Proceedings

of the

17th Annual
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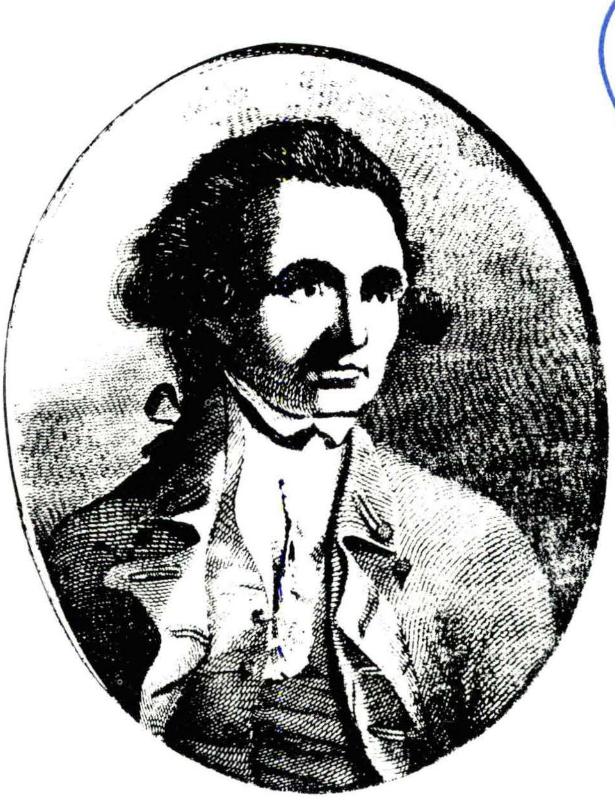

"COOK – HYDROGRAPHY 200 YEARS LATER"

Institute of Ocean Sciences
Patricia Bay
Sidney, British Columbia

17TH ANNUAL
CANADIAN HYDROGRAPHIC CONFERENCE

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Admiral G.S. Ritchie Captain "James Cook" Mike Bolton

W E L C O M E

The Pacific Region of the Canadian Hydrographic Service and the Pacific Branch of the Canadian Hydrographer's Association take pleasure in welcoming you to the 17th Annual Canadian Hydrographic Conference.

This is the first major Conference to be held at our new facilities in the Institute of Ocean Sciences and we consider it most appropriate that this first Conference should be hydrographic. Not only is hydrography the "senior service" in terms of disciplines within the broad oceanographic community but it also provided one of the primary incentives towards the construction of this Institute. Additionally the British Columbia celebration of Cook's bi-centennial provides an appropriate link with Canadian hydrography of yesteryear.

During the course of the proceedings you are invited to explore our facilities, question our Institute programs and enjoy our environment. Please accept our apologies for the incompleteness of the landscaping, but the addition of plants, shrubs, trees and lawns will be part of our ongoing development.

We hope your stay in Victoria will be pleasant, your attendance at the Conference instructive and your participation in the social activities enjoyable.

Mike Bolton.

Mike Bolton
Regional Hydrographer

Opening Remarks

G.N. EWING
Dominion Hydrographer
C.H.S. Ottawa

Since I addressed last year's conference in Burlington we have had a busy, sometimes trying but nevertheless an eventful and productive year. On the international scene there were a number of events that I would like to discuss. Last year I mentioned that on January 1, 1977 Canada adopted a 200 mile Fishing Zone on the Atlantic and Pacific coasts and this was extended to include the Arctic Ocean on March 1. In the past year our Territorial Waters Officers have had their efforts directed almost exclusively to providing information and charts required for negotiations with the United States on the delimitation of our common boundary. The chief of this unit, Mr. John Cooper, is now in Geneva as a member of the Canadian delegation to the Law of the Sea Conference.

The second international event was the XIth International Hydrographic Conference held in Monaco, April 18-30, 1977. The decision of this conference on the adoption of the report of the North Sea International Chart Commission (NSICC), and the decision to establish a Technical Committee on Chart Specifications to continue this work, has the potential for extremely far-reaching effects. Canada will be represented on this new committee. By the XIIth Conference in 1982 there should be a comprehensive specification for the standardization of all nautical charts at medium and large scale. The recommendations of the NSICC have already been adopted to the maximum extent possible in the new four colour, metric, bilingual, contoured presentation being used for new Canadian Charts.

The third event of international importance occurred a year ago when an agreement to establish a U.S./Canada Hydrographic Commission was reached. The Commission will provide a formal mechanism to coordinate the work of the U.S. National Ocean Survey and CHS in adjacent waters of mutual interest. The first scheduled meeting of the Commission was held here in this Institute yesterday. Initially it will have its greatest impact in the Great Lakes where eventually there will be one common medium scale for each of the major lakes and one common set of charts for the connecting rivers and confluence waters. The first two of these charts, Canadian Chart 2000, covering Lake Ontario and a matching N.O.S. chart of Lake Erie were issued early in 1977, and work is now underway on the production of a new chart of the southern end of Lake Huron by CHS and new charts for the east and west ends of Lake Erie by NOS.

On the national scene last September the Prime Minister announced that he planned legislation to separate the Department of Fisheries and the Environment into two separate departments. There has subsequently been considerable uncertainty as to the organizational components to be included in the new Environmental Administration and the new Fisheries Administration. Many of these uncertainties were clarified on March 13 when Mr. Romeo Leblanc our Minister informed Parliament that with their approval his

> "new department would be known as the Department of Fisheries and Oceans. This title is clear and brings the basic responsibilities sharply into focus for the public. This is important because the public of the Atlantic and Pacific coastal provinces understands the relationship between fisheries and the oceans and expects a strong and clear government response to problems and opportunities in this sector."

Amongst the specific responsibilities of the new department he identified "hydrographic surveying and charting." In elaborating on this the Minister stated that:

> "The Hydrographic Service of the Department of Fisheries and the Environment is now working closely with the Ministry of Transport in developing and providing more precise aids to navigation and positioning systems which contribute to the more effective management of the 200-mile fishing zone and the prevention of destruction of the fisheries resources by transportation accidents. These responsibilities would continue within the new Department of Fisheries and Oceans."

He also commented that:

> "Contrary to perceptions held by some people, ocean sciences programs in Canada have been characterized by a very healthy growth in recent years... Since 1973, despite a period of fiscal restraint, the Ocean and Aquatic Science division of the Fisheries and Marine Service has seen its annual budget grow from $33.7 million to $57 million. Canada's ratio of Ocean Science expenditure as a percentage of gross national product shows the following comparisons with other advanced maritime nations: in 1974 Canada spent 1.7 times as much as the U.S.A., five times as much as each of the U.K., France and Japan and 5.5 times as much as Australia."

We still await the legislation that will detail the allocation of responsibilities. The appointment of Mr. D.D. Tansley, presently Administrator of the Anti-Inflation Act, as Deputy Minister designate, effective May 1, was announced on April 6. There are still very important decisions to be made with respect to the allocation of common resources presently shared by the two departments and on the organization of the new department.

We have also had considerable activity on the drawing up of draft regulations covering the commissioning of a Canada Lands Surveyor, a new commission that will replace the former Dominion Land Surveyor and the Dominion Topographical Surveyor. These regulations are being drawn up under Bill C-4, an Act to amend the Canada Lands Surveys Act which was given Royal Assent on June 29, 1977.

One of its principal objectives is to redefine the professional standards of the present D.L.S. providing a broader based qualification that will embrace all persons engaged in surveying whether on land, over or under water (mainly the offshore environment) or from the air. The broader based qualification will result in higher educational requirements and will substitute training and experience for the present formal articling system. This latter change is significant in that it will allow commissions to be granted to qualified and experienced surveyors even though they have not had the opportunity in the past to article formally to a Dominion Land Surveyor. It will of course have a profound effect on professional hydrographers who have been carrying out surveys over Canada Lands for generations.

Before the revised Act can be proclaimed as law, a number of actions must be taken with respect to Part 1 dealing with examinations and powers and duties of Canada Lands Surveyors. One of the actions required is the development of a new set of examination regulations that I mentioned earlier and the appointment of a new Board of Examiners.

To deal with these matters, the Director-General of the Surveys and Mapping Branch appointed the Canada Lands Surveys Act Advisory Committee. The committee is composed of the heads of the federal agencies representing the four major fields of surveying which of course includes the Dominion Hydrographer, and has members representing the present Board of Examiners, the Dominion Land Surveyors Professional Affairs Committee, the Canadian Council of Land Surveyors and the private sector of the Canadian survey industry.

The Committee has developed a set of criteria to be used for the commissioning of Canada Lands Surveyors. These criteria represent the consensus of the committee on a number of topics such as,

a) The major fields of surveying to be covered by the new commission.

b) The new level of educational qualifications required.

c) The duration and type of required training and experience.

d) Provision for a grandfathering process of limited duration.

e) Transitional process from the present to the new system of qualification.

These criteria have been incorporated into a draft of new examination regulations. The committee has also been involved in the preparation of a new examination syllabus and the identification of minimum entrance requirements. This is a complex task and requires the setting of long term philosophies and objectives. Representatives of a number of Canadian universities have been involved in this part of the committee's work.

Hopefully, the committee's initial task will be concluded soon. The final phase will be the three following simultaneous actions:

- Proclamation of the revised Act.
- Appointment of the new Board of Examiners.
- Promulgation of new examination regulations.

It is too early yet to set exact target dates. It was originally hoped the act could be proclaimed by September 1978. However there may well be slippage past this date. If the act is not proclaimed by October 1, the Board will have to defer implementation of the new examination process until 1980.

Within the Service the first cartographers to be moved under our decentralization program have moved to the Atlantic, Pacific and Central regions as well as to the newly established region in Quebec City. This program will be continued in 1978 and completed in 1979. With almost all of the cartographic work to be carried out in regional offices we have had to carry out a careful examination of procedures and the allocation of responsibilities between headquarters and the regional offices.

Twelve New Charts, 87 New Editions and 90 Reprints were produced in 1977. Two new Chart Catalogues were published completing the replacement of our former twelve Information Bulletins by four catalogues. Five revised volumes of Sailing Directions were published in English and one in French.

In 1977 all elements of the Fisheries and Marine Service within our department were subjected to a Zero A-Base Review in which every task and the allocated resources had to be identified together with its legislative or other mandate. This exercise absorbed a lot of time of our senior staff but clearly identified to the senior management of the department the serious back-log of work that has accumulated in chart production. This is a result of the numerous additional jobs thrust upon us over the last two decades with no augmentation, indeed I believe a reduction, in total resources.

Partly out of the Zero A-Base Review, and partly out of the new federal government policy on contracting out the governments requirements in science and technology, a Task Force was established to review the extent to which hydrographic activities could be contracted to the private sector.

Phase II of the Zero A-Base Review started recently and we have just submitted a further report examining in detail the minimum and optimum resource levels for the CHS and the need for ships to be dedicated to hydrography. In our report we have used several comparisons to the level of effort by the National Ocean Survey and the British Admiralty in charting home waters.

In 1977, we were able to bring our Cartographic Training Unit up to full strength and give our first elementary cartography course. The syllabus for an advanced cartography course is now being developed. In 1978, we plan to run two Cartography I courses and planning is underway for a Cartography II course. These courses are intended to parallel our well established Hydrography I and Hydrography II courses. I also hope that our National Cartographic Appraisal Board will finally come into full effect this year.

As a result of our research and development efforts most of our new charts are now being digitized and the final line drawings prepared on our Gerber high precision plotter. This is now giving us a data bank of digital data which will in future be used to produce smaller scale charts. In addition GOMADS, the interactive editing system is now being fully implemented in all of the established regions.

The third generation of our automated hydrographic data logging system, incorporating micro-processors was evaluated in the field. This completely integrates the collection of time, position and depth data in digital form. The best method of editing this data prior to the field sheet being drawn on an automatic plotter is actively under review.

1977 was an active year for Loran-C calibration. An elaborate calibration of the Canadian West Coast chain using CSS Parizeau and subsequently CSS Vector, and staff and equipment from each of our regions and headquarters, was carried out in April and May. This determined the errors caused by transmitting the signal over long overland paths characterized by irregular terrain. Unfortunately, the calibration showed that the new chain did not provide adequate signal strength in Dixon Entrance and in the approaches to the Strait of Juan de Fuca. The Ministry of Transport now propose to establish an additional transmitter at the north end of Vancouver Island to solve this problem. Three small scale charts showing Loran-C lattices obtained from theoretical data were issued before the West Coast chain went on the air and a series of medium scale charts are being produced with latticing corrected for additional secondary phase factor.

Central Region have continued their monitoring of Loran-C around the Canadian shoreline of the Great Lakes to enable the lattices to be adjusted. The Navigation Group in Atlantic Region used CCGS Narwhal in November and December to carry out calibrations over the Grand Banks and along the Labrador Coast. They also evaluated a large number of commercial receivers.

The Canadian Hydrographic Service has been jointly sponsoring with the Canada Centre for Remote Sensing an aerial hydrography project. This is based on using an inertial navigation system to sense the exact attitude of an aircraft and to carry forward its position. This information is updated at very frequent intervals and recorded digitally. It is also provided to the pilot for navigational purposes. The aircraft flies over a cluster of known targetted points at the start and finish of each run to determine an initial and final position, the position and attitude of all intervening photographs can then be computed. This system holds great promise for covering chains of islands or coastline where normal techniques cannot be used. The camera will use colour film chosen to give maximum water penetration so that it should be possible to chart many of shallow water areas. The first field trials are in progress. The second phase will incorporate a laser to establish a profile on the sea bottom along the aircraft track to provide the necessary ground truth.

The imminent advent of 50' draft vessels in the Arctic makes it essential that we substantially improve our capability for Arctic surveys. One of our major thrusts at this time and in the near future will be to improve the charts in the Canadian Arctic to meet the needs associated with exploiting. This is fully evidenced by the fact that in 1978 all three established regions will operate major survey parties in Arctic waters.

Last Fall the Interdepartmental Committee on Energy R & D (Transportation Sector) approved an R & D proposal providing the CHS with $200K in the last fiscal year and an anticipated $300 - 400K/year for this and the following three to four years to develop improved equipment and operating techniques for the measurement of bathymetry in support of transportation in the Arctic. The program has as its research objectives, investigation into ice physics and electromagnetic and acoustic propagation in ice and ice covered waters. Research will also be done on survey vehicles with stress being placed on air cushion vehicles, helicopters, terrain contact vehicles and submersibles. The successful completion of this program will be a major milestone in Arctic hydrography.

We are now deeply involved in planning the International Hydrographic Technical Conference to be held in Ottawa, May 14-18, 1979 under the joint auspices of the Fédération International des Géometres, the Canadian Institute of Surveying and the Canadian Hydrographic Service. The theme of the conference is "Development of Ocean Resources" and the conference will include papers on bottom mapping techniques; location and emplacement techniques for drilling rigs, production platforms and pipelines; international concerns; and the education and training of hydrographers.

On a more personal note, I know that you will want to join with me in congratulating two presently serving members of the CHS, T.B. (Bert) Smith and Cyril Champ and one ex CHS member but very active hydrographer Tom McCulloch on their being awarded Silver Jubilee medals commemorating the twenty-fifth year of the reign of Queen Elizabeth II.

Two weeks ago, I attended the retirement ceremony for F.L. 'Dusty' De Grasse, and later this year we will say "au revoir" to Jack Chivas, Fred Smithers and Capt. Frank Green, former master of the Parry, Marabell, Vector and Wm. J. Stewart. We wish them well in their retirement.

We were all shocked by the sudden death of Ells Walsh on November 19th, less than two years after his retirement. Ells joined the Service in 1947 and was Chief Compiler from 1955 until 1968 when he became Chief of Chart Production. His last assignment was as International Hydrographic Bureau Officer. The new four colour, metric bilingual contoured format now being used on the joint U.S.A. and Canadian charts of Lake Erie and Ontario, will be an enduring monument to Ells' major contribution to Canadian and international charting.

As many of you know I have not been at my own desk for the past eight months or so, as I had been asked to assume the duties of Assistant Deputy Minister, Ocean and Aquatic Sciences in an acting capacity for an indeterminate period. Hopefully with the announcement on April 6, of a Deputy Minister pro tem for our new Department of Fisheries and The Oceans, some action will soon be taken to fill this post on a full-time basis and I will be free to return to my post as Dominion Hydrographer. In the meantime I would like to thank all of those who have shouldered a heavy load over an unexpectedly long period of time and in a time of great uncertainty as to where our future lay.

Captain Cook and the Pacific: A Graphic Survey

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Abstract

Captain Cook's Pacific Voyages (1768-71, 1772-75, 1776-80) are remarkable for many reasons; in an age when half a ship's company could die of scurvy in the course of an extended voyage, in the course of three 3-years long voyages Cook lost not one man from scurvy; in an age when, in the words of the Astronomer Royal in 1763, "even the ablest and most careful navigators" were often "five, ten or even fifteen degrees" in error in longitude "in the course of long voyages" Cook was seldom more than ½° in error during his first voyage and thereafter within 3' - 9'; as his great biographer J. C. Beaglehole said, "his competence changed the face of the world". While it did this geographically in the course of three dramatic voyages it effected far more, it established geography as "a science of facts", it enriched man's scientific knowledge of the living world on an unprecedented scale and with unprecedented rapidity, knowledge of the peoples, fauna and flora of the earth and of the denizens of the deep of no less than one third of the world; moreover, it did so pictorially, graphically and with the evidence of scientifically organized specimens over and above the long and detailed published reports and narratives. The influence of the scientists and seamen engaged on these voyages upon the artists accompanying them and the influence of their work upon European art and taste was significant and ineradicable.

Since April 1978 is the 200th anniversary of Càptain Cook's stay at Nootka Sound where he arrived on 29 March 1778 and whence he departed 26 April 1778, I thought it best to make my contribution principally in the form of illustrations made by artists on his three Pacific voyages - 1768-71 to the South Pacific, 1772-75 likewise and 1776-80 to the North Pacific. I think it useful to do so for, while it is well known that "his competence changed the face of the world:, what is not so generally known is that Captain Cook's artists influenced European art significantly whilst at the same time informing both the educated public of Europe and scientists of many nations as to the appearance of places and peoples inhabiting virtually, if not entirely, unknown areas of the world - one third of it, in fact - the Pacific.

As I am speaking to a professional body I have thought it best to let the Admiralty and Captain Cook do most of the explanation of the objects of the various voyages and his achievements since they are couched in official language of instruction and report, which will be familiar to many of you.

I propose therefore, to give the occasions for the voyages briefly, to let the chief actors declaim their parts, then put the artistic scene into perspective and, finally project the pictures letting them speak - as it were - for themselves with no more prompting from me than I deem necessary to put them into context.

In the 1760's there were some great matters of interest to the British government - the question of whether a habitable great southern continent existed in the southern oceans, whether a sea route practicable for sailing ships linked the North Pacific with the North Atlantic, whether practicable solutions of "general utility" to seamen could be found to the problem of finding longitude at sea and whether it was possible for a ship to keep the seas for voyages as long as three years far from a base - for such seemed to be the time necessary for voyaging to, across and from the Pacific from Europe, specifically, England. Cook settled the Admiralty's doubts on all these matters, once and for all, in the course of his three voyages and in doing so, undoubtedly proved himself to be, in Admiral Sir Hugh Palliser's words, "The ablest and most renowned navigator this or any country hath produced".

Mr. James Cook, Master, Royal Navy, was appointed to command the *Endeavour* bark, in April 1768, to take her to the South Pacific to observe, with an astronomer, the Transit of Venus. Promoted to Lieutenant, Cook, before departure took on board by Admiralty order, Mr. Banks and his party of two scientists, two artists and two servants, with their apparatus. After observing the Transit from Tahiti Cook opened sealed orders and read:

Secret
By the Commissioners for
executing the office of Lord
High Admiral of Great Britain
&c^{a}.

Additional Instructions for L^{t} James Cook, Appointed to Command His Majesty's Bark the Endeavour.

Whereas the making Discoverys of Countries hitherto unknown, and the Attaining a Knowledge of distant Parts which though formerly discover'd have yet been but imperfectly explored, will redound greatly to the Honour of this Nation as a Maritime Power, as well as to the Dignity of the Crown of Great Britain, and may tend greatly to the advancement of the Trade and Navigation thereof; and Whereas there is reason to imagine that a Continent or Land of great extent, may be found to the Southward of the Tract lately made by Capt^{n} Wallis in His Majesty's Ship the Dolphin ...

You are to proceed to the southward in order to make discovery of the Continent abovementioned until you arrive in the Latitude of 40°, unless you sooner fall in with it. But not having discover'd it or any Evident signs of it in that Run, you are to proceed until you discover it, or fall in with the Eastern side of the Land discover'd by Tasman and now called

New Zeland.

If you discover the Continent above-mentioned either in your Run to the Southward or to the Westward as above directed, You are to employ yourself diligently in exploring as great an Extent of the Coast as you can; carefully observing the true situation thereof both in Latitude and Longitude, the Variation of the Needle, bearings of Head Lands, Height, direction and Course of the Tides and Currents, Depths and Soundings of the Sea, Shoals, Rocks, &c^{a}. and also surveying and making Charts, and taking Views of such Bays, Harbours and Parts of the Coast as may be useful to Navigation.

You are also carefully to observe the Nature of the Soil, and the Products thereof; the Beasts and Fowls that inhabit or frequent it, the fishes that are to be found in the Rivers or upon the Coast and in what Plenty; and in case you find any Mines, Minerals or valuable stones you are to bring home Specimens of each, as also such Specimens of the Seeds of the Trees, Fruits and Grains as you may be able to collect, and Transmit them to our Secretary that We may cause proper Examination and Experiments to be made of them.

You are likewise to observe the Genius, Temper, Disposition and Number of the Natives, if there be any ...

You are also with the Consent of the Natives to take possession of ... the Country in the Name of the King of Great Britain ...

Upon falling in with New Zeland carefully observe the Latitude and Longitude in which that Land is situated, and explore as much of the Coast as the Condition of the Bark, the health of her Crew, and the State of your Provisions will admit of ...

You will also observe with accuracy the Situation of such Islands as you may discover ... and make Surveys and Draughts of such of them as may appear to be of Consequence ...

But for as much as in an undertaking of this nature several Emergencies may Arise not to be foreseen, and therefore not particularly to be provided for by Instruction before hand, you in all such Cases, to proceed, as upon advice with your Officers you shall judge more advantageous to the Service on which you are employed.

You are to send ... to our Secretary, for our information, accounts of your Proceedings, and Copys of the Surveys and drawings you shall have made ...

Given under our hands the 30th of July 1768.

E^{d}. HAWKE
Piercy BRETT
C. SPENCER

By Command of their Lordships
PH. STEPHENS

As a consequence Cook rediscovered and then surveyed New Zealand which done in six months he logged in his Journal:

March 1770 SATURDAY 31st March. It was therefore resolved to return by way of the East Indies by the following rout: upon leaving this coast to steer to the westward untill we fall in with the East Coast of New Holland and then to follow the deriction of that Coast to the northward or what other direction it may take untill we arrive at its northern extremity ...

The *Endeavour* anchored in the Downs on Saturday, 13th July, 1771, the voyage having lasted very nearly three years. Cook reported to Philip Stephens, Secretary of the Admiralty, on 23rd October, 1770:

Sir, -

Please to acquaint my Lords Commissioners of the Admiralty that ... arrived at Georges Island on the 13th of April. In our Passage to this Island I made a far more Westerly Track than any Ship had every done before; yet it was attended with no discovery until we arrived within the Tropick, where we discovered several Islands. We met with as Friendly a reception by the Natives of Georges Island as I could wish, and I took care to secure ourselves in such a manner as to put it out of the power of the whole Island to drive us off ... We were so fortunate that the observations were everywhere attended with every favourable Circumstance ... I spent near a month in exploring some other Islands which lay to the Westward, before we steer's to the Southward ... until we arrived in the Lat. 40° 12' S., without seeing the least signs of Land. After this I steer'd to the Westward ... until we discovered the East Coast of New Zeland, which I found to consist of 2 large Islands, extending from 34° to 45° of South Latitude, both of which I circumnavigated. On the 1st of April, 1770, I quitted New Zeland, and steer'd to the Westward, until I fell in with the East Coast of New Holland, in the Latitude of 30°S. I coasted the shore of this Country to the N., putting in at such places as I saw Convenient, until we arrived in the Latitude of 15°45' S., where, on the night of the 10th of June, we struck upon a Reef of Rocks, where we lay 23 Hours, and received some very considerable damage and made the best of my way to Batavia ...

I send herewith a copy of my Journal, containing the Proceedings of the whole Voyage, together with such Charts as I have had time to Copy, which I judge will be sufficient for the present to illustrate said Journal. In this Journal I have undisguised truth and without gloss inserted the whole Transactions of the Voyage, and made such remarks and have given such discriptions of things as I thought was necessary in the best manner I was Capable off ... as it is, I presume this Voyage will be found as compleat as any before made to the So. Seas on the same account. The plans I have drawn of the places I have been at were made with all the Care and accuracy that time and Circumstance would admit of. Thus far I am certain that the Latitude and Longitude of few parts of the World are better settled than these. In this I was very much assisted by Mr. Green, who let slip no one opportunity for making of Observations for settling the Longitude during the whole Course of the Voyage; and the many Valuable discoveries made by Mr. Banks and Dr. Solander in Natural History, and other things useful to the learned World, cannot fail of contributing very much to the Success of the Voyage ...

Having found no Southern Continent, Cook proposed he should search the South Seas on the highest latitudes for it in a proposed voyage, which Cook submitted to Lord Sandwich, First Lord of the Admiralty, on 6th February 1772. The memorandum runs as follows: -

Upon due consideration of the discoveries that have been made in the Southern Ocean, and the tracks of the Ships which have made these discoveries; it appears that no Southern lands of great extent can extend to the Northward of 40° Latitude, except about the Meridian of 140° West, every other part of the Southern Ocean have at different times been explored to the northward of the above parallel. Therefore to make new discoveries the Navigator must Traverse or Circumnavigate the Globe in a higher parallel than has hitherto been done, and this will be best accomplished by an Easterly Course on account of the prevailing westerly winds in all high Latitudes ...

The Yellow line on the Map shews the track I would propose the Ships to make ...

Cook resolutely and successfully followed this plan, the circumnavigation of the Antarctic occupied the three winters of 1772-3, 1773-4, and 1774-5, while the two intervening summers of 1773 and 1774 enabled Cook to conduct two highly important sweeps of the South Pacific.

He logged on Tuesday February 21st, 1775:

I had now made the circuit of the Southern Ocean in a high Latitude and traversed it in such a manner as to leave not the least room for the Possibility of there being a continent, unless near the Pole and out of reach of Navigation; by twice visiting the Pacific Tropical Sea, I had not only settled the situation of some old discoveries but made there many new ones and left, I conceive, very little more to be done in that part.

Thus I flatter myself that the intention of the Voyage has in every respect been fully Answered, the Southern Hemisphere sufficiently explored and a final end put to the searching after a Southern Continent, which has at times ingrossed the attention of some of the Maritime Powers for near two Centuries past and the Geographers of all ages...

Meanwhile the Royal Society had urged the Admiralty to mount an expedition to discover the NE or NW Passage from the Pacific. Cook volunteered and sailed in *Resolution* again with *Discovery* in company.

By the COMMISSIONERS for Executing the
Office of Lord High Admiral of
Great Britain and Ireland, &c.

SECRET INSTRUCTIONS for Captain James Cook, Commander of his Majesty's Sloop the RESOLUTION.

Whereas the Earl of Sandwich has signified to us his Majesty's pleasure, than an attempt should be made to find out a Northern passage by sea from the Pacific to the Atlantic Ocean; and whereas we have, in pursuance thereof, caused his Majesty's sloops Resolution and Discovery to be fitted, in all respects, proper to proceed upon a voyage for the purpose above-mentioned, and, from the experience we have had of your abilities and good conduct in your late voyages, have thought fit to intrust you with the conduct of the present intended voyage, and with that view appointed you to command the first mentioned sloop, and directed Captain Clerke, who commands the other, to follow your orders for his further proceedings; You are hereby required and directed to proceed with the said two sloops directly to the Cape of Good Hope ...

You are, if possible, to leave the Cape of Good Hope by the end of October, or the beginning of November next, and proceed to the Southward ... to Otaheite, or the Society Isles (touching at New Zealand in your way thither, if you should judge it necessary and convenient) ...

Upon your arrival at Otaheite, or the Society Isles, you are to land Omiah ... and then proceed in as direct a course as you can to the coast of New Albion, endeavouring to fall in with it in the latitude of 45° 0' North ... Upon your arrival on the coast of New Albion, you are to put into the first convenient port to recruit your wood and water, and procure refreshments, and then to proceed Northward along the coast, as far as the latitude of 65°, or farther, if you are not obstructed by lands or ice ...

When you get that length, you are carefully to search for, and to explore, such rivers or inlets as may appear to be of a considerable extent, and pointing towards Hudson's or Baffin's Bays; ...

At whatever places you may touch in the course of your voyage, where accurate observations of the nature hereafter mentioned have not already been made, you are, as far as your time will allow, very carefully to observe the true situation of such places, both in latitude and longitude; the variation of the needle; bearings of head-lands; height, direction, and course of the tides and currents; depths and soundings of the sea; shoals, rocks, &c^{a}; and also to survey, make charts, and take views of such bays, harbours, and different parts of the coast, and to make such notations thereon, as may be useful either to navigation or commerce. You are also carefully to observe the nature of the soil ...

On 14th February, 1779 Captain Cook was killed by natives at Hawaii, which island group he had discovered and returned to after finding no passage through the ice.

SYDNEY PARKINSON, ARTIST

The most important artist on the first voyage, he was the son of an Edinburgh brewer and apprenticed as a woollen-draper.

His skill in botanical illustration attracted the attention of Joseph Banks, who took him into his employ in 1767 and on the voyage employed him as botanical draughtsman.

1,300 drawings and sketches speak for Parkinson's industry in the face of extraordinary hazards. On Tahiti, for instance, flies were so numerous that, not only did they cover the subject, they even ate the colour off the paper as fast as he could lay it on.

He was one of the twenty-three who died of dysentery following the *Endeavour's* ten weeks' stay in Batavia for repairs.

The other artist, Buchan, died at Tahiti.

WILLIAM HODGES, ARTIST ON THE SECOND VOYAGE

"The Admiralty showed no less attention to science in general by engaging Mr. William Hodges, a Landscape Painter, to embark in this voyage, in order to make drawings and paintings of such places in the countries we should touch at, as might be proper to give a more perfect idea thereof, than could be formed from written description only..."

Hodges had started as an errand to the artist William Shipley (1715-1803) - who had founded the Society of Arts - and had been a pupil of Richard Wilson (1713-82), who was the most admired landscape artist of the day and one thoroughly imbued with the principles of classical idealism. Nevertheless, Hodges paintings, by their (then) unconventional portrayal naturalistic atmospheric and light effects upon landscapes and sea, frequently reflect the influence of the uncompromising naturalistic interests of the seamen and scientists on board the *Resolution*.

When the *Resolution* returned to England, the Admiralty employed Hodges at £250 a year to complete the drawings and paintings brought home in anticipation of publication of the account of the voyage. Several of these, or replicas of them, were exhibited at the Royal Academy in 1776 and 1777.

Hodges aspired to membership of the Royal Academy as a consequence and, because he was no longer under the direct influence of seamen and scientists these finished works compromise with the artistic conventions of the mid-1770's, in that classical idealism is often used as the theme for a picture which, upon examination, will be found to be painted in detail with scientific accuracy.

Hodges had not only to satisfy persons of taste and of scientific bent but also to reconcile the undoubted luxury of life in Tahiti and its lack of (in Western eyes) moral restraint with theological moralistic views upon the causes of the fall of man. Therefore scenes of happiness or beauty will be found to contain also intimations of the mortality of man in the form of an ancestral image *(tii)* or a *Toupapow* with its shrouded corpse.

Hodges sought to convey the concept that the living beauty of tropical abundance in a care-free island community was at least the equal of the nostalgic visions of an arcadia gone beyond recall, and that it too, was transient, a reflection of the frailty of man in comparison with the bounteous works of a Supreme Being.

On the Third Voyage the artist was:

JOHN WEBBER, ARTIST (b. 1752, d.1798)

Born in London, his father known by the name Weber was a Swiss sculptor, John Webber received his art training in Berne from J. L. Aberli, a German painter and engraver of picturesque views of Switzerland. Sent to Paris to complete his training he went, in 1775 to London to study at the Royal Academy.

In the following year Dr. Solander noticed a portrait by Webber. This led to his appointment as official artist to the third Pacific voyage that, in Cook's words, "we might go out with every help that could serve to make the result of our voyage entertaining to the generality of our readers as well as instructive to the sailor and scholar ...".

Webber, more than any of the artists of the previous voyages, was to act in the capacity of the modern press photographer: as a recorder pictorially of memorable events, certainly, but also as an illustrator of detail to supply "the unavoidable imperfections of written accounts," as Cook put it.

Webber's paintings, therefore, lack the breadth, originality and vigour of those of Hodges (who gave up painting for banking in Devon, and, when that failed, took his life), his use of colour is more conventionalised. Webber's insistence upon botanical detail often spoilt the composition of his work. On the other hand, he initiated, in that he often made an exotic plant the centre of interest of his painting. But his techniques did not lend themselves to conveying the brilliance of tropical light and colour and his rendering of the human form was often highly conventionalised.

Nevertheless, the "great Variety of Portraits of Persons, Views of Places, and Historical Representations of Remarkable Incidents, drawn by Mr. Webber during the Voyage, and engraved by the most eminent artists" (as the title-page of the official account of the voyage described them when it came out in 1784) became one of the main founts of the European vision of the Pacific for the next fifty years.

Furthermore between 1788 and 1792 Webber published a series of sixteen plates of Pacific views, etched and coloured by himself and, in 1808 Boydell's published a folio volume of his *Views of the South Seas.*

The Influence of the Artists upon Art

Natural Settings

The influence of the artists upon art was of no less importance than their influence upon science. The effect which their artistic representations of the native inhabitants, their clothes, weapons, tools, houses, boats and burial customs in their natural settings had upon the artistic conventions of the age was very considerable.

Classical Traditions

Seamen and scientists expected and demanded accurate representation of scenery and society, whereas the artistic traditions, training and taste of the artist and of the patrons of art in the England of the mid-eighteenth century was steeped in the classical tradition and the convention of the great masters of the Renaissance and the patrons expected and admired works of this nature.

The Royal Academy

Ironically the Royal Academy of Art of which Sir Joshua Reynolds (b. 1723 d. 1792), was the first President was founded in the very year that Cook set sail on this first voyage into the virtually unknown Pacific - 1768. Ironically, because its formation has been described as constituting "official recognition in England of those neo-classical theories of Italian origin which had been transmitted to Britain through French theorists like de Chambray and de Piles, nature it was said, was to be rendered by the artist not with her imperfections clinging to her but in her perfect forms. What those perfect forms were the artist could only learn by a close study of the masterpieces of the ancients and their Renaissance disciples". In the event it was the artistry of the natural artists who accompanied Cook on this and later voyages which was to prevail and transform English artistic expression.

Seamen and Scientists Influence the Artists

Cook was trained as a seaman to keep a log of the ship's movements, a journal of the day's events and, as a hydrographer, to make exact representations of the sea coasts and hinterland visible to the seaman. Banks, himself a natural historian, was the son and grandson. of antiquaries dedicated to the observation, description and explication of the material remains of history, he was further influenced in this way by the Society of Antiquaries, chartered in 1750, for it was a Fellow of that Society who got him elected to the Fellowship of the Royal Society at the age of twenty-three.

Since its foundation in 1660, the Royal Society had not only been devoted to the empirical observation of nature ("to study nature rather than books"), but as early as 1665, had issued *Directions for Seamen bound for far voyages.* specifying in detail what they should observe and record and how they should do so, including making *Plotts and Draughts of prospects of Coasts, Promontories, Islands and Ports:* it had been to further this injunction that the Drawing School at Christ's Hospital had been attached in 1693, to the Mathematical School which trained boys for the Navy, but the practice amongst seamen can be traced back to the fifteenth century.

Thus, the artists on the first voyage, under the combined influence of seamen and scientists, drew and painted pictures in defiance of the artistic conventions of the age. The ships brought back naturalistic pictures of almost idyllic scenery which started a trend that eventually culminated in the realism of nineteenth century art.

Two Artistic Cultures in Conflict

In the subsequent voyages other artists were employed and they were similarly influenced adding their contributions to undermine the foundations of neo-classicism.

Sources:

J. C. Beaglehole, (ed.) *The journals of Captain James Cook on his voyages of discovery.* 4 vols. and portfolio of charts. Hakluyt Society extra series, vols 34-37. 1955-70.

Accurate Chart Latticing for Loran - C

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A.R. MORTIMER *C.H.S. Pacific Region*
D.H. GRAY *C.H.S. Ottawa*

Abstract

Unless the Loran-C lattice has much the same accuracy as any other feature shown, the chart is out of balance. There is not much point in charting hazards with great precision if the mariner must allow a large margin for positioning error in his navaid.

The Canadian Hydrographic Services's calibration program aims eventually to improve our knowledge of radio wave propagation so that we can rely on a calculated lattice with only a very few check points to verify the predictions. While we work towards this, we also map the lattice in the field so that we can put it on the chart accurately now.

We calibrated the Canadian West Coast Loran-C chain in the Spring of 1977, using Satnav offshore to give the ±150 m accuracy needed for latticing small scale charts. We looked for and found the predicted coastal "phase recovery" using Trisponder and Sextant fixing. And we made observations on shore by helicopter and calibration van to give propagation data for future predictions.

Introduction

In an old history of Newfoundland, one of those 19th century tomes four inches thick, there are maps dating from John Cabot's discoveries onwards. The early ones are quaint and imaginative -- the sort of thing you see reproduced on a Christmas card or Kleenex box. Then abruptly you come across one as correct in shape and detail as anything from the 20th century. It is James Cook's map, based on his surveys from 1765-68.

In a much smaller way, we aim to do for chart lattices what Cook did for Newfoundland. On past charts the smooth hyperbolas were mathematically correct, but in fact somewhat imaginary. The reason is that nature is not tidy. Because the radio wave is slowed down by land the Loran-C position line is not a plane hyperbola but an irregular curve. The kinks in it can be both large and abrupt.

For example, the Y position line of the West Coast Canadian Loran-C chain is shifted 2 µs (450 m) in 20 km at the entrance to the Strait of Juan de Fuca, by the land effects illustrated in figure 4. (Note that 450 m - 1/4 n. mile - is the advertised maximum position error for Loran-C.)

Another example: In St. Johns, Newfoundland, a fisheries officer recently related how a Portugese fisherman anchored east of the Virgin Rock, on the Grand Banks, complained that the Decca readings put him to the west of the Rock. He was quite right, and if he had looked up "Radio Aids to Marine Navigation" he would have found a correction to Decca Purple that moves the fix two miles to the east. But how many mariners look up correction tables?

Computer controlled lattice drawing now allows us to warp the lattice to follow the real position line across the earth's surface. Using this technique, the Loran-C lattice should be correct to 1 mm on the chart like any other feature. After all, there is not much point in finding all hazards to navigation and positioning them with high precision, if the navigator cannot rely on the Loran-C lattice on the chart to keep him clear of them.

The problem is to know exactly where the position line runs. We would like to be able to predict this mathematically, but we don't yet know enough about radio wave propagation to do so. We therefore must go out and map the lattice using an independent positioning system, in much the same way as we map the depth contours. It is practicable to do this for offshore waters, where radio propagation is more predictable and the small scale of the chart hides small errors, so that we don't need very many samples. But inshore, the propagation anomalies are sharper and much more variable. Mapping them everywhere would be prohibitively expensive, and we are forced to leave the lattice off the chart until we learn more about propagation so that we can predict coastal anomalies from a small number of observations.

Loran-C

Loran-C is a medium accuracy hyperbolic navaid, which combines long range with relatively low cycle ambiguity by making phase comparison type measurements on a pulsed groundwave. Its range is limited by the reliability of cycle selection to about 750 n. miles over sea water, and to considerably less over land. The repeatability of a shipborne receiver is 0.2 µs, which is 30 m on the hyperbolic baseline, and this sets a limit on the accuracy to which the chart lattice need be calibrated.

Loran-C has been adopted by the U.S. Coast Guard as their standard coastal/confluence zone aid to navigation, and by 1980-81 the entire U.S. Pacific and Atlantic Coasts and the Gulf of Mexico will be covered, plus the Canadian Pacific Coast and the Great Lakes. The Canadian Coast Guard is considering a further Loran-C expansion over the Canadian Atlantic Coast to part way up the Labrador Sea.

While the Coast Guard in each country is responsible for providing and operating radio navaids, the U.S. National Ocean Survey and the Canadian Hydrographic Service are responsible for the lattices on the charts, without which the navaid is useless. The calibration we describe here was done by the Canadian Hydrographic Service in the spring of 1977 to produce offshore charts of the areas covered by the West Coast Canadian Loran-C chain.

Range Measurement Versus Time Difference Measurement

The normal ship-borne Loran-C receiver measures the time difference between the arrival of the master and the slave signal. Over this short period of less than a tenth of a second a standard low cost oscillator gives adequate timing accuracy.

At the Loran-C transmitters, however, very precise atomic clocks (frequency standards) are used to control the slave coding delays and the preset interval at which the Loran-C transmissions are repeated. We have a similar atomic clock attached to our calibration receiver. If we synchronise our receiver to the arrival of one transmission, and to the pulse repetition rate, we can then predict when the next and all succeeding transmissions will arrive; if a transmission arrives early, we have moved towards the transmitter, if it arrives late we have moved away.

Taking this a step further, if at the start we set up at a known point close to the transmitter, we can calculate the travel time (Δt) of the radio wave, from the known distance from the transmitter (Δd) and our best estimate of the propagation velocity (v):

$$\Delta t = \frac{1}{v} \Delta d$$

We then synchronise the receiver to the instant of transmission instead of to the instant of reception. At this short distance, an error in the assumed velocity will make only a very small error in the synchronisation travel time.

Then we move out to another known point at a much greater distance from the transmitter, calculate the distance from the transmitter, predict the travel time of the radio wave to that distant point. Because a small difference in propagation velocity will have a proportionately larger effect at long range, this comparison should give us a very sensitive measurement of propagation velocity.

A range measuring receiver is strongly affected by a change in propagation velocity. But if you look at the difference in arrival time between transmissions from two stations, the effect is very much smaller, particularly if the stations are nearly equidistant from the receiver. In addition, you cannot separate propagation velocity along the path to master from velocity along the path to the slave. Hence a standard time difference receiver is not of much use in calibration if you are looking for information on propagation velocity. This is why we use rho-rho (in navigation these receivers fix the ship by measuring two ranges, hence the name "ρρ" or "rho-rho") receivers with atomic clocks. In addition, our Austron rho-rho receiver gives us the time differences provided by a standard receiver, plus auxiliary information on signal strength, signal to noise ratio, and pulse shape.

Measuring travel times requires some special precautions. Even an atomic clock is not perfect, and we are looking at very small time differences -- 3 nanoseconds (10^{-9} s) per metre change in distance. There will inevitably be a very small difference in timekeeping between our atomic cloc and the one running the chain. It will only be a few parts in 10^{13}, but this is enough to introduce an unknown clock rate of some 50 ns (15 m) per day. We have to determine this clock rate carefully, by returning to the same point at intervals and find-

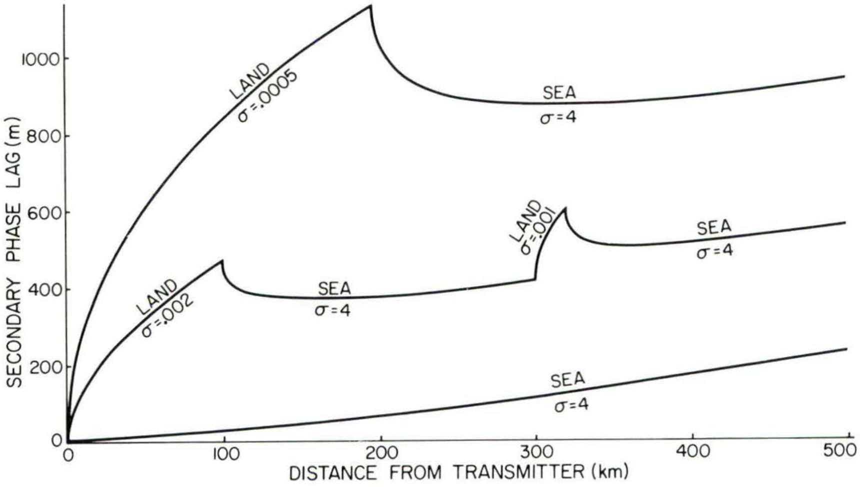

FIGURE 1 SECONDARY PHASE LAG OF RADIO WAVE TRAVELLING OVER MIXED LAND-SEA PATHS (From Brunavs, 1976)

The bottom curve shows an all seawater path. The middle curve shows 100 km of high impedance (rocky) land, then sea, with an island at 300 km. The top wave shows an initial 200 km of very high impedance mountainous land. Note the "phase recovery" on going from land to sea; it is large enough to have a serious effect on inshore chart lattices.

Phase lags are in metres, in comparison with a reference wave travelling through the atmosphere at 299 691.2 km/s. Ground permittivity of 15 e.s.u. is used throughout, and the conductivity in mhos/m is marked on the curve. The effect of the transmitter induction field is not shown.

ing out the rate at which the range measured to the transmitter is changing. We can then eliminate clock rate error from our calibration results.

Propagation Velocity and the Phase Lag Curve

A Loran-C receiver measures time, but the chart's dimensions are nautical miles, not microseconds. Only one position line, the baseline bisector along which master and slave are equidistant is independent of the propagation velocity. All other hyperbolas move across the chart depending on what value of v is adopted in

$$\Delta d = v\Delta t$$

Because we are interested in the corrections to a chart lattice, we tend to think in terms of shifts in metres, which we call phase lag, rather than of different velocities of propagation. The two are equivalent. For example, imagine you have two receivers set out so that they are both 500 km from the transmitter, but one has an all seawater path and the other a path over mountains. The wave travels so much faster over sea water that the pulse at the seawater receiver will be 1/3 way through the first cycle by the time the same pulse is just beginning at the land receiver.

