process of construction by the Philippine Island Government, were immediately begun. An appropriation was made for this work by the Philippine Government.

On October 3 a disastrous fire occurred in the building in which are located the Manila offices of the Coast and Geodetic Survey, but due to the timely assistance of a number of employees the loss sustained by the Coast and Geodetic Survey was of no consequence, and on the second day after the fire the routine business of the Bureau was being conducted as before.

Satisfactory progress has been made on the building to house the photographic plant, which was expected to be ready for occupancy upon the arrival of the machinery.

During the half year ending June 30, 1921, the party of the steamer *Pathfinder* was engaged in extending the hydrography off the north coast of Camarines Norte, between Jomalig and Catanduanes Islands, to the depth of 1,000 fathoms. This work included the search for the extensive 3 to 5 fathoms bank shown on the existing charts of this area. The work progressed satisfactorily and disproved the existence of any obstructions to navigation in the area formerly shown as dangerous. The party on the vessel also successfully completed the work of extending the triangulation on Negros Island to a junction with the triangulation on the south coast of Mindanao Island, at Sibuguey Bay.

The party of the steamer *Fathomer* was engaged during the year in combined operations on the west coast of Zamboanga Peninsula, deep-sea hydrography in the Sulu Sea, and a hydrographic survey of Cuyo West Pass, and the

detailed hydrographic work in the vicinity of the Cagayan Islands was brought to completion.

The steamer *Marinduque* was at Engineer Island, Manila, from July 1, 1920, to March 15, 1921, as it was impracticable to provide a sufficient number of officers to furnish a complement for this vessel. From March 16 to May 13 the party on this vessel was engaged in making a resurvey of Bacoor Bay, Cavite, and from May 24 to June 30 was engaged in revision work in the vicinity of Albay Gulf and Lagonoy Gulf.

[R. R. LUKENS, Commanding Steamer *Pathfinder*.]

SUMMARY OF RESULTS.—Triangulation: 4,705 square miles of area covered; 54 signal poles erected; 5 observing tripods and scaffolds built, heights 14, 17, 38, 42, and 65 feet; 22 stations in main scheme occupied for horizontal measures; 13 stations in supplemental schemes occupied for horizontal measures; 16 stations occupied for vertical measures; 61 geographic positions determined. Hydrography: 4,485 square miles of area covered; 1,907.2 miles run while sounding; 6,946 positions determined (double angles); 29,021 soundings made; 3 tidal stations established; 2 hydrographic sheets finished, scales 1:40,000 and 1:200,000.

After completing repairs at the Olongapo Naval Station, the steamer *Pathfinder* proceeded to Manila to take on stores and prepare for work off the east coast of Luzon. The vessel was ready to sail for the working grounds on July 15, but on account of the unfavorable weather her sailing was delayed until July 26 when the weather moderated sufficiently to permit a start.

The ship arrived at Batan Harbor on July 28, where the bunkers were filled with Batan coal. This coal is of an inferior quality, but owing to the high price of Japanese coal and the great distance to a coaling station it had been decided that the *Pathfinder* should make an attempt to use this coal. After some experimenting a method was discovered by which this coal could be used with fair results, and on the morning of July 30 the vessel started for the working grounds.

The instructions called for the offshore hydrography of a large area extending from Catanduanes Island to the Polillo group, and the development of a great 3 to 5 fathom shoal which appeared on all existing charts having been handed down from the earliest Spanish sailing directions.

The tide station was recovered in Sisiran Bay, a staff erected, and levels run to connect with the old bench mark. The readings of this staff were used for the reduction of the entire season's hydrography.

The ship's hydrography was at once taken up and continued with but few breaks to the end of the season. Lines were run in a north and south (true) direction one-half mile apart to the 100-fathom curve, and from there on gradually widened until they were about 5 miles apart at the 1,000-fathom curve.

Tanner-Blisch pressure tubes were used in depths up to about 40 fathoms with up-and-down casts about every tenth sounding. In deeper water vertical wire measures were made. Considerable time was saved by anchoring with a kedge and a rope wherever the ship happened to be when overtaken by darkness. At daybreak the line was simply continued. Officers and crew were assigned to regular watches so that the ship could operate 24 hours per day, and always did so when running out to the 1,000-fathom curve.

The shore signals could be carried barely to the 100-fathom curve, hence the work beyond that line depended upon astronomic fixes and dead reckoning.

The dangerous shoal shown on the charts was not found. However, at the edge of the great 40-fathom bank extending about 35 miles offshore, there was found a long ridge with 10 to 20 fathoms over it, extending in a direction parallel with the shore line. It is possible that this ridge through exaggeration has been reported as the "3 to 5 fathom bank." No dangers to navigation were found during the season.

While a large area was finished during the season, the work was not completed, and at least one more season's work is required.

Upon arrival at Manila instructions were received to prepare for field work on the northwest coast of Mindanao. The work assigned was to complete the triangulation started during the previous year by this vessel and to make a connection with the old work in Sibuguey Bay.

After having a few minor but essential repairs made at the Cavite Naval Station, and having outfitted the ship, the *Pathfinder* sailed for the working grounds on November 1.

While off the coast of Panay a typhoon warning was received, and as it was apparent that the storm would be a dangerous one for the Visayan

Islands, the *Pathfinder* sought shelter in Iloilo. This port was reached about five hours before the force of the storm broke, and a snug berth was found in the river. The center passed a short distance to the north, and very heavy winds were experienced in Iloilo, but no damage was done to the ship. Over 200 houses were blown down in that city, and several small craft were lost in the neighboring waters.

After the storm passed the *Pathfinder* continued her voyage and arrived on the working grounds in the early morning of November 6.

The triangulation to be accomplished was a scheme extending from southern Negros to Sibuguey Bay, a distance of about 95 miles, and involving several lines up to 75 miles in length. Most of the signals had been built the previous year and were standing, but observations at two stations only had been completed. More clearing was required at two stations, and station Labuk (*Fathomer*, 1920) had to be rebuilt. This was unfortunate, as it was a concluded station in the instructions of this party and otherwise would not have been visited. The longest line, Siaton-Dansalan, remained unobserved in either direction.