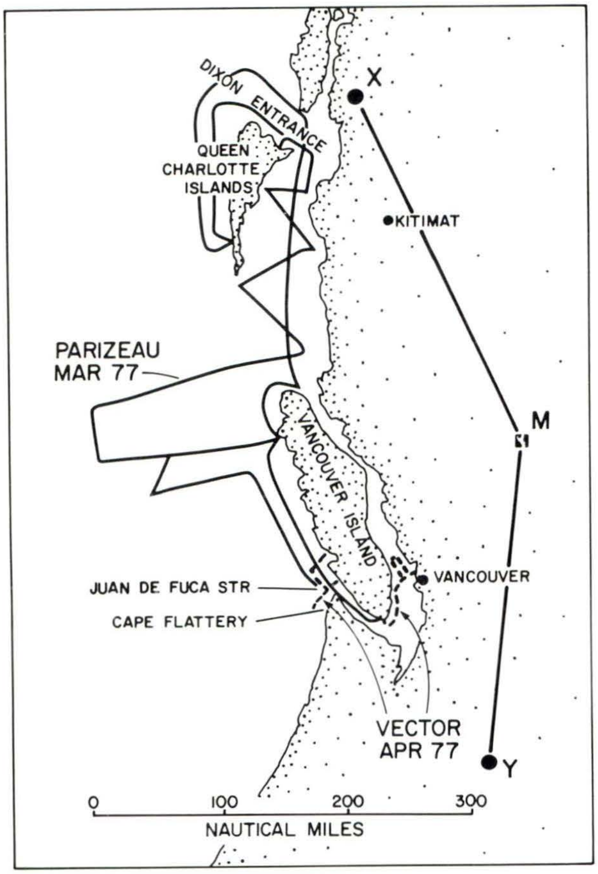

FIGURE 2 TRACKS FOR OFFSHORE CALIBRATION (FIRM LINE) AND INSHORE CALIBRATION (PECKED LINE)

The "overland phase lag" is 1/3 cycle, which is 3.3 μs, or about 1,000 m at the Loran-C wavelength of 3 km. A hyperbolic lattice for the area around the land receiver, which was based on the seawater velocity, would be in error by 500-2000 m, depending on the geometric spread of the hyperbolic position lines. In fact we would not use the seawater velocity for a land signal path, but choosing the correct alternative is not easy. Figure 1 shows how much the phase lag depends on ground conductivity, which is the main component of ground impedance. For example, at 100 km from the transmitter there is 350 m (1 μs) difference in phase lag between the middle curve for hilly land of conductivity 0.002 mhos m^{-1} (such as New England) and the upper curve for mountains of equivalent conductivity 0.0005 mhos m^{-1} (such as the B.C. Coast Range). Note how the phase lag offshore, represented by the right-hand half of the curves on figure 1, depends on the impedance of the land over the first part of the signal path.

Finding Ground Impedance: Land Calibration

We do not yet know enough to predict ground impedance accurately from the geology and roughness of the terrain. Incorrect estimates have produced lattice errors of 2 μs, which created serious inaccuracies. At present the only effective approach is to go out in the field and measure phase lag, or propagation velocity, by making travel time observations close to the transmitter and a long way from it, as described above. From this we can deduce the impedance, and then use this information to calculate the travel time to other points, (so long as we can reasonably assume the terrain on the path to them has the same impedance as the path we measured). After we have measured phase lag over a large number of lines, we hope to be able to predict impedance by matching similar paths on the geological map.

This Pacific Coast calibration was the first on which we have made land observations. We did so with some trepidation, as we knew that cliffs and mountainous terrain would cause phase anomalies, and so would power lines and buildings close to the observation points. For synchronisation, we chose geodetic points close to the master and Y slave transmitters that avoided these problems, and for the distant point we used the wharf at Patricia Bay (south end of Vancouver Island). (See figure 2.) We also planned observations at intermediate distances.

We decided to move by helicopter because of the long distances involved, and technician R. Loschiavo fitted the rho-rho receiver and its no-break power supply in a Canadian Coast Guard Bell 212, where it worked very well. We landed close to the geodetic station, put out an 8 ft. whip on a board over the plug, and connected it to the receiver with a shielded antenna lead. Having taken the reading we disconnected the antenna and moved to the next point. There was no need to track the Loran-C signal while flying, so long as we maintained synchronisation by means of the atomic clock.

After the usual initial problems all seemed to be going well with this operation when at one observation point we did an overdue experiment to verify the technique. We moved the antenna about 30 m towards the transmitter, expecting to see the equivalent 0.1 μs decrease in travel time. In fact the reading increased by 5 μs. Further tests made it clear that the reading varied depending on the orientation of the antenna lead relative to the transmitter, with shifts of up to half a cycle (5 μs) when within 50 km of the transmitter, and of 0.5 μs when 300 km from the transmitter. The antenna lead was perhaps acting as an auxiliary antenna, or as a re-radiator. We therefore moved the equipment into a van, where the antenna could be installed on the roof with a very short lead directly to the receiver. We found no measurable variation in reading as the van was turned through different headings relative to the direction of the transmitter.

We repeated the land calibration with this set-up until over-heating in the van (which was not air-conditioned) stopped work for the summer. The results were reliable, but still not as accurate as we had hoped. Agreement between repeated travel-time measurements was in the worst case ±1 μs over a travel time of about 1,000 μs, instead of the ±0.1 μs we aimed for. The value for land conductivity deduced from these measurements varies depending on the path from 0.0006 to 0.0015 mhos m^{-1}, with an estimated reliability of ±0.0005 mhos m^{-1}.

We expect to improve on this reliability in future, using the experience of the first test. We suspect that the clock rate of the atomic frequency standards is one source of error; we have to determine it very carefully, and in the calibration van it may vary due to vibration and temperature changes. We need to learn more about selecting good observation sites where the phase reading is not affected by buildings, trees, power lines, railway tracks, or nearby mountains. Finally, because the real life phase lag curve is not smooth, as shown in figure 1, but varies as the ground impedance changes slightly along the line, we must observe at a series of points along the curve and not just at both ends (as was planned for this test before time ran out).

Over-water Phase Lags - Offshore Calibration

In the land calibration we attempted to tie down the left-hand over-land part of the phase lag curve, (figure 1) with some success. Next, we looked at the flat right-hand over-water part of the curve -- passing over the abrupt jump at the land/sea boundary -- which we will come back to later. The impedance of sea water hardly varies and, so far as chart latticing is concerned, that part of the graph is really as smooth as it looks. However the level of the curve depends on the conductivity of the land in the first part of the signal path, and as noted we cannot yet predict that from geological information. Therefore we calibrated all along the B.C. coastline to measure this level, running a double line in order to verify any unexpected readings (see track of *Parizeau* on figure 2), and using Satnav as the position reference. As figure 3 shows, we could expect ±150 m accuracy from satellite fixes; since the scale of the charts for which we were calibrating was 1:150,000, that would limit errors to ±1 mm.

We sailed on *Parizeau* on 21 March, and were in Winter Harbour for clock rating on the 23rd, 199 years almost to the day later than Cook put into Nootka Sound, 80 miles to the south. We were luckier than Cook with the weather, as we had only one blow in our three week cruise, and we were able to follow the inshore passage that he certainly would have taken, charting as he went, had not spring gales forced him well clear of that lee shore.

More than 200 satnav fixes along *Parizeau's* track provided corrections to chart lattices, and the two lines westward to the 200 mile limit, along a radial from the master transmitter, verified that the graph has the shape predicted by the mathematical model we are using. Observations in any one area agreed with each other to 0.5 μs, (±150 m in range), which agrees with the expected accuracy of satnav.

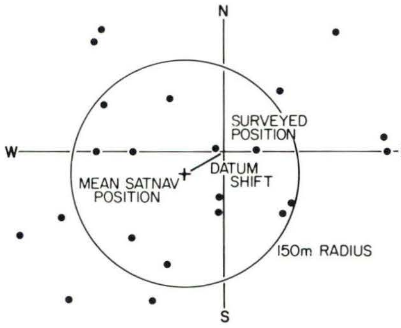

FIGURE 3 ERROR IN SATNAV FIX UNDERWAY AT SEA

A plot of the difference in position between simultaneous "Trisponder" precision microwave fixes having about 20 m accuracy, and Satnav fixes, observed on CSS *Hudson* in Lancaster Sound, September 1976.

The corrections were certainly significant. For example, we found an increase in correction to the X position line of 2.5 μs from west to east across chart 3652, which covers the approaches to the Strait of Juan de Fuca. If a mean correction were applied to this chart, the residual error of ±1.2 μs at either side would move the position line 3 mm on the chart or 450 m on the ground. The chart alone would be contributing the maximum 1/4 n. mile error advertised for Loran-C. Fortunately, computer draughting makes it feasible to warp the lattice and put the line in the right place.

There is one error in any phase comparison system, Decca or Loran-C, that swamps all others. The receiver must make the correct decision on which whole cycle to track. A cycle selection error in Loran-C is 10 μs, which could be catastrophic when close to hazards. Land path from the transmitters distorts the Loran-C pulse and makes such errors more likely, particularly at long range, and this chain has far more land path than any of the earlier Loran-C chains.

We had two standard hyperbolic receivers onboard, and at about half hour intervals the watchkeeper switched them both on for a cycle selection test. The results were alarming; in the centre of the coverage area cycle selection tests were only 80-90% correct, in Dixon Entrance with the southern

Y slave at maximum range only 70% correct, and in the Strait of Juan de Fuca where the signal from the northern X slave has to struggle over the Coast Range neither receiver would acquire groundwave (Mortimer, 1977). Adjustments at the transmitters, made after our tests, appear to have improved performance in the central part of the chain; subsequent tests by the Coast Guard have shown 100% correct cycle selection there, which is in line with extensive tests we have made on the Atlantic Coast. To remedy problems in the Strait of Juan de Fuca and in Dixon Entrance, a third slave will probably be built at the northern end of Vancouver Island. Meanwhile cautions on the chart warn mariners of cycle selection problems in these areas.

Phase Recovery at the Coastline: Inshore Calibration

The most intriguing feature of the phase lag curve in figure 1 is the striking "phase recovery" at the coastline as the wave passes from land to sea.

Visualising the wave front in three dimensions, the lower part of the wave, slowed by the drag of the ground, lags further and further behind the upper part as the wave crosses the land. At the coastline it suddenly encounters the much lower impedance of the sea, and in a very short distance the bottom tries to catch up with the top, as though the whole wave front were an elastic balloon.

Phase recovery is predicted by the mathematical model we use, as a consequence of the "reciprocity principle", which requires that the effective phase lag be the mean of the phase lag calculated from transmitter to receiver with that calculated from the receiver back to the transmitter (Millington 1949, Bigelow 1963).

Phase recovery was verified during tests on Decca transmissions across the south coast of England by Pressey, Ashwell and Fowler (1956). They also found that the change within half a wavelength (1.5 km) of the coastline was larger and sharper than predicted; and that there were variations from theory of about 1/100 cycle (0.1 μs or 30 m for Loran-C) out to five wavelengths (15 km) from the shore.

All this is unfortunate, because most hazards to navigation lie within 15 km of the shore. Although mariners can use radar there, identification of the point returning the echo is often uncertain, particularly on a featureless or low-lying coastline, and it would be very valuable if the Loran-C lattice could be located reliably enough to put it on the chart.

The inshore calibration of last spring was intended to explore this problem rather than to solve it, which may take years. We aimed to check that phase recovery actually does occur with Loran-C; to see how closely it follows the predictions; and to find out what effect the extreme topography of a B.C. coastal fiord has on phase lag and performance in general.

The first test in the *Vector* consisted of running out from Vancouver Island across the entrance to the Strait of Juan de Fuca past Cape Flattery, shown as a pecked line on figure 2. We planned to use trisponder positioning, but had trouble with one transponder and so used sextant fixing for part of the track.

The two lines running out to sea from Vancouver Island are radials from the master transmitter, and both showed clear evidence of phase recovery. The reduction in phase lag on leaving the shore was 1.0 μs for 30 km increase in distance from the transmitter, as shown on the top curve of figure 4 (next page). That is double the predicted phase recovery, perhaps due in part to the influence of the 1,000 m high mountains on Vancouver Island, which accentuate the land/sea boundary effect.

The path from the Y slave changes abruptly along the longer line running southwest from Vancouver Island. Initially, the signal arrives up the strait. Then as the ship comes under the "shadow" of Cape Flattery the path changes suddenly to land (figure 2). This shows up graphically on the lower curve of figure 4, with a 2 μs increase in phase lag over 20 km.

Finally, to test the performance of Loran-C among steep-to islands and in a mountain fiord, *Vector* spent four days in the Strait of Georgia, and up Howe Sound, just north of Vancouver. Howe Sound is only 3 km wide and the mountains go straight up to 1500 m another 3 km back from the shore, and so it was not surprising the signal strengths were marginal and the receiver lost lock on making the turn at the head of the fiord. However envelope shape diagnostics on the monitor receiver indicated that the signal was merely weak and not distorted.

Howe Sound is aligned almost exactly in the direction of the master transmitter, so that the signal was travelling along a channel one wavelength wide, with mountains on both sides at the head and all the way for 35 km down one side. One might have expected confused phase effects under these circumstances, but in fact the master signal showed a reasonably smooth phase recovery curve from 2 km short of the head of the fiord out into open water, with undulations of about 0.3 μs which may have been partly due to problems in sextant fixing on tangents of land (Mortimer, 1978).

The signal from the Y slave crosses the fiord at about 60°, so that the ship was within the half wavelength (1 1/2 km) zone of very high phase change most of the time. This phase change turned out to be a sensitive indicator of how close to the shore the ship was, indicating that the change, though steep, is regular.

Howe Sound widens at the entrance, with a large island in the middle. Visualised in three dimensions, the phase lag in the vicinity of this island looks like a tree stump, with a large buttress root falling away in a southwesterly direction, representing the phase recovery in the master signal. We ran a series of lines across this "buttress", and did in fact find a ridge of phase lag in the lee of the island, decreasing in amplitude as we got further away. As before, the phase lag was greater than predicted, but the excess decayed in a regular fashion:

Distance from coastline (km)	Excess of observed phase change over predicted (μs)
< 1	1.5
2	0.5
7	0.4
10	0.2
25	0.0
32	0.0

Table 1

Excess of observed phase lag over predicted phase lag close in to mountainous B. C. coastline.

The results from this inshore calibration agree quite closely with Pressey's conclusions quoted above. They indicate that some kind of scaling effect, probably associated with the ruggedness of the terrain, should be applied to predictions for the nearshore zone. An extension of P. Brunavs work on approximating the effect of terrain by adjusting the ground impedance (Brunavs 1976) may be successful in modelling this, as might the approach of Johler and Doherty in modelling the "Death Valley Anomaly" (Doherty, 1974).

The results indicate that the coastal effect depends mainly on the land on the direct line to the transmitter, and does not appear to be much affected by reflections from the land on either side. We need more evidence to be sure of this point, but it is a hopeful conclusion, as it would be impossible to predict phase lags if reflections had strong effect.

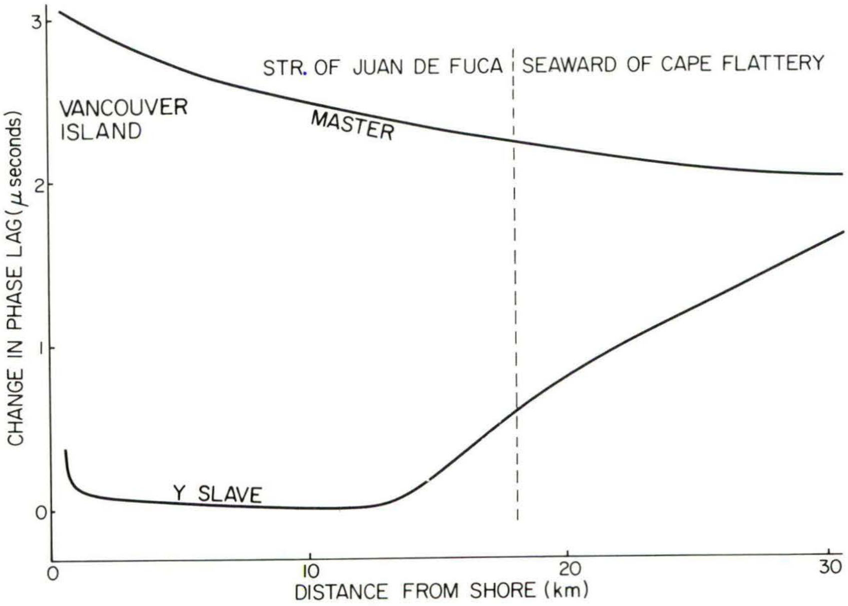

FIGURE 4 OBSERVED VARIATIONS IN PHASE LAG CLOSE TO SHORE

The top curve shows a phase recovery of a microsecond in 30 km as the ship steams away from the land along a radial from the Master transmitter. The bottom curve shows an abrupt increase in phase lag as the ship passes from the strait, where the Y slave is seen over water, into the shadow of Cape Flattery.

The track followed is shown on figure 3.

Conclusions

This calibration again demonstrated the effectiveness of Satnav in mapping the Loran-C lattice for small and medium scale charts, to 150 m accuracy.

We had moderate success in determining ground impedance from land observations; we learned a lot and expect improved results from future work.

We verified the general shape of the predicted phase lag curve, including phase recovery at the coastline.

We confirmed earlier observations that the phase change at the coastline is as much as 2 μs greater than predicted, but found that even under the extreme conditions of the B.C. fiord coastline, the excess phase change appears to be regular. This raises our hopes that extensions to the existing mathematical model will enable us to predict near-shore phase recovery, at least in less rugged terrain where the effect is not so pronounced.

Epilogue

If we want a father figure for hydrography, Captain James Cook is a prime candidate. He had great qualities of seamanship, a strong sense of scientific enquiry, and he treated his crew and the natives he came across with consideration. Bayfield and Boulton, who surveyed Newfoundland waters in the 1800s said of their predecessors that most of them were a danger to seamen: "Throw away Des Barres and the rest. Two only could be trusted -- Cook, and Lane" (Lane was Cook's senior assistant) (Beaglehole, p. 97). We aim to put the Loran-C lattice on the chart wherever it can be useful, and to make sure that the position lines we put down can be trusted.

Acknowledgments

The officers and ship's companies of the *Parizeau* and the *Vector* played a vital part in this work. Of the many other people who helped in the calibration, we particularly single out Mr. P. Brunavs, who pioneered precise phase lag measurement in the Canadian Hydrographic Service and has contributed to it ever since; Lcdr. W. Schorr, U.S. Coast Guard, who advised us on equipment and guided us when we had problems; and Mr. R. Loschiavo, the technician who made it possible to carry out the observations.

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Canada's Role in the International Tsunami Warning System

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Abstract

Canada has been an active participant in the Tsunami Warning System for the Pacific from the time of its internationalization.

This paper reviews alternatives for Canada's continuing role in view of the changing warning needs imposed by increase in coastal industries and populations, the potential use of satellites in warning systems, and the need to extend warning capability to ocean areas beyond the Pacific.

TSUNAMIS, THE INTERNATIONAL WARNING SYSTEM, AND CANADA'S ROLE.

Tsunamis, sea waves generated by impulsive submarine disturbances, have been a phenomenon known for many centuries. Most commonly they originate from the vertical crustal displacements in the trenches off island arcs and continents associated with underthrusting by tectonic plates. Occasionally they are produced by earthquakes where the motion is primarily horizontal, by submarine volcanoes, or by landslides. Earthquakes of Richter magnitude 6.5 or less are occasionally tsunamigenic, and 7.5 or greater, in shallow seas, frequently so.

Tsunamis may inflict havoc on coastal areas adjacent to the disturbance immediately or within minutes after the coast has been shaken. But then waves may also arrive without warning or tremor at distant shores, destroying homes and harbour facilities, taking lives and striking terror among unprepared people. The suddenness and the destructiveness of these waves has made them particularly threatening.

Geophysicists and oceanographers recognized that since tsunamis travelled in average ocean depths at about 700 km per hour, distant shores could have sufficient time for a warning of their approach. The communication technology developed during World War II made it possible to collect seismic reports from observatories after major earthquakes and determine each epicenter, interrogate tidal stations for possible wave action, and transmit warnings to national agencies responsible for threatened coasts.

The earthquake of April 1, 1946 in the Aleutian Trench triggered a tsunami that struck near and distant coasts. In Hawaii it produced waves up to 17 meters in height, and was rated as being the worst natural disaster in the history of the Islands. Resulting concern was sufficient to bring into being the U.S. Seismic Sea Wave Warning System, centered at the Honolulu Observatory to provide warning to civil and military agencies throughout the Pacific. Two years was required to provide instrumentation and communication for seismic and tidal networks, and the warning system came into operation in 1948. The System provided warnings for 4 major tsunamis in 16 years, from the Kamchatka earthquake on November 4, 1952, the Aleutians on March 9, 1957, Chile on May 22, 1960 and Anchorage, Alaska on March 28, 1964. In this period the Warning System gradually expanded, and supplied warnings to nine countries and island groups in the Pacific for the 1964 event.

Other countries were attempting to cope with the threat; Japan for example, had organized a national tsunami warning system in 1952, and it was functioning in time for the tsunami of that year. The USSR, as a result of that same tsunami, developed a warning system that began service in 1956. However, the scope of the tsunami problem is such that no nation could deal with it adequately alone.

The Seismic Sea Wave Warning System became an international tsunami warning system for the Pacific in 1965. This came about as a result of a working group meeting called by the Intergovernmental Oceanographic Commission (IOC) on the International Aspects of the Tsunami Warning System in the Pacific. This meeting was held in Honolulu in April 1965, and Canada was one of the 18 participating states and agencies. The recommendations of this working group to IOC were included in the General Conference Report of UNESCO 14C/15. In it the IOC Summary Report noted and accepted "with appreciation the offer of the United States to undertake the expansion of its existing facilities in Honolulu to become the International Tsunami Information Center" (ITIC) and recognized this Center as a part of the IOC. An International Co-ordination Group for the Tsunami Warning System in the Pacific (ITSU) was formed of Member States, to provide liaison, and advice on the operation of ITIC.

The Pacific Tsunami Warning Center (PTWC) is the operational headquarters of the International Tsunami Warning System. It is located at Ewa Beach near Honolulu, and is funded by agencies of the U.S. National Ocean and Atmospheric Administration (NOAA). The Center is staffed by geophysicists, technical and administrative support, and includes in its facilities advanced seismic and telecommunication equipment. Geophysicists live adjacent to the Center, and two are always on call at hours when staff is not actually on duty. Twenty-one seismic observatories and 53 tidal stations co-operate in the International Tsunami Warning System and have direct communication with the Center.

The occurrence of an earthquake of magnitude 6.5 or larger anywhere in the world will trigger an alarm at PTWC. By means of its own seismographs and by reports from co-operating observatories, the geophysicist on duty will determine the epicenter of the earthquake and its magnitude. In the event that it is in the Pacific and large enough to produce a tsunami, the nearest tidal stations will be interrogated, to advise whether unusual water levels are occuring during the time when a tsunami would be expected. At the same time, agencies served by the System are notified that a tsunami watch is in progress. When reports from the first tidal stations are received, a decision is made at the Center whether a significant tsunami has been generated. If it has, a warning is sent to disseminating agencies and press releases are issued. Messages give the current information on the size of the waves and expected arrival times, and these are updated. Local civil defense agencies in each country make the decisions on whether low lying areas are to be cleared, and what other precautions are to be taken. When the initial earthquake has a magnitude of 7.5 or larger, warnings may be issued prior to receiving a response from tidal stations.

Canada contributes tidal information for the Warning System from the stations at Tofino and Langara, and seismic information from the Victoria Geophysical Observatory. The Tofino station is unique in that since 1966 it could be telephoned from Honolulu and will report, unattended and automatically, the present water level and whether a tsunami is in progress.

ITIC has no operational involvement in the Tsunami Warning System at the time of warning, but fulfills monitoring, co-ordinating, and educational functions on behalf of participating Member States. Its responsibilities were redefined in a new mandate, approved by the IOC in 1977:

> MANDATE
>
> The mission of the International Tsunami Information Center (ITIC) is to mitigate the effect of tsunamis throughout the Pacific:
>
> 1. by monitoring the international tsunami warning activities in the Pacific and recommending improvements with regard to communications, data networks, data acquisition, and information dissemination;
>
> 2. by bringing to Member and Non-member States knowledge on tsunami warning systems, on the affairs of ITIC and on how to become active participants in the activities of the ICG for the Tsunami Warning System in the Pacific (ITSU);
>
> 3. by assisting Member States of ITSU in the establishment of national warning systems and improving preparedness for tsunamis for all nations throughout the Pacific Ocean;
>
> 4. by gathering and promulgating knowledge on tsunamis and fostering tsunami research and its application so as to prevent loss of life and damage to property;
>
> 5. by co-operating with the World Data Centres in making available and providing through appropriate channels all records pertaining to tsunamis;
>
> 6. by assisting national authorities in making investigations of all aspects of major tsunamis and developing standard survey procedures for such investigations.

ITIC is located on the campus of the University of Hawaii. It has two full-time staff members, a Director and an Associate Director. The Director is appointed and paid by the U.S. National Weather Service (NWS); the Associate Director is supplied and funded by a Member State other than the United States. In addition, the U.S. provides part time secretarial and technical support. The Associate Director for his period of service is under contract to UNESCO and as such is not responsible to any national authority. His position is of the utmost importance in enhancing the international status of ITIC, and in developing liaison with States throughout the Pacific.

Canada supplied the first Associate Director (the author) from 1975-77 and an appointee from New Zealand is fulfilling the responsibilities during 1978. The present system of funding the Associate Directorship makes it prohibitively expensive for many of the Member States to nominate, and there is in consequence, a serious threat of the position going unfilled.

ITIC is housed in a single office, which provides space for both full time and temporary staff, visiting scientists, and the ITIC library. The Director is without spending authority, other than by approval of NWS. Operations of ITIC are vulnerable to budgetary constraints of NWS, particularly in times of restricted U.S. Government spending. IOC and UNESCO provide some funding for travel, meetings, and publications, but the greater portion of ITIC costs are met by the U.S. and by the native country of the Associate Director.

ITSU, the co-ordination group composed of representatives of Member States, meets biennially. A Canadian, Mr. Dohler, is serving as chairman. The sixth and most recent meeting (ITSU-VI) was held in Manila in 1978. Meetings of ITSU have recognized that the resources of ITIC were inadequate to carry out the designated functions and recommended courses of action. A resolution was passed at the fifth session (ITSU-V) in 1976, recommending that IOC Member States make voluntary contributions, preferably on an annual basis, to the IOC Trust Fund, designating these to provide support for the staff and special projects being undertaken by ITIC, and to allow development of programs for regional and national tsunami warning systems. To date, only Canada has made such a voluntary contribution. National representatives at ITSU-VI in 1978 were asked to express to their Governments the urgency of this support.

Honolulu, and particularly University of Hawaii, offers many advantages as the site for ITIC. The city is central to the Pacific and is convenient both for ITIC staff visiting Member States or tsunami disaster areas, and for tsunami specialists for countries of the Pacific to come for visits and research, or to gather for technical training and meetings. The Hawaiian Islands are tsunami-prone, and the State Civil Defense based in Honolulu has a high competence to provide training for local and visiting personnel in dealing with tsunami disaster problems. The University is only 40 kilometres by road from PTWC. The East-West Center of the University has a rotating population representing many of the racial and linguistic groups of the Pacific, an asset to ITIC in preparing and translating educational materials. As a research base for tsunamis, ITIC has been diminished by the removal of World Data Center-A Tsunamis, to Boulder, Colorado, and by the reduction in 1977 of the Joint Tsunami Research Effort at the University. It is threatened by the possible loss of office space on the campus, which would remove it from proximity to library facilities of the University, and research agencies such as the Hawaii Institute of Geophysics. However, providing that immigration and national security agencies of the United States make it possible for the Associate Director, tsunami specialists and researchers from any Member State to participate freely at ITIC, Honolulu is the logical place for it to remain as an International organization.

THE GROWING THREAT OF TSUNAMIS, THE RESPONSE TIME OF THE WARNING SYSTEM, THE NEED FOR TECHNOLOGICAL IMPROVEMENT, AND CANADA'S ROLE.

The growth and development of coastal industries, and increase in tourist and resident populations on seacoasts has added to the potential for tsunami damage in the Pacific. In addition new types of facilities, such as atomic power plants and supertanker ports have made tsunamis a threat in other oceans where formerly they could, by their relative infrequency, be disregarded.

Present technology and operating procedures at PTWC permit the identification of earthquake epicenters and magnitudes for possibly tsunamigenic events to be made in a period of 30 minutes to an hour.

Selection of tidal stations nearest the epicenter and sending interrogating messages to gauge attendants is partially automated, and can be carried out in a few minutes. Following this is a period of uncertainty. Responses are dependent on the availability of the gauge attendants, the functioning of all communication links, and the tidal stations themselves being in good working order. Factual information on which to base a warning or no-warning decision may be available in 30 minutes after the interrogation, or may be delayed for hours.

At the ITSU-VI meeting in 1978 a group was established to report on technical improvements for the International Tsunami Warning System, and to develop an action plan. The group requested Canada and the U.S. to investigate the use of satellites in the Warning System, and for the USSR and Japan to provide information on their satellite programs. The group established, as a goal, that the Warning System should establish the existence of a tsunami in the Pacific within one hour after its generation. ITIC and PTWC are to define the system of gauges needed to achieve such a goal.

The GOES geostationery satellites over the Pacific provide a possible means of data collection from tidal and seismic stations that would eliminate much of the uncertainty in the present operations of PTWC. One possible use of the satellites is being explored by the U.S. Geological Survey, with the development of a prototype system that will transmit coded water level data on demand. The system is designed to be applied to existing float-operated tide gauges. Such a system would eliminate much of the uncertainty in collecting the water level data at the time of a tsunami. However, considering that float gauges are normally restricted to sheltered waters and harbours, the concept is thereby limited. Newer tidal systems using crystal pressure sensors, such as the Canadian made Aanderaa and Applied Microsystems tide gauges, can be deployed on exposed coasts as well as in sheltered waters. Such gauges transmitting via satellite, would offer a greater versatility to a tsunami warning system.

National and regional warning systems provide PTWC with warning of tsunamis originating in their areas of responsibility more rapidly than they can be determined at the Center. Three tsunami-generating regions are covered by these systems: Japan by the Japan Meteorological Agency, Kamchatka and Kuril Islands by USSR, and Alaska and Aleutians from Palmer, Alaska. Communication facilities at the observatory in Palmer are being improved, so that it can serve as an alternate International Warning Center in the event that the one in Hawaii were put out of action by earthquake or tsunami.

Establishment of a regional system on the Canadian west coast, perhaps serving as well the coasts of Washington and Oregon, needs to be considered. A seismically active zone with tsunamigenic potential exists and a regional system may be warranted both for early protection to the adjacent North American coast, and as a source of early warning to the rest of the Pacific. Tectonic plate underthrusting appears to be taking place, and zones of active seismicity are found along this coast and offshore. However, earthquake mechanism studies in the Vancouver Island region indicate predominantly strike slip faulting, in spite of the apparent subduction. The thrust faulting that is found in other similar regions has apparently not occurred in the 80 years of available seismic observation (Milne 1978). Earthquakes large enough to be tsunami-

-genic have been recorded, the greatest off the British Columbia coast being magnitude 8.1, in 1949, off Langara Island in the Queen Charlottes.

With this unknown potential to generate a major tsunami lying near our coast, there is a need to determine quickly the epicenters of the largest earthquakes, and to observe whether the nearest gauging sites or ports have been struck by a tsunami. Four seismic stations in British Columbia are now recording remotely at the Pacific Geoscience Centre(PGC) at Sidney, B.C. These are located at Haney, Pender Island, Victoria, and Alberni. The data are input continuously through a computer, and epicenters are computed automatically and are available on demand. Additional stations can be added to this network. Selected west coast tide gauges could be recording remotely at the Institute of Ocean Sciences, in the same facility as PGC, and if a tsunami were generated its existence would be known as soon as the waves reached the nearest transmitting gauge. The Provincial Emergency Programme in B.C., and PTWC in Honolulu could be notified immediately, to provide the earliest possible response to forewarn local and distant coastal populations. Likewise, if no tsunami had been generated the Centers could be advised promptly that no danger exists.

Instituting this system of preparedness would provide a direct service to Canada and also to the Pacific community. Beyond that, the successful application of this technology here would demonstrate its usefulness on other tsunami-prone coasts. It is appropriate for Canada to take such a lead as part of its role in the International Tsunami Warning System.

The cost of automating the tsunami warning system, to have unmanned tidal and perhaps seismic stations transmitting data to PTWC on schedule or on demand from around the Pacific may be in the order of $2,000,000 to $5,000,000. The questions arise of whether such an expenditure is warranted, from what government or other sources the funds may be provided, and how automation can be provided in time to be of service in the next Pacific-wide tsunami.

Funding for disaster preparedness tends to follow rather than precede the disaster. This is as true for tsunamis as it is for installing traffic lights at intersections. Five Pacific-wide tsunamis in the period 1946 to 1964 brought the immediacy of the problem to public attention, and funding for research and development was substantial. Fourteen subsequent years without an ocean-wide disaster have contributed to a diminishing of concern and support, even though each day brings the next destructive event one day closer.

The technology exists to provide an automated warning system, so that generated tsunamis could be registering at PTWC virtually the same time that they are being recorded at the local gauging station anywhere within the system. It would be possible, knowing the epicenter and the response of the gauge to events from various tsunami sources, to determine whether a potentially destructive tsunami has been generated, and to forecast its probable direction of propagation. With appropriate computer technology, much of the decision-making could be semi-automated, and substantial time savings in the system are possible. It would be hard to place a dollar value on an unknown number of lives saved by an earlier warning. However if one looked at specific industries, cost effectiveness may be readily calculable. For example, would an oil tanker loading or off-loading in a port facility be taken to sea if a major tsunami were approaching? How much lead time would be required to alert the ship's complement, and have those ashore return to the ship, disconnect fuel and mooring lines, obtain tugs, get under way and out to a safe distance offshore? Would additional warning time save a substantial loss, and would better decision-making capability at other times save the cost of unnecessary precautions? Such a time and cost analysis for a variety of industrial and commercial operations in tsunami-threatened areas, coupled with a frequency analysis of destructive tsunamis, would provide a cost-benefit basis for evaluating automation, and might provide legitimate grounds for seeking funding to support the automation.

Systematic knowledge on the frequency and impact of tsunamis is an essential prerequisite for a cost-benefit study of automation, and also for any tsunami preparedness planning. A partial study of tide records at Tofino, B.C. showed that of 70 large known tsunamis in the Pacific, 21 had registered on the Tofino gauge (Wigen 1978). The study showed that the Canadian west coast was most vulnerable to tsunamis originating in Alaska and the Aleutian Islands, Kamchatka and the Kuril Islands, Japan Trench, and Chile-Peru. The 1964 tsunami was most destructive, causing about $5,000,000 damage at Port Alberni, and that larger events than that of 1964 must be expected. No lives have been known to be lost on the Canadian west coast from tsunamis of distant origin. However, an earthquake of June 1946 centered in the Strait of Georgia caused one death by drowning (Hodgson 1946).

For Canada's Arctic coast, data are insufficient to determine whether a tsunami threat exists. For earthquakes in the period 1899-1961, it has been noted (Basham 1977) that there are sufficient uncertainties in the completeness and reliability of epicenter plots, that they can only be used to confirm that earthquakes of greater than magnitude 5 had occurred several times in northern Canada, notably in the Yukon Territory and the Baffin Region. The development of a Canadian seismic network in the Arctic in the 1960's has allowed more precise epicentral determination, and evidence for this limited period shows that tsunamis are at least a possibility.

Although about 80% of all tsunamis occur in the Pacific, destructive ones are generated in the Atlantic and Indian Oceans, and in the Mediterranean Sea. In 1929 an earthquake on the Grand Banks generated a tsunami that took 26 lives in the region of Burin, Newfoundland (Murty 1976). This was an unusual event, in that the epicenter was not located in a region of high seismicity. This tsunami shows that a limited threat exists on most if not all coasts. It raises questions of what degree of preparedness is warranted beyond the Pacific. Routine planning and civil defense training for tsunami disasters are certainly not required to the same degree on the Atlantic and Arctic coasts of Canada and other countries as in active zones of the Pacific. Furthermore, a warning system that will have to respond to a real emergency perhaps once a century may not be heeded when the disaster is impending. However, the possible impact of tsunamis may still be a design factor in planning of coastal facilities.

For any coast, an assessment of a tsunami threat can be made from a study of past tidal records. The frequency with which tsunamis have been recorded, the regions from which they have propagated, and the probable maximum wave that may be expected in any time period can all be determined. On this factual basis, decisions can then be made on the need for warning systems, and for including tsunami impact as a design criterion for any aspect of coastal engineering.

Canada is already taking a lead role in such an assessment, through the Historical Study of Tsunamis (Wigen, 1978). This is a project initiated at the International Tsunami Information Center, and being co-ordinated from the Institute of Ocean Sciences at Patricia Bay. Researchers and agencies are being supplied, on request, with a list of 1600 known or potentially tsunamigenic events of the past century, and are being invited to make a detailed investigation of diagrams from any one tidal station for evidence of these events. Standardized procedures have been set forth for data extraction.

The Study will provide systematized data of past tsunamis at that station. In addition, the collected results from many stations will show directionality of tsunami propagation from generating sources, and provide a body of knowledge for modelling of tsunamis in the ocean.

SOCIOLOGICAL ASPECTS OF TSUNAMIS, AND CANADA'S ROLE.

At a conference in Manila in 1976 on the Survival of Humankind, Philippine participants pointed out that their losses from natural disasters might in some years offset any growth in the economy, and might exceed the total benefits received from foreign aid. In the months prior to the conference, they had experienced typhoon, flood, volcano, earthquake and tsunami. The earthquake of August 17, 1976 in Moro Gulf, and the subsequent tsunami had taken 8000 lives, left 90,000 homeless, and disrupted the livelihood and economy of the region. In a report on the Tsunami (Badillo 1978) it is noted:

> The Moro Gulf tsunami of 17 August 1976 was the most disastrous tsunami experienced by the Philippines. There have been more severe tsunamis, but areas hit were less populated and had less manmade structures. A natural disaster is not merely a geophysical event but a human one as well. If any projection can be made it is this. What is now barren will be densely populated. Empty beaches will be filled with residences, tourist facilities, hotels, factories, power plants, etc. Offshore, there will be not merely seaweed and oyster farms and fish corrals but also storage facilities, tank farms and the like. Thus a tsunami prone coast is potentially a great disaster area. Such is the Moro Gulf coastline.

And what is true for Moro Gulf is valid for every country, developed or developing.

Tsunamis cannot be prevented, but with research, planning, and education their effects can be mitigated.

Systematic knowledge on the history of tsunamis provides a basis for forecasting their frequency, direction of propagation, and magnitude. Such studies provide input into planned land use and protection in low lying coastal areas.

Such an approach to the tsunami problem has only recently been undertaken in Canada. In 1976 the City of Port Alberni and the Province of British Columbia jointly undertook to have a development feasability study conducted for a low lying area within the City. The area, Lugrin Creek, had experienced flooding from runoff, and from the 1964 tsunami. Dyking had been carried out to protect against rivers and streams overtopping their banks. In looking to the alternatives for improving the area, the feasability study required an estimate of levels of a 1 in 200 year flood, and "an evaluation of tsunamis, and an estimation of the damage to dykes, and the likely effects...of overtopping...by tsunamis, as well as an assessment of the impact of this factor on further development in the Study Area." A study carried out by consulting engineers was able through a study of the history of tsunamis in the Tofino-Alberni area to make some estimate of possible sizes and frequency of tsunamis. This estimate became a significant factor in the recommended type of development of the land.

The development feasability study at Port Alberni has immediate significance to the City. But looking beyond, the techniques and engineering used for the study are applicable to other coastal sites in Canada and throughout the world. Canadian engineering consultants are employed in many developing countries and tsunami hazard evaluation should be an integral part of planning wherever tsunamis may be a threat.

The ITSU-V meeting in 1976 identified education as an essential factor in tsunami preparedness. UNESCO funding was sought for the preparation and publication of a variety of educational materials, tsunami catalogues, bibliography, semi-technical text books, a catalogue of tsunamigrams, brochures, films, and slide tapes. Funding was also requested for translation of some of these materials into the languages of the Pacific. Because of financial limitations, funding was provided by UNESCO for only one of these publications, an atlas of tsunami marigrams.

In the 1978 meeting, ITSU-VI, most of the national representatives, including Canada's, identified the need in their own countries for educational materials, and recognized that some of this requirement could be met through individual production and exchange of publications.

Some participants provided materials that could be copied and disseminated. Both the U.S. and USSR made a tsunami movie available; the Philippines, a book entitled The Broadcaster's Manual on Emergency Preparedness; Canada, the newly published textbook by Dr. Murty, Seismic Sea Waves, Tsunamis; and ITIC, a tsunami slide tape. A subcommittee addressed at length the needs to be filled by educational materials. Their conclusions, forming part of the Summary Report of the session, are sufficiently well stated to include below in full.

> Proposals for a tsunami educational programme
>
> The session, with the assistance of an *ad hoc* group set up by the Chairman, identified three groups with whom an educational programme on tsunamis must be concerned. One group is the scientific community, i.e. those researchers concerned with the technical aspects of tsunamis. Many in this group may never be directly involved in an actual tsunami event but all are necessary for the development of appropriate input to the Tsunami Warning System. Their needs for educational material are fairly well defined - catalogues of historical events, observed data, bibliographies of current research, etc.
>
> The next group has as its membership the co-ordinators and operators of the actual Tsunami Warning System. These may be civil and/or military authorities who have the responsibility for carrying out those actions required to save lives in the event of an actual tsunami. The needs for educational material here are less well defined and on a broader level than that for the scientific community. These may include internal training programmes on effective evacuation procedures, relief centres, etc., as well as the need to distribute educational materials in the form of brochures, slide presentations, films, etc. to the last group, the general public - or at least that portion at risk in an actual tsunami event.
>
> The educational requirements for the general public are of a completely different character than those for the first two groups. Reduced to bare essentials, the first group must know WHEN (based on WHY) something is happening, the second group must know WHAT must be done and the third group must know HOW to carry out these actions. This implies more of a sociological and psychological problem than a technological one, and this area of education appears relatively open for further development. The needs of this group are also most heavily oriented towards individual Member States and even localities. The response of the general community to risk will be most divergent, depending on local custom, religious practices, relationship to a central authority from whom an evacuation order may come, etc.
>
> To summarize this view, these three identifiable groups have markedly different educational needs, some of which may not have been adequately dealt with in the past.
>
> Based on an analysis of recommendation ITSU-V.13, it appears that the educational needs of the scientific community may be reasonably well met. The needs of the administrative community are being met to some extent, but there does not appear to be any co-ordinated effort to systematically exchange information and experiences between the appropriate authorities of the Member States. Finally, the educational needs of the general public have not been addressed adequately.
>
> In view of the weakness of the general public educational programme, the group emphasized that this element of the Commission's tsunami programme should receive special attention immediately. The public education programme should be directed towards: coastal residents, their local officials, school teachers, mass media people, policy makers and should include: straight lectures, group dynamics, live-in seminars, audio-visual aids, (slides with tape recordings, movies, stills - cartoons) drawings, pictures to be displayed in public places and on television, radio announcements, brochures and pamphlets.
>
> Funding of these activities are primarily the responsibility of each Member State. Support should also be provided by the IOC through its regular funds, Trust Fund and its new Voluntary Assistance Programme (IOC/VAP). The Group therefore decided that the Programme and Budget Forecast for 1981-1982 (see Annex VI), should include as **a** high priority item the preparation and publication of educational material. It was noted that the 1979-1980 Regular Budget does not have adequate funds for tsunami education for the general public. Thus, other funds should be sought for this purpose, perhaps through the Trust Fund.
>
> The impact that a public education programme will have is not fully understood. One method to address this problem would be to undertake one pilot educational programme within each country and Member States are urged to do so. A report of these activities should be disseminated to other Member States via the ITIC and an evaluation presented at the next session of ITSU.

The need for tsunami education in Canada has been addressed since the ITSU-VI meeting by the newly formed, ad hoc Joint Tsunami Working Group. Recognizing that 14 years have elapsed since the last disastrous Pacific-wide tsunami; that people have had time to forget its impact, and a new generation has not experienced it; and that the days of grace until the next event are being reduced one by one; there is an urgency to know both here and abroad what to expect and how to respond.

The foundation of effective response to a tsunami alert is a well-prepared Civil Defense organization. Such an agency requires a co-operative working relationship with support groups needed to respond to the warning. It also needs a central decision-making unit to receive warnings when a tsunami has been generated.

Civil Defense headquarters must be informed on the practical aspects of tsunamis, the sources from which a threat exists, the areas of coastline most vulnerable, and the number of hours after a wave arrival that the maximum waves may be expected.

It needs the communication network to relay its decisions to threatened communities. The local bodies in these communities need to respond to the warnings, take action necessary to clear beaches, low-lying areas, and get boats away from harbours. Pre-planning in local areas, designation of threatened sites, and periodic education programs to ensure elected civic officials and threatened populace are aware of the hazard are necessary. A balance is required, so that time spent on preparedness is kept to a minimum, and is efficiently used. Disastrous tsunamis may occur infrequently, and if much time is spent in preparedness it may be begrudged.

On the Canadian west coast, the Provincial Emergency Programme of the B.C. Government, is the co-ordinating agency. It holds planning meetings occasionally with officers of other agencies to review present state of knowledge, and to formulate plans and action items for tsunami preparedness. It also periodically brings to Victoria elected officials from B.C. communities for seminars on disaster preparedness, including tsunamis.

Just as the Provincial Emergency Programme has the responsibility after receiving the warnings from PTWC to decide on what action, if any, is warranted, so the elected officials in coastal communities, upon receiving a warning that a tsunami may be expected, have to make their own decisions of action to be taken.

There is a continuing need to evaluate what areas are threatened, and perhaps to designate zones for degree of hazard. Costs of evacuation are high, and response to tsunami threats needs to be adequate, but not excessive.

In the developing of preparedness procedures for other parts of the Pacific, Canada's local experience qualifies local individuals to make an input at international workshops and seminars. Such workshops are being planned and are part of the designated responsibility of ITIC. Participation of Canadian experts would be welcomed, and it is recommended that requests for their participation be favourably received.

RECOMMENDATIONS

Several Canadian activities are of particular importance in bringing the International Tsunami Warning System to a state of preparedness consistent with the threat of tsunamis.

ITIC and ITSU need continuing financial support from Member States, to carry out the functions assigned to them. The Canadian contribution through the IOC Trust Fund has strengthened their operations. It is recommended that this support for tsunami activities be specifically budgetted, so that it can continue to be made without sacrifice to the other activities dependent on Canada's IOC Trust Fund contributions.

The investigation of frequency and size of tsunamis in all oceans, now being co-ordinated at the Institute of Ocean Sciences, through the Historical Study of Tsunamis, needs to be brought to successful completion. The data to be collected can provide a realistic base for evaluating the need for tsunami preparedness in all its aspects.

Investigation of the use of satellites in the International Tsunami Warning System, as requested of Canada and the U.S. by the ITSU-VI meeting, should include in Canada a study of the use of automated technology in various modes. The development of a system prototype that could best meet Canadian and worldwide needs is recommended.

Development of a regional tsunami warning system to serve the Canadian west coast, and perhaps Washington and Oregon, would be a direct benefit both to Canada and to any participating country threatened by a tsunami from this coast. It is recommended this be investigated.

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From Hand - Lead to Hydrosearch

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ABSTRACT

A conference with the theme "Cook - Hydrography 200 Years Later" offers a suitable opportunity to review the progress made by one national hydrographic service since the days of Cook in providing the surveyor with the means of "looking" at the seabed and discovering the natural and man-made obstructions which lie upon it - and which it is his primary job to chart accurately. Such a review is not the mammoth task the uninitiated might expect as to all intents and purposes there were no advances until well into the present century, and it is only in the last thirty years or so that the advent of sonar has given the surveyor the ability to gather information about the seabed not only from directly beneath his ship but also from ahead and to the sides simultaneously. This paper traces very briefly the progress made in this field by the Royal Naval hydrographic service, and outlines the present policy and future requirements with regard to sonar equipment and operations.

INTRODUCTION

> "It is difficult to say that any one step in the construction of a chart is more important than another, as each is necessary for the completion of the whole, and an error anywhere may cause a disaster; but if any particular item is to be picked out, perhaps the sounding should rank in the highest place."

These words could well have been written by Captain Cook, but in fact they were written well over a hundred years after his death - by Captain Wharton, a Royal Naval surveyor of the last century, in his book "Hydrographical Surveying", a forerunner of the modern Admiralty Manual of Hydrographic Surveying. Wharton's manual went through four editions and the last of these, published in 1920, contains precisely the same description of sounding as was in the first edition of 1882, and which could just as well have been written in 1782:

> "The ordinary main plan of sounding is thus. The boat proceeds in straight lines in a direction, of a length, and at a distance previously decided on, with a man in the bow constantly sounding ... The pace at which the boat may go, and the necessity, or not, for stopping at the casts, will depend on the depth of water and the capacity of the leadsman."

For 150 years after the death of Cook, in order to measure the depth of water, it was necessary to lower a lead to the seabed by one means or another, and throughout this period the traditional method of obtaining soundings by marked leadline was used by surveying ships and boats. The leadsmen became extremely skilful at operating while underway, but sounding in over six fathoms in the boats, and twice that depth from the chains on board the ship, was beyond the capability of even the most expert. Various devices were introduced as the nineteenth century progressed in order to speed up or improve the accuracy of sounding in deeper water, but all involved stopping the ship and, in the case of oceanic soundings, a considerable wait "on station" while one depth was obtained. In order to lay the first transatlantic cable in 1858 the proposed route was surveyed using a lead and line to obtain one sounding every fifty miles - and each one needed about six hours to take in depths of from two to three thousand fathoms.

The Lucas sounding machine was developed in order to speed up the surveys of cable routes and by the mid-1880s a steam-operated version, using 5000 fathoms of piano wire, a measuring wheel and a sounding tube with self-releasing weights, was fitted in a number of ships. Although this machine improved both the speed and accuracy of sounding in deeper water the ship still had to stop, and so it was a development of some importance when in the early 1900s another Royal Naval surveyor, Captain Somerville, invented a mechanical apparatus for casting the lead ahead with the ship underway. By means of a wire operated from a steam winch in the after part of the ship, through a leading block on the mainmast and to a boom below the level of the bridge, the lead could be repeatedly released from well forward. The leadsman standing in chains well aft was then able to "feel" for the depth with the marked leadline as it came abreast of him, the leadline being kept taut by a trailing weight. A somewhat complicated and, at this distance in time, rather comical way of measuring depth, but one which considerably speeded up the work of the ship and enabled sounding to be carried out down to about 35 fathoms at a speed of five knots.

The hand lead, the Somerville sounding gear and the Lucas deep sea sounding machine remained in use until the outbreak of the Second World War. The first edition of the Admiralty Manual of Hydrographic Surveying published in 1938 gives detailed advice on their use and with regard to sounding in shallower water records only that "Sounding with the hand lead is gradually giving way to Echo Sounding..." However the book does then go on to provide a full description of the Admiralty echo-sounders then in use, and it is to the introduction of this type of equipment - which one distinguished ex-Hydrographer of the Navy has referred to as "probably the most significant advance" in hydrography "throughout the whole of the 200 years" since the days of Cook - that we must now turn our attention.

ECHO-SOUNDING

The introduction of echo-sounding into the Royal Navy stemmed directly from the knowledge of acoustics in seawater gained by Admiralty scientists during the First World War and the development of equipment for locating submarines. Trials of the first telephone audio-frequency system of echo-sounding to measure depth were carried out in HMS KELLET in 1923, the equipment consisting of an electro-magnetically operated hammer striking a steel diaphragm at regular intervals, causing it to emit audio-frequency waves. The echoes returned from the seabed were received in a small hydrophone and the operator, wearing earphones, manipulated a calibrated dial until he could hear the echoes and was then able to read off the depth. A variation of this later became the standard Admiralty Echo Sounding Gear which was fitted in a number of survey ships during the 1930s. It had a depth range of about 200 fathoms, making it suitable for work in all continental shelf waters, but in depths of less than six fathoms it became ineffective due to excessive interference between the transmitter and the hydrophone. This interference also prevented the set being put to any use in surveying motor boats, and in turn led to the development of a high frequency set which used directional sound impulses to prevent the need for screening between transmitter and receiver. Trials with such a set, using a condensor discharge for the transmission and a magneto-striction receiver, were carried out in a survey motor boat in 1930, and excellent results - with a continuous profile of the seabed being recorded on chemically-treated paper - were obtained at speeds up to eight knots. Two years later further trials, with the equipment fitted in a ship, HMS FLINDERS, were equally successful and depths down to 440 fathoms were recorded.

The subsequent development and production of these echo-sounders was placed in the hands of Henry Hughes & Sons (now Kelvin Hughes) and it is equipment manufactured by this firm which has been used by the Royal Naval Surveying Service ever since. The latest model, the MS 48, underwent extensive trials in HMS HECATE during 1975 and is now being fitted in all thirteen survey ships and their boats.

With the introduction of the ultrasonic echo-sounder and its automatic recorder hydrography moved into a completely new dimension; no longer was each sounding obtainable only by laborious manual labour, or latterly, from listening intently for distant echoes in a pair of earphones, but the surveyor was presented with a continuous profile of his track, available from the moment he entered the survey area until the time he left it. His ability to interpret each line of soundings, and compare it with adjacent lines, all represented on continuous strips of paper, improved the quality of his work beyond all measure and comparison of charts compiled before and after the advent of echo-sounding reflects this quite clearly.

THE INTRODUCTION OF SONAR

In parallel with the development of the echo-sounder and closely related to it, stemming from the same First World War experiments in submarine detection, another type of underwater equipment, sonar, was developed and fitted in ships during the 1930s. Survey ships were provided with sonar as a matter of course to enable them to assume a wartime role as necessary, but it was not until early 1939, when Commander Southern of HMS GLEANER wrote a report on the new equipment, that it became apparent that hydrography now had the means to enter a third dimension, with ships not only able to collect information about the seabed continuously from directly beneath them but at the same time capable of gathering data from ahead and to the sides as well.

Prior to the introduction of sonar the only method of carrying out a clearance sweep of the survey area was by means of Oropesa gear, which had been developed for minesweeping. This was a time-consuming and cumbrous operation involving the use of wires, depressors and floats, with the attendant dangers of fouling obstructions, being hampered by other ships and leaving gaps or "holidays" in the searched area, and the Southern report concentrated on the advantages enjoyed by sonar over this equipment. A copy of the report was issued to all survey ships and, in one form or another, remained for many years the main source of guidance available to surveyors with regard to the use of sonar for purely surveying purposes. The equipment to which it referred was a basic hull-mounted "searchlight" sonar, operating on about 20 kHz with a maximum range of 3000 yards, and similar sort of equipment - intended first and foremost for locating submarines (or later, midwater fish shoals) - has been fitted in all Royal Naval surveying ships ever since.

A new sonar, specifically designed for locating bottomed submarines, was developed immediately after the Second World War, and in 1947 it was considered that this set, together with the "searchlight" sonar already fitted, would suffice to meet the total sonar requirement of survey ships. The new set operated on a frequency of 50 kHz and worked by restricting the acoustic transmissions to a fixed fan-shaped beam, very narrow in the horizontal plane, below and abeam of the ship; and by switching between transducers it could be operated on either side of the ship as required. The returning echoes were used to mark a paper trace in the recorder which produced "shadow" pictures of objects on the seabed out to a range of 300 yards, from which length and height could be estimated. Problems were experienced in getting the set fitted and in 1949 the Hydrographic Department was told, in words which sound very familiar today, that "in view of the acute need for economy, approval must be sought in each case for it to be carried out, and a case stated". This set-back was overcome and the case made once and for all when HMS COOK, the first survey ship to be fitted, was involved in the search for the submarine HMS AFFRAY which was lost in the English Channel in 1951. The new sonar was used extensively during this operation and the Commanding Officer's report on its effectiveness in classifying all types of seabed features provided ample justification for fitting the set in other survey ships.

Here then, in the early 1950s, we had survey ships fitted with two complementary sonars - one intended for sweeping ahead of the ship with a basic operating range of about a mile, and the other intended for investigating and classifying any obstruction found by the first. A doctrine for carrying out an effective area search had been evolved and the completion of such a search became a standard requirement for most surveys. However, it was not until well into the next decade, and after the modernization of the survey fleet had been carried out, that sonar really came into its own.

MODERN SONAR EQUIPMENT

The re-structuring of the survey fleet into its present form, divided more or less equally between Ocean Survey ships, Coastal Survey vessels and Inshore Survey craft, began in 1958 with the introduction of the first of the Inshore craft. These were too small to be fitted with any naval sonar and it was necessary to look for a suitable commercial set. One was found in a fish-finder made by Kelvin Hughes - called appropriately the Fisherman's Sonar. This was fitted in all five Inshore Craft and later in the four Coastal Survey vessels built in 1968. The first three Ocean Survey ships, which were all in service by 1966, were fitted with a standard naval sonar. These sets did much the same job, providing the ships with a forward-looking sonar with which they could broadly examine an area; what they did not do was provide any permanent record of the search or allow any detailed investigation of the seabed between the sounding lines.

The demand for a purpose-built sideways-looking set to provide this sort of information began in the mid-1960s but it was not until 1970 that equipment was obtained which would meet this demand. In the autumn of that year an E G and G Dual Channel side-scan sonar was bought, issued to a ship for evaluation, and the entry of the Royal Naval Surveying Service into the true third dimension in hydrography can perhaps be dated from that time. The equipment was an instant success and further sets were ordered before the end of the year. By the spring of 1973 ten sets were in use, and by the end of 1977 the total had reached twentyfive, divided between equipment made by E G and G and the British firm Offshore Acoustics. It is intended to bring the total to at least thirtyfive within the next two years. It is now firm British policy that no survey on the Continental Shelf can be considered complete until a full search using towed side-scanning sonar has been completed and all potential seabed obstructions fully investigated. Every ship is being supplied with duplicate equipment, together with an extra set for use by her boats, to ensure that this policy can be implemented.

However, while the value of this type of sonar was immediately apparent the major drawback associated with its use was no less apparent, and from the first surveyors complained about the low speed, and consequent waste of operational time, which its constant use involved. This, together with the relatively short range, highlighted the need for continuing development of this type of equipment and in 1977 trials were carried out in HMS HECLA with a prototype side-scanning sonar developed by the Department of Physics at the University of Bath. This sonar, which utilizes a heavy towed body and a faired cable (which in turn allows the transducer to be operated at the optimum depth while remaining reasonably close to the ship), produced excellent results with ranges in excess of 700 metres at speeds up to six knots while operating in depths of 100 to 150 metres. It is hoped as a result of the trials that it will be possible to obtain production equipment based on the prototype for use in the Ocean Survey ships within the next few years.

But even a speed of 6 or 7 knots, which is probably the best that can be achieved using a towed transducer, is too low when used by ships designed to operate economically at ten knots or more. What is needed is a sonar which will provide complete coverage of the seabed, with a permanent record of the search and of any investigations carried out, and at the same time allow the ship to operate in the most economical manner.

The requirement for such a sonar, envisaged as a hull-mounted system combining the attributes of the forward-looking set and the sideways-scanning set with some form of automated data processing and display facility, was first voiced in 1968. At that time no Ministry of Defence resources could be made available to undertake such a project, and it was necessary for the Hydrographer of the Navy to stress the national importance of providing the type of sonar which would allow his ships to carry out the detailed surveys required, to guarantee the safety of deep-draught vessels and submarines, in the relatively shallow waters surrounding the United Kingdom. This produced the necessary results and responsibility for the development of a true hydrographic sonar was accepted by the Department of Industry at the end of 1969.

HYDROSEARCH SURVEY SONAR

From the beginning it was decided to base the new sonar on the high definition "within pulse sector-scanning sonar" (the principles of which are now well known and documented) which had been developed during the previous decade at the Admiralty Research Laboratory, and the next three and a half years were spent in preparing a detailed technical specification and in getting commercial organisations interested in its development. It became clear during this period that the production of the full surveying sonar system as envisaged - with both the forward looking and side-scanning aspects combined - could not be realized without a great deal of very protracted and equally expensive development work, and so the decision was taken to progress one aspect only and produce a sonar which could be used in either the horizontal or vertical mode. In September 1973 a contract was placed with Marconi Space & Defence Systems for the production of a prototype sector-scanning survey sonar; the firm proposed that this be called "Hydrosearch" and it is by this name that the set has been known ever since.

The prototype set was installed in HMS BULLDOG, one of the Coastal Survey vessels, at the beginning of 1977 and trials began in June. The probable operating procedure, which, because of the length of the trials programme (now delayed by an accident to the transducer which occured within a few days of the start), has yet to be proved in practice, is for the ship to carry out the survey of an area in the normal manner by running parallel, equidistant lines of sounding at speeds up to ten knots, while at the same time operating Hydrosearch in the horizontal mode with the transducer depressed to an angle dependent on the general depth of water to provide the best coverage of the seabed ahead of the ship. All the information obtained will then be recorded automatically while at the same time the operator will be able to register the appropriate details of any target or obstruction which will warrant further investigation. It will then be necessary for the ship to return to each recorded target to obtain further information by using the sonar either in the horizontal mode, to view from different aspects, or in the vertical mode to obtain height. At the end of the survey the surveyor will possess full pictorial records of the whole of the survey area, together with the position and dimension of every obstruction and the depth of water over it.

It is hoped to have Hydrosearch fitted in all four Coastal Survey vessels by the early 1980s, by which time the four Ocean Survey ships should be provided with a longer range version of the towed side-scanning sonar together with a hull-mounted Simrad SU survey sonar. These sets, together with the towed side-scanning sets now in general use, should provide sufficient flexibility for the survey fleet to carry out comprehensive surveys, from wide-ranging area searches to detailed investigations of particular seabed features, in all depths of water out to the edge of the Continental Shelf. Such surveys will not only be carried out in a more cost-effective manner than at present, but documentary evidence will be produced to demonstrate the thoroughness of their completion and which will be available for further research or closer analysis at a later date. In addition, in the case of the Ocean and Coastal ships, this range of equipment should be sufficiently modern and versatile to provide their total sonar capability for the remainder of their lives in service.

CONCLUSION

All this having been said it is still necessary to remember that the requirement for a survey sonar system, as first outlined at the end of the 1960s, remains unfulfilled. The Hydrosearch sonar provides only one part of the total system envisaged, and the ship using it will still need to pass through the survey area more than once to obtain all the data needed to guarantee completion of the survey. A system which will permit the ship to pass only once through an area, gathering all the data necessary both from beneath it and as far to either side of its track as the adjacent sounding lines, must remain the ultimate aim. The provision of Hydrosearch is a very large step towards achieving this aim, and using the experience which will be gained from its operational use the Royal Naval Surveying Service can, with some confidence, look forward to seeing the next generation of survey ships, which will be required early in the 1990s, designed around the first total survey sonar system.

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Bathymetric Swath Survey System(BS^3) An Effective Bottom Mapping Survey System for the Hydrographer

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ABSTRACT

National needs require improvement in present survey systems and techniques for acquiring and processing bathymetric data. The objectives of the National Ocean Survey's Bathymetric Swath Survey System (BS^3) project are: (1) to improve the effectiveness of marine surveying, (2) to improve data quality, and (3) to provide useful engineering data for nautical charts and bathymetric maps. Instrumentation - a high-resolution multibeam swath sonar, heave-roll-pitch sensor, tide telemetry instrumentation, as well as navigation sensor and a powerful minicomputer - has been developed to provide the hydrographer a total survey system. The system software will sample all the various sensors and provide for vessel navigation, sonar beam vertical depth and position determination, continuously zoned real-time tide correction, and real-time bathymetric contour graphics, as well as archived raw sensor data. The BS^3 surveying and processing techniques, aimed at improving the effectiveness of bottom mapping, are now being demonstrated and refined on Puget Sound near Seattle, Washington, aboard the NOAA Ship DAVIDSON.

INTRODUCTION

Marine commerce is an essential element of our nation's economic life and contributes significantly to the welfare and safety of people and property. The production of accurate maps of the ocean floor as well as related environmental data is required to satisfy navigational needs and to contribute to national goals such as managing ocean resources, developing basic ocean sciences, and supporting national defense programs.

The art of mapping the ocean floor has evolved very slowly. Land areas can be mapped to virtually any degree of accuracy and completeness using optical techniques provided by the well-established science of photogrammetry. Narrow-beam vertical echo sounders - the standard instrument used for ocean surveys - are functionally little more than efficient leadlines. In using echo sounding to produce nautical charts, only 2-5 percent of the area "surveyed" is actually seen or measured during the course of the survey. Even these measurements are frequently contaminated with gross, uncompensated errors caused by vessel heave, roll and pitch, requiring a tedious and subjective interpretation of graphic records to generate the data base used for the compilation of the finished chart. Truly, ocean surveying today is as much an art as it is a science.

Over the years the practitioners of this art have taken special care to insure that the resulting charts were adequate for use by all commercial vessels (with drafts up to 30 feet). Indeed, they have done a uniformly remarkable job. The advent of the very large crude carriers (VLCC's) with drafts approaching 100 feet, however, has raised some concern as to the adequacy of existing charts and of survey techniques, especially in the near-shore waters along the U.S. west coast and Alaska. Although these waters are not very shallow, the underwater features are of a very rugged character and are difficult to accurately delineate with conventional survey instruments.

The solution to this problem has taken on a very high priority within NOAA's National Ocean Survey (NOS). The development of the Bathymetric Swath Survey System (BS^3) by the National Ocean Survey is intended to move the art of bathymetric and hydrographic surveying firmly into the realm of science.

OBJECTIVES

The objectives of the BS^3 project are: (1) to improve the effectiveness of marine surveying, (2) to improve data quality, and (3) to provide useful engineering data for nautical charts and bathymetric maps.

The functional design of BS^3 was tailored to meet the following NOS program requirements:

- 100-percent bottom coverage when required,
- clear depth certification of west coast navigable areas,
- reliable detection, delineation and least depths on shoals,
- improvement in data quality as compared to present systems
- useful real-time hard copy graphic displays,
- reduction of overhead in survey verification and chart production.

SYSTEM DESCRIPTION

BS^3 merges three key elements to achieve these requirements. A high resolution multibeam swath sonar allows 100-percent bottom coverage of a survey area. Recently-developed Heave-Roll-Pitch (HRP) instrumentation provides vessel attitude data necessary to reduce the sonar beam data to accurate vertical depths and horizontal positions. A powerful minicomputer provides the computing horsepower needed to perform this data reduction and generate a bathymetric contour chart in real time.

The system provides for automated control of the various sensors. Computer-generated commands select the sonar depth scale and continuously adjust the sonar's gates to track the bottom. Synchronization commands are issued to the Heave-Roll-Pitch subsystem and interrogation orders are sent when HRP data are required. Event and timing marks are generated to mark external recorders. Alarms are sounded and messages displayed whenever invalid data are detected or system problems occur.

The system design that evolved includes as major elements:

- multibeam sonar to provide wide area swath coverage,
- Heave-Roll-Pitch instrumentation to provide vessel attitude data,
- navigation and ship's heading sensors to provide position data,
- tide telemetry and logging instrumentation for tide corrections,
- computer subsystem to assimilate data from the sensors and generate the required real-time displays and archive the raw data,
- flexible sensor interface to provide a bidirectional data link between each of the sensors and the computer,
- an electrostatic printer-plotter to generate bathymetric contour plots and data listings in real time,
- a pen plotter to generate navigation and swath position plots in real time,
- a steering display to depict computer-generated helm orders,
- a real-time software package to manage the data acquisition and generate the desired graphics and displays, and control orders to the various sensors.

Figure 1 identifies the BS^3 hardware elements; not included are the navigation, Heave-Roll-Pitch and tide telemetry subsystems.

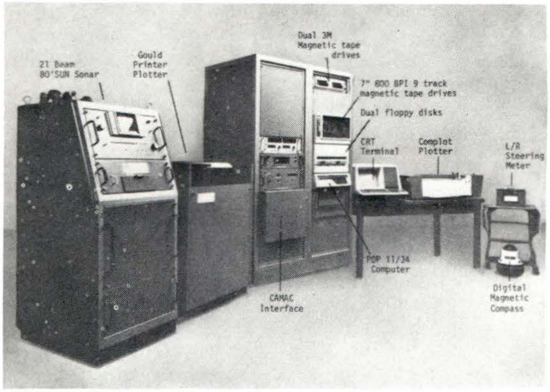


Figure 1. BS^3 Hardware Elements

Figure 2 details the architecture of the system hardware. Paramount in the architecture is the capacity for an orderly expansion of the system to include new sensors and computer peripherals as future requirements may dictate. Similarly, the architecture of the system software design provides the flexibility needed to accommodate new tasks that may be required in the future. The system was developed to NOS specifications by the Harris ASW Division of General Instrument Corporation, which also manufactures the system's primary sensor - the Bo'Sun Sonar.

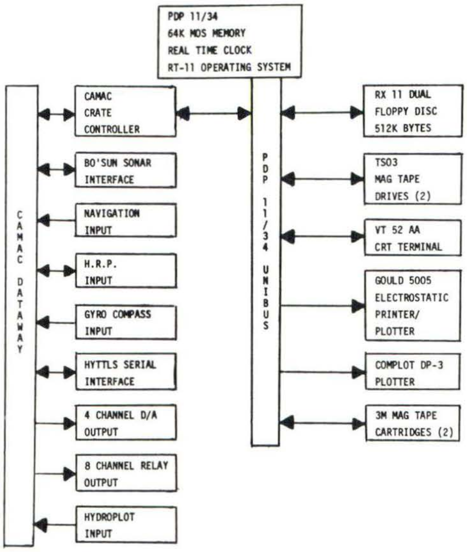


Figure 2. BS^3 Hardware Configuration

COMPUTER SUBSYSTEM

At the heart of BS^3 is the computer subsystem, shown at the top and right half of Figure 2. The Central Processing Unit is a Digital Equipment Corporation PDP 11/34 - a powerful 16-bit machine whose design has been optimized for multitasked real-time operations. The DEC RT-11 operating system manages the execution of the BS^3 software which is resident in 64K words of computer memory. A dual floppy disk drive provides 512K bytes of mass storage for programs and system tables. Two TS03 9-track magnetic tape drives are used for recording raw sensor data. A dual QANTEX 3-M cartridge drive is used to log the Survey Summary file. Other peripherals included in the computer subsystem are: a VT 52 CRT terminal where all operator entries, queries and commands are entered; a Gould 5005 electrostatic printer-plotter for generation of the contour plot; and a Houston Instrument DP-3 pen plotter for the swath position and navigation plot.

The computer subsystem by itself constitutes a very powerful and versatile data processing system. During actual survey operations, it is dedicated full time to executing the many tasks required to support real-time operation. When survey operations are not being conducted, the computer system is available to perform post-time reduction of previously-acquired survey data and to perform the many utility tasks needed to support survey operations.

INTERFACE SUBSYSTEM

Until recently, the most difficult, costly and time-consuming part of designing a system such as BS^3 has been in interfacing the sensor instrumentation to the data processing subsystem. The interfacing of sensors to BS^3 has been painless and inexpensive. The BS^3 design uses the CAMAC standard for interfacing all sensor instrumentation and external data communications. CAMAC is an IEEE standard (IEEE 583) adopted in 1975 that defines a digital interface bus and protocols for the transfer of data. The National Bureau of Standards actively supports CAMAC, and more than 50 companies worldwide manufacture CAMAC interface modules that will interface virtually any instrument to the CAMAC DATAWAY. Typically, interface modules are available off the shelf from several vendors and are priced competitively. BS^3 uses a variety of CAMAC modules - 24-bit parallel I/O, 110 Baud Serial I/O, 9600 Baud Serial I/O, Up-Down Counters, D-to-A Output, Relay Closure Output, PDP-11 Unibus Interface, and an Interrupt Vector Generator.

From a software standpoint, the PDP-11/CAMAC marriage has been a happy one. Sensors are addressed as though they are computer memory. When a sensor wants the computer's attention, a priority-vectored interrupt is generated. The left side of Figure 2 depicts the CAMAC DATAWAY, with the various sensor interface modules shown. The CAMAC CRATE in BS^3 has position for 24 plug-in CAMAC interface modules. CAMAC crates can be cascaded to provide unlimited system expansion. The system lends itself to a rapid reconfiguration of sensor inputs should the ship's mission dictate. With the appropriate CAMAC interface modules and mission software, the system could be reconfigured in a matter of hours to support oceanographic experiments, magnetic surveys, gravity surveys, or any other data acquisition activity that might be required.

SONAR SUBSYSTEM

The principal sensor in BS^3 is, of course, the sonar. The Bo'Sun sonar, built by Harris ASW Division of General Instrument, was selected for BS^3 because it was ideally suited for bathymetric swath surveying of near-shore west coast and Alaskan waters (depths of 10 to 300 fathoms). The Bo'Sun Sonar operates at 36 KHz and has a transmitted pulse width that varies from 1 millisecond for the shoalest range-scale, to 24 milliseconds for the deepest range-scale (2,500 feet). The sonar has a ranging capability of 4,000 feet and a resolution of 0.25 feet. Bo'Sun employs a unique cross-fan beam forming technique that synthesizes 11-5° beams athwartships on each side of the survey vessel, yielding a 21-beam swath that extends 50° either side of the vertical to provide a cross-track coverage 2.6 times the water depth. Referring to Figure 3, the transmitted pulse insonifies a fan-shaped volume that is narrow (5°) in the direction of the vessel centerline. Return echo energy from the athwartships strip illuminated by the transmitted pulse is received by each of 11 fan-shaped receive beams. The fan-shaped receive beams are narrow (5°) in the arthwartships direction and long in the direction of the vessel centerline. The intersection of the transmit fan and a receive fan define a 5° x 5° square synthesized beam. The 11 receive fans are formed in 5° increments from the vertical, to 50° above the vertical. In this way, 11-5° beams are formed on either side of the vessel.

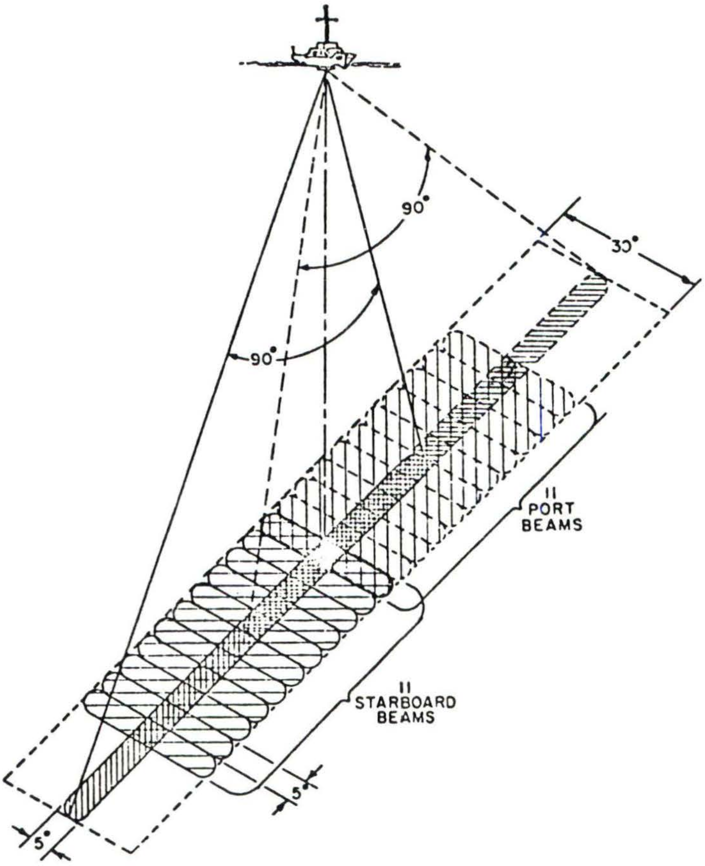


Figure 3. Bo'Sun Beam Pattern

The Bo'Sun receivers feature side lobe suppression circuits and "bottom match receiver filters" designed to optimize the performance of the sonar. The bottom match filters are selected by the transmitted pulse width and are designed to give near optimal receiver response to the expected bottom echo returns, taking into account the pulse stretching of nonvertical beams.

The sonar also features gated bottom tracking circuitry to reduce the influence of spurious echo returns. These gates can be set either manually or by computer control. Normally in BS^3 these gates are continuously adjusted by automatic computer-generated commands.

HEAVE-ROLL-PITCH SUBSYSTEM

If not the principal sensor of BS^3, the Heave-Roll-Pitch subsystem is the most important. For swath mapping, accurate vessel attitude information is an absolutely vital ingredient. In 100 fathoms of water, a 1° error in roll measurement will generate more than a 2-fathom error in the vertical depth determined from outer beam data. Vessel heave, if uncompensated, can add more than 6 feet of error to all depth measurements, depending on the sea state. NOS has been pursuing a solution to this problem for several years and has developed a design for a strap-down Heave-Roll-Pitch Correction Subsystem based on an engineering model developed by Arthur D. Little Corporation of Cambridge, Massachusetts. More recently, the DATAWELL Corporation of the Netherlands has developed a prototype system based on the designs of its WAVERIDER Buoy and its PIROG (Pitch-Roll) Sensor. The two systems use entirely different instrumentation techniques (although mathematically equivalent) to derive roll, pitch, and vertical (heave) acceleration.

Exact vessel heave can be determined from vertical acceleration; however, it cannot be done accurately in real time. In practice, real-time heave determination introduces a phase shift, which in turn introduces an error in the heave measurement that increases as the period of the wave form increases.

The result of this physical reality is that only approximate heave measurements can be made in real time, with errors increasing as the vessel heave period increases. BS^3 is designed to utilize these approximate real-time heave corrections for the real-time contour plot displays; however, the vertical accelerations of the HRP sensor are recorded on magnetic tape for exact heave determination in the post processing of the survey data. Both instruments are capable of providing accurate roll and pitch data in real time.

The DATAWELL Heave-Roll-Pitch Prototype instrument (HIPPY 120) has been integrated into BS^3 on board the NOAA Ship DAVIDSON and is capable of resolving roll and pitch angles of 0.1°, although its absolute accuracy is somewhat less. The bandwidth of heave motion the instrument is capable of measuring extends from 30 seconds to 0.6 seconds. The DATAWELL instrument incorporates its own onboard digital microprocessor which computes heave without phase errors after the fact. The microprocessor also manages the data communication between it and the BS^3 CAMAC interface.

HYDROGRAPHIC TIDE TELEMETRY AND LOGGING SUBSYSTEM

The tide telemetry and logging subsystem provides real time tidal data for the correction of hydrographic soundings obtained by NOS survey ships. The tide telemetry and logging subsystem includes a number of shore stations, interfaced to NOS standard field bubbler gages, and a shipboard station which controls the shore stations and accepts their data. The shore stations acquire tidal information from the field bubbler tide gage and, according to command from the shipboard station, transmit and/or store the information for future transmission. The shipboard station will receive the tidal data, record/display the data and/or pass the data on to the BS^3 CAMAC interface. The shipboard station communicates with the shore station to select a particular operating mode.

This system provides real-time zoned tide corrections and verification that the tide gages are operating properly during survey operations. Hourly heights are stored for up to 30 days at each gage during periods in which the vessel is nonoperational or beyond telemetry range of the tide gages.

NAVIGATION SUBSYSTEM

The present positioning systems used by NOS for near-shore surveys include Raydist, Del Norte, and Mini Ranger, as well as sextant and theodolite cuts.

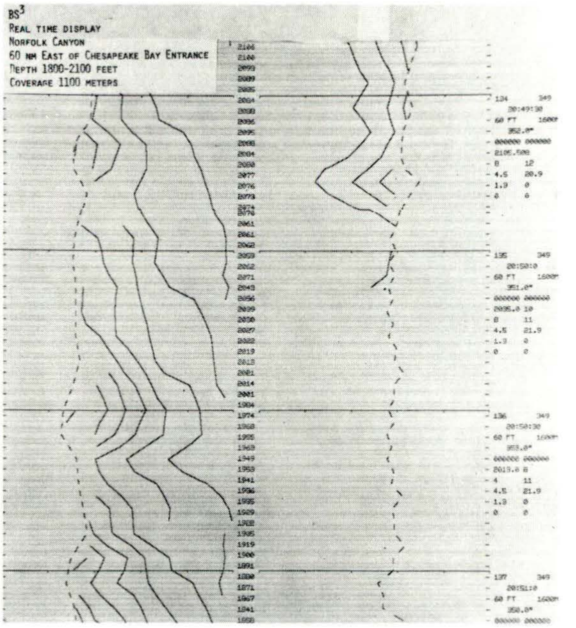
BS^3 will accept four lines of position through the CAMAC interface Range-Range, Hyperbolic, or a combination of each. Additionally, the ship's gyrocompass is interfaced to the computer to provide heading data accurate to ± .5°.

The positioning data and ship heading provide the horizontal XY data used to plot the track of the ship and the sonar coverage on the XY plotter in real time. These data are also used to determine location of the vessel, relative to the tide gages, for computing continuously-zoned tidal correctors. The positioning data are also used in real time to navigate the vessel along specified survey lines. Helm orders are displayed on a logarithmic left-right steering meter on the bridge.

OPERATIONAL TECHNIQUES

Emphasis has been placed on providing detailed hard copy graphic displays to the hydrographer in real time so that he or she will be able to accurately evaluate the quality of the data being obtained and the adequacy of the survey as it progresses. BS^3 generates two different hard copy graphic records in real time - a bathymetric contour plot and a swath position and navigation plot.

BS^3 was installed on board the NOAA Launch LAIDLY, a 55-foot launch based at the NOS Atlantic Marine Center in Norfolk, Virginia. Operations were conducted from October through mid-December 1977, for acceptance testing and system grooming. All major elements were integrated into the system, with the exception of the Heave-Roll-Pitch subsystem, which was not available in time. The system was exercised over a variety of bottoms in a wide range of sea states. The bathymetric contour plots shown in Figures 4, 5, and 6 were obtained during this period. The LAIDLY sea trials demonstrated the integrity of the equipment and the soundness of the system design.



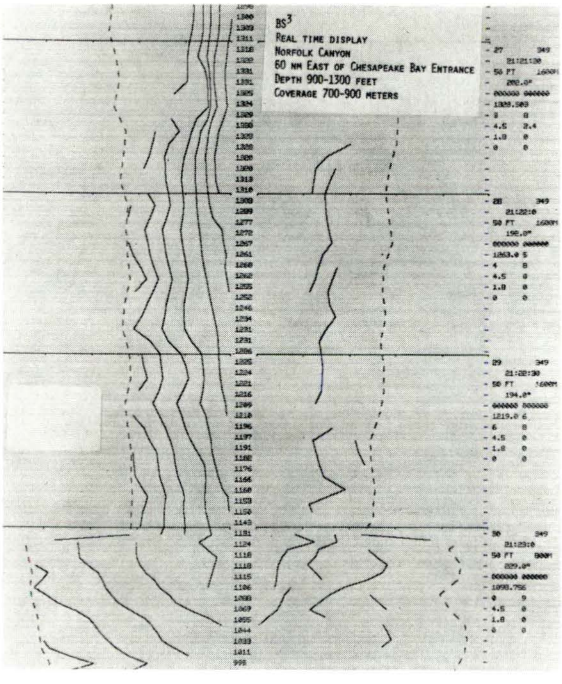


Figure 5. Bathymetric Contour Plot

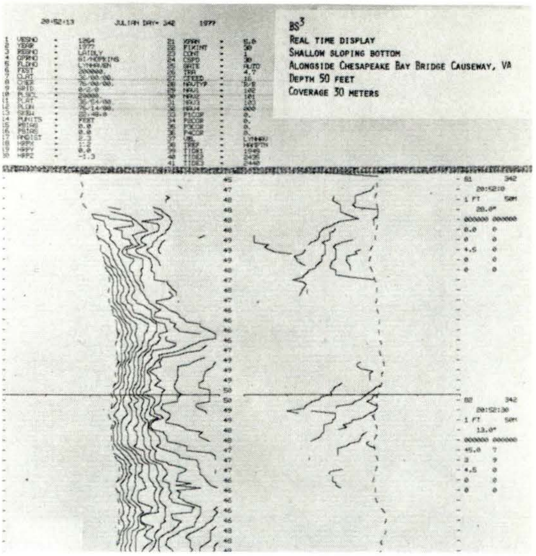


Figure 6. Bathymetric Contour Plot

Figure 4 is an example of the bathymetric contour plot. Corrected vertical depths below the vessel are printed down the center of the plot. Contours are generated athwartship for depths shoaler than the vertical depths beneath the vessel. The contour interval can be set to any desired level. To improve the clarity of the plot, no contours are displayed for depths deeper than the vertical depth. At specified fix time intervals, a cross-track scale is drawn, and raw data associated with that fix event are printed in the margin. A dashed line on either side of the contour plot shows the limits of the swath coverage. Figure 5 shows a contour plot of a section in the Norfolk Canyon, 60 miles east of Chesapeake Bay. The vessel is traversing from the top toward the bottom. Contour interval is set at 50 feet. The cross-track coverage varies from 900 meters to 700 meters as the vessel proceeds into shallower water. A change in the cross-track scale from 1,600 meters to 800 meters occurs automatically near the bottom of the plot. Some of the contours appear noisy because heave-roll-pitch compensation was not being applied to the data.

Figure 6 shows another contour plot of a shoal area in Chesapeake Bay. The contour interval is set at 1 foot, with a cross-track scale of 50 meters. Again, some noise in the contour is evident, caused by uncompensated heave-roll-pitch.

Figure 7 is an example of the swath position plot which graphically illustrates the swath coverage of a survey area. The continuous line represents the vessel track line, the numbers representing fix events, and the dashed lines represent the swath coverage, with the indexes pointing toward the associated track line. In addition to the graphic displays, the functional design provides for positioning and navigation of the vessel along prescribed survey lines. Orders are sent to a helm display to aid the helmsman in keeping on line.

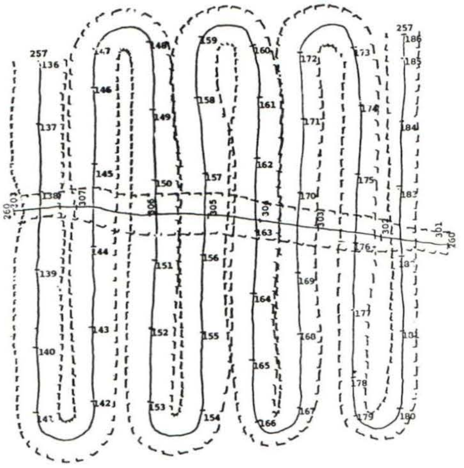
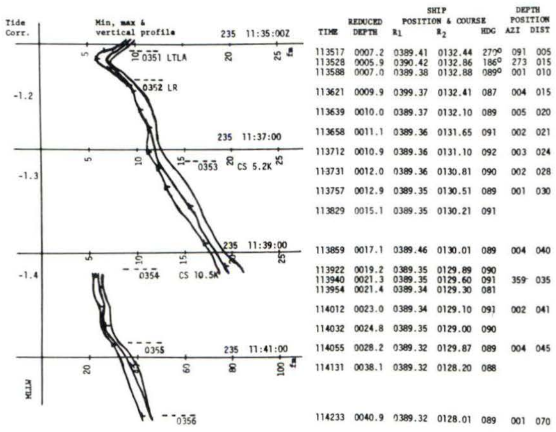


Figure 7. Swath Position Plot

Two archival magnetic tape data files are created as the survey operation proceeds. The first file records all raw data obtained by the various system sensors. The second file - the Survey Summary File - logs a running history of the survey operation and includes a record of the system configuration, parameters and correctors, system errors, and operator comments. After the survey has been completed, the Survey Summary File is edited to update it with the most accurate corrections and parameters. This file, along with the raw data tapes, are then used by a postprocessing program to compute the true depth of each archived echo range. The depths are arranged by the program into a file according to their XY position on the bottom. This file is divided into plottable unit areas (PUA) which are a function of the survey scale and size of depth unit to be plotted. The minimum and maximum depths and their true position will be selected in each PUA. However, only the minimum depth will be plotted. A sounding plot is then generated, as well as a profile plot and selected depth listing.

Figure 8 is an example of the profile plot and selected depth listing. Tide corrections are listed above the mean lower low water datum line; below this line is the minimum, vertical and maximum profiles of the bottom annotated with time, depth scale and various remarks. Selected depths are indicated, and the true depth and position information is printed below the profiles. These graphics records provide for the visual verification for completeness and quality prior to departing the survey area.

The system has been installed onboard the NOAA Ship DAVIDSON, a modern 175-foot coastal survey ship. A field experiment is underway in Puget Sound near Seattle, Washington, to develop operational techniques to make the most effective use of the system for NOS hydrographic survey operations.