For the long lines special heliotropes were made on board with mirrors 12 inches square. This large size was considered necessary, owing to the fact that the atmosphere is usually hazy at this time of the year and a powerful glare is needed to penetrate it.

Upon arrival the various signal structures were inspected, and four parties of observers and heliotropers were immediately put in camp, while the ship recovered the station on Aligbay Island and built a signal over it. This station was also occupied by a party from the ship during the time it was tending the various parties encamped ashore.

By November 21 it was necessary to go for coal, so the ship left for Sandakan via Zamboanga, where a subparty was dispatched to Sibuguey Bay to rebuild and do the necessary clearing at station Quipit. They arrived at Sandakan early on November 24, and after taking on 284 tons of coal, sailed at 6 p. m. the same day. This was an unusually quick coaling.

Upon return to the working ground it was found that the observations had been completed to the line Dansalan-Talinga. Parties were then sent to rebuild and clear at Coronado and to rebuild Labuk. By December 10 this work was completed, and the ship proceeded to Sibuguey Bay to start that end of the work.

An observer with heliotropers was put in camp on Mount Quipit, and the ship took up the work of recovering and building signals over old stations Pan and Wedge located on islands in Sibuguey Bay. These stations formed the line to which the connection was to be made.

After completing this work the *Pathfinder* returned to the northwest coast of Mindanao to pick up the party left at Coronado. A bad surf was running, but the party was finally picked up without serious accident. The whaleboat was damaged somewhat and the theodolite soaked with salt water, but none of the party received injuries.

The ship then returned to Sibuguey Bay, and on December 22 a party of 1 officer and 15 men was dispatched to station North End (*Fathomer*, 1920) to rebuild and occupy that station, also to clear lines of sight to points in Sibuguey Bay. With observers and heliotropers stationed at Quipit, Pan, and Wedge, they were in a position to complete the work as soon as North End made its appearance. On December 28 North End suddenly appeared, and in a short time observations on it were completed.

By December 31 all parties were back aboard the ship, and the vessel left that night for Manila.

The officer who was in charge of the party at North End ran into a very heavy job of clearing and was unable to finish in the time estimated, thus necessitating that the party go on short rations for several days. After the signal was erected he sent 12 of his men back and remained with 3 men to finish the observing. He completed his program but was forced to travel 36 hours without food before reaching the beach. The party was badly exhausted but rapidly recovered without serious results.

While encamped under the signal structure at Disacan this party had a narrow escape from serious accident. During a heavy electrical storm the signal was struck by lightning and partially destroyed, but fortunately none of the party were struck by falling timbers. They reported that the wire guys were repeatedly red hot and that several of them fused. None of the party were injured by the shock.

Taken as a whole this piece of triangulation was a very difficult one, and the hard and conscientious work performed by the various officers and crew is hereby acknowledged.

Acknowledgment is also made to the superintendent of the San Ramon Penal Farm who furnished large parties of prison laborers on two occasions for the very difficult expeditions. These men are far stronger and better on the trail than the sailors aboard the ship, and they proved a great assistance in the successful prosecution of the work.

From January 1 to 5 the *Pathfinder* was engaged in combined surveys on the west coast of Mindanao when she was taken to Olongapo Naval Station for repairs.

Necessary repairs having been completed, the *Pathfinder* arrived on her working grounds in Lagonoy Gulf March 16, and was engaged in surveying operations from that date until May 16, when she proceeded to Jomalig Island and took up hydrographic work in that vicinity.

In June the hydrography in the vicinity of Jomalig Island was finished, and the vessel began the work of deep-sea sounding between Jomalig and Catanduanes Islands, which was in progress at the close of the fiscal year.

[K. T. ADAMS, Commanding Steamer *Fathomer*.]

SUMMARY OF RESULTS.—Leveling: 6 permanent bench marks established; 19.5 miles of levels run. Magnetic work: 5 land stations occupied for magnetic declination; 2 stations at sea at which ship was completely swung. Topography: 322.5 square miles of area surveyed; 211 miles of coast line surveyed; 3 miles of shore line of rivers surveyed; 7 topographic sheets finished, scale 1: 20,000. Hydrography: 7,882.9 square miles of area covered; 11,803.6 miles run while sounding; 13,817 positions determined (double angles); 73,199 soundings made; 8 tide stations established; 3 current stations occupied; 11 hydrographic sheets finished, scales 1: 20,000, 1: 40,000, 1: 80,000, 1: 100,000, and 1: 200,000.

Ship hydrography was in progress by the *Fathomer* in Cuyo West Pass from July 1 to August 4. On August 5 the ship discontinued work temporarily and sailed for Manila for minor repairs and supplies. The week from August 7 to August 15 was spent at Engineers Island. On the 16th the ship sailed again for the working grounds in Cuyo West Pass, arriving early on the morning of the 17th. Ship hydrography was at once resumed. This was continued, with interruptions by unfavorable weather, until October 3, when the work in this vicinity was completed. The ship sailed for Manila the same day, arriving on the 4th. From the 5th to the 30th the ship was again undergoing minor engine repairs and deck repairs, including docking and painting. During that time the officers were preparing the records for transmission to the office.

On October 30 the *Fathomer* sailed for the working grounds along the west coast of the Zamboanga Peninsula to resume the combined operations which were closed on May 12 in accordance with instructions.

Work was begun at once. An automatic tide gauge was established at Port Santa Maria, and one officer was put in camp to do the topography in that vicinity. The ship proceeded to Sibuko Bay, where a tide staff was established and another officer put in camp for topography. From here the ship went south to continue the work done on the first topographic sheet of the previous season, from San Ramon north. The first few days were spent in building and recovering old signals. The third topographic party was started at once and soon established enough signals to control the launch hydrography which was then started. From that time the work advanced rapidly, with but slight interruption to the end of the year. Ship hydrography was started after the first coaling. That also progressed without interruption until the week before the Christmas holidays, when rough weather, caused by a typhoon to the north, and very hazy weather, made it impossible to get any distance offshore.

The work in Cuyo West Pass is taken up in detail in descriptive report accompanying the hydrographic sheet. As stated there the greatest hindrance was the haze, which was especially bad during July and August. Later there was much excellent weather, with but one interruption, due to a bad typhoon, which made the ship seek shelter.

The work on the Zamboanga Peninsula proceeded rapidly. With the exception of the southern end of the first sheet the coast is extremely steep to. This limited the launch work to not more than a mile offshore, where more than 300 fathoms are sometimes found. Consequently the launch hydrography proceeded very rapidly. By December 31 two sheets were completed and several days' work done on a third. Extremely rough weather held up the work

on this sheet for several days. No shoals or indications were found on any of these sheets.

The ship hydrography also advanced satisfactorily. The launch as well as one topographic party worked from the ship, and it was necessary to arrange the work so that these parties could be picked up at night. The work was carried from limits of the launch sheets to points 15 or 20 miles offshore. While the bottom is in general quite irregular no dangers were found. In fact the only shoal found is one with a least depth of 48 fathoms with from 200 to 700 fathoms near by.

The first six weeks were in general quite favorable for topography, and rapid progress was made on three sheets. Afternoon rain squalls and cloudy mountain peaks were a hindrance though not serious. During the latter half of December rough weather made landing on the rocky and exposed coast a hazardous undertaking, and little was accomplished. This unusually rough weather was probably due to the combined effects of the regular northeast monsoon and a typhoon. The former blows with increasing vigor during the months of January and February and further unfavorable weather is to be expected.

Three 1:20,000 sheets were practically complete, and some progress was made on two others. Also a subsheet 1:10,000 of Port Santa Maria Harbor was completed.

Work was in progress on the triangulation at the end of December. This was for the purpose of establishing control for the topography above Port Santa Maria. The party of the steamer *Pathfinder* observed on some of the latter while occupying triangulation stations to the northward.

Five magnetic stations were occupied in the Cuyos, at three of which magnetic disturbances were found. No stations were occupied on the Zamboanga Peninsula.

While the launch work was in progress on the sheet above San Ramon the ship observed currents nightly. This was done every hour by the quartermaster on watch.

The steamer *Fathomer* was at Manila undergoing repairs from January 13 to April 16, 1921. On April 17 combined operations were begun in the Sulu Sea in the vicinity of the Cagayan Islands, and this work was in progress at the close of the fiscal year.

After December 31 one inshore hydrographic sheet on the Zamboanga Peninsula was completed and another about two-thirds completed. When the ship left the working ground all of the hydrography had been completed up to a point about 1½ miles north of Port Santa Maria.

Three of the four hydrographic sheets in the vicinity of the Cagayan Islands were completed, and the fourth was nearly completed.

The topography was completed from San Ramon north to a point about 3 miles north of Port Santa Maria.

On the Zamboanga Peninsula two new triangulation stations were established and six stations occupied for topographic control.

In the Cagayan Islands two main-scheme stations were built, two rebuilt, and all were occupied. Three intersection stations were built for hydrographic control.

In addition, five floating signals were built on the Nicholson Shoals and the Sultana Banks and were located by extant angles on a scheme running northward from the existing triangulation.

[H. A. COTTON, Commanding Steamer *Marinduque*.]

SUMMARY OF RESULTS.—Topography: 15 square miles of area covered; 20 miles of general coast line surveyed; 20 miles of shore line of ponds surveyed; 8 miles of roads surveyed; 1 topographic sheet finished, scale 1:10,000. Hydrography: 11 square miles of area covered; 384 miles run while sounding; 3,938 positions determined (double angles); 40,158 soundings made; 3 tidal stations etsablished; 1 hydrographic sheet finished, scale 1:10,000.

The steamer *Marinduque* was at Engineers Island, Manila, from July 1, 1920, to March 15, 1921, as it was impracticable to provide a sufficient number of officers to furnish a complement for this vessel.

From March 16 to May 13 the party on this vessel was engaged in making a resurvey of Bacoor Bay, Cavite, and from May 24 to June 30 was engaged in revision work in the vicinity of Albay Gulf and Lagonoy Gulf.

The topography comprised that between the coast line and the railroad from a point about midway between Las Pinas and Paranoque to a point on the west

shore of Cavite Peninsula opposite the former railroad junction. It included all of the Cavite Peninsula except the town of Cavite.

The hydrographic survey comprised the water area south of latitude 14° 30′ and east of the Cavite Peninsula with the exception of Canacas Bay.

An automatic tide gauge was in operation during the work, and tide staffs were established and connected with the gauge by simultaneous readings.

VIRGIN ISLANDS.

[E. R. HAND.]

SUMMARY OF RESULTS.—Triangulation, teritary: 18.5 square miles of area covered; 16 signal poles erected; 2 observing scaffolds built, height 20 feet; 6 stations in main scheme occupied for horizontal measures; 2 stations in supplemental schemes occupied for horizontal measures; 19 geographic positions determined. Magnetic work: 7 land stations occupied for magnetic declination. Topography: 33 square miles of area surveyed; 28 miles of detailed shore line surveyed; 40 miles of shore line of creeks surveyed; 135 miles of roads surveyed; 2 topographic sheets finished, scale 1:10,000.

Under instructions dated October 23, 1920, an officer of the Survey left Washington, November 12, for St. Thomas, Virgin Islands, taking passage on the 15th on the naval transport *Hancock*, but owing to various delays did not arrive at St. Thomas until December 2.

Preparations were immediately begun for the organization of the party for work on the island of St. Croix.

While in St. Thomas a revision was made of Harbor Chart No. 933, which was completed on December 15.

On December 22 the party sailed for Frederiksted on the island of St. Croix and crossed over overland to Christiansted, where the headquarters of the party were to be. The hands had been sent directly to Christiansted on the small schooner. The remaining portion of December was spent in revising a topographic sheet completed during the previous season, as required by the instructions for this work.

Up to the middle of January the party was engaged in the verification of this sheet. By January 15 work was begun on another sheet including an area of 24 square miles through the center of the island of St. Croix from shore to shore.