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                         SHIP                    DEPTH
          REDUCED   POSITION & COURSE          POSITION
  TIME     DEPTH    R1        R2       HDG     AZI  DIST

113517  0007.2  0389.41  0132.44  270°   091  005
113528  0005.9  0390.42  0132.86  186°   273  015
113588  0007.0  0389.38  0132.88  089°   001  010

113621  0009.9  0399.37  0132.41  087    004  015

113639  0010.0  0389.37  0132.10  089    005  020

113658  0011.1  0389.36  0131.65  091    002  021

113712  0010.9  0389.36  0131.10  092    003  024

113731  0012.0  0389.36  0130.81  090    002  028

113757  0012.9  0389.35  0130.51  089    001  030

113829  0015.1  0389.35  0130.21  091


113859  0017.1  0389.46  0130.01  089    004  040

113922  0019.2  0389.35  0129.89  090
113940  0021.3  0389.35  0129.60  091    359  035
113954  0021.4  0389.34  0129.30  081

114012  0023.0  0389.34  0129.10  091    002  041

114032  0024.8  0389.35  0129.00  090

114055  0028.2  0389.32  0129.87  089    004  045

114131  0038.1  0389.32  0128.20  088


114233  0040.9  0389.32  0128.01  089    001  070
```

Figure 8. Profile & Selected Depth Printout

Water depths vary from 8 to 150 fathoms and are characteristic of the rugged west coast and Alaskan topography for which the system was designed. A comparison survey will be run by DAVIDSON, with BS^3 operated in parallel with HYDROPLOT - NOS standard automated survey system.

Three distinct hydrographic smooth sheets of the survey area will be produced. The first sheet will be derived from HYDROPLOT data acquired using conventional survey techniques. The second sheet will be based on BS^3 data acquired in parallel with the HYDROPLOT data of the first sheet. The third hydrographic smooth sheet will be based on data acquired by BS^3 (Figure 9). A critical comparative evaluation will be conducted to assess the effectiveness of BS^3 and the newly-developed operational techniques.

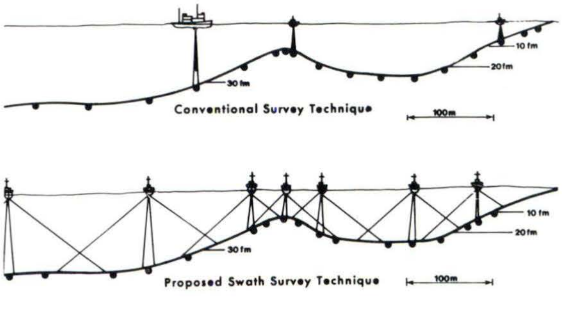

Figure 9. Surveying Procedures

During this same period, DAVIDSON will also conduct a carefully-controlled experiment to characterize the accuracy of each of the 21 sonar beams. Highly accurate data are expected from the vertical and near-vertical beams; however, the further the beams progress from the vertical, the more sensitive the accuracy of the data becomes to pulse stretching, as well as small error in the measurement of vessel roll. The LAIDLY sea trials have shown that all outer beam data are useful for the qualitative real-time contour graphics. However, the accuracy of some of these outer beam data may not meet NOS' accuracy standards for use in NOS chart compilation.

CONCLUSION

The Bathymetric Swath Survey System is intended to move bathymetric surveying firmly into the realm of science. The latest state-of-the-art instrumentation and analytical techniques have been brought together to provide the hydrographer the tools for more accurate and effective surveying. The operational and processing techniques which were proposed and now under development, will be evaluated and modified as necessary to provide the best quality and quantity of data for bathymetric and nautical charting.

ACKNOWLEDGEMENTS

The authors wish to acknowledge the contributions of Donald J. White, Harold Farr and William J. Capell of Harris ASW, General Instrument Corporation, for the development of BS^3; Richard S. Stone and Donald L. Sullivan of Arthur D. Little, Inc., for the analysis and development of heave-roll-pitch instrumentation; and Louis C. Adamo, Louis C. Adamo Corp., Datawell Corporation, the Netherlands, for the development of HIPPY 120.

Single Vessel Sweep System

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C.H.S. Atlantic Region

Abstract

This paper describes the development and operation of a single vessel sonar sweep system intended for use on a small vessel operating under precise positional control.

While there are currently in existence a number of commercially available operational systems, the frequency of application by the Canadian Hydrographic Service, Atlantic Region, makes it difficult to justify the purchase of a large automated system. A small, three transducer system similar to the Raytheon "Channel-Sweep Survey System" was developed.

The components of the system described herein are currently utilized by the Canadian Hydrographic Service, Atlantic Region, on conventional charting surveys, thus are readily available with no capital expenditure.

The primary function is to provide sweeping capabilities in order to ensure complete bottom coverage in areas of critical depth. The system provides 100% bottom coverage in depths of from 5 to 30 metres when sounding at line spacings of up to 25 metres.

Development and trials were conducted at Bedford Institute in the spring of 1977. The system was operated successfully during a production survey later the same year.

Introduction

During the spring of 1977 the Revisory Surveys Establishment of the Canadian Hydrographic Service, Atlantic Region, was given the task of conducting a large scale survey at the port of Dalhousie, New Brunswick. Requirements for this survey were such that specialized hydrographic survey procedures were considered and developed.

The area to be surveyed was approximately 800 metres long and 500 metres wide (Figure 1). Average depth in the channel along the range line was approximately 10 to 15 metres. The purpose of the survey was to determine the existence and location of any submerged hazard to navigation, as well as to delineate the extent of the channel for navigation purposes. Because of the narrow width of this channel, it was decided to use a sounding procedure which would give bottom coverage equivalent to sweeping.

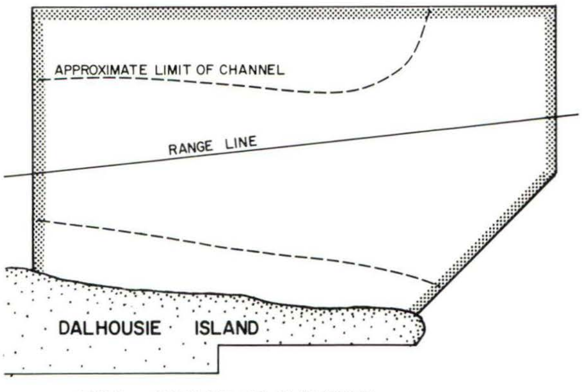


FIG. I AREA TO BE SURVEYED

System Concept

During recent years, various configurations of sonar sweeping systems have been developed and operated. One system which seemed quite suitable for this project would have been one similar to the Raytheon "Channel-Sweep Survey System", using a modified DE-719 Fathometer and four transducers (Figure 2). With this system, four advantageously spaced transducers produce four offset traces on the recorder graph. As this system was not readily available, it was decided to develop one along the same lines. The system to be developed would operate on three rather than four transducers. Figure 3 shows the system concept of a three transducer sweep system. An odd number was chosen in order to utilize the hull mounted transducer and mount a balanced array.

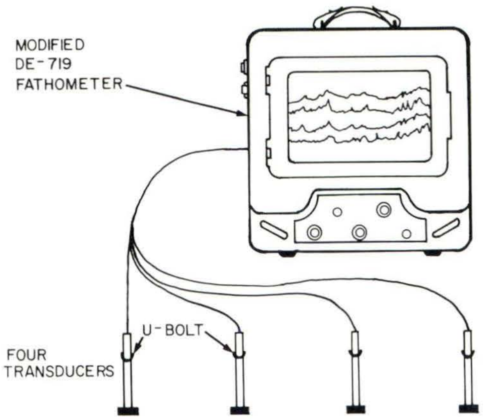


FIG. 2 RAYTHEON CHANNEL SWEEP SURVEY SYSTEM

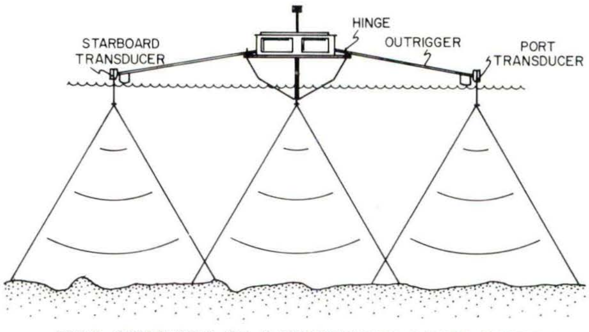


FIG.3 SCHEMATIC OF 3 TRANSDUCER SWEEP SYSTEM

The major departure from the Raytheon "Channel-Sweep Survey System" was that it was decided to utilize a separate recording unit for each transducer. This was designed to provide three distinct advantages. First, it eliminated the need for modified hardware thus eliminating possible technical or operator difficulties due to modifications. Secondly, and perhaps more important, by using "off-the-shelf" components, it allowed the assemblage of the system with a minimal input of time and effort. Thirdly, using this approach, a system could be developed with no capital investment for sounding instrumentation, as the instruments were already available.

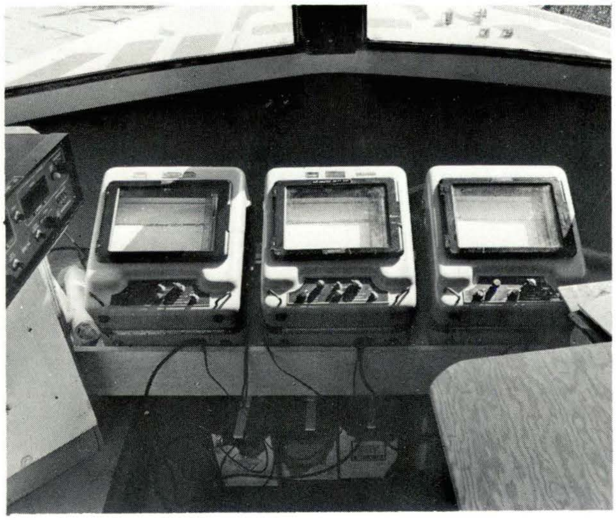
Equipment

a) Sounders

The only sounder given practical consideration was the Raytheon DE-719; it being the only lightweight, easily portable instrument readily available and in current use by the Canadian Hydrographic Service, Atlantic Region. Depth measurements have proven to be within accuracy standards as required by C.H.S. Survey Standing Orders.

These sounders could be operated on either 200 KHz or 208 KHz. Where the three sounders on this system were not slaved to transmit at the same instant, it proved of some advantage in reducing interference (cross-talk) between units. The two outer recorders were operated at 200 KHz while the centre one was operated at 208 KHz.

The recorders were mounted side by side on a simple plywood rack inside the cabin of the launch, where they would be easily accessible to the operator and visible to the hydrographer. Installation aboard a conventional 25 ft. (7.6 metre) survey launch is shown below.



3 SOUNDERS INSTALLED ONBOARD CSL *DUNLIN*
MAY 1977

As each recorder/transducer pair was matched, all connections were labeled to avoid confusion. Power was supplied by three 12-volt batteries which were stowed under the recorder rack. A multiple "Fix" button was installed to record events on the three instruments simultaneously.

b) Transducer Mounting

The centre transducer was mounted on the hull of the launch, approximately 3 metres from the stern. The outboard transducers were mounted on fibreglass floats. These floats were made of light plywood framing covered with fibreglass and were one foot square in section and five feet long (Figure 4).

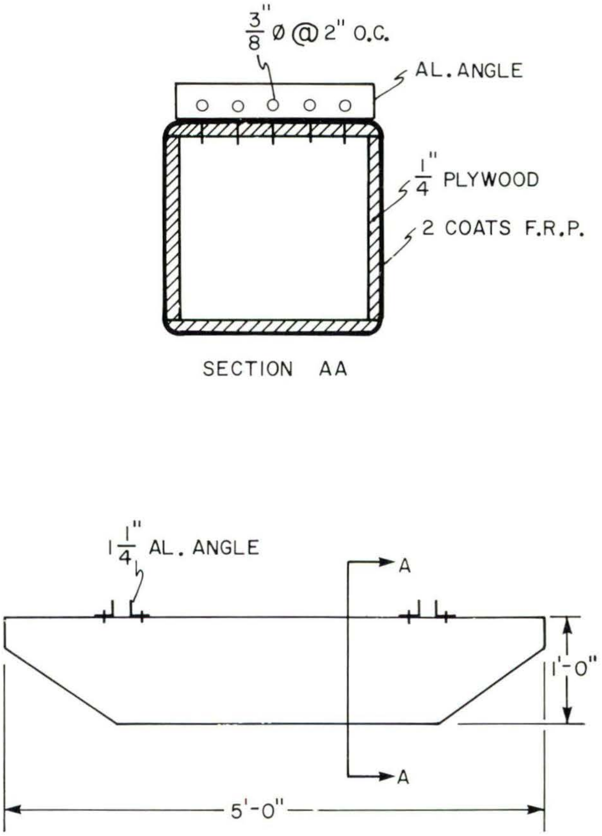


FIG 4. TRANSDUCER FLOATS

The five foot length proved ample to maintain the transducers vertical in the fore and aft plane. The shape of these particular floats was not necessarily ideal as they were salvaged from a previous experiment; however, they proved adequate.

The two outboard transducers were model 2445 AD (200 KHz) units supplied as standard equipment with the DE 719 recorders. They were mounted to the fibreglass floats by means of an aluminum bracket made of 3/8-inch aluminum plate (Figure 5). The transducers were attached to the brackets using 1/4 inch "U" bolts. Depth of each unit was adjustable, as was attitude with respect to vertical in the athwartships plane.

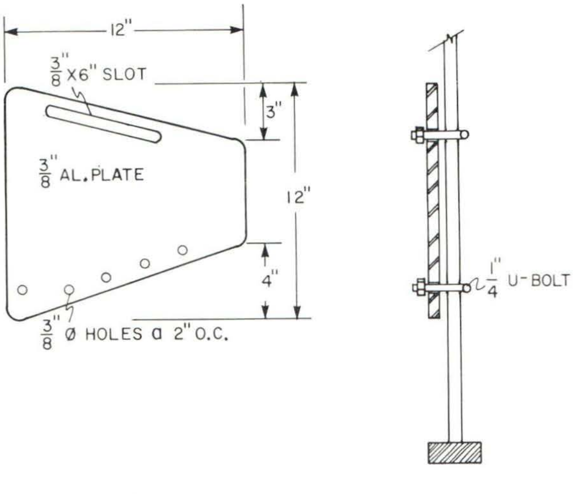


FIG. 5 TRANSDUCER BRACKET

The final step was to attach the floats to the launch and secure for operation. This was done using lengths of 1 1/4 inch square aluminum tubing (Figure 6) as outriggers.

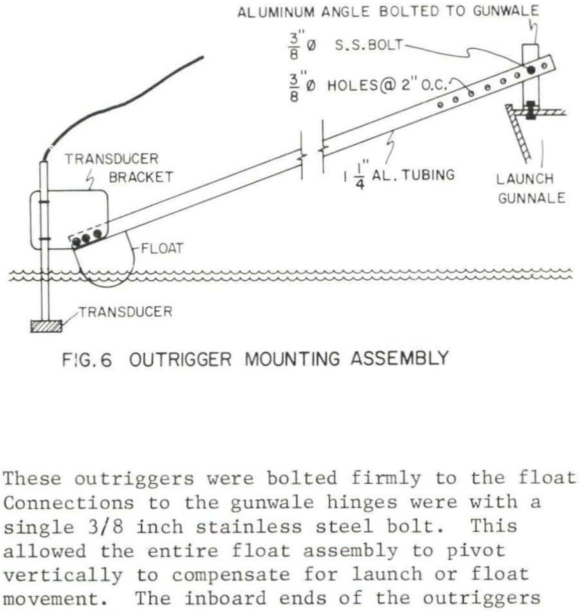


FIG.6 OUTRIGGER MOUNTING ASSEMBLY

These outriggers were bolted firmly to the floats. Connections to the gunwale hinges were with a single 3/8 inch stainless steel bolt. This allowed the entire float assembly to pivot vertically to compensate for launch or float movement. The inboard ends of the outriggers were drilled at 2 inch intervals so that the transducer spacing was adjustable. Towing strain was taken up by 3/8 inch polypropylene rope from the front of each float to a forward cleat.

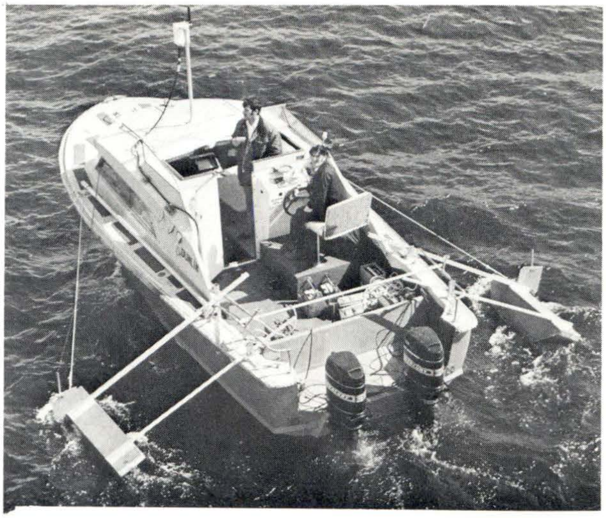


FIG. 7 SWEEP SYSTEM ON CSL *DUNLIN*

FIG. 8 SWEEP SYSTEM ON CSL *PHEONIX*

Operation

For ease in stowage and transportation, the components were completely dismantled. At the survey area the system was assembled, transducer depth and spacing set, and transducers secured in a vertical position. This took approximately two hours. While steaming from dockside to survey site, the outriggers could be pivoted upwards to a vertical position and secured (Figure 9). To resume sounding operations, the outrigger assembly had only to be given a push and it was ready to go.

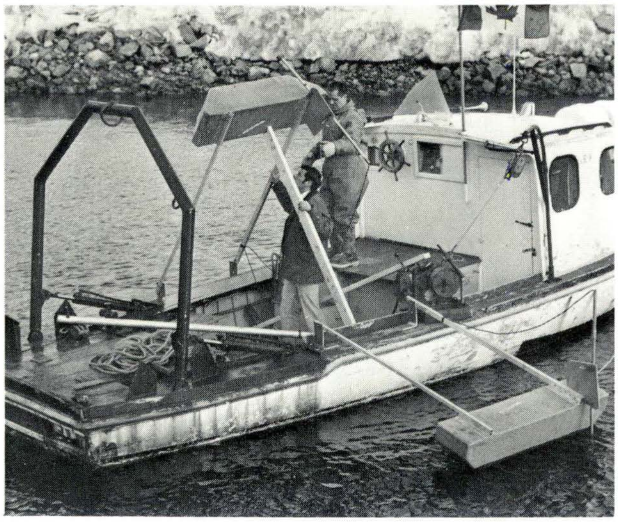


FIG. 9 TRANSDUCER FLOAT SECURED FOR STEAMING

Transducer spacing was determined as a function of the usable portion of the transducer beamwidth and the depth of water in the area of operation. The DE-719 Fathometer with 2445 AD (200 KHz) transducer is specified by the manufacturer to generate an 8^{o} conical beam to the -3 Db (half power points. It was found, however, that significant echoes were recorded at the -12 Db (one-quarter power) points in depths of up to 30 metres. This meant that in this depth range the effective beam width was 16^{o}.

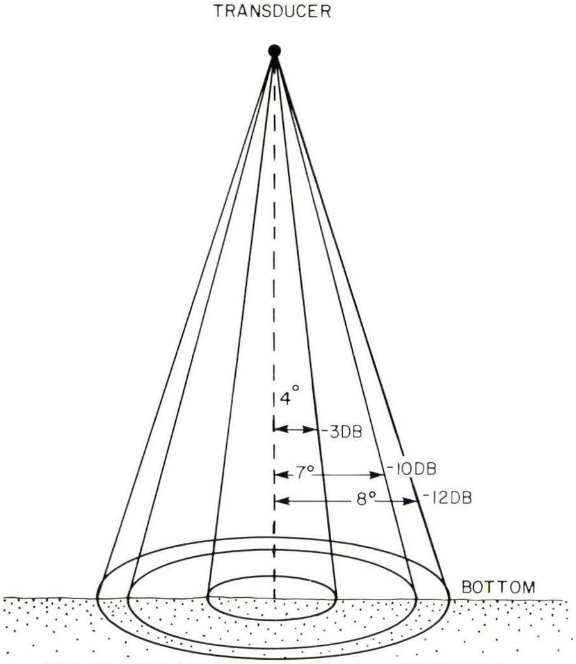


FIG. 10 TRANSDUCER BEAM PATTERNS

The accuracy to which this 16^{o} beamwidth would record bottom features could therefore be computed as shown in Figure 11.

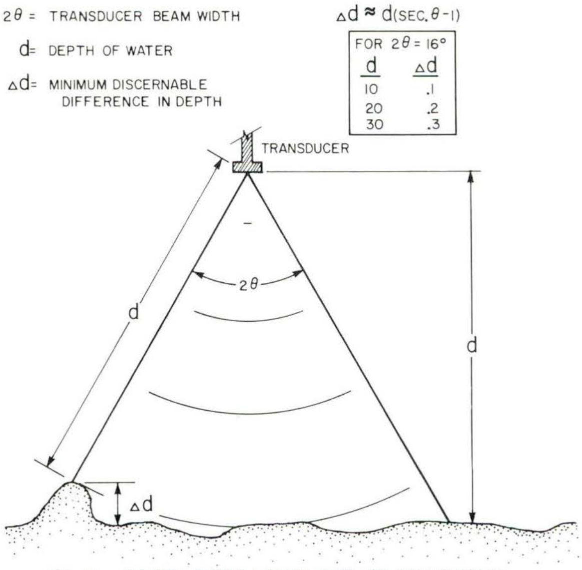


FIG. 11 DEPTH RESOLUTION FOR 16° BEAMWIDTH

It was thus deduced that an object which protruded greater than 0.3 metres above the bottom anywhere within the 16^{o} beam would be recorded within our stated accuracy requirements.

Transducer separation was determined as a function of this 16^{o} beamwidth and the depth in the area of operation. The required distance between transducers was the maximum which would allow overlapping beams in the depth of water being surveyed.

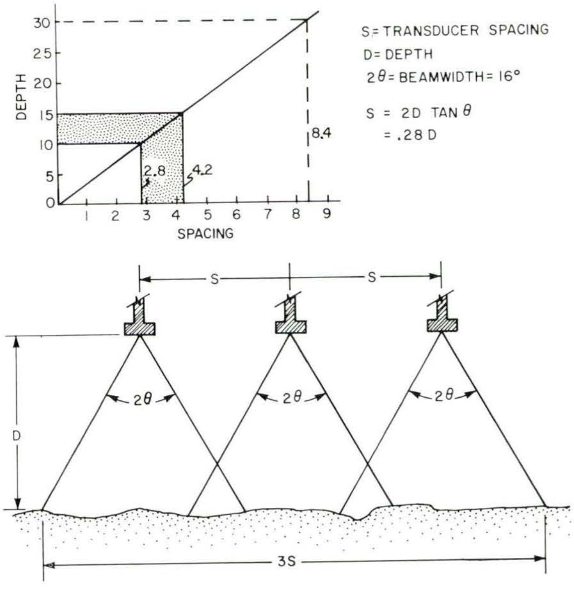


FIG. 12 TRANSDUCER SPACING Vs. DEPTH

The required spacing to ensure 100% bottom coverage at various depths is shown in Figure 12. For an average depth between 10 and 15 metres, a spacing of between 2.8 and 4.2 metres was required. For the 1977 project, a spacing of 3 metres was chosen.

Once the spacing was determined for the appropriate depth, the width of the insonified swath in those depths was three times the transducer spacing (From Figure 12). This meant that in our operational area the insonified strips were 9 metres wide.

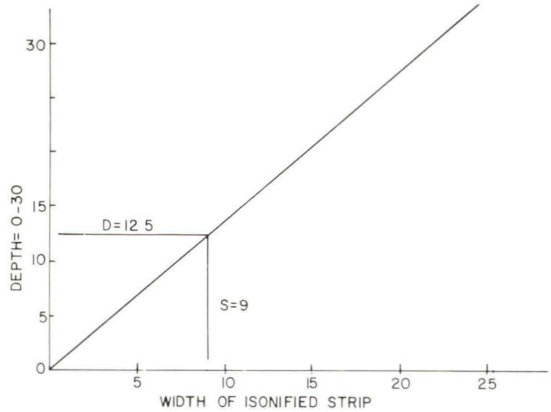


FIG.13 WIDTH OF ISONIFIED STRIP VS. DEPTH

The maximum allowable line spacing was thus the width of the strip insonified, less twice the on-line position accuracy. On-line position was monitored using shore based theodolite and portable radios. It was found that, albeit difficult with a strong cross current, the vessel was kept on line to within 1 metre. When the vessel went off line by more than this amount the line was rerun. The allowable line spacing was thus limited to 7 metres. Partly to simplify plotting and partly to provide some safety factor, lines were run at 6 metre intervals.

Discussion

The results of the production survey using the system were quite encouraging. The only technical difficulty encountered was minor and consisted of a mechanical malfunction of one recorder which repeatedly broke styli.

The maximum operating speed of the launch with the outboard units rigged was found to be 6 knots. At faster speeds the floats tended to submerge as well as visibly strain the outriggers. Optimum operating speed was approximately 5 knots. Vessel maneuverability and line-keeping ability were not impaired at these speeds. The outboard float did tend to submerge during a fast turn; however, this did not occur when trials were done using a vessel with less freeboard.

The system was found to be operable only under optimum weather conditions; that is, with waves less than one foot, and during periods of light winds.

Measurements were taken to determine float planing when underway. No planing was detected at launch speeds of up to 6 knots. At 6 knots, a vertical displacement of 2 inches downward relative to the launch was measured. This was thought to be caused by the launch planing. In any case it was considered insignificant.

Calibration of each recorder was carried out using standard bar check or cone check device. For the outboard units the cone check was suspended from a snatch block on an aluminum pole (Figure 14).

FIG. 14 CALIBRATION OF OUTBOARD SOUNDER

Interference (cross-talk) between sounders operating at or near the same frequency and in close proximity proved to be less troublesome than was expected. At a spacing of 3 metres between the centre (hull mounted) transducer and each outboard unit, cross talk between the two outboard units was negligible. It could in fact be eliminated by slightly lowering the receiver gain controls. Cross talk between hull mounted and outboard transducers could not be eliminated. This proved troublesome only when recorder stylus drive motor speeds were almost identical. The result of this situation is shown on the graph following (Figure 15). This shows the transmission pulse from the starboard sounder being recorded on the graph of the centre recorder. The fluctuation of the graph of the cross talk was due to variation in the relative motor speeds. The large fluctuations were caused by minute adjustments to the "speed-of-sound" control to test the sensitivity.

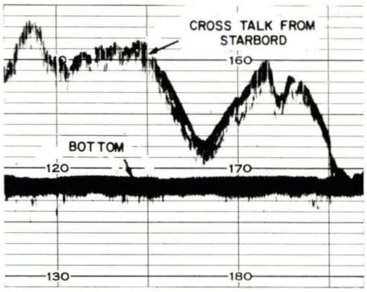
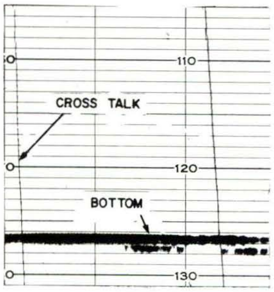


FIG. 15



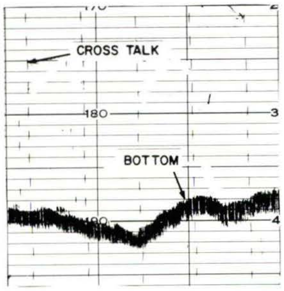


FIG. 16

FIG. 17

Fortunately, this pattern could be, and was, eliminated by adjustment of the stylus drive motor speed of the outboard recorder. This produced acceptable patterns of "cross-talk" (Figures 16 and 17) which could be easily identified and were not confused with the bottom echo. The adjustments to the motor speeds necessary to generate the acceptable "cross-talk" patterns resulted in negligible differences in depth measurements. When checked with the "cone check" device to 30 metres depth, no difference could be detected on the recorder graphs.

This survey showed the system capable of providing excellent bottom coverage at a survey scale of 1:1200. In depths of from 5 to 20 metres, minimum bottom coverage obtained was approximately 87%. In the critical areas (depths from 10 to 20 metres) bottom coverage was 100%.

It should be noted that on more than one occasion isolated echoes were recorded on one recorder and not on the others. These could quite possibly have been missed using conventional sounding techniques and instrumentation.

Conclusions

The conclusions drawn from this exercise are neither startling nor revolutionary. The concept of sonar sweeping is hardly original.

This project simply demonstrated that with certain limitations it is possible to sweep an area using existing sonar equipment which is usually readily available to any hydrographic survey party. Any hydrographer could build a sonar sweep system in the field if or when the need arises. This also shows that survey procedures can be developed to implement electronic sweeping on a large scale survey.

Measurement of Currents in Narrow Passages using *IN SITU* Pressure Gauges

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C.H.S. Pacific Region

Abstract

A program is presently underway to measure currents in Dodd Narrows and in Active, Porlier and Gabriola Passes (British Columbia) using in situ *pressure gauges. No long term current measurements had ever been made in these four locations due to a combination of marine traffic, strong currents and related equipment limitations. An* in situ *pressure gauge is installed at each end of the narrows under study and the hydraulic head derived from the pressure difference is used to calculate the current from an empirical model of the relationship of hydraulic head to current. This empirical model is calibrated from simultaneous measurements of the pressures and current. From measurements made in January 1978, results are presented of a preliminary calibration of these relationships for Dodd Narrows, Active Pass, and Porlier Pass. The length of data record required to produce reliable predictions is discussed, along with problems involved in making current measurements in these areas and equipment used, past and present.*

The Area

The Gulf Island passes, by which we mean Active, Porlier, and Gabriola Passes and Dodd Narrows (see Figure 1), are the major channels between the outer Gulf Islands. Most of the commercial traffic through these channels consists of fishing vessels, towboats and ferries, but these are easily outnumbered by pleasure craft, particularly in summer.

Currents and Their Prediction

The current through each of the Gulf Island passes is driven almost entirely by the difference in the water levels between the two ends of the channel. Typical differences in the water levels of 20 cm. are attained due to differences in the range and phase of the tide trapped by the outer Gulf Islands and the tide propagating into the Strait of Georgia through the larger channels to the east. Maximum currents in the narrowest parts of these passes of at least five knots can normally be expected at spring tides with nine knots being attained at times in Dodd Narrows. The flow is often violently turbulent and accompanied by severe rips.

Predictions of the current at these places are of considerable importance to the mariner. For the purposes of predicting the current it is necessary--as a bare minimum--to have hourly measurements of the current for one lunar month. Predictions of current based on harmonic analysis of this amount of data will be accurate for the most part, but this accuracy will vary in time due to long term changes that are not resolved by the short series of measurements. Such is the state of the present predictions of the current in Dodd Narrows. In order to properly resolve the long term variations and to ensure that variations caused by storm surges, etcetera, do not affect the analysis, current observations for a period of one year are highly desirable.

Previous Current Measurements

In the early 1960's a program of current measurements was undertaken in the Gulf Island passes. The methods available at that time required the continuous attendance of a field party so that measurements were taken for at most one month.

That very tedious method of measuring currents, drogue tracking, has been employed at many sites in the Gulf Islands. The method produces perfectly satisfactory results in the passes, although in the employment of this method one must consider the requirement for personnel to deploy the drogues and to man the tracking station for one month, twenty-four hours a day. Other difficulties with the drogue tracking method are the feasibility and safety of operations at night and spatial variations in the current which make the observations strongly dependent on the position of the drogue. The present predictions for Active Pass are based on current measurements made by drogue tracking, supplemented by one year of slack water time observations.

In places where the current runs at nearly full strength quite close to the shore, a current meter mounted to a small boat was held approximately thirty metres out in the channel by a large mast and boom. This method still required the attendance of a field party but the work was reduced to recording the readings (wiring from the meter ran up the boom to the observer's hut) and swinging the boom in to allow passage of marine traffic such as towboats with log booms. The present predictions for Dodd Narrows are based on measurements made by this method. (see Figure 2)

It may be seen that to obtain one year of continuous data, some unattended system of measurement is required.

Use of Recording Current Meters

While it might seem at first glance that the development of submersible recording current meters would solve the problem of current measurements in the passes, such instruments are of little use. Certainly current meters are built that will withstand the strong currents, but holding them in position is extremely difficult. Mounting the unit close to the bottom is difficult due to the presence of the turbulent boundary layer; conventional taut-line moorings are soon cut by towing cables, even if one could be built to withstand the natural rigours of the currents. A structure strong enough to withstand towing cables is likely to pose a serious hazard to navigation.

Currents from Measurements of Hydraulic Head

The objective of the program presently under way is to obtain current records for a period of one year to better establish current predictions for each of the four passes. The current in each pass is calculated from the hydraulic head across it which is measured by two *in situ* (submersible, internally recording) pressure gauges installed at the ends of the channel.

One would expect to be able to make accurate calculations of the current in a channel from the two corresponding pressure records if the following hold:

a) momentum advected into the channel is small with respect to that developed in the main flow so that the current is almost entirely driven by the hydraulic head;

b) the head developed across the pass is large with respect to the accuracy of the pressure gauges.

In order to calculate the currents from the pressure differences, one must be able to define some suitable mathematical relationship between the two. The complexity of most passes makes a direct theoretical approach impractical,

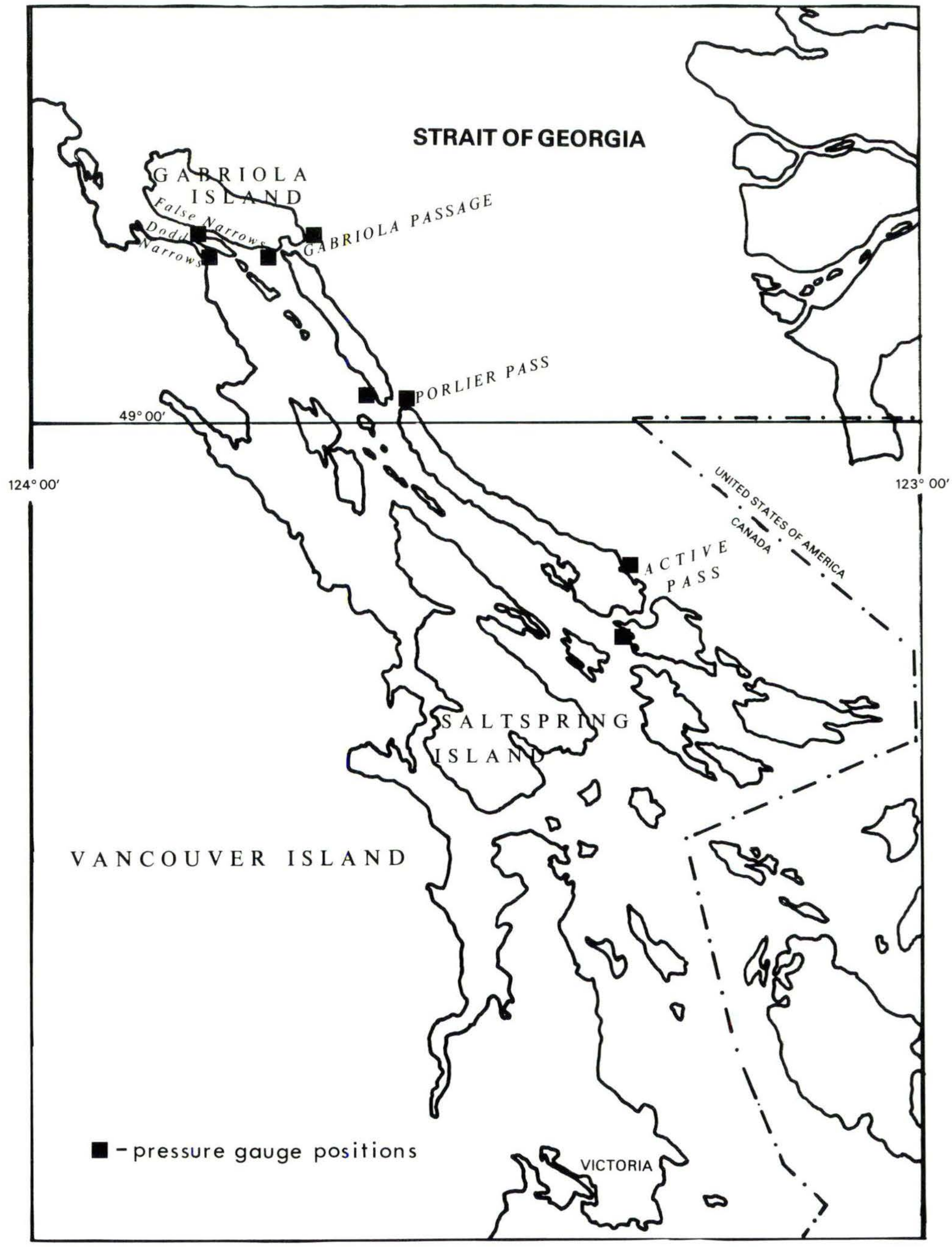


Figure 1 The Gulf Islands

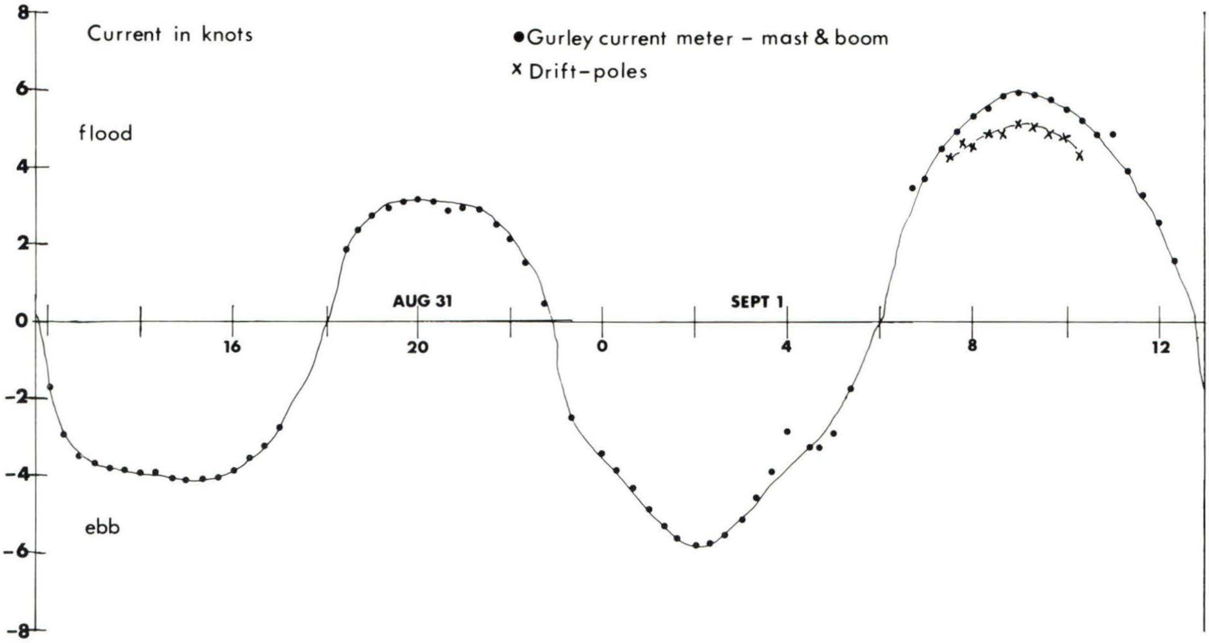


Figure 2 Current Measurements in Dodd Narrows - 1960

so current measurements must be obtained simultaneously with the pressure measurements for a time sufficient to determine an empirical relationship. A measure of the utility of this method is the number of current measurements necessary to calibrate the empirical models. The installation and servicing of the pressure gauges is a fairly simple matter (all eight being installed in one day); the bulk of the work is in the measuring of the currents.

Pressure Gauges and Their Location

The positions of the pressure gauges are shown in Figure 1. These positions were chosen to satisfy the following requirements:

a) out of the influence of the main flow, yet close enough to the channel ends to give accurate results;

b) accessible by ship for the installation of the instrument anchors;

c) protected enough to reduce the effect on the measurements of surface waves and to allow the servicing of the instruments by divers from a small boat;

d) having a solid bottom to minimize the settling of the instrument anchors;

e) at a depth of approximately 15 meters, deep enough to help reduce the effects of surface waves, yet shallow enough to keep the diving operations simple.

Anchors for the pressure gauges consisted of concrete blocks (700 kg in air) fitted with plastic holders to carry the instruments. An acoustic beacon or "pinger" (Helle ¼ watt, 27KHz) was attached to each anchor to provide an easy method of relocating the instrument and a brightly coloured float was tethered three metres above the bottom to aid in visual location.

Pressure gauges of two companies, Aanderaa Instruments Ltd. (2-model TG2A, 2-model TG3A) and Applied Microsystems Ltd. (4-model 750A) are being employed. All are fitted with quartz pressure sensors (Paroscientific Inc.) with full scale pressure of 45 psia and an accuracy of 0.01% of full scale (3mm of water). Both makes of gauge average the pressure over a time interval which will hereafter be called the integration time.

The four Applied Microsystems units were chosen for the two most important passes, Active and Porlier. This choice was made on the basis of their superior reliability and endurance and upon their capability of being configured to an integration time of 450 sec. to average out a seiche which was known to exist at one of the locations and to average wave effects at the exposed outer locations. The Aanderaa TG3A units which have a fixed integration time of 28 sec. were placed in the most sheltered locations, at Gabriola Pass. The two TG2A's were set for 100 sec. integration time for the moderately sheltered locations at Dodd Narrows. All of the instruments were set to record the pressure every quarter hour and synchronized so that the integration times were centered on the quarter hour.

Current Measurements

As it was hoped that relatively few current measurements would be necessary to calibrate the empirical models, a method of measuring the current involving the continuous attendance of a field party was considered satisfactory. A Dumas Neyrpic current sensor (small screw style rotor) was carried by a steel strut fastened to the side of a fast launch and projected two metres below the bottom of the hull. A digital readout calibrated directly in knots was built for the project by Applied Microsystems Ltd. who also fitted the sensor with a solid state rotation sensing device. This combination of launch and current meter worked very well in the field. Currents up to ten knots could be measured with an accuracy of approximately 0.1 knots as long as the sea was relatively calm. The field operations consisted of stemming the current in the pass at the place where the current was found to be strongest--usually slightly downstream of the narrowest part of the channel. Position was maintained by range marks established on the shore.

Determination of the Empirical Models

Condiser steady frictionless irrotational flow through an open channel. From Bernoulli's equation:

$$u|u| \propto \Delta h \qquad \ldots 1$$

where u is the velocity of the current
Δh is the hydraulic head

The pressure gauges measure the sum of hydraulic pressure above the pressure port and atmospheric pressure. If mean sea level is the same at both ends of the channel, then the mean should be removed from the hydraulic pressure differences to obtain results proportional to the hydraulic head, neglecting effects due to changes in the density of the water column. If there is a difference in mean sea level between the ends of the channel then some constant must be added to the hydraulic pressure difference to obtain hydraulic head. Equation 1 becomes:

$$u|u| = k\Delta p + c \qquad \ldots 2$$

where k is the constant of proportionality
Δp is the difference in total pressure
c is some (small) constant

The difference in atmospheric pressure between the two pressure gauge sites is usually negligible, so that when the total pressure differences is calculated we are left with a result which is proportional to the hydraulic head. However, if the atmospheric pressure difference was significant, it would drive the current in the same manner as does the hydraulic head and the use of the total pressure difference in Equation 2 is still correct. The constant c will be affected by net transport through the pass as well as by any difference in mean sea level. Note that the form of Equation 2 is not changed if a friction term proportional to the square of the velocity is introduced.

Results of the Preliminary Calibrations

In January 1978 current observations were taken at Active and Porlier Passes and Dodd Narrows over the period of a week. The pressure gauges, which had been installed in mid-December 1977, were serviced in early February to verify their operation before leaving them in for six months and to recover the data for this preliminary assessment of the method. The current velocity squared (positive taken for flood, negative for ebb) was plotted against the pressure differential to discover how well the measurements obeyed Equation 2. When interpreting these plots it should be remembered that the absolute error in the square of the velocity increases with magnitude and that one millibar of pressure is approximately equal to that due to one centimeter of sea water.

It is seen in Figure 3 that for Dodd Narrows the relationship between current and pressure differential is very well defined by Equation 2. It might be expected that the constant k would be different for the two directions of flow, depending on the form the flow takes in each direction. This appears not to be the case at Dodd Narrows and may be due to the simplicity of the channel. One would expect inertial effects to be relatively unimportant as the volume of water involved is quite small--the channel is approximately 50 metres wide between the 2.5 fathom contours and quite short at the narrowest part--although as the pressure difference becomes small and slack water is approached, the inertial effects will predominate, if only for a short time. As the current measurements were taken every 15 minutes and their progression corresponded well with that of the pressure differences, the error in the time of slack water introduced by determining the currents indirectly from the pressure difference might be estimated to be of the order of ten minutes. More measurements are certainly necessary to confirm these results, for there are only five hours of current measurements defining the relationship. It is expected that observations for several tidal cycles will be sufficient to confirm the results.

The results for Porlier Pass are shown in Figure 4. The main channel is approximately 1 km long and 300 metres wide between the 2.5 fathom contours although the width is nearly 700 metres if the shoal areas are included. Vortex shedding from the many shoals causes the flow to be mostly turbulent. The plot of pressure differential versus the square of the velocity shows that Equation 2 is no longer sufficient to explain the results. The effect of inertia due to the large mass of water involved necessitates the addition to Equation 2 of an acceleration term proportional to the first derivative of the velocity with respect to time. The plot of the observations is separated into two branches by this term, the lower corresponding to the positive derivative and the upper corresponding to the negative derivative. Not only is the acceleration term important, but there is a distinct change in the slope of the relationship when the pressure differential is less than -14 mb. This may be attributed to the onset of some additional mechanism of energy dissipation, perhaps the onset of critical flow. It should be noted that this only occurs on the ebb, but whether this is caused by the effective shape of the channel in that direction or the lower water levels at that stage or some combination of both is unknown as yet. In addition to this sudden change in slope, it is possible that some form of variation in the friction term with water level can be identified when more data becomes available.

The mass of water involved in the flow at Active Pass is considerably larger than at Porlier Pass and one would expect the acceleration term to be correspondingly more important. As may be seen in Figure 5, the channel is approximately 4 km. long with two narrow parts of approximately 400 metres width at each end, connected by a body of water having a mean width of roughly 1 km. The plot of the observations reveals the strong effect of the acceleration term. It is unfortunate that observations were not made from flood through to ebb so that a more complete assessment could be made of the feasibility of the method at this location. However, the measurements we do have are quite consistent and give every indication that a suitable empirical relationship can be established; further comment would be premature.

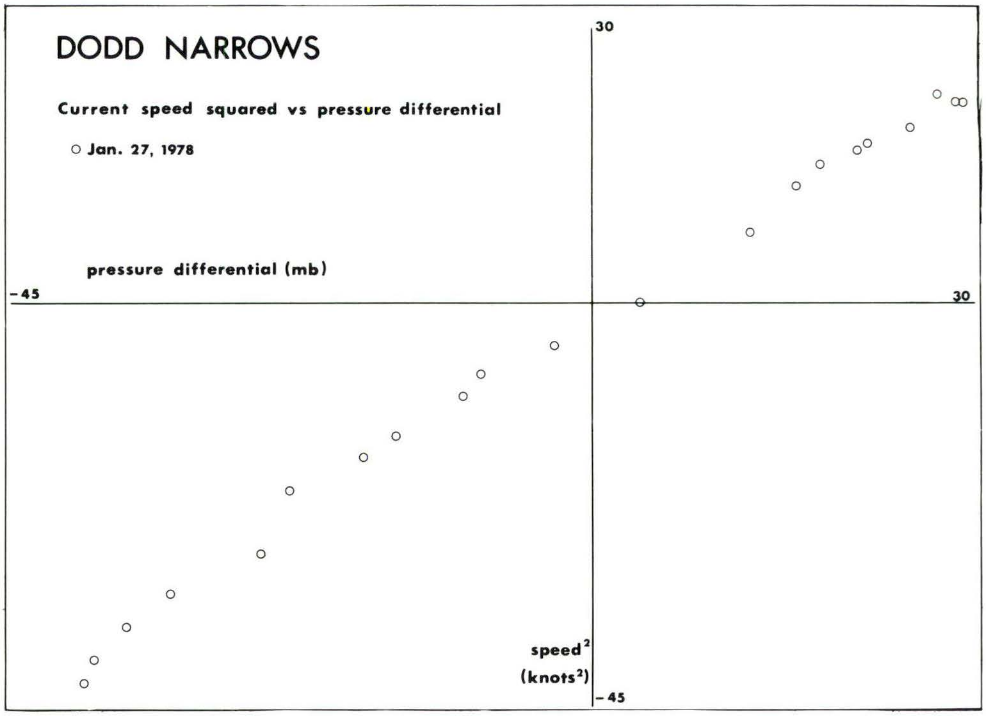
Plans for Further Measurements

This summer, when we expect conditions will be pleasant, more current measurements will be made in the Gulf Island Passes to properly define the empirical models of current versus pressure differential. In Active and Porlier Passes, where the importance of the acceleration term makes the determination of the models more complex, current measurements will be taken for several weeks. The pressure gauges are to be serviced after these current measurements have been made in order to obtain the data to make the final determination of the empirical models, or to determine that more current measurements are necessary. The pressure gauges will remain in position until January 1979 to provide data for an entire year.

There are many locations on the Pacific Coast where strong currents are generated in narrow passes or entrances due to a difference in water levels. Prediction of these currents is often limited to the time of slack water with respect to a tidal station and may be inadequate and/or unreliable. This method of calculating currents from the hydraulic head is an effective way of obtaining the data necessary to provide accurate current predictions in many of these locations as well as providing valuable water level information when an additional pressure gauge is installed as a barometer and the necessary bench marks are established. It is expected that measurements will be undertaken using this method at several of these locations in the near future.

Conclusion

The calculation of currents in narrow passes from hydraulic head measurements obtained by *in situ* pressure gauges is an effective way of obtaining enough current data to make reliable current predictions. While some care must be taken in the employment of the method--in the decision of whether or not the method is suitable at a given site--the relatively low cost of mounting such a program of measurement and the low risk of equipment loss makes the employment of this method quite attractive.


DODD NARROWS
Current speed squared vs pressure differential
○ Jan. 27, 1978
pressure differential (mb)
-45
30
30
speed^2 (knots^2)
-45

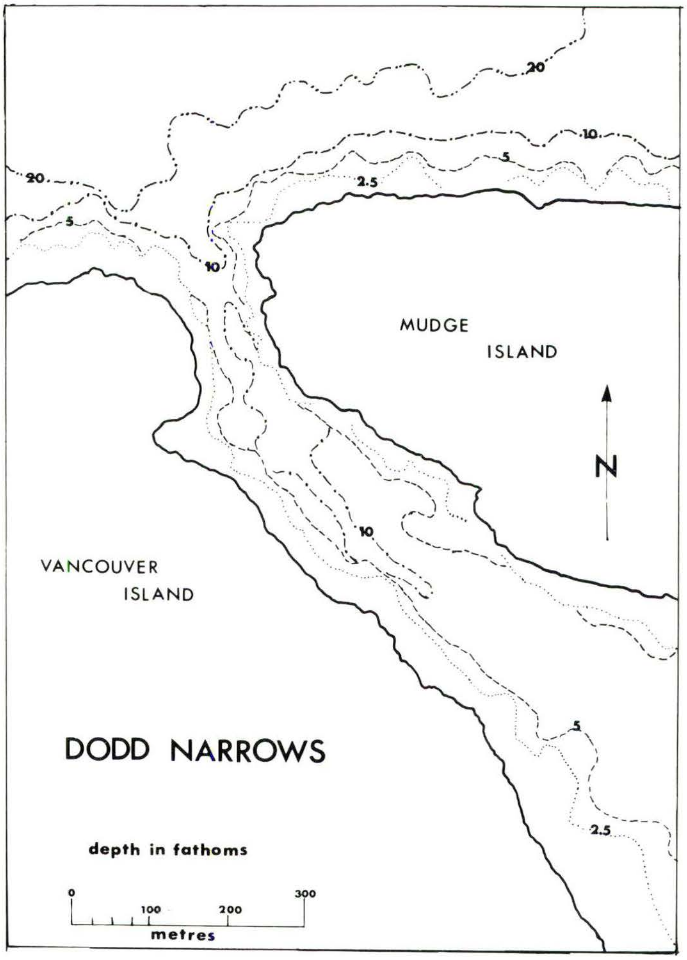
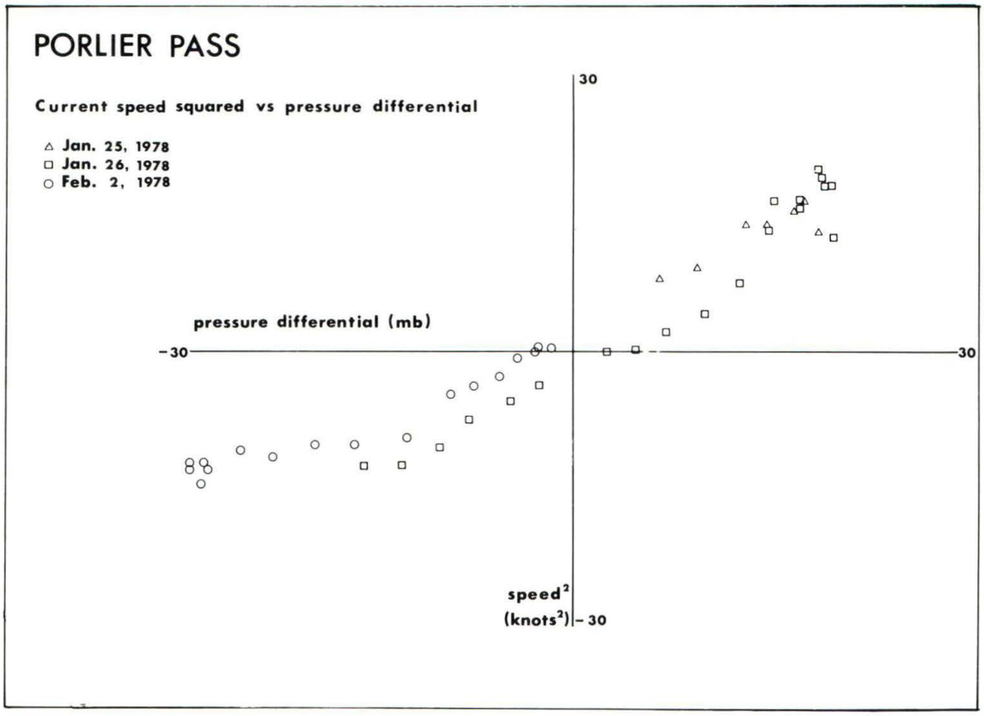

20
10
5
2.5
20
5
10
MUDGE ISLAND
N
10
VANCOUVER ISLAND
5
2.5
DODD NARROWS
depth in fathoms
0
100
200
300
metres

Figure 3


PORLIER PASS
Current speed squared vs pressure differential
△ Jan. 25, 1978
□ Jan. 26, 1978
○ Feb. 2, 1978
30
pressure differential (mb)
−30
30
speed²
(knots²)
− 30

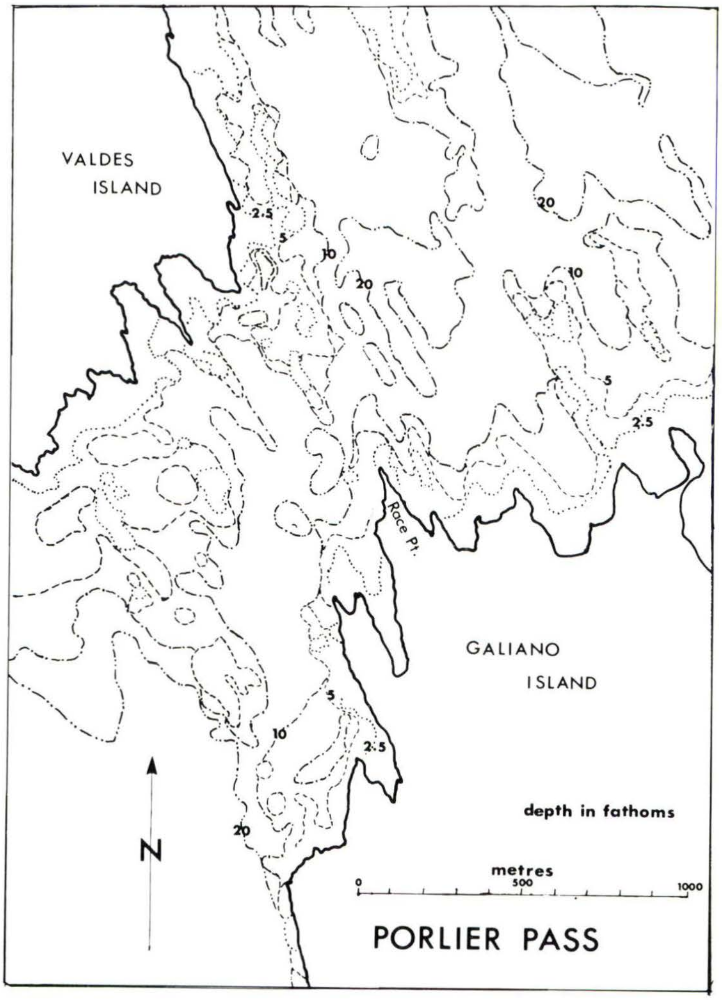

VALDES
ISLAND
GALIANO
ISLAND
Race Pt.
2.5
5
10
20
N
depth in fathoms
metres
0
500
1000
PORLIER PASS

Figure 4

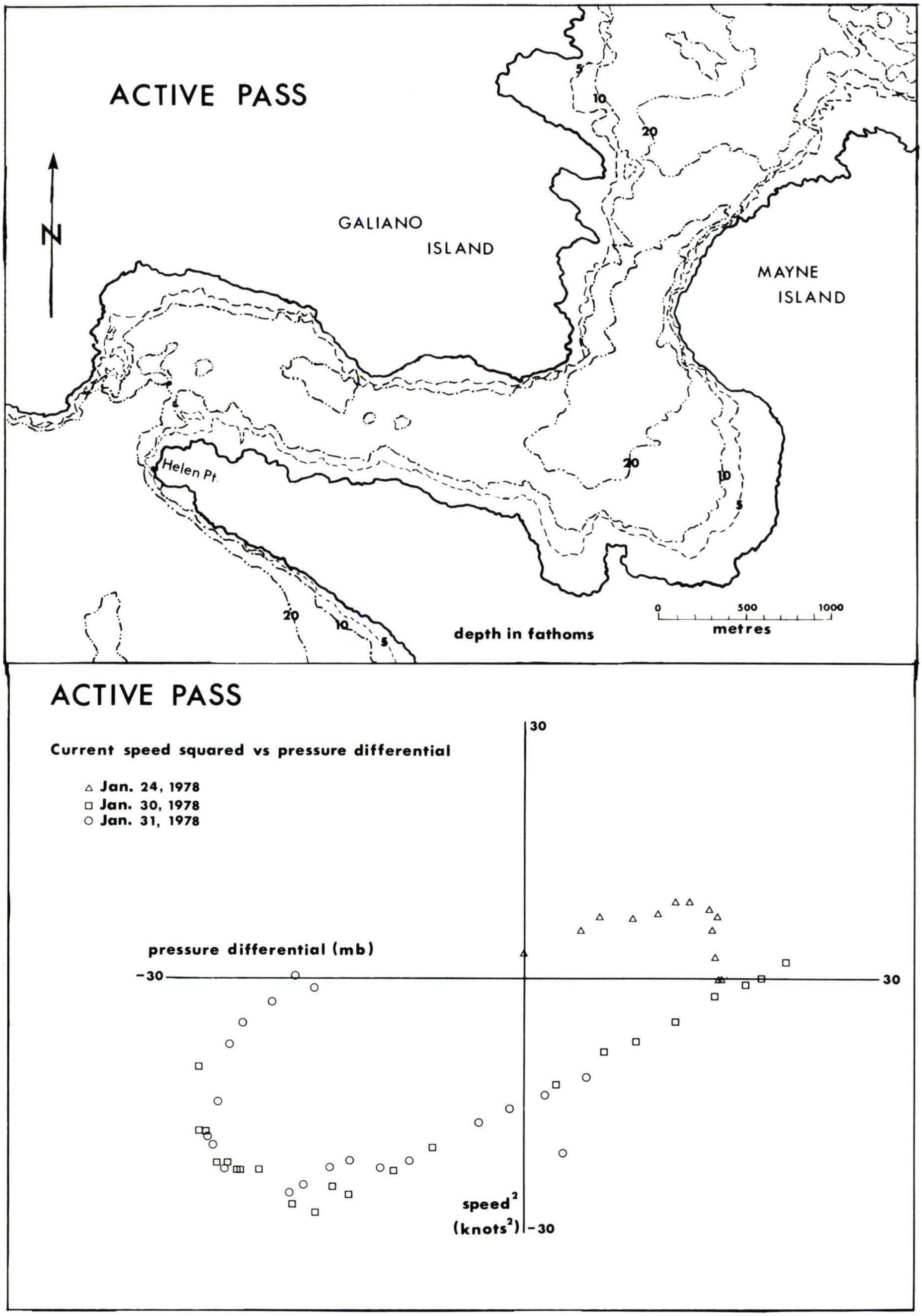

ACTIVE PASS
N
GALIANO ISLAND
MAYNE ISLAND
Helen Pt.
5
10
20
depth in fathoms
0
500
1000
metres
ACTIVE PASS
Current speed squared vs pressure differential
△ Jan. 24, 1978
□ Jan. 30, 1978
○ Jan. 31, 1978
pressure differential (mb)
-30
30
30
speed^2 (knots^2)
-30

Figure 5

Cook and the Crumpled Echogram

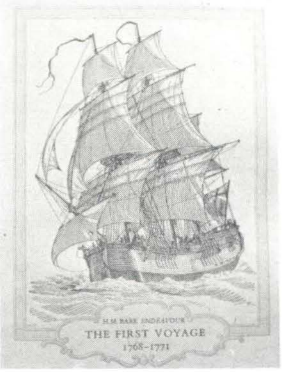
C. MAGEAU
C.H.S. Ottawa

ABSTRACT

Although navigation and surveying techniques have been refined since the eighteenth century, two aspects of contemporary surveys have undergone little change: 1) the storage of documents collected at sea has not kept pace with technical developments; and, 2) hydrographic cruises are only slowly returning to the multi-disciplinary mentality which existed in earlier times.

Echograms and seismic records are essential tools in the interpretation of bathymetric data and the production of bathymetric and morphologic maps. Negligence in their care and preservation results in their deterioration and/or loss. It is proposed that these documents be copied onto 35 mm microfilm and the original documents granted archival status. The cost of this operation is minimal when compared to cruise costs.

Pre-season briefings, a greater participation by scientists in cruises and an extension of the rotation systems for the hydrographer to include a familiarization period with the production of bathymetric and morphologic maps is suggested. This would result in a greater scientific return and closer co-operation between scientists and hydrographers.



INTRODUCTION

The early explorers set out, not to unravel the mysteries of nature but rather to find the riches of the world and claim them for their sovereigns. Their successes were measured more in terms of treasure-laden galleons and exotic spices than in scientific revelations.