While engaged on this work a rapid reconnoissance was made with a view to the selection of sites suitable for landing fields for airplanes, as the result of which Mannings Bay was reported to be the only site available without extensive preparation.

After the completion of field work in this locality further information was gathered as to boundary lines and estate names which were required to be shown on the sheets. This requirement made necessary a close examination of the ground and the determination of an unusual number of controlling elevations.

The survey of the eastern end of the island of St. Croix, part of which had been left unfinished at the close of the previous season, covers an uninhabited region practically without roads and covered with a dense tropical growth. Buck Island and Green Bay were included in this survey. Work in this section was begun about the middle of April.

The triangulation was carried along with the topography and the entire survey was concluded about the 7th of June. This brought to a close the land survey of the Virgin Islands begun in 1918.

Triangulation control was extended over the east end of the island, including Buck Island, from the line Sight-Green determined in a previous season.

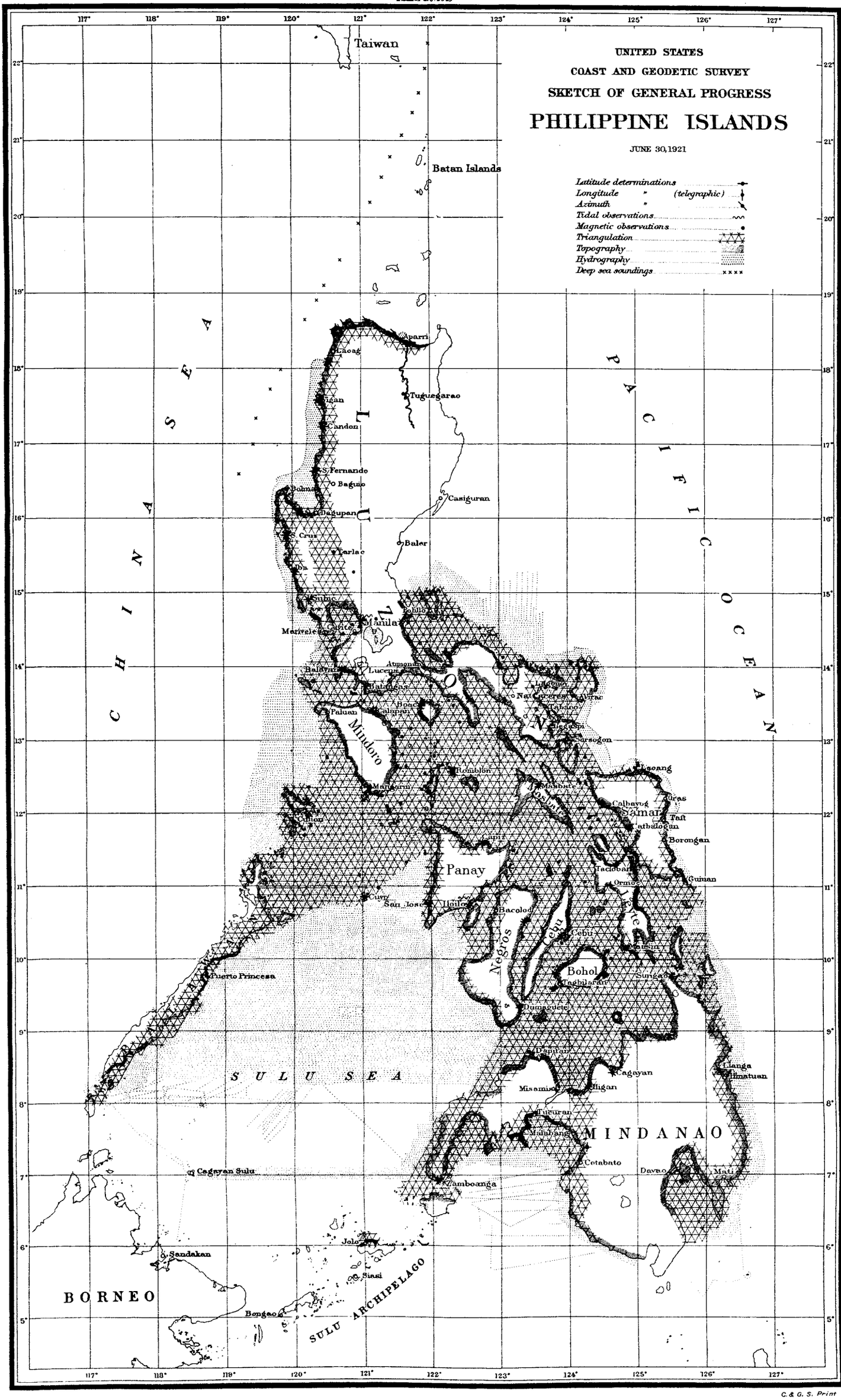
Four of the triangulation stations were occupied for magnetic declination.

PORTO RICO.

VIEQUES OBSERVATORY.

[WM. WALTER MERRYMON, July 1–Sept. 10, 1920. WALLACE M. HILL, Sept. 11, 1920–June 30, 1921.]

The work of the Porto Rico observatory was carried on throughout the year with only one serious interruption. On June 14, the magnetograph clock stopped, and it was found that the mainspring was broken. When the reserve recording apparatus was mounted that also failed to run because of injury to the escapement wheel. A watchmaker was finally found in San Juan who was able to



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substitute the mainspring of the reserve clock for the broken one, and registration was resumed on June 24. From May 13 to 17, 1921, a very severe magnetic storm was recorded.

The Z variometer required considerable adjustment during the first part of the year, due principally to the pivots, in one case the jarring due to a severe earthquake shock being sufficient, apparently, to dull the points. A new pair of pivots was installed about the middle of the year, and the variometer gave very satisfactory record for the remaining six months.

A comparison of magnetometer No. 19 and dip circle No. 56 with the observatory instruments was completed during July, 1920.

The seismograph was in continuous operation, and 25 earthquakes were recorded.

Absolute observations were made once a week, scale value determinations at least once a month, and meteorologic observations daily.

Time was determined by means of equal altitudes of the sun.

SPECIAL DUTY.

INTERNATIONAL COOPERATION CONFERENCE.

[WILLIAM BOWIE and H. G. AVERS.]

On March 8, 1921, the chief of the division of geodesy, accompanied by H. G. Avers, geodetic computer, went to Ottawa, Canada, for a conference with the Superintendent and other officials of the Geodetic Survey of Canada in regard to plans for cooperating in carrying precise triangulation along the forty-ninth parallel boundary and from Puget Sound into Alaska.

Plans were also made at this conference to make several additional connections between the precise leveling nets of the two countries and then adjust the two nets together. This will eliminate any possibility of troublesome discrepancies along the border.

PAN-PACIFIC SCIENTIFIC CONFERENCE.

[J. T. WATKINS.]

Under instructions dated July 12, 1920, an officer was designated by the Department of State as a delegate to the First Pan-Pacific Scientific Congress, to be held in the city of Honolulu, Hawaii, August 2 to 20, 1920. Under verbal notification and instruction issued by the Director dated July 8, 1920, this officer left Washington July 10, arriving in San Francisco on the 16th, and sailed from San Francisco for Honolulu on July 21 on the steamship *Manoa* in company with 14 others on the same mission.

Immediately after arrival at Honolulu on July 28 visits were made to the officials of the Territorial Government and others and preliminary work for the conference was begun.

The general organization of the conference was effected at the first meeting on August 2 and is outlined in the program submitted. The subdivision of the membership into sections, to which were assigned groups of closely related subjects for consideration and recommendation, and the formation of subsections within the sections where the major subject embraced several clearly defined and differentiated topics, greatly facilitated the deliberations of the conference and contributed much toward extending the scope and increasing the thoroughness of its work.

While the sessions of the conference were devoted to the presentation of general policies and subjects in their broader aspects, as indicated in the programs, the sections and subsections were more or less continuously engaged in the consideration of their assigned topics in detail and in the preparation of reports and recommendations which served as a basis for the adopted resolutions.

By reason of his connection with the Coast and Geodetic Survey the interest of the representative of the Survey centered largely in the section of geography, and more particularly in the subsections of physical oceanography; he is responsible for those parts of the resolutions which have to do with (*a*) "Magnetic Survey" and (*b*) "Survey of the Shore Line and the Coastal Waters."

The conference was informative to an unexpected degree, and in that respect will doubtless contribute notably toward cooperation and coordination in the several interdependent lines of work to be undertaken in the scientific explora-

tion of the Pacific Ocean. It was apparent at the early sessions that work in many fields of inquiry had been pursued without a full knowledge of the extent of the collected data on other related subjects or a clear understanding of their common interests. In establishing the necessity for such research work, indicating its great scientific and economic value, and pointing the way toward a more complete utilization of existing material, the avoidance of duplicaton and a closer cooperation, the conference was a success.

The proceedings of the conference dealt only with technical and scientific subjects and the ways and means of obtaining in satisfactory fashion desired results in various lines of research. No engagements were entered into and no commitments made; the activities of the delegates did not go beyond a statement of the present and future needs in the various fields of inquiry and expression of deep personal interest and a pledge to forward in all legitimate ways the projects recommended in the resolutions.

The work of the conference was made pleasant and profitable largely through the labors of the local organizing committees of the Pan-Pacific Union and to a marked degree by the untiring efforts of the Territorial Government and the citizens. The intelligent and appreciative interest displayed by the people of the islands and the sympathethic support tendered by them on all occasions served as a strong urge to the conference and encouraged the hopes that many of the projects embodied in the resolutions will soon be initiated.

The record of the proceedings of the conference was in preparation when this report was written, and it was the expectation that it would be published early in 1921.

The conference concluded its labors on August 20 and adjourned.

While in Honolulu the representative of the Coast and Geodetic Survey was engaged part of the time with matters having to do with various branches of the work of the Coast and Geodetic Survey in the islands and bearing only indirectly upon his duties at the conference.

INSPECTION DUTY.

[C. V. HODGSON.]

In the latter part of October, 1920, the assistant chief of the division of geodesy went to Yonkers, N. Y., to consult with the city officials and to inspect the precise triangulation covering the city, which was being done under the city engineer.

The scheme of precise control was found to be very well planned, and the work was making satisfactory progress. Some suggestions were made as to details of the work to bring the methods more nearly in accord with the most recent practices of the Coast and Geodetic Survey. The city officials expressed their appreciation of the assistance rendered them.

[WILLIAM BOWIE.]

On July 11, 1920, the chief of the division of geodesy started on an inspection trip which included two leveling parties in Oregon, the magnetic observatory near Honolulu, a triangulation party in Arizona, and a traverse party in Illinois. While in the Hawaiian Islands he attended and took an active part in the meetings of the Pan-Pacific Scientific Congress and also had numerous conferences with the governor and surveyor of the Territory of Hawaii, and with other officials as to the need for work by this Bureau in the islands. He returned to Washington on September 9, 1920.

Later, on February 11, 1921, he went to Boston, Mass., for a conference with the inspector in charge of that field station and with various city officials in regard to certain level lines needed in and around Boston and in regard to plans for cooperation between the city and this Bureau for doing the work.

[C. V. HODGSON.]

At the beginning of the fiscal year inspection was made of the work of a precise-traverse party operating in Indiana, and shortly after the beginning of the fiscal year an inspection was made of a primary triangulation party working in California and Oregon.

In the latter part of October, 1920, three days were spent at Yonkers, N. Y., inspecting the triangulation which was being executed by the engineering department of that city.

NEW YORK.

[CHARLES SHAW.]

SUMMARY OF RESULTS.—Triangulation: Length of seaplane speed trial course, 17 miles; 9 stations occupied for horizontal measures. Topography: 11 square miles of area surveyed; 35 miles of shore line surveyed.

On September 25 work was begun at Jamaica Bay, N. Y., on a speed trial course for seaplanes in the neighborhood of Rockaway, N. Y., and in determining points for photography in the same vicinity. Nine triangulation stations were occupied for this purpose.

This work was completed November 12.

AERIAL PHOTOTOPOGRAPHY.