In August of 1768, James Cook set sail on H.M. Bark Endeavour on what was to be one of the first scientific voyages of the eighteenth century. The development of the reflecting quadrant, the sextant, the astronomical quadrant, azimuth compass, theodolite and chronometer provided the eighteenth century explorer with the tools required to conduct accurate coastal surveys. These advances marked the beginning of a new era in hydrography and an age of intense activity in sea-borne commerce and, unfortunately, warfare.

Although Captain Cook's voyages have often been cited as examples of fine hydrographic surveying they were also seminal in that his goals were not simply to survey the ocean. Much emphasis was placed on the scientific pursuit of knowledge and both crew and officers were involved in this quest according to their interests and abilities. It is speculated that this was one of the reasons the crew enlisted time and again in spite of the perilous nature of these voyages. In this respect, eighteenth century cruises were fore-runners of the later naturalist cruises of the Challenger, Meteor, Discovery and Galathea.

Precise instrumentation and specialized techniques in chart construction were developed as the art of navigation and marine surveying evolved. One of the most important instruments in marine surveying, the echo-sounder, was developed early in the twentieth century. Whereas previous surveys had, for the most part, restricted themselves to the potentially dangerous coastal waters, offshore charting became possible with the advent of this new instrument. Over the years, the continuous use of the echo-sounder resulted in the accumulation of much topographical information about the sea floor. This increase in the knowledge of the configuration of the ocean floor lead to the development of the bathymetric map which is different from the hydrographic chart. The bathymetric map seeks to represent the actual shape of the ocean floor as closely as possible, while the hydrographic chart instructs the mariner as to the dangers to surface navigation, particularly within coastal waters. To construct hydrographic charts, the shallowest depths recorded on the echogram are emphasized to stress the navigational hazards. Bathymetric maps, however, are based on the totality of the data recorded on the echogram and seek to interpret these values based on an understanding of geological processes which mould the topography of the ocean. Professeur Vanney (1976) summarizes this concept in his recent book stating:

> 'La carte bathymétrique est la traduction explicative des sondages et diffère selon les auteurs;elle constitute déja le prime jalon de l'interprétation morphologique'.

In this respect, a bathymetric map is analogous to a scientific paper, the scientific data and its interpretation presented pictorially rather than by the written word.

DISCUSSION

1. Data Interpretation

As our knowledge of the physiography of the ocean floor has increased, so has the realization of the complexity of the forces which have moulded it and of the processes which modify its profile. Oceanographers, fishermen, marine geologists, engineers and legists need particular knowledge of the composition, structure and morphology of the ocean floor and the processes which affect it. The development of these different disciplines in the marine sciences, their specific requirements and the limitations of the contoured bathymetric maps have resulted in the development of several other methods of portraying the ocean floor. Heezen and Tharpe (1959) extrapolated from bathymetric contours and echograms to draw their physiographic diagrams of the sea floor (Fig. 1), while Boillot (1963) used sequences of bottom profiles (Fig. 2) and Monahan (1971) presented an oblique view of contours to illustrate the sea floor (Fig. 3).

Block diagrams, colour-coded bathymetric maps and sounding sheets are three of the most extensively used means of representing the sea floor. To complement the use of colour-coded bathymetric maps, the Geoscience Mapping Unit of the Canadian Hydrographic Service (C.H.S.) also employs medium scale morphology maps (Monahan and MacNab 1974). These maps combine the physical outline of features, their spatial distribution and permit identification of features too small to be reflected by the contours.

The typical procedure to generate a bathymetry/morphology map follows. The profile of the ocean bottom as actually measured by the echo-sounder and displayed on the echogram is examined prior to contouring the data points numerically represented on the field sheets. In areas where the sea floor exhibits high relief, the echograms are transferred in their entirety onto a clear plastic overlay (Fig. 4).

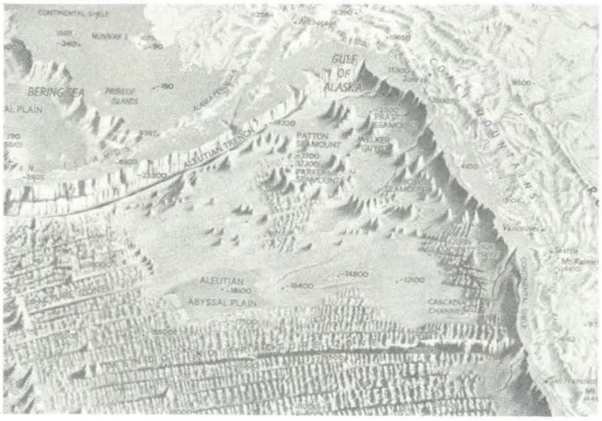


Figure 1: Physiographic diagram of sea floor after Heezen and Tharpe.

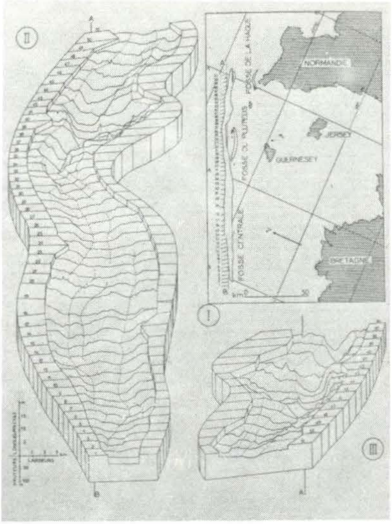


Figure 2: Sequence of bottom profiles.

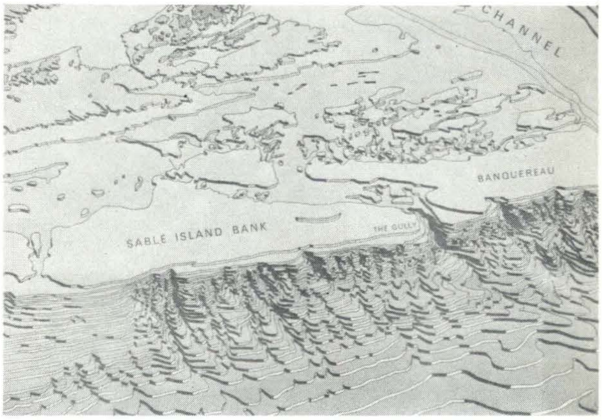


Figure 3: Three dimensional representation of submarine relief.

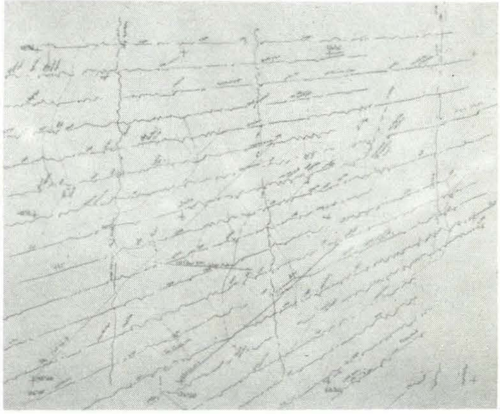


Figure 4: Trace of bottom profiles along the ships tracks.

The echograms are adjusted for distortions induced by changes in ship speed, paper speed and phase changes to yield the true shape of the ocean floor. In areas where there are only occasional irregularities on the sea floor, bottom categories are established and colour-coded and individual features such as ridges, valleys and block faults are indicated. The relative intensity and the frequency of the occurrence of certain features and general bottom conditions are noted in order to establish the morphological categories on which the provinces will be based. As each echogram is examined, interpretations of the individual features are made, regarding their mode of formation and their relationship to the geological history of the area. Adjoining echograms are compared to trace the progression of individual features, such as the lateral extent of a ridge, to determine if it bifurcates, broadens into a plateau or slowly slopes to the ocean floor. Continuous seismic profiles, side scan sonar, gravity and magnetic data, as well as additional information obtained from the geological literature are used to assist in the interpretation of the echograms. The location of suspected faults, trends of features, the composition of bottom samples collected by the hydrographers and sedimentological data inferred from the echograms (King 1966) and seismic lines (Stoll 1977) are plotted on the overlay (Fig. 5).

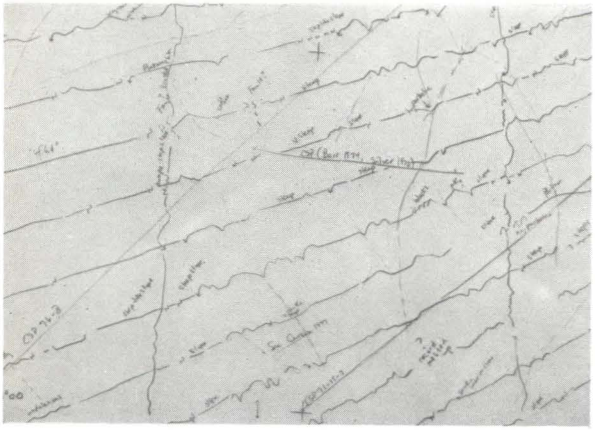


Figure 5: Plot of bottom profiles, location of CSP lines, key references, suspected fault traces ...

The first step in the production of morphology and bathymetry maps, therefore, consists in producing a working copy on which the locations of features, changes in slope and pertinent geological information are indicated. Areas exhibiting similar morphology are outlined, labelled and described according to their dominant characters. The relief provinces of the final morphology map are defined by these areas (Fig. 6).

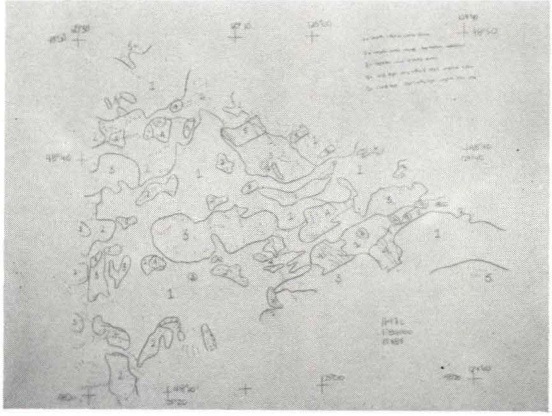


Figure 6: Outline of morphological provinces, categories and dominant features.

The numerically coded provinces, the trend of features, variations in valley shapes, angularity of elevations and degree of continuity of slope are depicted on the morphology map by the use of appropriate symbols (Fig. 7).

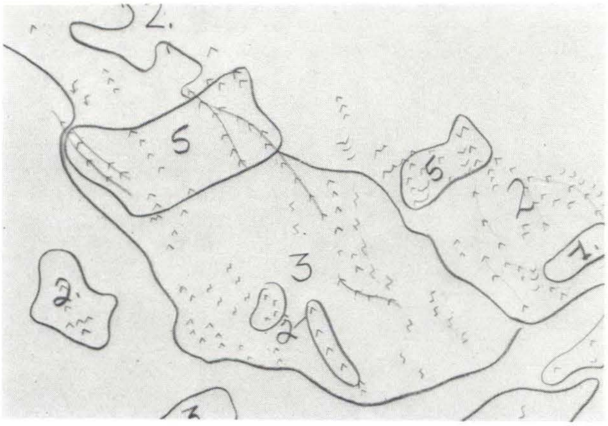


Figure 7: Enlargement of morphology map, symbols representing peaks, ridges, steps, breaks in slope. Numbers indicate morphological provinces.

The field sheet and the overlay are then superimposed and the field sheet contoured. These contours, however, are based not only on the numerical values as selected on board ship, but also on the geological and geomorphological information derived from the echogram analysis. By outlining trends of valleys and ridges, and complementing the bathymetric data with information obtained from different sources, additional information is extracted from the depth values. It is obvious that examination of the echograms becomes more important as the distance between sounding lines increases. Figures 8, 9, 10, depict the configuration of the preliminary contours based only on the numerical values. Some of the features outlined

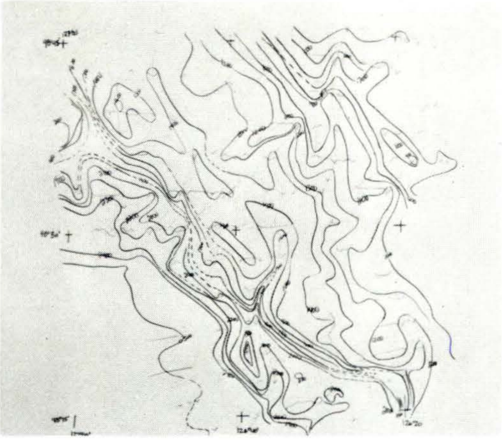


Figure 8: Contours based on field sheet data only.

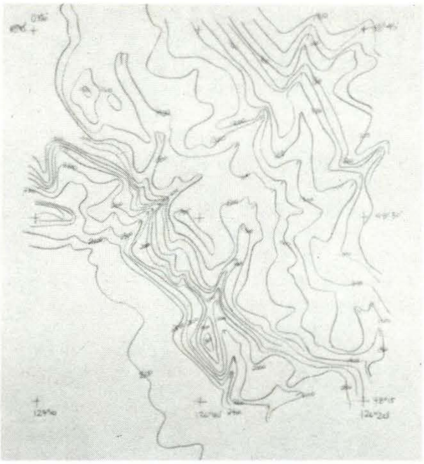


Figure 11: Contours interpreted from echograms, seismic and geological data (corrected contours of Figure 8).

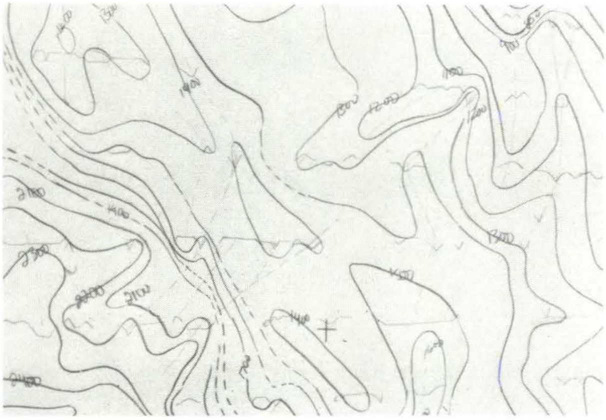


Figure 9: Disagreement between numerically generated contours and features, trends, delineated by the echograms.

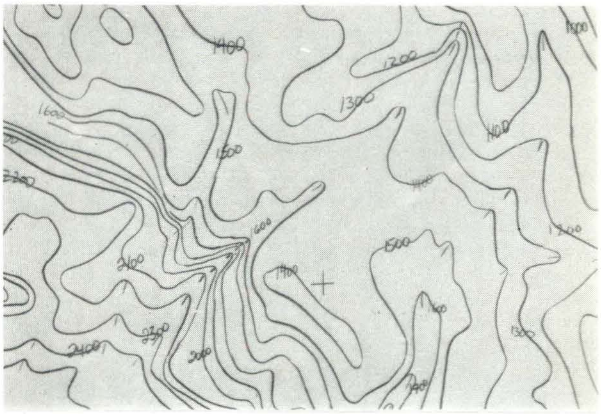


Figure 12: Configuration and trend of valleys and ridges interpreted from echograms, seismic records and geological data (corrected contours of Figure 9)

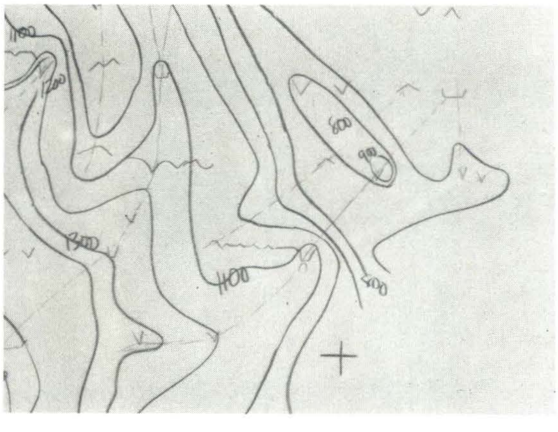


Figure 10: Geologically unrealistic contours based on field sheet data only.

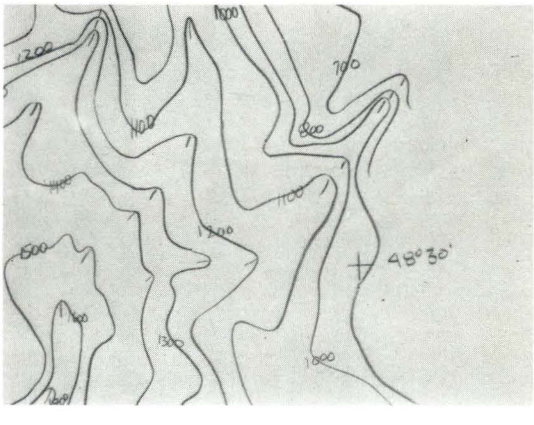


Figure 13: Interpretation of contours between soundings and sounding lines (corrected contours of Figure 10).

by the echograms are superimposed on the contours (Fig. 9 & 10). It can be seen that the trend of some of the valleys and ridges differ somewhat from the trend outlined by the numerically based contours. Furthermore, by considering the general trend of the topography, it is possible to modify the contours that fall between soundings and sounding lines to present a more realistic solution. Figures 11, 12, & 13 illustrate the corrected contours and demonstrate the importance of the information not normally included in the data set recorded on the field sheet but revealed by the echogram.

RECOMMENDATIONS

1. Archival Importance of Echograms:

The interpreter is greatly dependent of the quality of annotation and physical state of the echograms. In the view of the interpreter, the ideal echogram consists of a clearly and consistently annotated profile that indicates the times, dates, changes in ship speed, changes in paper speed, changes in phases, ships course, sea state and reasons for unusual artifacts on the records. These details are necessary to accurately position the echogram, correct for distortions and enable a more realistic interpretation of the data. Omission to annotate changes in the operation of the echo-sounder may lead to errors. For example, adjusting of the gain to give a strong first arrival will prevent subsurface geomorphological information from being recorded digitally or on the echogram. This will give rise to imcomplete information as to the nature of the bottom and perhaps cause an erroneous interpretation.

Similar care must be exercised when drafting the boat-boards, for it is essential that the morphological symbols derived from the analysis of the echogram, be properly positioned to supplement information given by the soundings. Colour-coding of days on the boat-board should be consistent throughout the survey area and the fixes should be labelled with indelible markers. Annotations of the boat-boards must include the location of the beginning and ending of sounding lines and co-ordination of reference marks between field sheets and boat-boards as well as between adjoining boat-boards. All of these criteria are outlined in field manuals for hydrographers, but it would seem that with the advent of automated systems of data collection, plotting, storage and (God forbid!) interpretation, that these time consuming and laborious tasks might appear less important. There is a danger of relying too heavily on the computer generated records. In the eventuality of a computer malfunction discovered after a cruise, the hydrographer should be able to correct the discrepancies by referring to well annotated echograms. If the echograms have not been well annotated during the field season, the losses incurred in terms of finance and manpower are considerable.

Given the important role played by echograms in the production of bathymetric and morphologic maps and the fact that these echograms constitute the only tangible product of a hydrographic cruise, why then are they not treated with proper and due care? In spite of the archival importance of echograms, the monetary cost (i.e. tax dollars) and human costs (i.e. loss of internal equilibrium), these records are often considered a nuisance by the institutions who store them. Crumpled, dried out, rolled and unrolled, sent hither and yon, the echograms deteriorate to a point where they are illegible (Fig. 14).

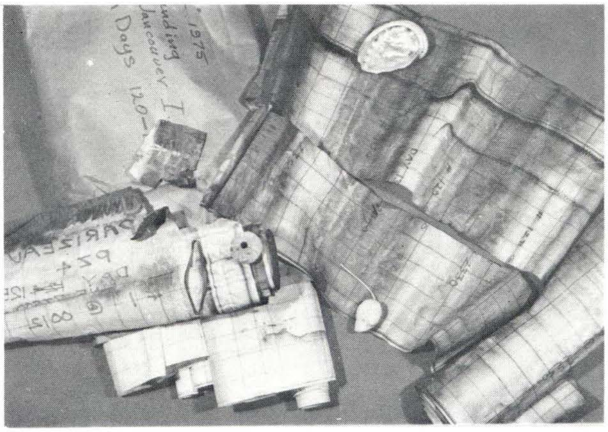


Figure 14: Echograms collected in 1975 - brittle, water stained and torn.

The proposal which follows represents the first step in the move to preserve these documents. Several scientific institutions in the United States and Canada have undertaken to systematically transfer their seismic records and echograms onto continuous reels of 35 mm microfilm. These reels can be examined by use of a microfilm reader which displays the information on a screen and from which photocopies of the documents can be obtained. This microfilming method would present advantages in storing, handling and shipping of the echograms. It would also result in an increase in the ease of retrieval and reproduction which might in itself broaden the distribution of these echograms and hence increase the value of the survey. For archiving purposes it might also prove wise to preserve boat-boards and field sheets in negative form or include them on the microfilm as some institutions have done. These improvements in the storage methods can be justified if the prospective users of these documents are considered: marine geologists, who produce bathymetric, morphologic and sediment distribution maps; pleistocene geologists concerned with glacial deposits; petroleum companies involved in drilling and dredging operations; economic geologists looking for mineral deposits; marine engineers; fishermen and legists.

Custodians of microfilmed records have commented that for a time, users of these documents are reticent to adopt the new data format. This is only a question of habit. The ability to photocopy relevant portions and to rapidly scan through the records surely outweighs the drawbacks caused by the unusual display. The quality of the microfilm reproduction does not present a problem and the echograms can be viewed at several magnifications by simply replacing the objective lens of the reader-printer. It is proposed that the original documents be placed in archival storage and made available on an open file basis only.

The practice of sending perishable original documents halfway across the country could be costly, both financially and in terms of human effort. Considering only the cost of operating a ship and an average cost of $7,000 per day for the Parizeau, it cost the government more than $550,000 to complete the 79 days of bathymetry collected during the 1975 summer field season off the West Coast of Canada (Lusk 1975). Now consider the cost of microfilming the material collected during this hydrographic survey. Three and one half reels of 35 mm film, each 100 feet in length would be required to reproduce the more than 37,000 kilometers surveyed. This process can cost as little as $60, if the echogram is photographed as a continuous strip by use of a flow camera, or as much as $1,000 if the echogram is photographed in overlapping sections (Appendix 1). This represents as little as one hundredth of one percent of the cruise cost, or in the latter case, less than .2% of the cruise cost!

Considering the period of time that will likely elapse before this offshore area is resurveyed and considering the cost of resurveying the area because the computer tapes have been accidently erased and the echograms have deteriorated or are lost, it is not wise to try and preserve these data in a better fashion?

When reading accounts of Captain Cook's voyages it is difficult not to admire his meticulous nature and the accuracy and the care he gave his work. Would he have treated precious echograms with such disrespect and relegated them to some dark and damp section of the hull? Would we hold this man up as a symbol of an accomplished explorer and hydrographer if he had allowed echograms, boat-boards and seismic records to crumble into oblivion?

2. Multi-disciplinary Surveys:

As mentioned earlier, it was the quest for knowledge of the sea which inspired his crew and himself to roam the seas. Artifacts, sketches and observations on the culture and character of the people and their lands were valued as highly as the charts of the waters which bound them. Only recently has this concept returned to our ships in the form of multi-disciplinary surveys. One aspect, however, is still missing to make our identification with the past complete, that is total co-operation toward achieving the same goal. Unfortunately, all too often scientists descend upon a ship like a dreaded disease and are considered, and perhaps, behave as an interference. In spite of many seasons of co-operation, some field hydrographers and crew do not really understand why anyone could be interested in echograms, or care to know the nature of the sediments beyond the mud, sand and gravel category. Could there not be an effort made to stimulate the curiosity of those on board to understand the full importance of the data they have collected? Perhaps by giving them the satisfaction of seeing the final product and explaining its uses, those responsible for the collection of the raw data would have the tools, experience, and knowledge to fully understand the importance of that which they are monitoring.

As a result of the need to acquire and process increasingly larger amounts of data, there has developed a necessary division of labour which has contributed to the deterioration of the co-operative effort characteristic of the eighteenth century cruises. Since he is responsible for the supervision of many disciplines which constitute a hydrographic survey, the hydrographer-in-charge needs to keep abreast of all the advances in these disciplines. Several years ago, at the 12th Hydrographic Conference, Crowther et al. (1973) suggested the extension of the rotation programme for hydrographers to include participation in Chart Production. Recently, Pelletier (1977) underlined the need for instruction of hydrographers in the field of marine geology. Why not combine these proposals and encourage hydrographers to spend some time familiarizing themselves with the interpretation of bathymetric and morphologic maps during their rotation periods? This could be done by a prolonged visit or training period with the Geoscience Mapping unit.

A more realistic proposition and one which may seem more acceptable to most hydrographers, is to encourage the involvement of scientists who gain by the collection of bathymetry, in both cruise preparation and participation. This closer co-operation between marine scientists and hydrographers would result in a greater scientific return both from the hydrographic and geologic point of view. Finally, may I suggest that there be a pre-season briefing, outlining the general geology and oceanography of the survey area, the problematic areas, the questions to be answered and the type of information required to answer these queries. An understanding of the geological problems of the survey area would enable the hydrographer to establish the location and orientation of the sounding grid and to select a bottom sampling interval to help resolve some of these questions. This could only result in a greater return of geologically valuable data in addition to obtaining the required hydrographic data. It would also represent a financial saving by eliminating the necessity to return to this area.

Furthermore, close co-operation between these related disciplines might initiate the return of that spirit of adventure and quest for knowledge which prevailed in Captain Cook's days, for it is stated in the hydrographer's bible, The Admiralty Manual of Hydrographic Surveying:

> 'The Surveyor should endeavour to collect any information likely to be of value to

> the advancement of scientific knowledge generally; e.g. a record of metereological conditions in the survey area, all types of oceanographical observations..... He also has unique opportunities of studying and collecting fish, birds, mammals and insects, and will always receive advice and encouragement from the various museums on the subjects.'

Cook himself considered the task of marine surveying and exploration as inseparable: 'The world will hardly admit of an excuse for a man leaving a coast unexplored he has once discover'd' (Skelton 1954).

ACKNOWLEDGEMENTS

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APPENDIX 1

Case study: Parizeau cruise, April to October 1975.

1. days of bathymetry collection assumed to be 79
2. total of 37,128 km of sounding lines or 469 km per day
3. cost of ship time \$7,000/day, Cruise cost = \$553,000

Microfilming reduction of echograms collected during this survey:

- echogram recorded at a paper speed of 3 ft./hr. will accumulate 72 ft. of record/day
- 1 day is represented by 4.5 ft. of 35 mm film

therefore 4.5 ft. of film = 72 ft. of echogram = 469 km and 1 reel of microfilm holds 100 ft. of film, which represents 22 days of bathymetry. Therefore, approximately 3½ reels of 35 mm microfilm would be required to store the entire bathymetric data for this cruise.

Cost:

a) echogram recorded as one continuous strip on 35 mm film

- material and handling costs for 1 reel range from \$14.50 to \$20/100 ft. reel which represents an expenditure of \$50 to \$70 for the entire cruise or 1/100 of 1% of the total cruise cost.

b) echogram recorded in overlapping sections 3 ft. in length on 35 mm film

- reduction from 3 ft. section to 1 frame 1½ x 1¾
- cost of 1 frame varies from .35¢ to .45¢
- 1 day = 4.5 ft. of film = approximately 30 frames
- 79 days of bathymetry = 2,347 frames at a cost of .35¢ = \$821
  .45¢ = \$1,056

Cost of microfilming the bathymetric data represents .2% of the total cruise cost.

Chart Evaluation Surveys in the National Ocean Survey

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ABSTRACT

The National Ocean Survey (NOS) recently instituted a Chart Evaluation Survey (CES) program designed to expeditiously provide hydrographic data in response to a recognized need for timely maintenance of published charts. This survey program is designed to address several primary areas of concern. Chief among these concerns are the investigation of all discrepancies which result from the necessary charting of reported data prior to field verification and the resolution of deficiencies reported or discovered subsequent to the most recent chart production. Field units assigned to the program also evaluate the adequacy of existing hydrographic information charted by employing a system of reconnaissance sounding lines and actively pursue the verification or revision of the information published in the appropriate Coast Pilot. Finally, a public relations effort is emphasized to inform the boating community and other nautical data users of the products and services of the National Ocean Survey and to obtain from them feedback pertinent to improving these products and services. Expanding use of the CES program provides the National Ocean Survey with flexibility in survey operations necessary to satisfy chart requirements in an expeditious manner within time constraints mandated by the cyclic chart printing schedule without being restricted to the relatively slow and expensive procedures of complete hydrographic surveys. In those areas discovered to be inadequately charted or in need of extensive updating hydrography, this program serves the additional purpose of documenting deficiencies and justifying a basic survey effort.

INTRODUCTION

Although the Chart Evaluation Survey program involves recently adopted terminology and documentation by the National Ocean Survey, many of its major concepts have been previously employed in other programs. These programs--Chart Revisory Surveys, Chart Deficiency Surveys, and Chart Adequacy Surveys--had evolved through the years and were the basis of the CES.

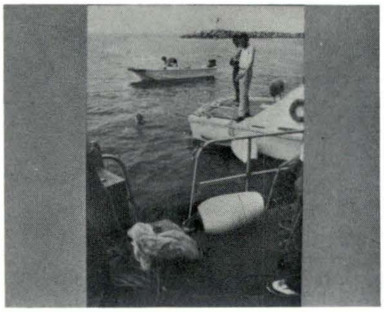
As early as 1937, the Lake Survey District of the U.S. Army Corps of Engineers employed a Chart Revisory Survey program to update the United States charts of the Great Lakes and their major tributary waterways. A triennial investigative survey coverage program assured contemporary coverage and chart maintenance of these waters. This program continued after responsibility for Great Lakes charting was transferred to the National Oceanic and Atmospheric Administration in October 1970. Key aspects of the revisory survey program included reconnaissance soundings in the approaches to each harbour, along the important waterfront areas, and in all other water areas privately maintained for commercial and recreational boating; verification of prominent landmarks and aids to navigation; surveys to include both natural and manmade changes to the nearshore or waterfront topography; and the updating of the Great Lakes Pilot.

The National Ocean Survey has identified and investigated specific items for many years. These "items of opportunity" were kept in active files at the Marine Centres and assigned to vessels operating near a particular item. Frequently these items would be maintained in files for years awaiting assignment. In more recent years, a mobile field party has been assigned full time to the investigation and resolution of these "deficiency items." Chart Deficiency Surveys thus were oriented towards the investigation and resolution of items of recognized concern.

Having a somewhat different purpose, NOS initiated a Chart Adequacy Survey program in 1973. For the first time, a major hydrographic vessel was assigned to a project specifically dedicated to investigate the adequacy of existing charts. Ship time was allocated and a specific area of investigation was defined for these projects. This program included the more important aspects of the chart revisory and chart deficiency programs; however, the additional manpower involved enabled the survey to cover a much larger charting area with a correspondingly greater public awareness of and participation in the effort.

The similarities of these three programs made it apparent that a single, all-encompassing program would be desirable and would be easier to administrate. This resulted in the Chart Evaluation Survey program being developed in the spring of 1978. This program retains the flexibility of its predecessors by utilizing all or any part of the basic objectives. Perhaps the most important aspect of the CES, however, is the comprehensive outline of desired reporting procedures.

There are three factors that have been positively effected by the evolution of the CES. Although the total requests for surveys and the acknowledged deficient areas have not changed appreciably, the portion of the NOAA fleet dedicated solely to the hydrographic mission has diminished to six vessels and five field units. As recently as 1971, the hydrographic fleet consisted of nine ships and three field units. To help cope with this decline in available units, it has been determined that some survey requests and many deficient areas can be addressed and brought to a contemporary status without implementing a basic hydrographic effort. Considerable time and expense can be saved by using a CES program. The field unit moves into the charted area, resolves the identified problem items, investigates the associated chart waters, and makes its recommendations relative to the chart depiction. If it recommends no further surveying action and office inspection confirms this recommendation, the appropriate charting changes are made and no further surveying effort is assigned.

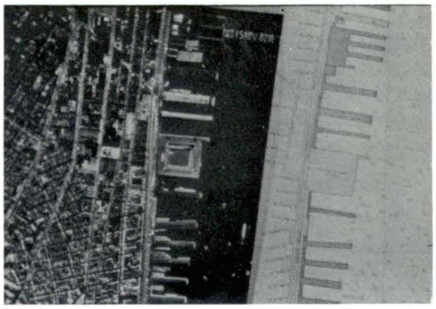


Diver Examination of a Located Hazard to Navigation

Reconnaissance hydrography is the primary basis for recommending either the acceptance of the chart as produced, for making minor revisional changes to the chart, or for the assignment of a basic hydrographic survey effort in the future. The density of reconnaissance soundings will vary depending on bottom characteristics, history of the area, known dynamic processes affecting the area, and traffic density. Whenever reconnaissance lines indicate a need for basic hydrography, immediate coordination is effected between the field and office to evaluate this indication of need. The extent of the need, whether the need should or can be addressed immediately or whether it must be assigned to a future hydrographic survey of the area, is determined. Changes to the original instructions are provided as necessary to the CES field unit should additional basic survey efforts be required in the investigated area prior to continuing the investigation of other assigned tasks. To minimize problems associated with comparing the reconnaissance soundings to the charted soundings, these surveys are surveyed at the scale of the existing charts and are plotted as overlays. Although this differs from standard NOS practices, it enables rapid and direct field comparison. If it is apparent that additional development is necessary in a particular area, a larger scale survey can then be addressed.

Within harbours, reconnaissance is made along all active slips and pier faces to verify charted depths and contours. The orientation and density of the sounding lines are determined by the general size of the vessels using the facilities and the complexity of the charted depiction. One sounding line is always run along the approximate track of the keel of vessels approaching and mooring to the pier. Additional reconnaissance work is carried out in the remaining areas of the harbours concentrating on water areas outside the maintained channels. Tabulated channel depths are verified by running existing ranges or confirming charted controlling depths.

The charted waterfront topography is visually compared to the existing topography in sufficient detail to assure that the charts accurately portray the area. Cartographic factors such as scale of the chart must be given consideration. When discrepancies are discovered which are within the field unit's capabilities, they are resolved. Frequently U.S. Army Corps of Engineers surveys, construction drawings, private surveys, and city or county maps are utilized by the field unit to expedite their field operations. Of course, such documents must be confirmed by the field party to assure that they meet NOS surveying or charting standards before they are used as a data source. If the discrepancies are beyond the scope of the unit, recommendations must still be made for resolution, such as scheduling chart updating photography or more extensive surveying effort.



Charted Waterfront Topography Compared to Existing Topography

All charted landmarks or other fixed aids to navigation are evaluated for existence, accuracy of position, and usefulness to navigation. Accompanying recommendations suggest the addition or deletion of landmarks. During the course of the survey, floating aids to navigation are also checked for charted accuracy. At the same time, the appropriate Coast Pilot is evaluated for the accuracy and completeness of the information describing the area of operations. Revisions or changes to the current edition of the Coast Pilot resulting from the CES efforts are submitted to NOS Headquarters in accordance with prescribed reporting standards.

The field unit makes random checks throughout the survey area to verify the accuracy of the predicted tides or water levels which are available to the mariner.

Every opportunity is taken to obtain user evaluations of the NOS products. This includes comments and suggestions concerning existing chart layout, scale, format, colour, availability, accuracy, etc. Users also may suggest new products for NOS to address or changes which may be applied to existing products. The evaluations were originally addressed in a questionnaire which was distributed in a variety of methods; however, an extremely poor return rate discouraged this format. Recently, person-to-person interviews with a wide range of the boating public has proven a far more effective method of gathering input.

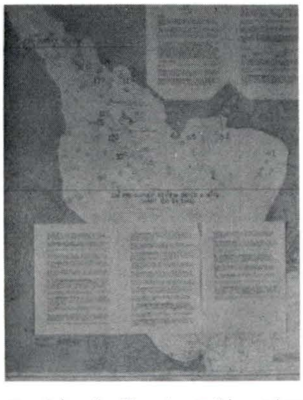
The field unit also makes a concentrated effort to reach the public describing its particular current effort and the services and products of NOAA in general. The news media is encouraged to feature the unit in programs describing the NOS mission and the specific project

If, on the other hand, the field unit recommends that a basic survey is justified and office review confirms this recommendation, a priority is assigned to the project for future surveying. The CES recommendations provide excellent justification for the project and identify specific difficulties which can be expected.

Another positive effect of Chart Evaluation Surveys is in the realm of public cooperation and relations. Since basic hydrographic operations are frequently conducted along open coastal areas and in relatively unpopulated regions, much of the boating public has no contact with the work of NOS. Most of the CES work to date has been in more congested harbours, waterways, and population centres; therefore, considerable contact with the public user has been possible with the associated benefits of user recommendations and publicity.

PREPARATION

Although the identification of a project area may occur years before the field work is initiated, actual preparation for the project usually commences approximately 6 months prior to field operations. Far and away the most time-consuming portion of the preparation is the selection and documentation of the deficiency items. Each chart to be addressed by the field unit is researched by an office cartographer and the source of each sounding and feature ascertained. Any soundings or charted features that are questionable in any way are identified for investigation. Included are wrecks, ruins, submerged obstructions, reported shoalings, and charted channel depths. Files are checked for all pertinent background information which consists of prior surveys, cooperative charting letters, Notices to Mariners, Local Notices to Mariners, private letters, etc. Charts are annotated to identify all items needing investigation, the recommended method of investigation is stated in a cross-referenced description, and all appropriate background information is assembled for reference. When all background research has been completed for a particular chart, it is not uncommon to have as many as 40 separate items identified for specific investigation on a harbour chart and 10 items assigned along a coastal chart.



Nautical Chart Indicating Items for Investigation

The charts are also marked with recommended vessel tracks for reconnaissance purposes as required by the particular project. These tracks are generally positioned to obtain soundings over noted bottom features and important channels with the rationale being that these areas would be more susceptible to change; therefore, investigative soundings obtained along these tracks would be apt to illustrate any possible bottom change.

During this preparation period and at least 3 months prior to beginning field operations, specific project instructions are written by NOS Headquarters. The instructions cover specific objectives of the total Chart Evaluation Survey program which are applicable to the particular project, amplifying appropriate sections as necessary. Anticipated special support needs are identified and references made to unusual surveying or data processing techniques required. The instructions, complete with marked charts and supporting information, are then sent by Headquarters to the field unit.

It is frequently advantageous to the field party to send an advance party to the project area, particularly if the project involves user evaluation or public relations work. These individuals can set up meetings and presentations and initiate the publicity effort. The inherent mobility of a CES field party often demands horizontal control over a broader area than required to support conventional hydrographic surveys. The advance party can also respond to this need.

SURVEYING

A Chart Evaluation Survey is usually composed of several types of survey or data collection operations. These operations are discrepancy investigations, reconnaissance hydrography,harbour reconnaissance, waterfront topography verification, landmark verification, aids to navigation verification, Coast Pilot inspection and update, tides/water levels observations, user evaluation, and public relations efforts. The specifying of these operations is made in the project instructions and is generally dependent on the area to be investigated and the capabilities of the field unit.

Discrepancy investigations consist primarily of those items which have been identified for examination by the office reviewer prior to the field work. However, the field unit is encouraged to investigate additional questionable items uncovered during their own surveys or through contacts with local persons. Some of the items can be resolved by visual examination and others by standard hydrographic techniques. However, a large number of the items require modified wire sweep or drag techniques with subsequent diver examination to assure absolute resolution. It is hoped that the future will see the use of side scan sonar to help resolve questions on subsurface items investigated by the CES.

being addressed. Open houses are held whenever and wherever possible. Perhaps most important are meetings with the local U.S. Army Corps of Engineers, U.S. Coast Guard, U.S. Coast Guard Auxiliary, U.S. Power Squadrons, sea grant marine advisors, port authorities, pilot's associations, and commercial fishing organizations.

PROCESSING