NEW JERSEY AND LOUISIANA.

[G. C. MATTISON.]

SUMMARY OF RESULTS.—Triangulation (New Jersey): 3 stations in supplemental schemes occupied for horizontal measures; 2 geographic positions determined. Topography: 83 square miles of area photographed; 225 miles of detailed shore line photographed; 61 miles of shore line of creeks photographed; 16 miles of shore line of ponds photographed; 250 miles of roads photographed; 21 topographic mosaics finished, scale (approximate) 1:10,400. Triangulation (Louisiana): 305 square miles of area covered; 3 signal poles erected; 7 stations in main scheme occupied for horizontal measures; 3 stations in supplemental schemes occupied for horizontal measures; 41 geographic positions determined. Topography: 57 square miles of area photographed from an altitude of 5,000 feet, 175 square miles from an altitude of 8,000 feet.

Although an extensive program of aerial phototopography had been mapped out early in the year, the Air Services of the Army and Navy were unable to cooperate with this Bureau to the extent expected, and only a small portion of the work requested was done. Requests were made on the Air Service of the Army for a total of 2,660 square miles, comprising specified areas along the Atlantic coast from New York to Florida. They were unable to photograph any of these areas during the year. The only area requested from the Navy Air Service was the Delta of the Mississippi River, and 232 square miles of this area were photographed in the spring of the year. This project will be continued in the coming fiscal year.

The office work on the photographs of the New Jersey coast, which were taken in March, 1920, and which were referred to in the last annual report, was completed. Briefly, the process was as follows: Mosaics were constructed of convenient length, control points identified, and reductions made by means of the pantograph to the scale of the chart, only those data being reduced that were to appear on the chart. After the data had all been compared with the existing chart, it was found necessary to make a field inspection in order to account for discrepancies to fill in shore line missed by the photographs, to verify features which were not clear in the photographs, and to obtain other information otherwise not shown. The mosaics were examined in turn as the trip was made from Cape May to Seabright. Notes were made directly on the mosaics. After the field inspection only a few hours' office work was necessary to correct the reductions previously made.

Although the photographs covered an area 120 miles long and over a mile wide, the land area actually covered totaled only 83 square miles. The total cost of this work, including reduction to chart form, is about one-third the estimated cost of a plane-table revision of the same area.

The coast of New Jersey is covered by four charts. The aerial survey corrections are being applied whenever new editions of these charts are found necessary. One of the charts is already being issued with the corrections on, while two others are in process of correction.

In March an officer of this Bureau was detailed to represent the Coast and Geodetic Survey in a cooperative aerial survey of the Mississippi River Delta. The aerial photography was done by the Naval Air Service, the Corps of Engineers furnished equipment for the handling of the plane while at anchor and in the river, and also assisted in the location of the control points, while this Bureau determined the location of the control points.

South and Southwest Passes were photographed at an altitude of 5,000 feet, in order to furnish information for the constructing engineer. The remainder of the work was done from an altitude of 8,000 feet.

Office work on these photographs was in progress at the end of the year.

The Delta of the Mississippi is a locality where aerial phototopography has a marked advantage over other methods of surveying. It is a marshy area, a region of no relief, and covered with a rank growth of vegetation consisting chiefly of wild cane, which grows to a height of 12 feet or more. It can be readily seen how the engineer would be hampered in trying to make a topographic survey by ordinary methods.

The work was discontinued early in May, and will be again taken up in the fall of the year, when it is expected to complete the Delta. It is expected that the final results of this phototopographic survey will be a strong argument in its favor in this type of terrain, especially as regards cost and completeness of topographic detail.

The importance of aerial views other than those made purely for mapping purposes should not be underestimated. Oblique views often furnish valuable information to the cartographer, and they also assist in the compilation of the Coast Pilot. The Air Services have been requested to furnish this Bureau with copies of aerial views that might be of value. Considerable use was made of miscellaneous views during the year, especially along the Florida coast.

A new stereoscope is being designed for this Bureau by the Bureau of Standards. Arrangements were made in the latter part of the year to have this instrument constructed, as a stereoscope is a very valuable aid in the interpretation of aerial photographs.

Arrangements were made with the Corps of Engineers, U. S. Army, to obtain from them a transformer for the rectification of tilted photographs.

An officer of this Bureau was engaged during the past year in the study of aerial photosurveying, but almost all his time was taken up by the development of the practical side. During the latter part of the year a computer was assigned to devote part of his time to a study of the theoretical side.

Assistance was furnished to the Board of Surveys and Maps, through the Committee on Photographic Surveying, in the compilation of the comprehensive report on Aerial Photographic Surveying.

The results of the past year's work on this subject demonstrate the advantages of aerial phototopography quite clearly. Along the coastal plain of the Atlantic and Gulf coasts this method has a marked advantage over the old as regards time, cost, and minuteness of detail. The value of the photographs as historical records should not be overlooked. The topographic sheet contains certain specified data, while the photograph records everything visible.

DISTRICT OF COLUMBIA.

[C. A. MOURHESS.]

Under instructions issued June 15, 1921, and after conference with the officer in charge of the Anacostia Radio Compass Station, the necessary stations in the tertiary triangulation were recovered and occupied for the purpose of locating the position of the Anacostia Radio Compass Station.

No expense was incurred in the execution of this work.

MARYLAND AND VIRGINIA.

[EARL O. HEATON.]

SUMMARY OF RESULTS.—Triangulation: 1 station recovered, 2 stations determined.

In March, 1921, request was made by Lieut. Waikhart, U. S. Navy, for certain work in connection with the torpedo firing line on the lower Potomac River. The expenses of this work were met by the Navy Department, which furnished quarters, subsistence, and transportation to the observer.

The work done was the reestablishment of the forward range mark at the 8,000-yard point. This mark was supposed to have been destroyed but was recovered by use of the reference mark.

In addition to this work several range signals were built and two line buoys were located, one at the firing point and one at the 4,000-yard point. A tug and a 40-foot launch were used during the work for the transportation of the observer.

VIRGINIA.

[CHARLES SHAW.]

At the beginning of the fiscal year work was under way on the triangular speed trial course for airplanes in the vicinity of Hampton, Va., which had been undertaken at the request of the Navy Department. This work was finally completed in the early part of August.

Between August 5 and 24 the observer was engaged in establishing points by triangulation at the mouth of the Piankatank River as mentioned in another abstract.

SUMMARY OF RESULTS.—Triangulation, tertiary: 7 square miles of area covered; 3 signal poles erected; 1 observing tripod and scaffold built, height, 85 feet; 6 stations in main scheme occupied for horizontal measures; 4 geographic positions determined.

August 5 and 24, 1920, two triangulation stations, Boss and Cherry, were established and determined at the mouth of the Piankatank River for use as base stations for all future surveys required in the river, the old station marks having been washed away.

To make station Boss permanent it was necessary to place it just inside a wood and to construct a double scaffold 85 feet high to see Windmill Point Lighthouse over the trees along Stingray Point.

The triangulation was done at the request of the Commission of Fisheries of the State of Virginia for use in its surveys of oyster beds in the Piankatank River.

VIRGINIA AND NORTH CAROLINA.

[W. H. OVERSHINER.]

Between July 11 and 22, 1921, determinations were made by triangulation of the geographic positions of the Naval Radio Compass stations at Poyners Hill, N. C., Hog Island, Va., and Virginia Beach, Va., and an azimuth was determined at each station.

For this purpose stations of the Coast and Geodetic Survey triangulation were recovered and occupied.

The compass station at Poyners Hill is located about 50 meters northeast of Coast Guard Station No. 169. The latter it was found had been moved about a mile to the southward of the position shown on the charts.

The compass station at Hog Island is located in the yard of the Coast Guard station on the southern end of Hog Island, and is about 75 meters northeast of the Coast Guard station. This station was occupied eccentrically.

The compass station at Virginia Beach is located in the yard of Coast Guard Station No. 162 and about 20 meters north of the Coast Guard station.

CALIFORNIA.

[F. G. ENGLE.]

In April and May, 1921, the positions of the Naval Radio Compass stations at Point Reyes, Bird Island, Farallon Islands, and Montara Point, Calif., were determined by officers detached for that purpose from the *Natoma*.

At each station an azimuth was determined.

[FREMONT MORSE.]

SUMMARY OF RESULTS.—Triangulation: 26 signal poles erected; 32 stations in main scheme occupied for horizontal measures; 28 geographic positions determined.

During the period between March 9 and April 27, 1921, the positions of 6 Naval Radio Compass stations located along the California coast from San Diego to Point Arguello were determined by triangulation. Those connected with the Coast and Geodetic Survey triangulation were Imperial Beach, San Diego; Point Loma, San Diego; Avalon, Catalina Island; Point Fermin, San Pedro; Point Hueneme, Ventura County; and Point Arguello, Santa Barbara County.

At San Diego and Hueneme transportation in motor cars was provided by the naval authorities. At Point Loma, in order to connect with the triangulation, it was necessary to lay out a scheme involving three quadrilaterals with

short sides. At this station a meridian mark was established south of the radio compass as far away as the topography would permit.

At Imperial Beach the compass station is located on the ocean shore west of the southern limit of San Diego Bay. In order to connect with the triangulation it was necessary to go as far up the bay as National City on the east side and Marsh Point on the west side. After the triangulation had been computed a meridian mark was set south from the compass instrument.

In the reconnoissance for this triangulation the old station Field was recovered.

At Avalon, Catalina Island, it was found owing to local conditions which deflected the wireless waves and rendered the radio compass bearings unreliable, the station had been dismantled and abandoned. For this reason the position of this station was not determined.

At Point Fermin, San Pedro, it was necessary to determine a new triangulation station, located at the end of the point and about in line with the middle of the two windows of the compass house. Here the compass house is not oriented north and south, and it was decided not to set a meridian mark, since in testing the adjustment of the circle of the compass it would be far more convenient to sight from the station, which could be seen from the windows, rather than from a meridian mark from which the instrument could not be seen.

At Point Hueneme, Ventura County, there was a lack of triangulation points in the immediate vicinity, and in order to make connection it was necessary to make use of a long line, Laguna to Point Hueneme Lighthouse. Laguna is one of the primary points and is about 9 miles from the lighthouse. Two new stations were established near the lighthouse and an elongated quadrilateral observed. From one of the stations of this quadrilateral located so as to see through the windows of the compass house the distance and azimuth of the compass instrument were measured. Here also the compass house is not oriented north and south, and no meridian mark was set.

At Point Arguello, Santa Barbara County, two old triangulation stations established in 1874, were recovered, and from the line joining them the position of the radio compass station was determined. At this station a meridian mark was established.

The Point Arguello Lighthouse had not been connected with the triangulation of the Coast and Geodetic Survey, and advantage was taken of this opportunity to make the connection.

WASHINGTON.

[T. J. MAHER, Commanding Steamer *Surveyor*.]

In February, 1921, determinations were made by triangulation of the geographic positions of Naval Radio Compass stations on Puget Sound, and true meridian lines were laid out for use in connection therewith by two officers detailed for the purpose from the steamer *Surveyor*.

At Smith Island a metal reference mark was set in concrete in the light keeper's yard. It marks true north and is about 110 meters from the radio compass.

At Cattle Point two monuments were set in a true westerly direction from the radio compass, one a nail in cement in the top of a pipe set in concrete 5 meters from the radio compass, and the other a metal reference mark set in concrete 14 meters west from the radio compass. At New Dungeness a reference mark was set in concrete about 150 meters east of the radio compass station.

The stations are calibrated by setting a transit on the top of the radio compass house and setting it to read true azimuths from north, and a vessel then sends wireless signals from near the center of the area to be covered by the radio compass. The transit and radio apparatus read the azimuth of the vessel, and the radio circle is rapidly set to agree with the compass. The vessel then steams as nearly around the radio compass as possible, and simultaneous readings are taken with the transit and radio apparatus; from these a correction table or curve is made for the radio compass readings.

In determining the positions of the radio compass stations, three direct and reverse directions were observed and the horizon closed where practicable.