Because of the special nature of these surveys and the need to reduce the time between field data acquisition and chart application, special modifications are made to the data processing routine established for conventional surveys. Whereas normal surveys undergo meticulous verification at both the NOS Marine Centres and Headquarters, the CES are shipped directly from the field unit to Headquarters. The field unit therefore is responsible for processing all revision data to a point where it can be applied directly to a chart with a minimum of additional data reduction or evaluation required by Headquarters personnel. Extreme care must be exercised to assure that the plotting of data on chart overlays or plotting sheets is done neatly and accurately. All sounding data are reduced using appropriate vessel corrections and correctors determined from predicted or real-time tides/water levels observations. Many revisions or comments concerning land and water features are made directly on chart copies employing colour keyed notations. A concise yet comprehensive Descriptive Report is included for each chart addressed so that the office cartographers can readily determine and evaluate the merits of procedures employed by the field hydrographer. It is particularly important that the techniques employed in investigating discrepancy items be carefully and completely described.

Upon receipt of the survey data in NOS Headquarters, the information and recommendations are carefully reviewed at two different levels and the final comments and recommendations assimilated. This finalized product is forwarded to the appropriate cartographers who apply the new information to the manuscript from which the revised chart will be published.

SUMMARY

The National Ocean Survey has accepted the Chart Evaluation Survey program as a valuable addition to its charting program. Whereas basic hydrographic surveys presently require an average elapsed time of 11 months (the NOS goal is 12 months) from the completion of data acquisition to their availability for chart application, the CES surveys are ready for charting within an average of 8 months after data acquisition. Furthermore, it should be recognized that the special data from CES cover a much broader coastal area and are concentrated on items of more critical interest to the mariner than conventional surveys would normally provide. For this reason, CES are becoming increasingly important to NOS as the Agency strives to keep their charts as current as possible.

The current rate of discrepancy item resolution is nearing 100 percent as opposed to only 60 percent as recently as 1976. A number of factors have contributed to this increase in resolution rate. The increasing familiarity among field personnel of the unique surveying techniques and information reporting procedures coupled with closer coordination of operations between Headquarters and the field unit has had a positive influence on effectiveness. More judicious office selection of items for investigation has also contributed. It is anticipated that further resolution may result from the recent publishing of definitive survey guidelines and reporting procedures.

Finally, the CES has served to resolve the possible need for more comprehensive surveys in many areas and to provide justification for more comprehensive surveys in the remaining areas. Information thus derived increases the total effectiveness of the NOS hydrographic program and further assures the best use of the survey resources.

Multi-Disciplinary Survey of the Sénégal/Gambia Continental Margin

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ABSTRACT

The hydrographic results of a major Canadian Hydrographic Service and Atlantic Geoscience Centre multi-disciplinary survey using CSS BAFFIN off Sénégal and The Gambia are presented.

A compiled bathymetry map of the shelf and continental margin of Sénégal and The Gambia has been produced for the area from 11°N to 18°N and 15.5°W to 22.5°W. The continental shelf north of Dakar is relatively narrow and is highly incised by active canyons that pass across the continental slope and rise to feed two channel systems that drain south to the Gambia Abyssal Plain. Immediately south of the Cayar Canyon, which has incised the shelf almost to the shoreline, there appears to be a lack of active canyons, and there are only two canyons west and southwest of Dakar; both are probably inactive features that ceased to operate when the Cayar Canyon captured their sediment supply. The Cayar and Mauritania/Nouakchott Canyon systems flow into the Cayar and Mauritania deep-ocean channel systems respectively and both drain south onto the Gambia Abyssal Plain.

Various Seamounts are mapped offshore. Slumping is mapped on the continental slope including the major Cayar Slide complex which has moved from north of Cayar Seamount and flowed west over 400 km to collide with the Bafoulabé Rise. The density and possibly the initiation of canyons along the shelf edge and slope is believed to be realted to the amount of slumping.

Additional salt domes are mapped off the Casamance. Minor variations in depth on the shelf are caused by salt dome intrusion, exposed volcanic rocks, sediment piled into ridges by longshore drift or wave conditions and by relict beaches. Aeolian-laid sediment deposition may be responsible for flattening of the shelf and prograding of the shoreline just north of Sénégal off southern Mauritania.

INTRODUCTION

When the Canadian International Development Agency requested the Canadian Hydrographic Service (CHS) to carry out a multi-disciplinary offshore survey off Sénégal in 1976 the initial response of CHS was to suggest adequate pre-cruise planning time and a deferral of the actual survey till 1977. As it turned out CHS in conjunction with the Atlantic Geoscience Centre (AGC) of Bedford Institute of Oceanography mobilized C.S.S. Baffin on less than a year's notice and carried out a survey from January to April of 1976, beginning and ending in Halifax with 3 port calls in Dakar, Sénégal.

CHS ran the cruise and handled the on-board collection of bathymetric data using a Raytheon Deep Sea depth-digitizer with a hull-mounted 12 Khz transducer with a full beam width of 34 degrees; positioning was provided by a satellite navigation system interfaced with a Loran-C Accufix receiver (Marshall, 1977). A chemical oceanographic sampling program (Pocklington, 1977) and a continuous bird and sea-life observation program (Brown, 1977) along with oil and surface tows were integrated with the program. CHS also set up an offshore current and tidal station (Marshall, 1977).

The geophysical/geological program consisted of continuous measurements of the earth's total magnetic field and gravity field. Shallow seismic data were obtained in the second phase, using a 40 cu. in. airgun over the slope and a Huntec deep-towed boomer system on the shelf (Meagher et al, 1977).

CHS was responsible for publication of the initial results of the cruise and undertook to have the bathymetry of the area compiled while A.G.C. undertook the responsibility of producing the gravity, magnetic and seismic report. From the beginning, CHS was concerned that the 30km line spacing (14 km on slope and shelf edge) would not provide sufficient data on a slope that was in all probability disected by a number of shelf-edge canyons; Cayar Canyon was already known to traverse the whole shelf and slope north of Dakar (Dietz et al, 1968). Dakar is the major port between the Gulf of Guinea and Morocco and it was well-known within CHS that a number of American cruises such as the I.D.O.E. cruises of Woods Hole Oceanographic Institution, and those of Lamont-Doherty Geological Observatory as well as British and West German cruises had entered Dakar for port calls. It was therefore CHS's concern to amplify Baffin's grid of east-west lines with whatever other data could be gained from the oceanographic community. A contract was let to Geomarine Associates Ltd., of Halifax to compile the bathymetry and write an interpretative report (Ruffman et al, 1977). The same firm had provided technical support for the cruise and a chief geoscientist for Phase I and later Geomarine Associates was also to produce the geophysics/geology report (Meagher et al, 1977).

No one realized how successful the process of assembling other data would be. This was only done for bathymetry; the gravity and magnetic maps were constructed almost entirely from Baffin data with only minor input from 2 other sources. Baffin collected about 16000 km (8600 n. mi.) of bathymetric data in the survey area on her regular and systematic pattern of lines. Geomarine Associates was able to assemble the digitized data of over 33 other vessels of at least 8 nations through the co-operation of at least 17 agencies. This process permitted approximately an additional 37000 km (19,950 n. mi.) of raw deep-ocean data to be compiled and integrated with Baffin's data.

The assembly process is not straightforward. There was no index map and no data centre could provide such an index. Much of the process depended upon personal knowledge of cruises and a series of phone calls and letters to draw out the data. In most cases the data were released through a desire for interagency co-operation or through the fellowship that exists in the scientific community; CHS's obligation in return was to produce a final map and circulate it. Cost to the CHS was limited to the cost of computer printouts or in some cases duplication.

The data assembly was not limited to gathering deep-ocean data. The French Hydrographic Service, the British Admiralty and two oil companies had done a large number of surveys on the Sénégal shelf itself and 65 nearshore field sheets were assembled (Fig. 1).

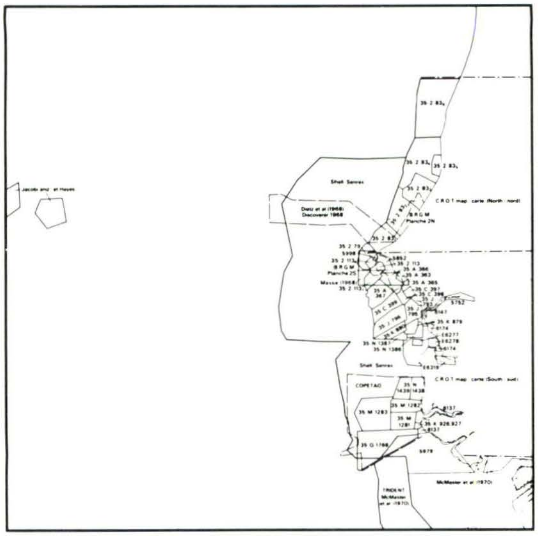

Fig. 1 Index map of Senegal-Gambia area. Boxes are outlines of detailed surveys by other areas.

No estimate has been made of the number of kilometres of data in the nearshore sheets but we suspect that it represents a further 25-3500 km. In total it is estimated that over 125 documents beyond the basic seven field sheets of CHS were used in the compilation of the final map. In addition the data or interpretation of 18 authors were incorporated from the open literature or from preprints of unpublished manuscripts. The CHS report contains a full listing of all the data sources, field sheets, authors and vessels (Ruffman et al, 1977). Suffice to say here that we recognize and welcome the tremendous contribution of other hydrographers and researchers to our final map produced in the CHS report.

With such a data base available before the cruise the question then must be asked, "had there been time available prior to the cruise to do this data assembly and preliminary compilation would we have run the same cruise?" or perhaps "Would we have run it at all?" considering only the scientific questions. Of course the question is academic for the Sénégal cruise but is by no means academic when we next consider such a large expensive offshore venture. None of us would ever dream of running a field program in the Arctic without pulling our previous field sheets and judging the coverage, spacing and quality of data. For overseas projects one must be prepared to launch a much wider search, spend longer at it and deal with a myriad of scales, data in fathoms or metres, measured at assumed velocities of 1463 or 1500 m/s, with and without Matthews' Tables velocity corrections and with a variety of positioning systems ranging from sextant to sophisticated systems such as Baffin. A full year should be allowed for this data assembly and preliminary compilation.

In the case of the Sénégal survey a glance at Figure 1 and the final map will indicate where Baffin's track might have been altered. The shelf edge is disected by a tremendous number of canyons and few of the accurately fixed data run north-south along the shelf edge to permit recovery of a lot of this detail. The confluence of the Mauritania, Nouakchott and Cayar Canyon systems is a very complicated area with subtle changes in depth that requires more detail. The possible reefal structures west of Cap Vert at 500 m. still remain a puzzle as does the lower end of the Dakar Canyon and the exact density of seamounts along the 13°N fracture zone.

One must hasten to add that in a multi-disciplinary survey such as this other features must be added such as density of previous gravity, magnetic and seismic data. There are significant other geophysical data but by no means the same amount as seen in the bathymetry. However in the case of potential field measurements often one does not need the same density especially in the deep ocean in the magnetic quiet zone. The need for overall synoptic measurements of temperature, oil tows or bird observations might again alter the pattern of a cruise; the point is that it is extremely valuable to know the existing data base before a multi-disciplinary cruise is planned.

RELATIONSHIP OF BATHYMETRY TO GEOLOGY

Seamounts

As in all parts of the ocean, off Sénégal and The Gambia there is an intimate relationship between the shape of the bottom and the underlying geology.

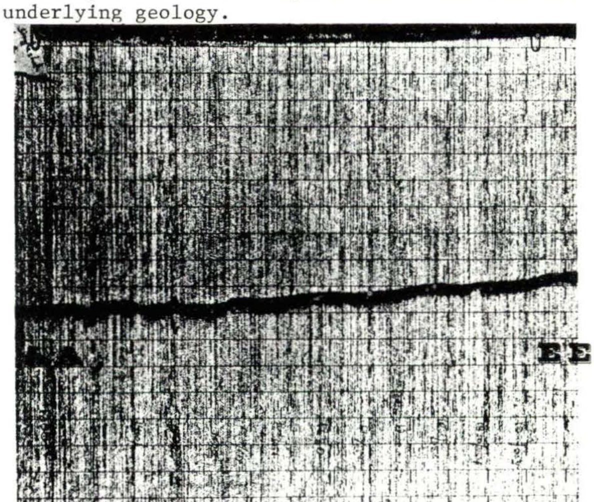

Plate 1. Bathymetry profile from 12°29.8"N, 18°30.0"W to 13°34.8'N, 18°30.1'W across a small high (v) that may represent the top of a buried seamount protruding through the sediment. (Full scale 10 sec, 375 m/division).

The bathymetry profile AA-EE shown in Plate 1 illustrates this problem. The small high on the bottom could be contoured as simply a small circular "bump" on the bottom or might be a linear feature with a number of orientations. The interpreter often will not have adjacent lines of data sufficiently close to resolve the question, nor will the hydrographer planning subsequent cruises desired to fill in areas or to delineate bottom features. Thus an understanding of the underlying geology is of paramount importance in both cases and indeed it could be argued that in both cases the interpreter and hydrographer cannot really do their jobs properly unless they understand the geology.

In the example of Plate 1 the high may result from a number of sources ranging from an outcrop of a resistant bed, an outcrop of the top of a seamount, topography related to slumping, drowned beaches, glacial moraines or reefs. Obviously the depth of water eliminates certain possibilities as does the feature's location. In the absence of other information the above example is judged to be a small volcanic outcrop of a solitary buried seamount. Plate 2, a profile across Bissau Seamount and Plate 3, a profile over Senghor Seamount illustrate two other seamounts in various stages of burial. Bissau Seamount is almost buried and is in the very south of the survey area near The Gambia Abyssal Plain. It may be related to east-west fracture zones detected by the magnetic surveys. Senghor Seamount, on the other hand, is only partially buried and rises close enough to the ocean surface to serve as an anchoring area for fishing buoys; it clearly is related to the same volcanism that created the Cape Verde Islands and is simply an island that did not break surface. The tiny high to the northwest of Senghor Seamount may also be a buried volcanic peak but because of adjacent data is believed to be a low ridge probably related to the same volcanism.

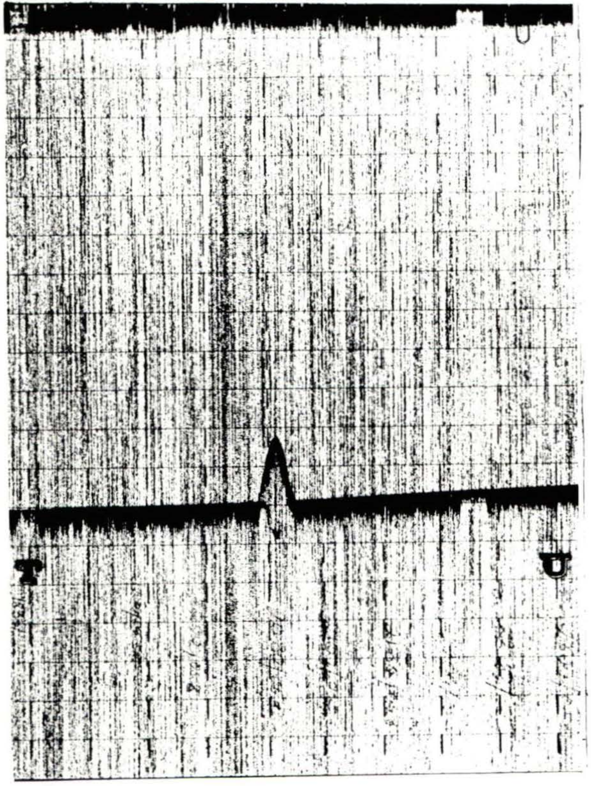

Plate 2. Bathymetry profile from 11°39.5'N, 20°25.3'W to 11°41.5'N, 19°40.5'W across buried Bissau Seamount that stands about 600 m above the surrounding area (full scale 10 sec, 375 m/division).

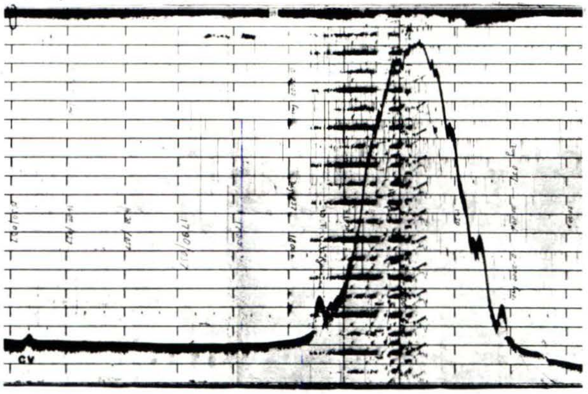

Plate 3. Bathymetry profile from 17°49.7'N, 22°24.5'W to 16°55.6'N, 21 48.0'W across a minor ridge of basaltic outcrop on the Cape Verde Rise (cv) and across Senghor Seamount that rises to 302 m. (full scale 5 sec, 187.5 m/division).

Clearly one would like to be able to see into the masking sediments to discover the relationship of bathymetry to geology. This can be done with the seismic method using airguns or sparkers or, to a lesser degree, a low frequency echo sounder or profiler such as a hull-mounted 3.5 Khz system. Plate 4 shows a 40 cu. in. airgun profile over a section of the Labrador Sea of similar depth. The vessel was moving at regular survey speeds of 10-12 kts and in addition to the regular high frequency echo sounding data a whole wealth of sub-bottom geological data has been gathered that allows less ambiguous interpretation of various highs. Baffin carried an airgun system but its use was restricted in general to the shelf edge and continental slope; only 5 lines ran into the deep ocean and none crossed the volcanic occurrences of Plates 1, 2 and 3.

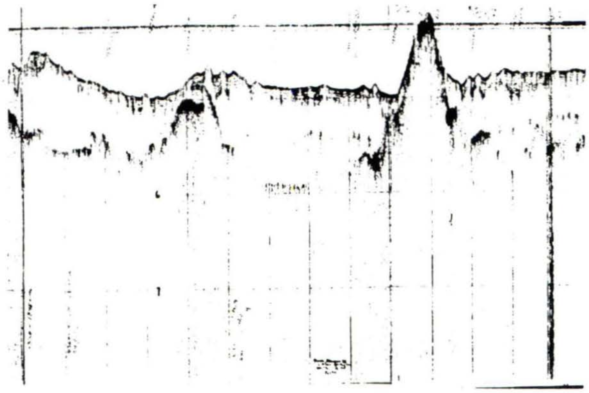

Plate 4. Portion of 40 cu.in. airgun record of Glomar Challenger obtained at 10-12 kts in the Southern Labrador Sea. Various seamounts protrude through the sediments and the burried basement joining their bases can be seen.

DROWNED BEACHES

Profile P-Q west from Cap Vert crosses a probable drowned beach (br on Plate 5) in about 70 m. of water. Masse (1968) interpreted this rise to be a linear relict beach and CROT (1975) and Domain (1977) interpreted the rises to be a series of "bancs rocheaux" lying along the 50 m and 70 m contour south of Dakar (Fig. 2). These features are too small to be recorded on the bathymetry map of Masse or of CROT and indeed are too small to appear on our 1:1,000,000 map. In certain instances the highs may represent outcrops of the Cap Vert volcanics, (e.g. Banc du Séminole) but these areas are clearly indicated by very high frequency, high amplitude anomalies in the magnetic field.

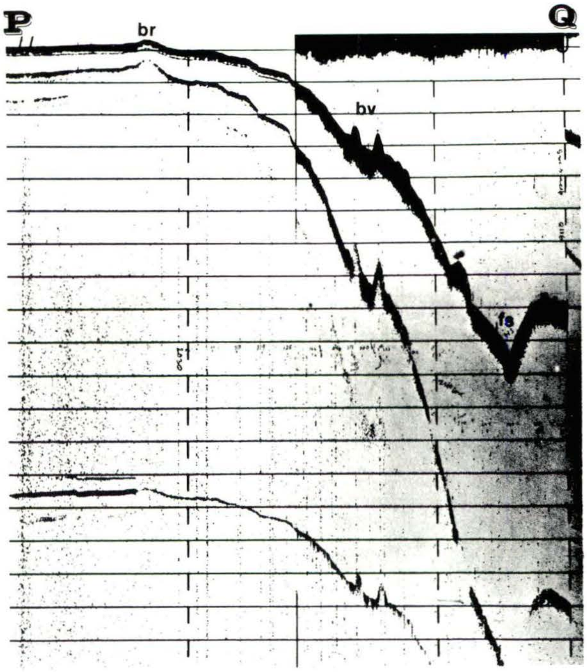

Plate 5. Bathymetry profile from 14°40.0'N, 17°33.1'W to 14°47.2'N, 17°41.4'W across a slight rise near the shelf edge (br) and two sharp peaks (bv), (full scale 2 sec, 75 m/division).

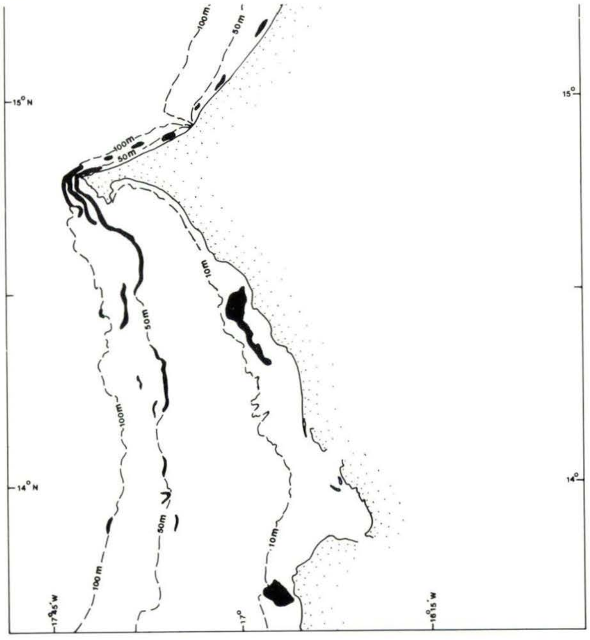

Fig. 2. Map of "les bancs rocheaux" discussed in text.

These breaks or ridges on the shelf at 50 m and at 70 m are almost certainly the record of stillstands of sea level and related relict beaches. McMaster et al (1970) found that a number of submerged lithified beaches off the Bijagos Delta were lithified at their crests. We suggest that the "bancs rocheaux" are very similar especially since they are parallel to the regional slope of the shelf (Fig. 2). The beaches were probably lithified prior to their submergence and there may have been selective algal growth or breaching in certain locations along their lengths since submergence.

REEFAL STRUCTURES

On Plate 5 at a depth of 400 m there are two peaks standing 20-30 m high and marked "bv". These peaks and their origins are subject to considerable speculation. Initially the authors assumed that they were simply more outcrops of Cap Vert volcanics because of their proximity to the Cap. However G. Wissmann of the German Federal Institute for Geoscience and Natural Resources who was working on the METEOR data brought these features to our attention. (Personal communication, 1976). We re-examined our data in this area and recontoured the data between 300 and 700 m at the head of Sarakolle Canyon to show a series of north-south ridges outcroping on the continental slope (Fig. 3).

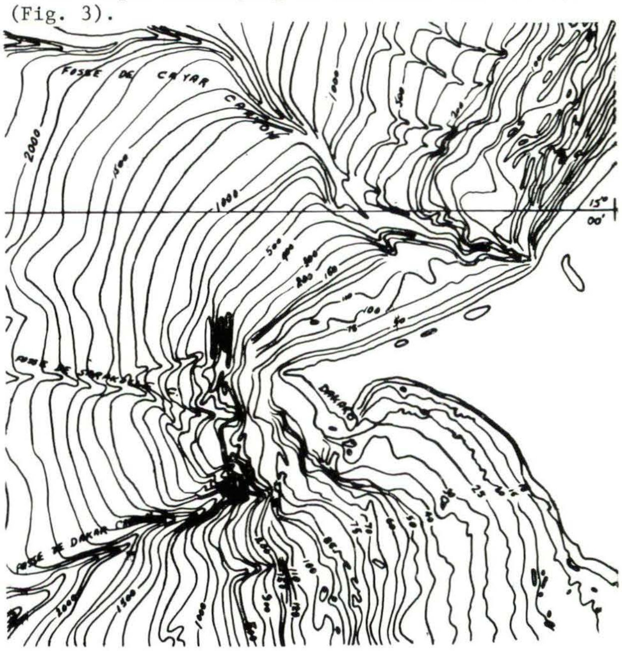

Figure 3. Portion of bathymetry map 839A showing even west of Cap Vert.

When we wrote the bathymetry report we tended to dismiss Wissmann's suggestion that these ridges may have been reefal in nature. However the zone of high intensity magnetics mapped by Meagher et al (1977) does not extend as far west as these features and they show no anomalous magnetic signature. We now believe these ridges may represent old reefs that grew near the shelf edge at one time and have been further submerged through a combination of post Pleistocene rising sea levels and subsidence of ocean floor. They do remain as one of the "bumps" on the bottom that are still a puzzle.

CANYONS, CHANNELS AND CHANNEL SYSTEMS

Cayar Canyon (Fig. 4) was reported in the literature as early as 1968 (Dietz et al) and was documented by P. Bonnin in 1934 on his field sheets entitled Région de Cayar (1934). Almost certainly the fishermen of Cayar knew of the canyon for many years previously and indeed one may hypothesize that Cayar, a famous Sénégalese fishing village, was not located by accident in the coastal reentrant at the head of the canyon. There are almost certainly associated physical oceanographic effects of deep water approaching almost to the shoreline and these effects would have been observed by early fishermen.

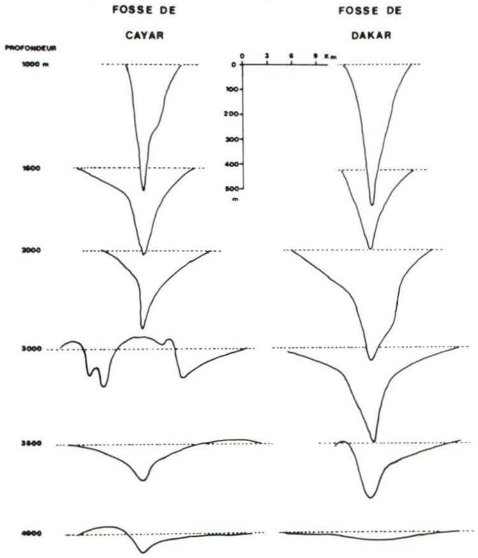

Figure 4. Bathymetric cross-sections of the Cayar and Dakar Canyons at 500 m depth intervals.

Cayar Canyon is as striking as Scripps Canyon in California and is lacking only the onshore gultch to be totally comparable. The canyon disects the shelf to within a few hundred metres of the beach and is responsible for the marked inflection of the shoreline; there may even be a relict onshore portion indicated by the low of Lac Tomna.

Most of the Sénégal/The Gambia shelf edge and slope is cut by a series of canyons that generally originate at the shelf edges, although north of Dakar several incise the shelf with Cayar and Mauritania Canyons being the most prominent. The canyons are highly dendritic and we found even at our 1:300,000 working scale we could not document all the detail. In contouring the shelf edge and the heads of the canyons the slightest positioning errors became critical and when combining the data of several sources extreme care had to be taken. Constant reference back to the raw analogue data rather than merely digitized values was absolutely necessary.

The concentration of canyons along the continental margin seems about constant. There are two exceptions; one is real and one simply fortuitous. There appears to be few canyons in the north between the Mauritania and Nouakchatt Canyons; this is not real and reflects only the absence of recent data with good positioning which is contained in two French Field Sheets which were not available to the project. However the short stretch of shelf edge without canyons southwest of Cayar Canyon and again south of Dakar Canyon appears to be real. The reason for the paucity of canyons may reflect particular (and unknown) bedrock conditions possibly related to the presence of the Cap Vert volcanics. A more likely reason, that will be detailed in the next section on geologic processes, is that the major canyons draw off so much of the sediment that is normally moving along the shelf from north to south that there is no erosive material immediately available to cut new canyons.

The major canyons pass across the slope and with the exception of the Dakar Canyon finger into two major deep-sea channel systems. We use the term channel system introduced by Laughton (1960) to recognize the fact that the channel systems have a somewhat dendritic nature. Thus the Cayar Channel System is linked to Cayar Canyon and the Mauritania Channel System to the Mauritania and Nouakchatt Canyons. The two channel systems appear quite distinct throughout the area and are found in the deepest part of the basin. They may join at about 11^{O}N, we do not have sufficient data in these areas to do any more than speculate.

Deep sea channels are missed by hydrographers who depend upon only digitized data. Their signature on an echo sounder is subtle, especially if one operates an echo sounder at full scale and slow paper speeds, and does not have a programmable sounder following the bottom on an expanded scale. We show a traditional channel in our area on Plate 6 and another crossing Plate 7. Leeves were not common in the map area. The smaller between 0730 and 0800 is significant and one must make constant reference to the raw sounding rolls to delineate and follow these features when compiling deep-sea data.

The study of the channels and feeder canyons leads us from the inter-relationship of bathymetry and geology to the relationship of bathymetry to geologic processes in the next section.

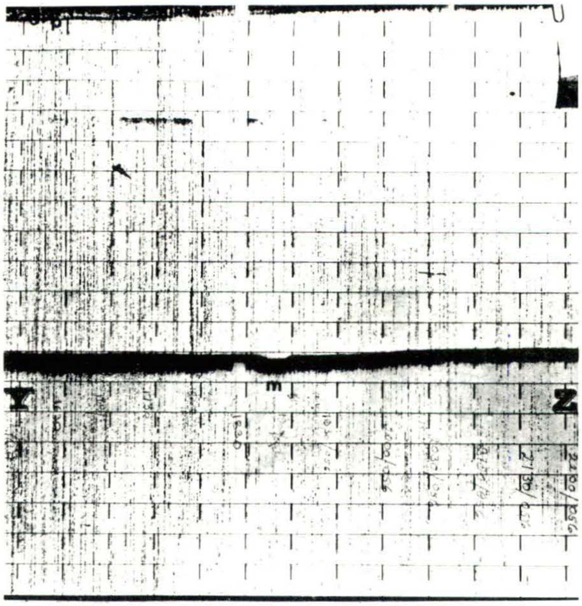

Plate 6. Bathymetry profile from 13°41.0'N, 21°57.9'W to 13°41.0'N, 20°51.7'W across the Mauritania Channel System (M). This crossing of the 60 m deep channel shows the typical shape of a deep-ocean channel. There is no indication of levees (full scale 10 sec, 375 m/division).

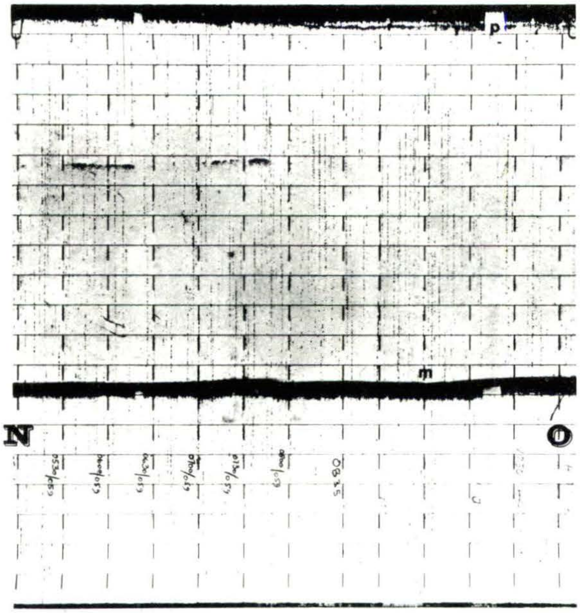

Plate 7. Bathymetry profile from 12°59.3'N, 22°13.6'W to 12°59.9'N, 21°07.4'W across a poorly defined portion of the Mauritania Channel System. The small shoulder at 0747/059 marks the western margin of one arm of the channel, and the very slight low (m) marks the axis of the main channel. (full scale 10 sec, 375 m/division).

RELATIONSHIP OF GEOLOGY TO GEOLOGIC PROCESSES

It is important to realize that the shape of the ocean floor is not only a response to the underlying geology but also to the processes that are actively affecting the bottom. Nature is constantly transferring material from the continent to the shelf and via the canyons and other processes moving it on down onto the abyssal plains. Erosion and deposition are relentless processes which may not make their presence felt during any one hydrographer's lifetime but the bathymetry measured during any survey and that published after a compilation such as ours is the result of a long dynamic process that we freeze but for an instant on our maps. Indeed our map is an average instant because we have used data from 1934 to 1976.

LONGSHORE DRIFT AND CANYON CAPTURE

The coastline north of Cayar through to Mauritania is one long continuous smooth beach with dunes developed in a number of areas. There is virtually no opening save for the mouth of the Sénégal River near St. Louis. All of this coastline is subject to wave-induced longshore drift of sediment from north to south.

Considerable work has been done on the area just north (or upstream in the longshore current) from Cayar Canyon in looking for offshore placer deposits (B.R.G.M., 1974; Horn et al, 1975; Circa 1975). An ocean swell is documented of wavelength 300 m, period 14s and a velocity of 21 m/s. This suggests that during storm surges sand at depths to at least 30 m are reworked. Demoulin (1967), Masse (1968) and Dietz et al, (1968) have documented a swell from the northwest that impinges on the Cayar Coast and on Cap Vert and a swell from the southwest that strikes the coastline immediately south of Dakar in Baie de Gorée. The resultant longshore movement of sediment is from north to south along almost all of Senegal's coastline, with some reversal south of Thiaroye and M'bao just east of Dakar. The predominant north to south movement of sediment is reflected in the southward extensions of river mouth bars at the mouth of the Sénégal, Saloum and parts of the Casamance Rivers. The longshore drift and wave action also affects the offshore bathymetry.

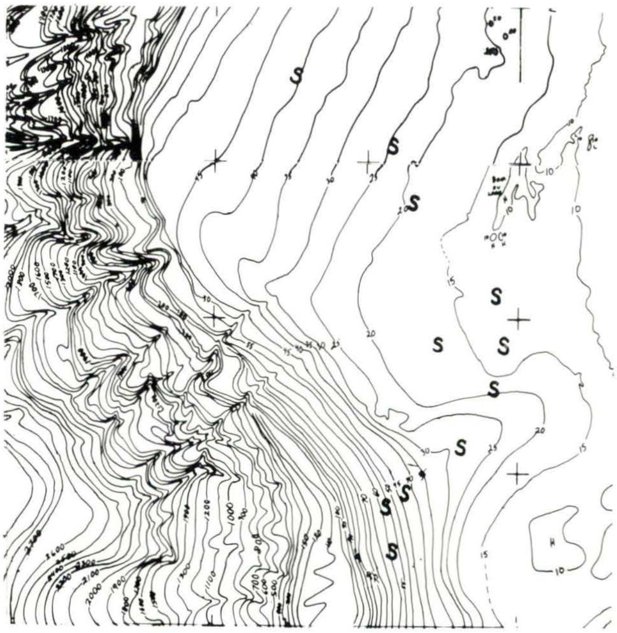

Figure 5. Portion of bathymetry map 839A off the Casamance River. S marks the location of known salt domes.

This influence is probably seen in the wavelike form of the 10 m contour at 12°50'N, (Fig. 5). It may show up again in microtopography, off M'bour (14°20'N, 17°07'W) and possibly offshore in the same area (13°45'N, 17°13'") although it is difficult to differentiate between bathymetry affected by earlier stillstands and relict beaches without more geological data.

The contouring of the very detailed data on the shelf from the French field sheets revealed considerable detail, despite some problems with the positioning of the earlier surveys. In the north from 16°45'N to 17°N on the continental shelf a series of north-south ridges less than five metres high are interpreted nearshore (Fig. 6). These appear to be grouped up-current from the head of a major canyon system - the Mauritania Canyon. An even more pronounced series of ridges are observed up-stream of the head of Cayar Canyon (Fig. 3). Both series of low ridges are sub-parallel to the shoreline and to the regional slope of the shelf. We suspect that this apparent relationship between the ridges and the head of a major canyon is not fortuitous but rather reflects a more intimate relationship.

One might continue Dietz _et al's_ (1968) arguments with respect to the Cayar Canyon and suggest that not only is there a marked north to south movement of sediment under the influence of the steady northwest swell but alos that there is an "overloading" of the "longshore current". Thus in an analogy with river currents when the longshore "current" overloads there is deposition. The overloading and deposition of the ridges seen on the bathymetry map then may be hypothesized to be a seasonally related phenomenon or more likely related to the particular geometry (and depth) of the shelf and coastline. Thus in the areas of overloading the observed ridge system develops and it may even be that the overloading and build up of sediment in certain shelf areas can be responsible for the initiation of the formation of certain canyons.

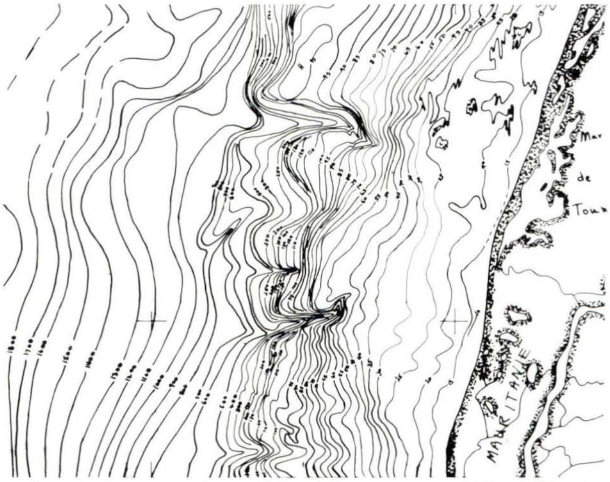

Figure 6. Portion of bathymetry map 839A off the Senegal River and Marais de Toumbos.

There is a considerable difference between Dakar Canyon and Cayar Canyon when considered in profile at their distal or downstream ends. (Fig. 4). Cayar Canyon cuts across the shelf and starts at the coastline; it continues as a well developedchannel system into the abyssal depths. On the other hand, Dakar Canyon starts at the shelf edge and terminates at 4100 m and does not continue as a channel system. This suggests that Dakar Canyon is inactive and represents a relict feature. However, both Dakar and Cayar Canyons are erosional features and both show truncated beds in section. The lower end of the Dakar Canyon appears to be marked by turbidity.

The question then arises as to the relative ages of Dakar and Cayar Canyons. The Dakar Canyon cuts a seismic discontinuity, D_2, that has been mapped as Oligo-Miocene in age by Uchupi and Emery (1974) and hence is younger than about 25 million years. Ruffman et al (1977) and Meagher et al (1977) suggest a two step process for the formation and stagnation of Dakar Canyon related to the two ages of volcanism seen on Cap Vert. The intensive events on Cap Vert are mapped as Oligo-Miocene and Plio-Pleistocene. Possibly prior to these intrusions there was no major westward protrusion of the shoreline at Cap Vert. Initially the intrusion of the volcanics at Cap Manuel, due east of the head of Dakar Canyon in the Oligo-Miocene may have formed islands off the coast and caused the initial interruption of longshore drift and the formation of a large tombolo. Baie de Gorée was then south-east of the new tombolo and a long continuous beach stretched north from Cap Manuel through the Lak Tamna area near the town of Cayar and on north towards St. Louis. The formation of the Canyon sometime after the Oligo-Miocene volcanic activity. Thus, the sediment moving south along the coastline via longshore drift would have accumulated and periodically passed down the Dakar Canyon (assuming that the Cayar Canyon did exist at this time).

When the younger Plio-Pleistocene volcanics that form Pointe des Almadies and Les Mammels errupted 0.9 to 1.2 million years ago, north of Cap Manuel the curvature of the beach would have been again interrupted and a new beach developed between the Lac Tamna area and Cap Vert with an inflection point developed at about the town of Cayar. It appears that the sediment load feeding the Dakar Canyon was cut off for a period of time while the new coastline developed and during this time an "overloading" occurred in the shelf west of the town of Cayar with the subsequent initiation of Cayar Canyon (Ruffman et al, 1977). Cayar Canyon then would have pirated the sediments feeding Dakar Canyon. If the above sequence is correct then Dakar Canyon has been relatively inactive since the initiation of Cayar Canyon 0.8 to 1.2 million years ago. The Sarakolle Canyon directly west of Cap Vert also dies out at 3200 m and may too have been relatively inactive for the same period of time.

As sea levels rose after the Pleistocene, Cayar Canyon erosion has kept pace with the transgressing sea and the head of the canyon still lies very close to the shoreline and still captures most of the longshore drift. The stagnation of Dakar Canyon is analogous to stream capture on shore and could be dubbed "canyon capture". The near complete draining off of longshore drift sediment can be seen in a number of ways. Dietz et al, (1968) recorded that the beach for one kilometre south of the head of Cayar Canyon was almost devoid of sand and very narrow and irregular beyond that for a significant distance. Horn et al (1974, 1975a, b) noted that characteristic heavy minerals present in samples north of Cayar Canyon did not occur in samples south of the Canyon. The shelf also noticeably narrows and steepens south of Cayar Canyon. (Fig. 3). The lack of sediment south of Cayar is also reflected in the inactivity of Dakar and Sarakolle Canyons and in the reduced number of shelf edge canyons immediately south of Dakar Canyon.

SLUMPING ON THE CONTINENTAL SLOPE

To this point in the paper we have been talking about features that are related to either highs or lows on the ocean floor as seen on the echogram. Plate 8 shows a profile G-H running east-west north of Cayar Seamount down the continental slope across the Cayar Slide Complex (Jacobi, 1976). The record shows a textural variation which would have been seen much more clearly had the recorder been operated with a one-second sweep and faster paper speed to avoid the severe compression of data seen on records recorded at a 10-second sweep. Jacobi has correlated the textural variation seen on G-H with evidence of a massive slump complex that has moved downslope leaving a pronounced "slide scarp" (SS on Plate 8) that can be traced over almost 200 km in an elongate horseshoe-shaped pattern north of Cayar and Little Cayar Seamounts (Jacobi, 1976; Meagher et al, 1977). Jacobi had an added interpretative tool in that the Lamont-Doherty Geological Observatory survey vessel had a low frequency (3.5 Khz) echo sounder that gave a certain amount of penetration into the upper sedimentary layers and allowed one to see the contorted and disturbed bedding in the lower parts of the slide complex. In addition VEMA's lower frequency continuous seismic profiles gave even more definition of deeper internal structure. Baffin's programs generally restricted the use of the airgun to the shelf and shelf edge areas and few lines ran down the slope into the deep ocean. However two of Baffin's deep water airgun lines did cross the Cayar Slide Complex and this data in combination with Jacobi's (1976) low frequency 3.5 Khz profiler and our compressed bathymetry records did allow us to define the extent of this massive downslope movement of material. The Cayar Slide Complex stretches as a tongue from its cuspate slide scar on the slope between about 100 m and 200 m westward over 400 km into depths of 4000 m.

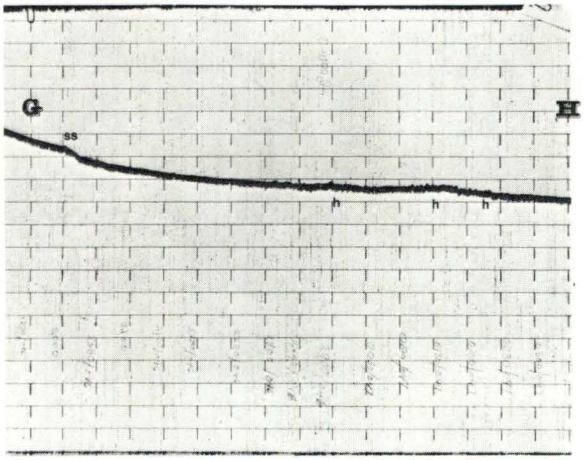

Plate 8. Bathymetry profile G-H from 16°00.3'N, 17°23.5'W to 16°00.5'N, 18°55.7'W across the continental slope and rise north and northwest of Cayar Seamount. This is one of the few records of BAFFIN on which deductions as to the nature of the seafloor can be made despite the compressed nature of the record resulting from a very slow paper speed. The change in slope at (ss) marks a slump scar, and downslope a series of hyperbola or flow material from slide-generated turbidity flow deposits and there is no cone of sediment forming at its lower end. The head of the Dakar Canyon is presently in 100 m of water and the canyon cannot tap the active paralic zone of sand transported by longshore drift.

Plate 9 shows a portion of a similar but much smaller complex in the marine clay deposits of the Champlain Sea. The only difference is that the Champlain Sea was a Pleistocene sea in the Ottawa region and now stands well above sea level. The slope of the original field seen along the top of the photo is similar to the true slope of the ocean floor along profile G-H (Plate 8) and the downslope sliding of the marine clays at South Nation is similar in nature to its modern analogue with a major upslope slide scarp and a series of subsidiary arcuate shallow slide scarps downslope. Figure 7 shows a line drawing of an airgun profile D^1-D across the southern slope off Casamance. This section displays only 3 seconds vertically and has much more vertical exaggeration than the bathymetry profile G-H. Here a series of small slump scars are in evidence along with associated faults and contortion of bedding. The analogy should be drawn to the South Nation photo of Plate 9; Profile D^1-D consists of a number of slumps each of which is of a similar size to that shown at South Nation.

Plate 9. View of slump in Pleistocene age marine sediments now exposed on the South Nation River near Ottawa. The main slump seen appears from the right middle ground to the background. Subsiduary fault planes which have given the slump its rough upper surface are visible in centre of photograph. Compare with Plate 8 and Figure 7.

There may well be a relationship between continental slope slumping and the initiation of canyons. Off Senegal and The Gambia, especially in the south of our map area, there appears to be a direct relationship between the density of canyons and even their existence and the amount of slumping seen. On Fig. 6 a number of the notches which mark slide scarps and slide scars have been interpreted to be minor arms of the dendritic canyon system found on the continental slope. The suggestion may be made that the topographic lows developed at slide scars and the associated faults serve as erosional foci for downslope movement of turbidity currents and evlove into eroded canyons.

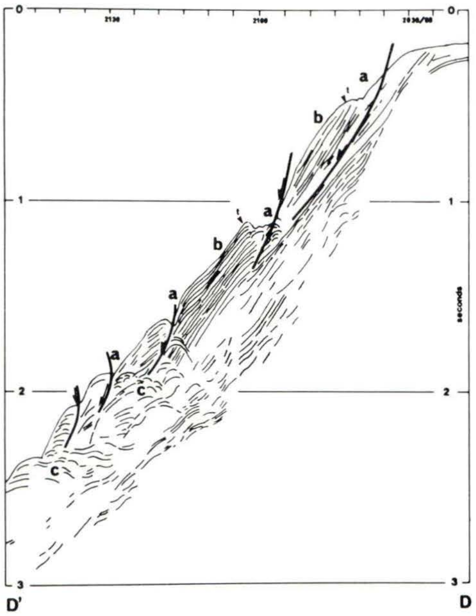

Figure 7. Line diagram of slumps on continental slope of profile D'-D across slope at 12°54'N. A series of upslope vertical or inclined fault planes become asymptotic to the bedding planes downslope. The slump mass probably slid downslope on a bedding plane fault, and there may be compression of beds in the foot of the slump (c). Truncated beds (t) can be seen at the upslope end of the undeformed slump strata (b), with the respective slump scars and related scarps (a) forming depressions that may later develop into part of a canyon system. There may also be underthrusting of slump slabs in this area as well.

Immediately south of Dakar Canyon we earlier noted a near absence of canyons; this area also shows an absence of slumping. Work done by Geomarine Associates on the continental slope of Nova Scotia for a commercial customer shows 3 slump blocks separated by two minor canyons and lends strength to our interpretation off Sénégal and The Gambia.