Smith Island and Cattle Point radio compasses were computed as part of the quadrilateral from Smith Island Lighthouse and New Dungeness Lighthouse.

New Dungeness is computed from three triangles, the bases being New Dungeness Lighthouse-Smith Island Lighthouse, New Dungeness Lighthouse-Discovery Island Lighthouse, and Smith Island Lighthouse-Discovery Island Lighthouse. When at New Dungeness radio compass observations were also made on Ediz Hook Lighthouse.

At Slip Point three triangulation stations were found, no two of which are intervisible and from only one of which the radio compass is visible. A new station was selected on a tide reef from which all three of the stations named and the radio compass are visible. This station was marked with a metal triangulation mark set in rock below high water. Slip Point is located from the new station and station Reynolds. Slip Point Lighthouse was observed, but the new station was not visible at the stage of the tide at the time.

Tatoosh radio compass is located by a single triangulation. Tatoosh Lighthouse station mark was found in good condition, but Tatoosh radio compass is not visible from it.

WASHINGTON AND OREGON.

[J. D. CRICHTON.]

The geographic positions of the U. S. Naval Radio-Compass stations at Grays Harbor, Wash., and Fort Stevens, Oreg., were determined, and the true meridian lines were laid out at those stations between November 1 and 15, 1920.

Respectfully,

E. LESTER JONES, *Director.*

To Hon. HERBERT HOOVER,
Secretary of Commerce.

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U.S. COAST AND GEODETIC SURVEY

CONDITION OF FIELD OPERATIONS

UNITED STATES

1921

Wire drag surveys completed	Triangulation completed
Wire drag surveys required	Triangulation begun
Unchangeable areas, no present work required	Precise traverse completed
Unchangeable areas, additional work required	Precise leveling completed
Changeable areas, recent surveys	Precise traverse and precise leveling completed
Changeable areas, old surveys	Gravity stations, positions
Reconnoissance work or unsurveyed	

Statute Miles 100 0 100 200 300

Nautical Miles 100 0 100 200 300

C. & G. S. Print

95°
90°
85°
80°
75°
70°
65°
45°
40°
35°
30°
25°
NOVA SCOTIA
CANADA
MAINE
VERMONT
N. HAMP.
MASS.
CONN.
R.I.
NEW YORK
LAKE ONTARIO
LAKE ERIE
LAKE MICHIGAN
LAKE HURON
LAKE SUPERIOR
MINNESOTA
WISCONSIN
MICHIGAN
IOWA
ILLINOIS
INDIANA
OHIO
PENNSYLVANIA
NEW JERSEY
DELAWARE
MARYLAND
W. VIRGINIA
VIRGINIA
KENTUCKY
TENNESSEE
NORTH CAROLINA
SOUTH CAROLINA
GEORGIA
FLORIDA
ALABAMA
MISSISSIPPI
LOUISIANA
ARKANSAS
MISSOURI
KANSAS
NEBRASKA
OKLAHOMA
TEXAS
FARGO
DULUTH
MINNEAPOLIS
ST. PAUL
SIOUX FALLS
SIOUX CITY
OMAHA
LINCOLN
DES MOINES
MADISON
MILWAUKEE
CHICAGO
LANSING
DETROIT
CLEVELAND
BUFFALO
ALBANY
BURLINGTON
MONTPELIER
AUGUSTA
PORTLAND
CONCORD
PORTSMOUTH
BOSTON
WORCESTER
PROVIDENCE
HARTFORD
NEWPORT
NEW HAVEN
NEW YORK
NEWARK
TRENTON
HARRISBURG
PHILADELPHIA
WILMINGTON
DOVER
BALTIMORE
ANNAPOLIS
WASHINGTON D.C.
PITTSBURGH
WHEELING
COLUMBUS
INDIANAPOLIS
SPRINGFIELD
CINCINNATI
CHARLESTON
RICHMOND
NORFOLK
RALEIGH
WILMINGTON
COLUMBIA
CHARLESTON
SAVANNAH
ATLANTA
BIRMINGHAM
MONTGOMERY
MERIDIAN
JACKSON
MOBILE
TALLAHASSEE
JACKSONVILLE
TAMPA
KEY WEST
HABANA
CUBA
BAHAMA ISLANDS
TOPEKA
KANSAS CITY
ST. LOUIS
JEFFERSON CITY
EVANSVILLE
LOUISVILLE
FRANKFORT
NASHVILLE
MEMPHIS
WICHITA
MUSKOGEE
OKLAHOMA CITY
FORT SMITH
LITTLE ROCK
DALLAS
BATON ROUGE
NEW ORLEANS
AUSTIN
SAN ANTONIO
GALVESTON
GULF OF MEXICO
ATLANTIC OCEAN

160° 170° 180° 170° 160° 150°

60°

A R C T I C O C E A N

S I B E R I A

Pt. Barrow

Icy Cape

Pt. Hope

STR.

BERING

Nome

St. Michael

St. Lawrence I.

YUKON

RIVER

KUSKOKWIM RIVER

St Matthew I

Nunivak I.

Nushagak

Iliamna

PENINSULA

BRISTOL BAY

Pribilof Is

ALASKA

Unimak I.

Shumagin Is

Unalaska I

Umnak I.

B E R I N G S E A

A L E U T I A N I S.

Attu I

Kiska I

Tanaga I

Atka I

East from Greenwich.

180° 170° 160°

N

C & G.S. Print

U.S. COAST AND GEODETIC SURVEY

CONDITION OF HYDROGRAPHY

ALASKA

1921

Wire drag surveys completed	shown
Unchangeable areas, no present work required	shown
Unchangeable areas, additional work required	shown
Changeable areas, recent surveys	shown
Changeable areas, old surveys	shown
Reconnoissance work or unsurveyed	shown

WIRE DRAG WORK

Approximately 50 per cent of the water areas, with depths less than 50 fathoms, of the inside passages and harbors of Southeast Alaska, Prince William Sound, Cook Inlet, and coast of Alaska Peninsula and Aleutian Islands require wire drag surveys.