Certainly one puzzle remains when one examines the bathymetry map of Sénégal-Gambia - "what is the source of all the sediment that makes the shelf south of Cap Vert so much wider than that north of Cap Vert and which gives rise to the larger amount of slumping in the south?" In addition the continental slope south of Cap Vert is steeper than that north of the cap which is another indication of outbuilding through sedimentation. Most of the sediment moved south by longshore drift is captured by Cayar Canyon and the shelf to the south, including Dakar Canyon, is starved of sediment. The slow moving rivers such as the Saloum, Gambia, Casamance and Geba do not appear to have any great erosive power and the sediment source is uncertain. While the southern rivers do not appear to be great sediment sources we know of no actual measurements of their sediment load or of the seasonal variation. The Archipel dos Bijagos represents a classic example of a drowned delta and implies that the Geba River at least in the recent past was a major source of sediment.

AEOLIAN INFLUENCE

On a number of occasions during the Baffin's cruise the ship was coated with a layer of fine sand carried seaward by the steady northeast Harmattan that blows off the Sahara. Rona (1971) has suggested that aeolian transport of such fine desert material may have operated over a long enough time to shape the Cape Verde Rise and generally prograde the continental rise. We may see one local example of this north of St. Louis where there is a slight westward bulge in the shoreline and offshore there is a seaward migration of the contours to delineate a broad flat area of the shelf off Marais de Toumbos (Fig. 6). In this same area onshore in the south of Mauritania and extending right into the outskirts of St. Louis there are extensive longitudinal sand dunes oriented northeast-southwest to reflect the persistent Harmattan. The shoreline bulge and flattened area offshore may represent an area of increased aeolian sedimentation. The area on Fig. 6 could also represent a recent delta of the Sénégal River with Marais de Toumbos as part of an old channel which existed prior to the exit being cut off by longshore drift and flow being directed southwards in a nearly 90° turn to the present exit near Gandiole.

SALT TECTONISM

Another geologic process that may be influencing the shape of the bathymetry is that of active salt intrusion. Aymé (1965) reported on the sald domes off the Casamance and our bathymetry map records 11 such features though Aymé's somewhat ambiguous paper can be interpreted to show up to 14. Aymé's contoured bathymetry map (Aymé, Fig. 4) showed the 30 m contour wrapping around a dome; our data show a similar disruption of the 30 m contour around a dome's rim syncline in what may be the old Casamance River embayment (12°17.5'N, 17°06'W. (Fig. 5). The COPETAO and French field sheet data can be interpreted to give rise to another circular bathymetric feature at 12°21'N, 17°13'W (Fig. 5). There is no seismic data available over this feature and we can only assume that it too has resulted from salt diapirism.

We suspect that active salt tectonics may have had some influence on maintaining the shallowness of the area north of the major embayment including Banc du Large. This area of the continental shelf has the same dimensions as Sable Island Bank on the Scotian Shelf or as the Magdalen Islands high in the Gulf of St. Lawrence. All three areas are the focus of near-surface salt tectonics and drowning and all three areas may owe their relatively high relief to the influence of salt.

At 12°35'N the shelf is marked by a broad ridge seen in the 25 to 40 m contours; this ridge is probably not related to salt tectonics but rather may reflect the outbuilding process of the "Casamance Delta" in this area. Similarly the broad sinusoidal waves seen in the 100 m contour at 12°05'N, 17°20'W are probably not related to salt tectonics but rather depict broad low ridges (sand waves) on the sea floor. These broad ridges do not represent poor positioning during the original survey since they are crossed by a number of tracks of data and only the one contour is affected.

CONCLUSIONS

As we move more and more into multidisciplinary surveys, it is important for hydrographers to realize that underneath all their bathymetry there is a fascinating geological story reflecting either rock and sediment type or a geological process that has shaped the bottom. The hydrographer who understands this intimate relationship will plan and execute a much better survey. So too will the hydrographer enjoy and understand the results more. As the CHS moves into multiparameter surveys, the mandate of the Service is changing from one of making charts for navigation to one of mapping the ocean floor for a whole host of uses including that of making charts. In this light we would advocate running recorders specific to the geological user with an expanded scale and faster paperspeed. In addition when low frequency echo sounders are operated the total value of the survey will be greatly enhanced.

It is very important that before embarking on a foreign survey such as that off Sénégal and The Gambia, one does a complete assembly of existing data and if possible a preliminary compilation. With this basic framework complete the hydrographer can plan a survey to highlight geological questions on areas with uncertain or thin coverage. With the preliminary compilations decisions as to priority areas can be made with more certainty and the hydrographer in charge can better balance the demands of the various parallel surveys (bathymetry, gravity magnetics, geology, biology, etc). We were surprised how much data was available off Senegal and The Gambia and the same sort of density may well exist off the coasts of many developing countries if the time is taken to assemble it. The data will be made available, in our experience, if the time is taken to establish personal contact and if the agency approached can be assured that the completed map or report will be returned in exchange.

Finally all cruises whether domestic or foreign will be much more rewarding in a scientific sense if the full range of users are kept in mind. This will require hydrographers with an interest in these other uses of their data and with a willingness to add certain equipment to increase the line kilometer cost effectiveness of their vessels.

ACKNOWLEDGEMENTS

On a massive compilation such as this there is a long list of persons to thank. These were all listed in Ruffman et al, 1977 and in Meagher et al, 1977. It is suffice here to express our thanks to R.A. Marshall the chief hydrographer on the BAFFIN 76-001 cruise, to our many colleagues in Sénégal and The Gambia and to the large number of persons who willingly provided their data for the compilation. It is true to say that without such co-operation this compilation could not have been realized to such a high degree.

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Back to Cook: The Role of the Hydrographer in Delineating Topography and Culture

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Abstract

One of the traditional roles of the hydrographer, as established by Cook and others, was to decide what topographical information was of value to the mariner and should be shown on charts. Since the advent of modern topographical mapping, Canadian hydrographers have left that task to the cartographer. The paper will illustrate this evolution and then analyse the needs of the navigator and assess whether they are best met by providing him with an exact copy of the topographical map. The convergence of recent Canadian thinking with that of the philosophy developed by the North Sea International Chart Commission will be described. The paper will conclude with a suggestion on how the hydrographer should once again become responsible for recommending what topographical and cultural information should be shown on charts.

Introduction

The concepts for this paper were formulated during the period April 1975 to March 1976 when I was a member of the Chart Presentation Steering Committee of the Canadian Hydrographic Service (CHS). This Committee, under the chairmanship of the late Ells Walsh, was charged with the task of developing a new presentation for Canadian charts to meet the needs of metric conversion and bilingualism. A third requirement was to ensure that where practicable, the presentation would agree with the international chart specifications then under development through the North Sea International Chart Commission (NSICC).

The initial work of the Committee focussed on methods of showing bathymetry and chart scheming as described in papers given at the 15th Conference in 1976[1,2]. Subsequently a decision in principle was reached on the basic concepts to be followed in showing topography and culture on Canadian charts. This paper reviews the historical evolution of how land features have been shown; comments on the inadequacies of the current presentation, then explores the new philosophy and compares it with that developed by the NSICC.

Definitions

The features shown on the land areas of charts are of two types:

Topography

- the contours, peaks, saddles between peaks, gullies, cliffs, nature of the shoreline, rivers, lakes, glaciers, etc., required to permit the mariner to visualize the shape of the land and nature of the coast he can see from seaward and to identify prominent summits, ridges, etc., which he can use to position his vessel either by visual bearings or by radar bearings and ranges, or by a combination thereof, or by establishing clearing lines and transits.

Culture

- the man-made additions to the landscape such as roads, railways, and conspicuous buildings such as churches, towers, domes or other buildings, etc.

Historical Development

A direct line in the development of Canadian hydrography can be traced back to July 27, 1758, the day after the surrender of Louisburg, when James Cook,

> "... the master of the Pembroke was ashore at Kennington Cove...His curiousity was much aroused by the behaviour of a man carrying a small square table, supported by a tripod; the man would set his table down so that he could squint along the top in various directions, after which he would make notes in a pocket-book... He was a military engineer; he was making a plan of the place and its encampments, his name was Samuel Holland".[3]

That meeting laid the foundation for Cook's career as a hydrographer and explorer. Cook expressed an ardent desire to be instructed in the use of the instrument and Holland agreed. Cook produced his first chart of Gaspé Harbour that fall but it does not show any land features. During the following winter Holland worked with Cook compiling the charts to be used when the fleet sailed to beseige Quebec. He also assisted Cook to master the intricities of spherical trigonometry and astronomy so this really was Cook's apprenticeship as a hydrographer. In 1759 Cook played a major role in surveying the approaches to Quebec, especially the Traverse below Ile d'Orleans from which the French had removed all the navigation marks.

After the war was over Cook was chosen to start the first regular surveys of Newfoundland. In Beaglehole's judgement,

> "Cook was to carry out many accomplished pieces of surveying, in one part of the world or another, but nothing he ever did later exceeded in accomplishment his surveys of the southern and western sides of Newfoundland from 1763 to 1767... He was so successful because he could deploy all the technique he had acquired from the military 'engineers'; because he could work at times on land as well as from the sea.[4]
>
> The large charts are indeed tremendous productions: the 'exact trigonometrical survey' of the west coast is about ten feet long, on an inch to the mile scale, and includes much inland topographical drawing, ... This was raising British hydrographic surveying to a new power.

> ... the distinctive characteristic of Cook's manuscripts, it has been said, is the care and fullness with which topographical detail on land is drawn, a good deal of brown and green brushwork marking relief and landcover, in the manner of military mapping. Cliffs appear in semiprofile, an old convention.[5]"

A portion of the chart of the west coast of Newfoundland is shown as figure 1. It will be seen that Cook besides showing the areas of high land also made considerable use of views of the coast.

Over the next century the depiction of topography became an art form in its own right as shown in figure 2. This is a portion of Chart 4669, Red Bay in the Strait of Belle Isle, surveyed by the Admiralty in 1890. In fact, as can be judged from the oblique air photo on page 317 of the Sailing Directions, Newfoundland, fifth edition, 1977, the topography is probably exagerated since the highest hill is only 497 feet.

Figure 3 taken from Canadian Chart 1204 surveyed by Lt. Miles, R.N., and Mr. Savory in 1907-9, showing a portion of the Lower St. Lawrence, is in my opinion an almost ideal representation. It is economical in effect but presents the mariner with the critical information he needs. Figure 4 from chart 4714 surveyed in 1951 probably comes close to the nadir of the hydrographers contribution with its use of "pimples" to show a series of isolated high points. How far this is from a good presentation can best be judged from the inset showing the detailed topography that became available shortly after.

From the early 1950's onwards topographical maps at scales of 1:50,000 and 1:250,000 became increasingly available and the hydrographer rapidly stopped showing land information on his field sheets and the compiler added it to charts usually to their full limits, from the topographical maps.

I think it can be shown that this has lead to a degradation in the information available to the mariner and at the same time has increased the drafting work, to the point where on some charts the land information accounts for up to 75% of the time spent drawing a chart.

Figure 5 is taken from chart 3450 as it existed before 1968 when the topography was drawn by the hydrographer and Figure 6 shows the current edition compiled from Topo maps. I think that it has to be agreed that the earlier chart, with its use of the cliff and steep slope symbols presents a far more accurate picture of the terrain than the bland, rather rounded appearance of the later chart.

Similarly figure 7 shows the plan of Porlier Pass as surveyed in 1905. The cartographer omitted all topography from the plan on chart 3473 probably because he felt that it would be bad practice to enlarge the 1:50,000 topo map four times to the 1:12,000 scale of the plan. He therefore preferred not to show any topography at all! Surely this was a bad error of judgement. It also ignores a very significant fact - the mariner is rarely interested in the absolute accuracy of topography, he is interested in general shape. The only time that a mariner wants an accurate height is when he is judging at what distance off he can expect to see a feature, either visually or by radar. It also overlooks the ironic fact that, although maps are prepared in photogrammetric plotters, where the photogrammetrist has a complete birds-eye view of the ground, topographic contours are only specified to have an accuracy of plus minus 50% of the contour interval! The hydrographer even though he is working through the opaque medium of water strives, and in critical depths certainly has to do better than that!

One experimental presentation was used on our first three small craft charts 6301, Athabasca River, 6302, Slave River, 2303. Parry Sound to Byng Inlet, and one standard chart 2042, the Welland Canal. This was the use of a mosaic of air photographs to show land detail. These charts aroused little comment when they were issued and no complaints when the mosaic was abandoned at the next edition. From the users point of view the biggest weakness of a mosaic is that it only shows culture and vegetation and not topography. Also probably even fewer chart users are used to interpreting an air photo than a map. From the producers point of view the major objection is that the only way to update the mosaic is to obtain new aerial photography.

Role of the Hydrographer in Determining what Topography and Relief Should be Shown

In view of these imperfections, and others to be illustrated later, it is apparent that the hydrographer must once again be much more involved in deciding what land information should be shown on charts. It is therefore proposed that field parties will be supplied with a mosaic showing the best available topographic information for the limits of each chart which they are surveying or revising. This should be annotated in red to show the information that should be emphasized and in yellow to show the information that should be deleted on the finished chart. In making this assessment, the hydrographer should seek the assistance of the ships officers and others.

Before leaving for the field a review of existing and cancelled charts of the area should be made to see if any exist where the topography was compiled by a hydrographer. These will usually provide a good guide as to what topography should be shown. The hydrographer should also discuss with the Chart Production Chief and consult the Chart File to determine the source of the shoreline on existing charts of the area. Especially in northern waters it will only occasionally be found that the shoreline on existing charts originally published before 1960 is derived from mapping tied to the North American 1927 datum. Northern Canada was only covered by trimetrogon photography in the period 1944-1950 and the resulting planimetric plots underwent a series of adjustments as the control networks were extended slowly northwards. The 1:250,000 mapping was only completed in 1967 and small changes can be expected as the 1:50,000 coverage is extended.

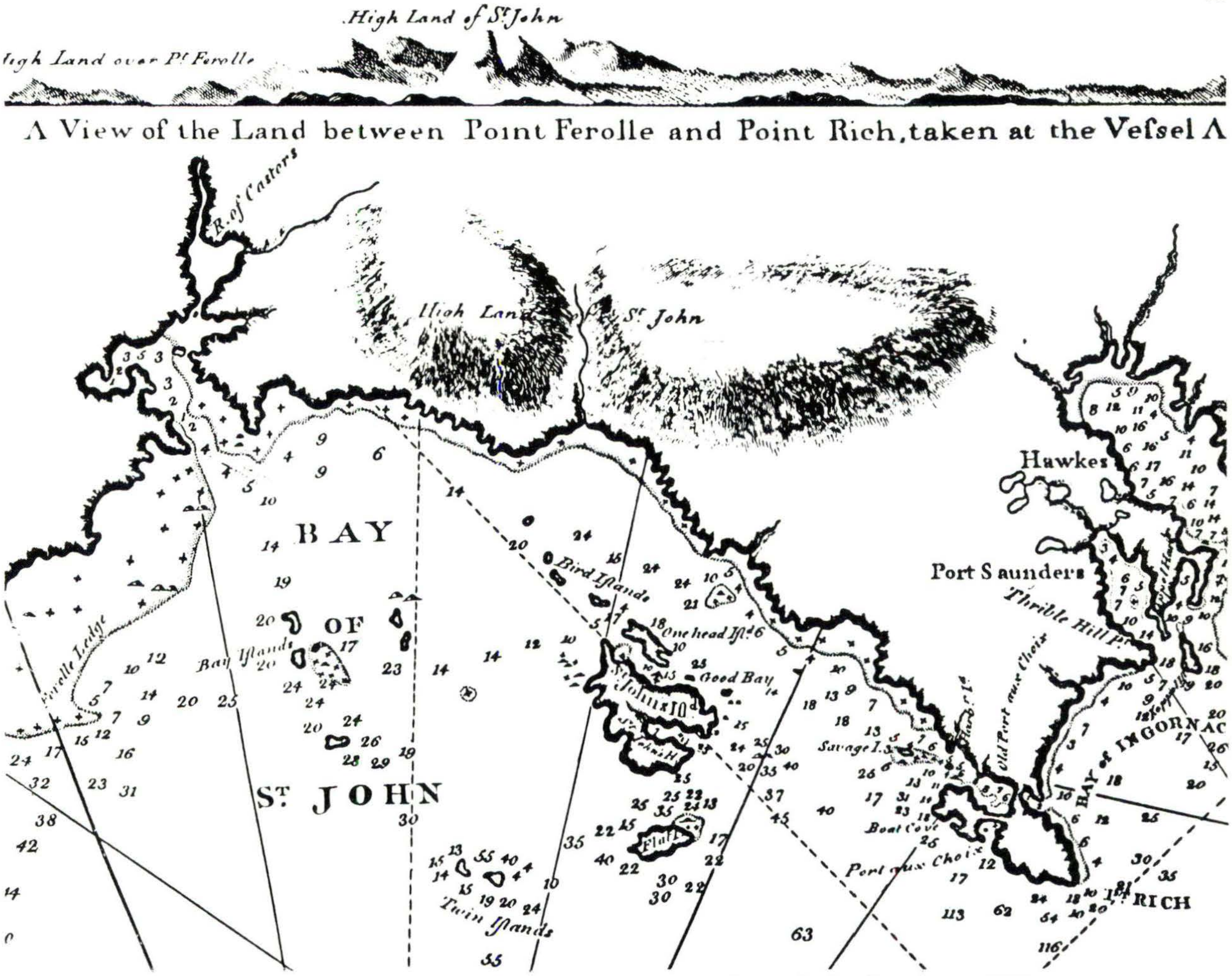
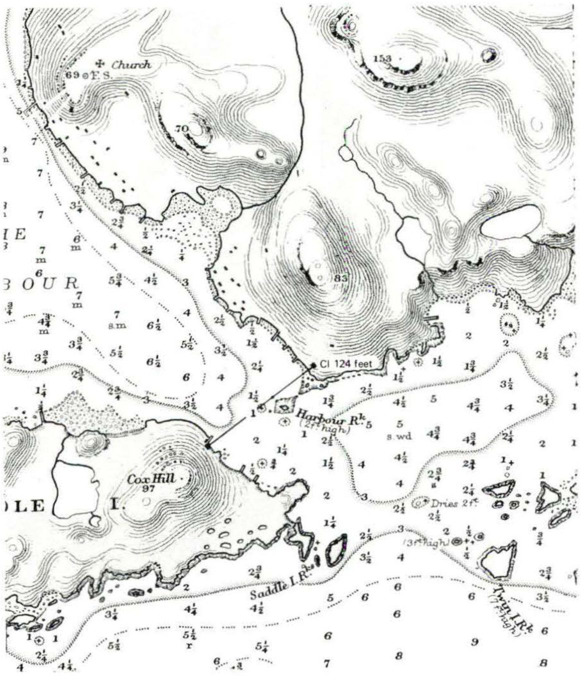


Figure 1. "A Chart of the West Coast of Newfoundland,... By James Cook, Surveyor, 1769. Scale 1:72,000 approx.



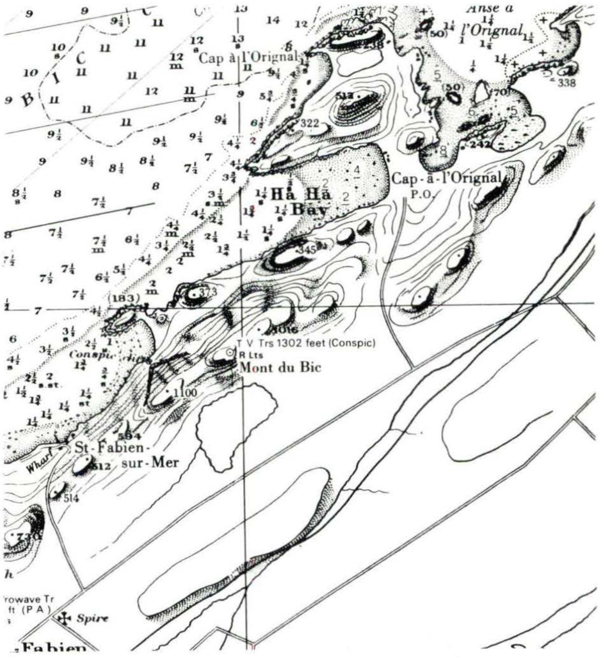


Figure 2. Chart 4669, Red Bay, Surveyed 1890. Scale 1:12,000.

Figure 3. Chart 1204, Ile du Bic to Ile Vert. Surveyed 1907-8. Scale 1:77,800.

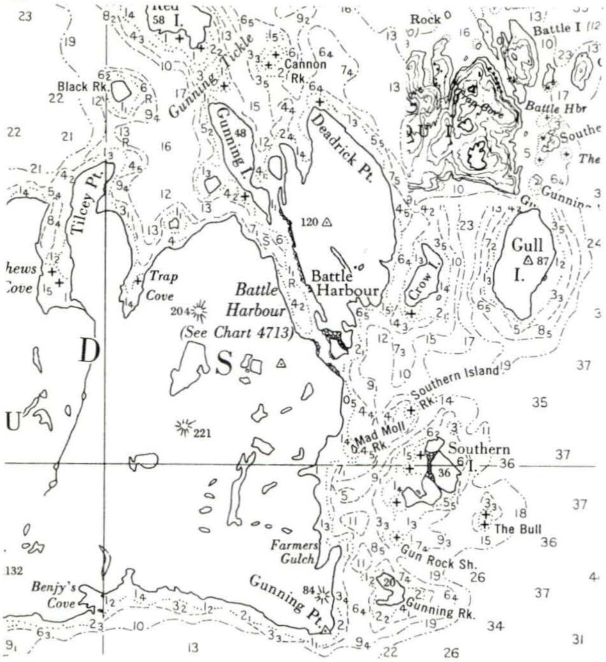


Figure 4. Chart 4714, Cape St. Charles to St. Mary's Harbour. Surveyed 1951. Scale 1:25,000 with inset of Chart 4701 Ship Harbour Head to Camp Islands, 1:75,000.

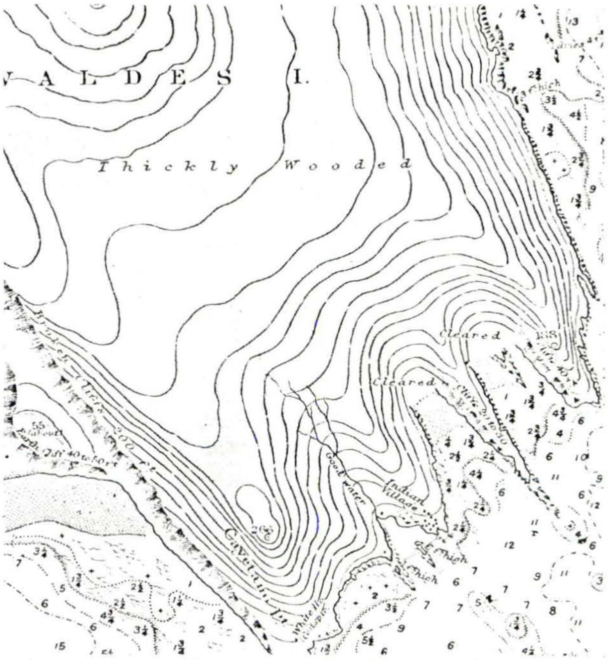


Figure 7. Admiralty Chart 3574. Porlier Pass, Surveyed 1905. 1:12,100.

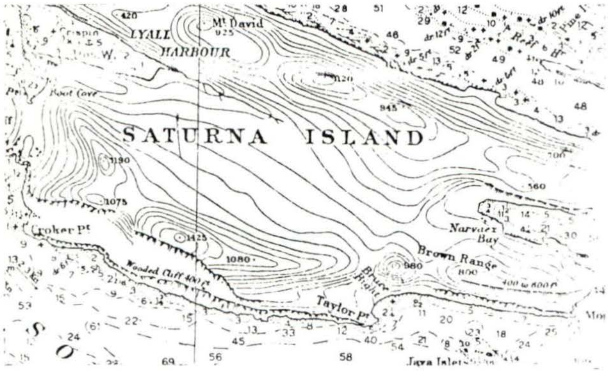


Figure 5. Chart 3450. East Point to Sand Heads, First published 1937, 1:80.000.

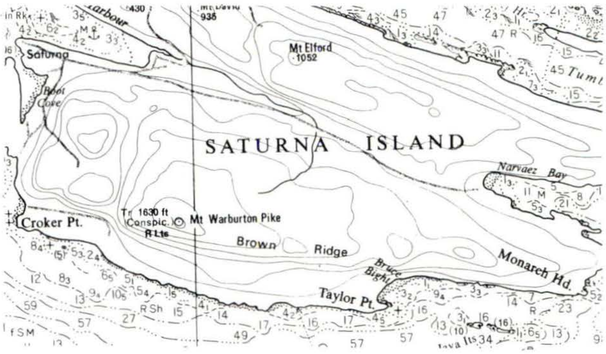


Figure 6. Chart 3450, East Point to Sand Heads, 1968 edition, 1:80,000.

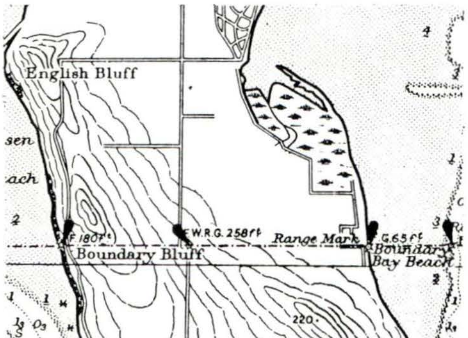


Figure 8. Admiralty Chart 576, Strait of Georgia, Alden Bank to Nanaimo. 1952. 1:76,500.

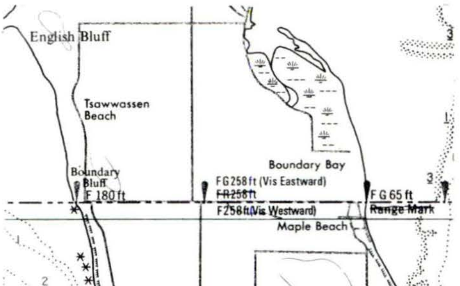


Figure 9. Chart 3450, East Point to Sand Heads. 1968, Scale 1:80,000.

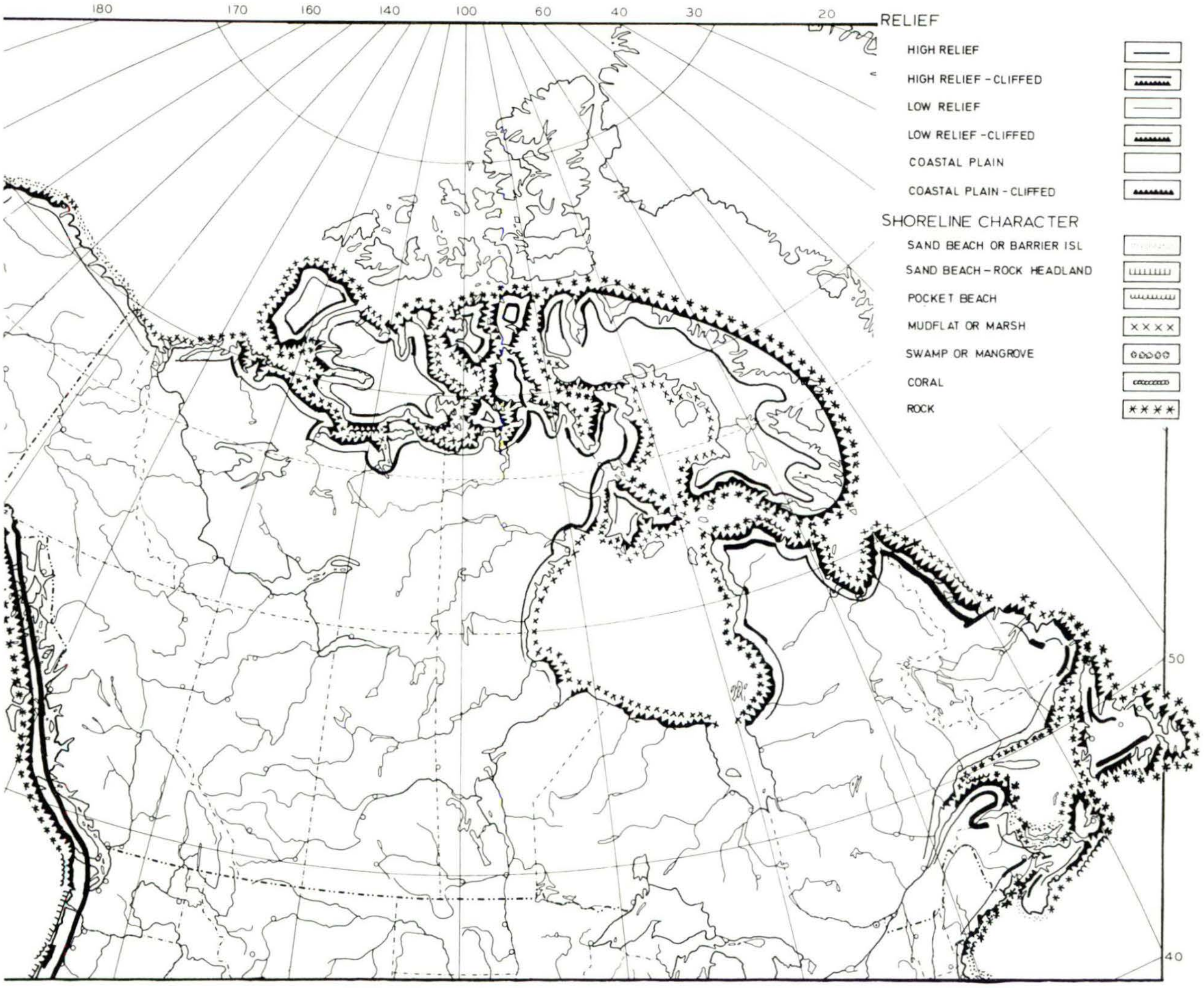


Figure 10. Coastal land forms[7]

Where no previous charts exist, and for the cultural information to be shown, the hydrographer should be guided by the guidelines to be described.

The Mariners Requirement

In their discussions, the Chart Presentation Steering Committee agreed that the only topographic and cultural features to be shown on a Chart should be limited to those which the mariner needs to:

1. Using visual and/or radar fixes, make a safe landfall upon unknown coasts to avoid all dangers, and to safely enter a harbour. In an emergency, the mariner may have to decide very rapidly where he could most safely beach his ship or the best direction in which to seek help. Medium scale charts are usually used for these purposes.

2. Manoeuvring and docking within a harbour by reference to conspicuous features using large scale harbour plans to conduct harbour business as efficiently as possible by having a knowledge of dock areas and the location of various offices and facilities.

Any information which is not needed for one of these purposes is redundant and should not be shown. However, it must be remembered that the chart has to serve the needs of a wide variety of users ranging from large commercial ships to fishermen and yachtmen. It is important that the topographical information shown meets the needs of all these users, be it the navigator of a bulk carrier or warship, equipped with a variety of sophisticated electronic positioning devices, or the recreational yachtsmen relying solely upon basic visual observations. In fact it is the navigator of a yacht or fishing vessel who will make the most use of transits of headlands, islands and topographic features. It is he who, under adverse conditions, such as seeing a coast for the first time or intermittently through a fog, will need to use all the clues given by studying the topography carefully to locate his position.

Information Required at Different Scales

1) Large Scale Charts

It is felt that it would be enough to show the limits of built-up areas plus the buildings back to the first street line, together with the customs house, office of the medical officer of health, the post office, nearest hospital, the harbour masters or other port authorities office, etc., and enough of a street plan to enable them to be located.

The conspicuous objects that may be used by the mariner in accurately positioning his ship while manoeuvring to anchor or berth must all be shown on the chart, remembering that the mariner will prefer to use those closest to him rather than those far off. However, this may not always be possible, for on misty mornings objects close to the water front may be obscured while those at a higher elevation may be visible. Features of navigational interest such as permanent tide and water level gauges will be shown even though they are not visually significant. In major harbours there are usually sufficient conspicuous cultural features to enable the mariner to position himself so the amount of topography to be shown by contours can be held to a minimum.

This is very close to the NSICC preferred representation which is:

> "reasonably full details of roads and buildings in dock areas and adjacent to the coastline generally, to the extent that a mariner unfamiliar with the port gets an indication of the layout of the port and access to shore facilities of general maritime interest. Full depiction of landmarks is required but surrounding built-up areas need not necessarily be shown"[6] (Para. 320)

2) Largest Scale Continuous Coastal Series

The NSICC states the requirement for cultural information well,

> "Inshore navigation requires the navigator to pay constant attention to his precise position often by visual means, because of the danger of running aground. Natural features close to the coast are most important on this scale." (Para. 350.2)

> "... Roads, railways and even minor tracks running down to, or along, the coast, buildings near the coast, and all tall structures which may be visible should be charted to assist identification of position, usually by visual means. At night the limits of the built-up areas are particularly important because, at such times, the lights of navigational aids be difficult to identify in the vicinity of a well-lit urban area." (Para. 360.2)

> "Airfields within a few miles of the coast shall be charted on large and medium scales; they are significant to coastal navigation because of the many visual and aural features associated with them and the related air traffic." (Para. 366)

On charts providing the largest scale continuous cover, sufficient formlines shall be shown to enable the mariner to positively identify the topographical features and also the conspicuous objects visually or by radar. On these charts all possible information should be shown on the nature of the coast - does it have high or low cliffs, is it marshy, is there a rocky foreshore or a sand or shingle beach? The mouths of all rivers and streams should also be shown as they have some influence on the waters into which they empty.

Topography

The chart must show the mariner by the use of contours, or the cliff symbol, the topographic features which he can use for radar or visual fixing, without confusing them by showing features which he cannot see and therefore cannot use. As a general rule no topography, except for the courses of major rivers, should be shown on charts unless it shows an area which can definitely be seen from somewhere to seaward on that particular chart. The topography to be shown is that of most use to a mariner navigating the coast for the first time. Therefore the first impressions of the coast may be more valuable than those obtained after considerable familiarity when minor inconspicuous features assume an importance for a particular purpose.

It is proposed in future that all contour lines derived from topographical maps be treated as form lines and not be labeled. This is partly due to the fact that it will be many years before topographic maps showing metric contours are available for all of Canada. Therefore we will be using contours which are not at standard metric intervals. More important there is a consensus that far fewer contours are required than we are now using to show the shape of the topography. The NSICC specifications state that,

> "Ideally the contour interval should be chosen so that fewer than 10 contours are needed for the full range of height on a single chart or particular series of charts (for clarity and economy)." (Para. 351.4)

There is one point on which our thinking diverges from that of the NSICC. The preceeding quotation states:

> "The contour interval shall be uniform for any chart, or series of overlapping charts on the same scale, except that the lowest contour may be a supplementary one..."

Figures 8 and 9 show two examples of this charting of Point Roberts. This is on the same chart as figures 4 and 5. This is a case where on one side of the Strait of Georgia the relief is of the order of 5000 feet while on the other side it is only 250. Anyone who has stood on the ferry as it leaves Active Pass and heads for Tsawwassen would have to agree that English Bluff behind the ferry terminal is a significant feature even though it is a mole hill compared with the mountains and hills behind you on Vancouver Island. This is another good illustration where the old chart, figure 8 in this case Admiralty Chart 576 is far superior in its depiction of topography than the modern Canadian chart, figure 9, which relies on one 250' contour taken from topo maps.

Spot Heights

Spot heights of summits, and the top of cliffs, are important as they enable a mariner to predict the distance at which he may see the object visually or on radar. Therefore many more spot heights are to be shown than has been our practice. Many features, such as tapering mountain summits, can be seen a long way to seaward, yet will not be visible on radar due to the land formation. As extreme accuracy is not important, where no height is given on either the field sheet or topo map, it should be estimated by adding half the contour interval to the height of the nearest contour. Where a spot height is derived in this way, no dot will be shown. More preferably the hydrographer should obtain an accurate height by survey. The Hydrographic Data Centre at H.Q. has on file many of the compilation drawings for the 1:250,000 maps of the Arctic. These were drawn at a scale of 1:125,000 and the sheets of the outer coast have 100' contours. This would enable more accurate spot heights to be derived than from the published maps which only show 500' contours.

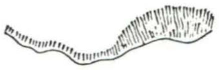
Cliffs

One of the topographic features on which the CHS has allowed itself to be too heavily influenced by topographic maps is the use of the cliff symbol. In Europe, hill shading and rock drawing is regarded as the highest expression of the cartographers art. In Canada, probably under the influence of engineers, the cliff symbol rarely appears. Figure 10 shows a general analysis of the coastal landforms of Canada, excluding the Queen Elizabeth Islands. This clearly shows that cliffs are the predominant landform yet these are not shown on our main source document. Another odd point is that no technical definition of a cliff appears to exist.

The NSICC specifications are extremely lucid on this subject,

> "A Steep Coast, i.e., a coast backed by rock or earth cliffs, gives a good radar return and is useful for visual identification from a considerable distance off, where cliffs alternate with low lying coast along the shoreline. Where cliffs are prominent features they should be charted on scales larger than 1:500,000 generally as an exception, where cliffs predominate over extensive stretches of coastline, it may be neither feasible nor particularly useful to insert a cliff symbol throughout. Cliff-top heights are useful for calculating or estimating distance off, (for clearing inshore dangers) and should be shown where possible.
>
> A steep coast shall be represented by the accompanying symbol, with the cliff crest in its true position of the largest scales. On medium scales the crest may have to be displaced inland slightly for the symbol to be drawn clearly.

> Where it is considered desirable to distinguish between different types of steep coast the above symbol should be used to represent a coast with rocky cliffs and, where the rocky symbol is not appropriate, hachures should be used thus:



"

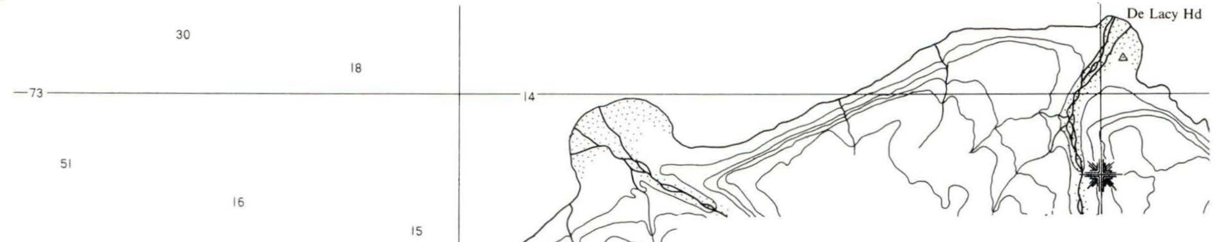
(Para 312.1)

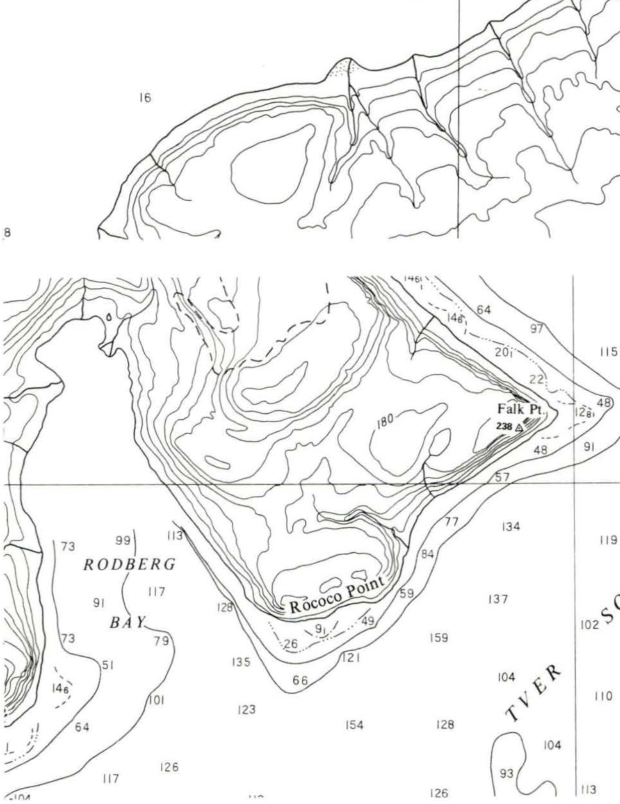
Figure 11 shows North Kent Island, between Hell Gate and Cardigan Strait as it appears on 1:500,000 Chart 7950. Figure 12 which shows the north and south coasts of the island taken from 1:75,000 chart 7930. I think the larger extract shows the economies that could be achieved on this type of coast, which is so typical, by using the cliff symbol rather than drawing large numbers of contours close together. It would also give the mariner a more immediate appreciation of the nature of this inhospitable coast. The 1:500,000 chart with its reliance on a 300m (originally 1000') contour interval is a complete disaster in this respect as can be seen by looking at the photograph on page 406 of the Pilot of Arctic Canada, Vol. II. The northern part of the 1:75,000 chart shows a rather more subtle point. At the west end at 'A' there are probably cliffs 120m high and at 'B' probably cliffs which reach 150m at the highest point. These would be good radar targets and should certainly appear on the 1:500,000 chart but unfortunately no attempt was made to interprete this information from the larger scale chart.

Figure 13 shows the better appreciation that existed one hundred and fifty years ago when Capt. Bayfield surveyed Lake Huron. His practice of using roman numerals to show the height of the cliffs is not recommended for modern usage, in fact I wonder how many Victorian navigators were instantly able to convert "CCXXX to CLXXX" into "230 to 180 feet"?

Glaciers and Ice-caps

Ice-caps and glaciers should always be shown on medium and small scale charts, if it is physically possible to see them from seaward because of their conspicuous appearance. Extensive icefields may also be useful even if they are not directly visible as they lighten the sky above them. Glaciers that reach the shoreline must always be shown to warn the navigator of the risk of calving icebergs.





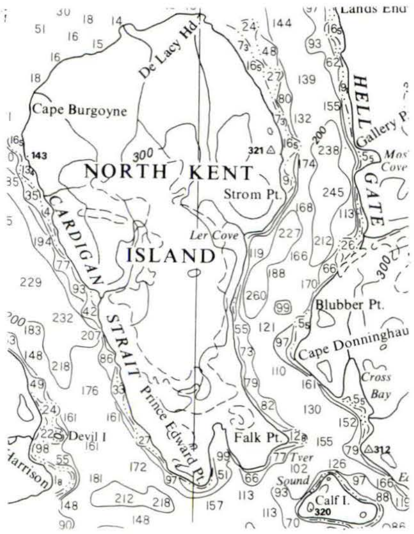


Figure 11. Chart 7950 Jones Sound,...1974
Scale 1:500,000

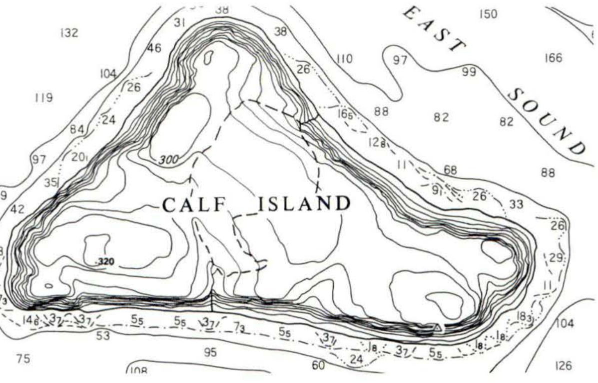


Figure 12. Chart 7930 Hell Gate and Cardigan Strait. 1974. 1:75,000.

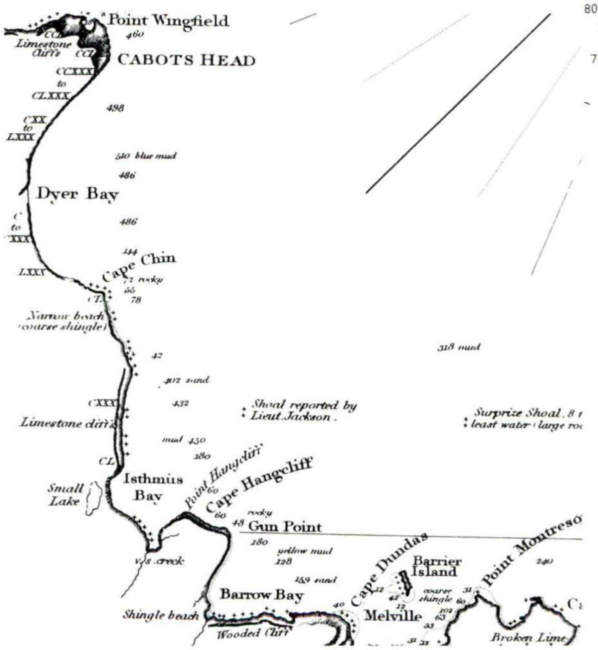
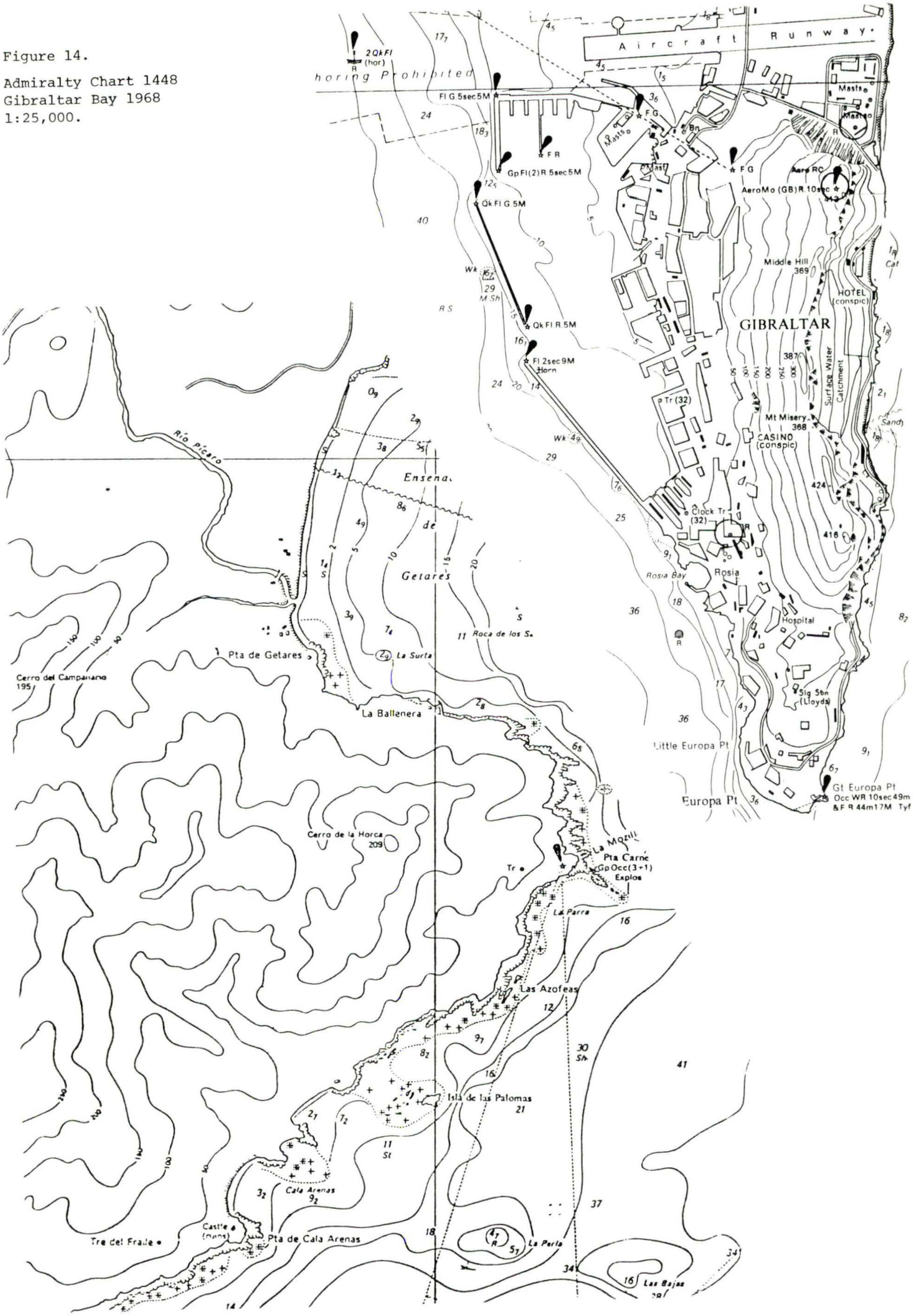


Figure 13. Lake Huron Sheet III, Surveyed by Capt. W.H. Bayfield, 1822.

Figure 14.

Admiralty Chart 1448
Gibraltar Bay 1968
1:25,000.



Conspicuous Objects

The hydrographer will continue to show the location and description of conspicuous features on his field sheets, as required by existing Standing Orders. The field sheet will continue to be the primary source for this information for the cartographer. The hydrographer should remember that in surveying the area he had the benefit of numerous sounding marks established for the purpose. These will largely have disappeared when future revisory surveys are carried out and only those which were permanently marked will be shown on the chart. The hydrographer should therefore consider the needs of the hydrographer making revisory surveys and show on his field sheets points which could serve this purpose.

Small Craft Charts

As one of the primary purposes of small craft charts is to stimulate tourism, as well as to serve the needs of recreational boaters, these charts should serve the needs of a combined map and chart. This is necessary as topographical maps are not so readily available and their sheet limits would often require a boater to carry an inordinate number to cover his cruise. The amount of topographic and cultural information that can be eliminated will therefore be less than on a standard chart. The hydrographer should also be alert to other information such as historic sites, etc., which should be identified.

The Task of the Cartographer

The main task of the cartographer in the future will be to compile a mosaic of the best available topographic maps which the hydrographer will then annotate in the field. These will usually be the National Topographic Services for medium and small scale charts. For large scale charts, especially major harbours, the cartographer should check to see if the municipality or province has had their own large scale plots prepared.

If a guide to the topographic information to be shown, selected in accordance to the criteria described, is not available the Regional Hydrographer is to be asked to name a hydrographer familiar with the area to assist the cartographer in making his selection. A review of existing and cancelled charts of the area should also be made to see if any exist where the topography was compiled by a hydrographer. These will usually provide a good guide as to what should be shown. For northern and Arctic waters the oblique trimetrogon photographs may also be useful, especially in determining where the cliff symbol should be used.

Conclusion

The obvious question is what will a chart prepared using these criteria look like. Figures 14 and 15 are taken from Admiralty Chart 1448, Gibraltar Bay, published in 1968, amongst the earliest of their new metric format. In its depiction of topography it is in fact close to the NSICC specifications except that these state that,

> "Formlines shall be shown as continuous lines, preferably made bolder in the SE quadrant to represent light coming from the NW." (Section 351.6)

This is going back to a rather similar method used in figure 3.

It will be noted that these charts have a clean uncluttered appearance but all of the essential information needed by the mariner is there.

It has taken over two hundred years for the pendulum to swing from the days of James Cook, when he probably put as much time into surveying topography as he did hydrography, through the days when the Canadian Hydrographer left it to the compiler to copy the topo maps, back to the present where we are again putting the onus back on the hydrographer. I only hope that they will respond to that challenge as well as Cook did.

Acknowledgements

I would like to thank those with whom I served on the Chart Presentation Steering Committee and whose criticisms of my earlier discussion papers were so valuable and at times so forceful.

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4. Ibid. p. 69.

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6. "North Sea International Chart Commission. Specifications - 300 Section - Topography - 3rd Draft, October 1977."

7. Dolan, R., et al., 1972, Classification of the Coastal Environments of the World, Part 1, The Americas; Dept. of Environmental Sciences, Univ. of Virginia, Tech. Rept. No. 1, 163 p. Reproduced as figure 15 in E.H. Owens. Coastal Environments of Canada: the impact and clean-up of oil spills. Economic and Technical Review Report EPS-3-EC-77-13. Fisheries and Environment Canada, Environmental Impact Control Directorate, Ottawa, April 1977.

Automated Hydrography and its Impact on the Working Hydrographer Workshop Session 1 Chairman's Summary

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C.H.S. Pacific Region

Both Workshop presentations followed the same format. Each speaker was allowed five minutes for his presentation, and a brief rebuttal period followed the third speaker. The chair then opened the workshop to the floor, and the panel responded to a variety of questions and challenges. In both sessions response was excellent, and, limited by time, the chair was forced to close both sessions before recognizing all who wished to participate. The following is a brief summary of each presentation.

The first speaker, Rob Tripe, indicated a new role for the hydrographer. This would have the hydrographer present a digital field sheet, and also have him actively involved in the chart production process.

Several factors make this an ideal time to implement this proposal. Decentralization of chart construction to the regions is now a reality. This fact lends itself to a coordinated approach to chart compilation. A second factor is the advance made in data acquisition in the last decade. Logging and processing of bathymetry is now well in hand. Present techniques do not require the full resources of a field party to process, edit and plot the bathymetry. This frees the remainder of the party to proceed with assembling and digitizing all other data which appear on the field sheet. Eventually, the conventional field sheet could be presented in digital form on a suitable computer compatible medium.

In order to achieve full benefit from the plan the hydrographer should be encouraged to think in terms of the chart rather than the field sheet. One method of achieving this would be to assign a field party to a block of charts over a period of several years. Normal field work would be performed during the summers, and the winters could be spent working alongside the cartographic group in compilation of the data to chart format.

Advantages include making most efficient use of manpower being made available through improved acquisition techniques, at the same time providing more responsibility in the chart compilation process, thereby relieving some of the tedium of automated data collection. By being involved with a block of charts over an extended period the party could make more efficient use of field survey time.

The coordinated effort of the hydrographer and cartographer could be mutually beneficial, and would allow concurrent survey and compilation processes, thereby speeding up the production of, and improving the quality of the final product, the chart.

Tim Evangelatos briefly described the present status of computer assisted chart construction and outlined how automated methods might affect chart production.

Although much has been said and written of automated cartography, at the moment chart compilation is still a manual process which requires specialized skills. At headquarters, for new charts, the automation comes later. The manually prepared compilation sheet is being digitized manually and drawn automatically. A logical extension would be to now automate the compilation stage. Is this feasible?

Anyone who becomes familiar with the power and limitations of the computer quickly discards the simple view of an automated system where the field data goes in at one end and the chart comes out the other. The computer will only satisfactorily perform the more straightforward mechanical functions. The hydrographer and cartographer will still have to make the important decisions. Another major hurdle is that most of the data required is in graphic form. The compiler must study all available documents pertaining to the chart area. Collecting and sifting through all the information from this myriad of field sheets, charts, engineering plans and drawings, etc., etc., most at different scales and projections, is a very time-consuming task. To automate this task would be very desirable, but would require all of these source documents to be in digital form. At the present time we do not have the resources to do this.

From all of this it seems clear that until all source documents are in digital form we cannot think of automated compilation. We should, however, consider computer assisted compilation. To demonstrate the feasibility of this, chart 8015 is being done this way. The over one dozen field sheets involved were photographically reduced to chart scale, contoured, and then the contours and selected soundings were digitized. These data were mosaiced by the computer and the digital output was edited where necessary using GOMADS, our interactive graphics system. For the foreseeable future, the sounding selection will remain a manual process, but could be done through a display terminal if working from digital field sheets.

Once the chart is published the problem remains to maintain it. Some regions keep a maintenance copy where all new and significant data for the area are noted, and readily available when a new edition is to be prepared. Formalization of this approach has been suggested by Neil Anderson, which he calls the qualified data base.

It provides an orderly approach to the maintenance of hydrographic data in the graphic form, but also could significantly reduce the volume of data to the extent that we could consider digitizing it.

The third panelist, Milton Hemphill, expressed a concern that automated hydrography may not yet be at a state where results can be completely trusted. Because of this the hydrographers workload has been increased. As well as maintain the automated equipment he must record and log manually as well. All of the data checks, scrutinizing of sounding rolls, manual data recovery and editing required after processing are all extremely time consuming.

The hydrographer, however, has persevered through this period of adversity, and major breakthroughs are being made. As we are continually taxing our resources almost to the breaking point because of austerity and the ever-increasing demands for surveys, automation is a viable avenue to increased production within existing resources. It is time to push harder than in the past for a foolproof system.

Last fall I had the opportunity to evaluate an integrated navigation and processing package. Although it requires improvement in a number of areas, I was more than impressed with its ease of operation and the continuous checks provided for all data collected and recorded on tape.

I can envisage the day in the very near future when using a similar system, one hydrographic technician and one seaman will be all the bodies required on board a launch for the systematic collection of data in less complex and open-ended areas. Note the term hydrographic technician, not necessarily a full-fledged, highly trained hydrographer. The role of the hydrographer will change very little, but two of his most important tasks will be the necessary constant monitoring, and compilation of results obtained using automated equipment.

During the process of rescheming Atlantic coast charts as a prelude to metric conversion it became clear to me that not only some charts, but a large number of field surveys were overscaled. When automated hydrography becomes an absolute reality, scale of survey could have a tremendous impact. For example, using a system sampling at once a second, both survey and compilation time could be considerably reduced if the base, projection and scale of the survey and chart were identical. The scale of the survey or the survey plot make little difference as long as all shoals, hazards and contours can be delineated with sufficient accuracy and clarity for the final product - the chart.

Contract Surveys Workshop Session 2 Chairman's Summary

T.D.W. McCULLOCH
Ocean and Aquatic Sciences
Central Region

The Chairman opened the session by briefly describing the Canadian context and background regarding contracting out. He quoted the Glassco Commission 1963 Report which underlined the need for government sides to encourage and allow industry to take a bigger role in research and development and the Stewart-Dickie Report, 1971 which emphasizes that growth in hydrographic surveying activities should be handled by the private sector; the influence of the "Make or Buy" Phase I and Phase II documents, the thrust into contracting in Georgian Bay in 1972 terminated by lack of funding in 1976.

The Chairman briefly touched on the experience of other countries such as the U.K. with a huge survey industry stimulated by North Sea activities, the hope that something similiar even if smaller might develop in Canada and that with hydrocarbons in short supply there would be a frantic search in the nearshore over the next quarter century and that that requirement and the law of the sea and its implications made it incumbent on Canada to establish and maintain a viable worldwide offshore survey industry.

The first panelist, S. MacPhee spoke on what could and should be accomplished by contract. He pointed out that contracting is not new to hydrography in Canada, that ships have been chartered for hydrographic operations for more than 25 years. In addition, positioning systems have been provided, helicopters have been chartered, equipment has been repaired just to mention a few of the parts of the hydrographic programme that have been carried out by the private sector. Mr. MacPhee then discussed the Glassco Commission, the Senate Special Committee on Science Policy, the Science Council of Canada "Ad Mare: Canada looks at the Sea", and our reaction to these documents by contracting out surveys during the years 1972 to 1975.

These surveys were terminated due to lack of funding. However the C.H.S. learned a lot about contract surveying and some companies learned a lot about hydrography. Four points were particularly noted at the termination of this learning period:

1) without adequate resources and a long-range plan neither government nor industry will benefit;

2) the conduct of even a straight-forward hydrographic survey is a unique activity requiring a high level of specialized expertize;

3) the idea of automatically selecting the lowest bidder is out of the question;

4) constant on-the-job monitoring is essential.

In April, 1977 the T.B. directive on policy and guidelines on contracting out the government's requirements in science and technology was published and supported the requirement for a continuing hydrographic capability in the private sector. That same year as part of a Zero A Base Review, a special report on contracting out of hydrography was completed for the Deputy Minister. Two additional points surfaced from that report:

1) Is it of optimum benefit to the taxpayer to develop an industrial capability if it is to remain soley dependent upon government funding?

2) The area of liability.

Mr. MacPhee indicated that as a result of these concerns, the C.H.S. has recommended that all surveys in the intricate inshore and all chart production for navigation charts should be done by government, at least until a number of Canadian companies have become sufficiently proficient in offshore surveys and in surveys for pleasure boating to warrant further consideration. He indicated also that C.H.S. have recommended that the following functions are immediately amenable to contracting out:

1. Offshore surveys and the production of natural resource maps;
2. Hand amendments to charts in stock;
3. Aerial hydrographic development;
4. Software development beyond and "in-house" experise;
5. Pleasure craft charts;
6. Engineering surveys;
7. Associated aerial photography, reprographic functions and the preparation of type.

He summarized as follows:

1. Recommendations have been made on what should be contracted and what should be maintained in-house.
2. A set of rating factors has been set up for evaluating industry submissions.
3. A set of Standing Orders to be followed by industry has been prepared.

In conclusion he noted that the one remaining requirement that is to be met is the availability of a stable source for contracting activities.

He was followed by G. Henderson whose talk was entitled "A Regional Viewpoint". He noted that past experience has shown that although the private sector in Canada noes not fully appreciate all the complexity of hydrographic surveying it has a demonstrated competence in hydrographic activities. The critical factor in hydrographic surveying is an appreciation of the inter-relationships between the various disciplines and the implications of each towards all the others. The merging of relevant aspects of each discipline towards the compilation of a unique hydrographic data structure for any particular area has historically been the role of the professional hydrographer. Although competence in each of various disciplines mentioned unquestionably exists, the private sector has had, until fairly recently, no incentive to develop expertise in the field of hydrography or, more simply, to "put it together".

The necessary installation of this expertise will best be accomplished, initially, by fostering a co-worker environment under the terms of reference of a contract. Two options are available under this arrangement - either hydrographers go to work with private industry or private industry comes to work with the government. In most respects, the latter appears to be the more realistic and workable approach.

As the contractor develops a demonstrated competence in more complex areas of hydrography, the hydrographer's involvement will decrease towards the eventual position of a monitoring and inspecting agent only. During the course of this training and development period, the contractor should have access to all existing hydrographic training programs within the Service.

Final batter at the plate was R. Brocklebank, President of McElhanney Surveying & Engineering Ltd., Vancouver. He emphasized how pleased he was to be given the opportunity to discuss contracting out hydrographic surveys as his Company is one of the few in Canada that has some capability and experience in certain types of hydrographic surveying including offshore positioning. He also mentioned Phase II "Make or Buy" and indicated that although this document has been in circulation throughout the public sector for some time it is disconcerting to find that the majority of government agencies most affected by the policy appear to be resisting the contracting out strenuously. It is not a question of whether the C.H.S. should contract a substantial portion of their activities but one of a methodology for implementation and scheduling of the transfer. Only some 6% of the total expenditure of 1,664M on scientific activities in 1977/78 will be contracted to industry, a percentage which has not increased over the last several years. Although T.B. policy and guidelines are specific and clear, if one tries diligently enough, some "loop-holes" to circumvent these may be found. He suspects that a lot of time and energy is being expended by affected federal agencies to develop arguments against contracting-out by their subjective interpretation of a few phrases in the guidelines.

There is only limited capability currently existing in the private sector for performance of the scope of the activities carried out by the C.H.S. "Lean" market demands explains the limited capability. The Canadian private sector capability that does exist has been developed largely through engineering surveys for harbour development, underwater structures and utility lines and positioning surveys for the offshore petroleum industry.

In a free enterprise system competitive capability is created rapidly wherever there is a market opportunity to be serviced. Similarly, it is rare that an export market can be developed where a domestic base does not or has not existed. With a "lean" domestic market, not only is it difficult to export expertise and services, it is equally difficult to compete with strong foreign companies striving to "skim the cream" off the Canadian home market.

In his opinion the science of hydrographic surveying is no more difficult for the private sector to execute than many other types of professional and technical services it has already successfully carried out. And he proposed that this capability, combined with the government's stated intention to ensure maximum industrial participation in ocean management, justifies the contracting-out of hydrographic survey programs to the private sector.

An analogous model for comparison can be found in the Canadian aerial survey industry. Many similarities exist between aerial and hydrographic surveying. Both have a graphical portrayal of physical information as a normal end product, technologies have become equally sophisticated, measuring equipments are both complex and costly, expensive platforms are required for the measuring or sensing instrumentation, data collection is at the mercy of the elements, and many others. The primary domestic and export markets for industry of regional and national topographic mapping and of engineering surveys for resource development are aslo similar.

The aerial survey industry was in an embryo state 25 years ago. Contracting-out by the federal government allowed the industry to establish a domestic base from which to export successfully. Canada today has an enviable international reputation in the field of aerial surveying as a result of private sector initiative nurtured by federal government support. Last year the aerial survey industry earned $50 million, $17 million of which was in the export business in which Canadian industry was able to project its expertise internationally. Today, thanks to the current contracting-out policy, the aerial survey industry is looking forward to renewed impetus through increased participation in the national mapping program.

The Chairman congratulated the panelists on their excellent presentations and invited the audience to participate in the workshop. Several interesting discussions ensued. C. Champ expressed the feeling that perhaps the wrong audience was being addressed and that such a presentation would better be made to the oil companies. M. Bolton disagreed and noted that the fault lay with the bureaucracy and that it was the bureaucracy that must exert itself and overcome the inertia to enable success in the "Make or Buy" program. Several participants supported the contention that the biggest barrier to success was an entrenched civil service. Admiral Powell, N.O.S. and R. Brocklebank had considerable discussion regarding liability with the view prevailing that liability per se in this issue may be largely a "red herring". Panelist MacPhee defending the bureaucracy underlined the fact that continuity in programming only comes through government. G. Collins demonstrated several times that he and the Department of Supply and Services are agreed to play an active role in ensuring the effectiveness of contracting out. Many other individuals involved themselves in the discussion and I take this opportunity to thank all for making the workshop such a success. It was particularly noteworthy at the first session where discussion and involvement was lively and continuous. At the second session, not so well attended, participation was somewhat forced and artificial. However, altogether a thorough on-going success which should be repeated at a future conference where one can assess whether it is all just "pie in the sky" or a very early real step in establishing a new, strong Canadian industry.

Contract Surveys

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Abstract

Federal government policy regarding Canadian scientific activities advocates increased contracting-out of ocean management related programs to the private sector. Since first being recommended by the Glassco Commission in 1962, implementation of the policy has been slow, particularly in the science of hydrographic surveying. This mini-paper contends that the private sector's existing embryo capability should be nurtured and that it would be of optimum benefit to Canada to do so. A request that the Canadian Hydrographic Service increase its contracting-out is made.

It is a pleasure for me as a representative of the private sector, to have this opportunity to discuss the question of contracting-out hydrographic surveys. I accepted this honour with some trepidation, as I cannot claim to be trained or experienced in the science and art of hydrographic surveys. However, the company I represent is one of the few in Canada that has some capability and experience in certain types of hydrographic surveying including offshore positioning. Also, representing the interests of industry--which unfortunately is usually in an adversary role with government--before an audience predominantly governmental, makes one feel like the proverbial skunk at the tea party!

The federal government's policy regarding the contracting-out of scientific activities is clearly stated in the 'Policy and Guidelines on Contracting-Out the Government's Requirements in Science and Technology' published in April 1977 by the Treasury Board.(1) As this document has been in circulation throughout the public sector for some time, it is disconcerting from the private sector's viewpoint, to find that the majority of government agencies most affected by this policy appear to be resisting contracting-out strenuously. To my mind it is not a question of whether the Canadian Hydrographic Service *should* contract a substantial proportion of their activities, but one of a methodology for implementation and scheduling of the transfer.

Historically, the contracting-out (make or buy) policy was recommended by the Glassco Commission in 1962. A decade later it was endorsed by the Ministry of State for Science and Technology, and was further defined and expanded by the Treasury Board in 1976 to encompass all "related scientific activities", including "scientific data collection" and the specifically noted examples of "routine geological, hydrographic, oceanographic and topographic surveys".(1) Implementation is proceeding very slowly. Only some 6 percent of the total federal expenditure of $1,664 million(2) on scientific activities in 1977/78 will be contracted to industry--a percentage which has not increased over the last several years.(2,3,4&5)

Although the Treasury Board Policy and Guidelines are specific and clear, if one tries diligently enough, some "loopholes" to circumvent its acceptance may be found. I suspect a lot of time and energy is being expended by affected federal agencies in developing arguments against contracting-out by their subjective interpretation of a few phrases in the guidelines.

Five of the six criteria statements relating to security; maintenance of limited in-house competence; support to a regulatory function; up-keep of national standards; and the retention of federal testing and research facilities, all for justification of some in-house performance, cannot, in my opinion, be construed to preclude contracting-out a substantial proportion of CHS' hydrographic surveying. These arguments against contracting-out, I submit, will not for long stand objective scrutiny under the policy as stated.

One criterion however forms the basis upon which the decision of contracting-out of CHS services must hinge. This criterion states, "A department would fulfill a requirement in-house ... where the science and technology capability needed to perform the mission of the department is inappropriate to the private sector, or does not exist in the private sector, and it would not be of optimum benefit to Canada to create one." This question needs to be addressed seriously by all concerned.

As the CHS knows, and the private sector must admit, there is only limited capability currently existing in the Canadian private sector for performance of the scope of the activities carried out by the CHS. Of the, perhaps, dozen Canadian companies with some capability and experience in hydrographic surveying, only five are listed in the recent Department of Industry Trade and Commerce's publication "Ocean Industries Canada".(6) "Lean" market demand explains the limited capability. The Canadian private sector capability that does exist has been developed largely through engineering surveys for harbour development, underwater structures and utility lines, and positioning surveys for the offshore petroleum industry.

In a free enterprise system competitive capability is created rapidly wherever there is a market opportunity to be serviced. Similarly, it is rare that an export market can be developed where a domestic base does not or has not existed. With a "lean" domestic market, not only is it difficult to export expertise and services, it is equally difficult to compete with strong foreign companies striving to "skim the cream" off the Canadian home market.

The basic question to be answered by CHS then is: "Is this capability appropriate to the private sector and would it be of optimum benefit to Canada to create such capability in the private sector?" As an embryo competency already exists, a mature capability could be developed naturally by "nurturing" rather than "creating".

In my opinion the science of hydrographic surveying is no more difficult for the private sector to execute than many other types of professional and technical services it has already successfully carried out. And I propose that this capability, combined with the government's stated intention to ensure maximum industrial participation in ocean management(7), justifies the contracting-out of hydrographic survey programs to the private sector.

An analogous model for comparison can be found in the Canadian aerial survey industry. Many similarities exist between aerial and hydrographic surveying. Both have a graphical portrayal of physical information as a normal end product, technologies have become equally sophisticated, measuring equipments are both complex and costly, expensive platforms are required for the measuring or sensing instrumentation, data collection is at the mercy of the elements, and many others. The primary domestic and export markets for industry of regional and national topographic mapping and of engineering surveys for resource development are also similar.

The aerial survey industry was in an embryo state 25 years ago. Contracting-out by the federal government allowed the industry to establish a domestic base from which to export successfully. Canada today has an enviable international reputation in the field of aerial surveying as a result of private sector initiative nurtured by federal government support. Last year the aerial survey industry earned $50 million, $17 million of which was in the export business in which Canadian industry was able to project its expertise internationally. CIDA contracts accounted for about one-third of the export volume. Today, thanks to the current contracting-out policy, the aerial survey industry is looking forward to renewed impetus through increased participation in the national mapping program.

Finally, as just one spokesman for the private sector, may I express the hope that the Fisheries and Marine Service Branch of Environment will increase its support of industry by contracting-out a significant proportion of its allocated $88 million in current annual science spending(2).

Thank you. I look forward to the forthcoming discussions.

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Contract Hydrographic Surveys: A Regional Viewpoint

G.W. HENDERSON
C.H.S. Atlantic Region

For a number of years now, there has been considerable discourse throughout the public and private sectors on the possibilities of contracting out hydrographic surveys in Canada. The Canadian Hydrographic Service has, during this period, ventured to the extent of contracting out a number of projects, some of which have come closer to meeting expectations than others.

The release of Treasury Board's "Policy and Guidelines on Contracting Out the Government's Requirements in Science and Technology" in April, 1977 added further fuel to the fire by directing federal departments to identify those activities which have to be done inhouse and then to develop a plan to eventually relinquish all other activities to the private sector.

The subsequent study carried out by the Canadian Hydrographic Service, identified among others, the following activities which could possibly be let to contract:

(i) the offshore, milti-parameter survey program;
(ii) some of the surveying and chart production for recreational boating and restricted pleasure craft operation;
(iii) engineering surveys for marine construction; and,
(iv) an increase in the number of ship charters.

The report excluded the possibility of contracting out coastal and inshore hydrographic surveys.

In the light of today's budgetary climate, the Canadian Hydrographic Service must anticipate that its resources are going to remain static for quite some time to come. With the ever increasing demands for our services, these resources are being directed more and more towards small, high priority projects at the expense of our systematic coastal charting programs.

Consequently, from a regional viewpoint, the prospect of contracting out all types of hydrographic surveys is seen as a viable approach to coping with the present backlog situation.

Past experience has shown that although the private sector in Canada does not fully appreciate all of the complexities of hydrographic surveying, it has a demonstrated competence in many aspects of the profession. Credence is given to this fact by the inclusion of data from previous contract surveys into published navigational charts.

Hydrography, today, embraces a working knowledge, to varying degrees, in a multitude of disciplines, including astronomy, physical and geometric geodesy, surveying, photogrammetry, oceanography, geology, geophysics, hydrology, hydraulics, computer science, electronics, and seamanship and navigation, to name but a few.

The critical factor in hydrographic surveying is an appreciation of the interrelationships between the various disciplines and the implications of each towards all the others. The merging of relevant aspects of each discipline towards the compilation of a unique hydrographic data structure for any particular area has historically been the role of the professional hydrographer. Although competence in each of various disciplines mentioned unquestionably exists, the private sector has had, until fairly recently, no incentive to develop expertise in the field of hydrography or, more simply, to "put it all together".

The necessary instillation of this expertise will best be accomplished, initially, by fostering a co-worker environment under the terms of reference of a contract. Two options are available under this arrangement - either hydrographers go to work with private industry or private industry comes to work with the government. In most respects, the latter appears to be the more realistic and workable approach.

As the contractor develops a demonstrated competence in more complex areas of hydrography, the hydrographer's involvement will decrease towards the eventual position of a monitoring and inspecting agent only. During the course of this training and development period, the contractor should have access to all existing hydrographic training programs within the Service.

Obviously, we are not discussing a short term, one-shot deal. Past experience again, has shown the drawbacks of an ad hoc allocation of funds and a piecemeal, single project approach.

The program must be directed towards the systematic completion of relatively large portions of Canada's coastal and offshore zones by means of a comprehensive, package approach implemented as outlined above. On the part of government, this will require long term financial commitments and the design of an effective monitoring and inspecting mechanism.

Industry will have to prepare to demonstrate its willingness to accept this commitment in an honest and sincere manner and to see the projects through to completion with the utmost integrity.

Only through such a long term, comprehensive and co-operative approach to contract hydrographic surveys can we in the Atlantic Region hope to maintain a meaningful, systematic charting program in support of the hydrographic mandate in Canada.

Contract Hydrographic Surveys: What can and should be accomplished by contract.

S.B. MacPhee
C.H.S. Ottawa

ABSTRACT

The Government of Canada has, over the past fifteen years, strongly advocated that a larger proportion of Canada's research and development be done by the private sector. In conformance with this demand the Canadian Hydrographic Service has done an extensive examination to determine what functions should be done "in-house" and what functions should be carried out by contract. In this short paper an attempt is made to summarize the result of this examination and provide some rationale for the decisions that have been made.

Contracting is not new to hydrography in Canada. To supplement the existing complement of government-owned vessels, ships have been chartered for hydrographic operations for more than twenty-five years. In addition, positioning systems have been provided through contract, helicopters have been chartered, equipment has been repaired and refurbished by contract and many other phases of the hydrographic program have been carried out by the private sector. In all the instances I have mentioned, the data have nevertheless been collected, evaluated and transcribed by hydrographers working for the Government of Canada.

The Royal Commission on Government Organization (the Glassco Commission) in the course of its mammoth study of the federal bureaucracy published a report in 1963 and centred one of their major points on the relative balance in the total Canadian research effort among the major sectors of performance; the government, the universities and industry. The Commission felt that, compared to several other advanced countries, a disproportionately large part of Canada's research was performed in government and a correspondingly small part in the industrial sector[1].

The Commission noted that one of the original purposes of public support of research was to encourage Canadian industry. It observed that "from being a primary goal this has, over the years, been relegated to being little more than a minor distraction - a desirable but rather difficult task and certainly of less pressing urgency than other items on the program."[2] It therefore laid great stress on the need for the government science sector to allow and encourage industry to perform a relatively greater role in research and development.

In 1967 the Senate of Canada decided to establish a Special Committee on Science Policy. The Committee hearings began in March 1968, and the first volume of these hearings was published in December 1970. In Volume IV of this Science Policy for Canada Series, published in 1977, the Senate Special Committee concluded that a broader "make or buy" policy must extend to ongoing science and technical activities.

In September 1971 the concept of contracting out hydrographic and other technological requirements was discussed when a Special Study for the Science Council of Canada entitled "Ad Mare: Canada Looks to the Sea"[3] was published. Under Responsibilities and Opportunities it was stated that:

> "Canada has had a systematic program in marine hydrography which has resulted in a great improvement in the mapping of underwater topography surrounding our shores. However, there remains very much to be done. Emery[4] shows the Canadian continental shelf to be poorly or only fairly well-known in contrast to American and European areas. Our shorelines and shelves are so vast that no end is in sight for this work. Further, the increase in pleasure traffic and the demands of offshore oil exploration call for detailed mapping not previously anticipated. In addition, both wave climate information and the mapping of currents are much less complete than is desirable. One can thus anticipate a steady growth of hydrographic survey operations.
>
> It is our opinion that virtually all of this growth should take place by systematically contracting our surveys. The government in-house surveying capability need not expand, and could eventually even contract slightly. The Department of Energy, Mines and Resources will have to continue to take responsibility for the reliability of charts produced and for determining priorities of areas and parameters to be charted. Increasingly, government duties should be concentrated on setting standards and ensuring quality control. More and more of the routine surveying should be let to contract with private operators. Contracts should not occupy the full capability of these operators, who would be expected to sell their services not only to the government but also to private concerns such as, for example, oil companies and private marine operators. Private survey vessels could also be available to be contracted as research vessels by other government agencies and by universities."

What the Stewart-Dickie report did, in fact, was to outline the requirement to create and maintain an effective hydrographic survey industry in Canada. This, coupled with several other similar initiatives provided some encouragement to the private sector and consequently the Canadian Hydrographic Service received its first proposal to contract a major survey in early 1972. Tenders were called and in June 1972 a contract was let for a survey in Northwestern Georgian Bay. For this first contract, tenders ranged from $45,000 to $250,000. The contract was awarded at $89,000 because of a good proposal, some experienced personnel and relatively low cost. The lowest bid was not accepted because of the unrealistically low estimate, poor proposal and the lack of understanding of the survey task. (It is interesting that the company submitting the highest bid had the best proposal reflecting the fact that this firm fully understood the hydrographic survey requirement).

In the years 1972-75, five contracts were let and over $1M was spent on contract surveys. Two of the surveys met CHS expectations but none exceeded them. However, the four years were a necessary learning period. The CHS learned a lot about contract surveying and several companies learned a lot about hydrography. Some of the points that came to light were:

1. Without adequate resources and a long-range plan, neither the government nor private industry will benefit. In this instance, the failure to produce a competitive private hydrographic survey capability was largely due to insufficient financial resources. In the years 1972-75, funds could be obtained from allocated resources to carry out surveys. When the funding was cut back in 1975, so also was the contract survey activity.

2. The conduct of even a straightforward hydrographic survey is not just routine scientific data collection. It is a unique activity requiring a high level of specialized technical expertise.

3. The idea of automatically selecting the lowest bidder is out of the question. Tender submissions must be evaluated according to well-defined rating factors.

4. Constant on-the-job monitoring is essential. Contract hydrographic surveys were most effective when a senior hydrographer followed the project through from beginning to end.

5. In a number of instances, companies bid on contracts merely to get a foot in the door. In some instances, this factor accounted for the wide spread in tender prices.

Due to the lack of funding, the contract survey activity has been virtually non-existent since 1975. The government did nevertheless evaluate the impact of the earlier contracting out by all departments and in April 1977 published a Treasury Board Directive outlining a "Policy and Guidelines on Contracting Out the Government's Requirements in Science and Technology".[5] This directive clearly showed that the services being performed by CHS are subject to the TB Guidelines on contracting out, and once more pointed to the requirement for a continuing hydrographic survey capability in the private sector.

In August 1977, as part of a Zero A Base review in our department, a comprehensive report on the "contracting out" of hydrography[6] was done for our Deputy Minister. Two of the more salient concerns that emerged at that time were:

1. Is it of optimum benefit to the Canadian taxpayer to develop an industrial capability if it is to remain solely dependent upon government funding? Since the revenue from chart sales is less than 5% of the survey and chart production costs, and since it is a federal responsibility to provide navigational charts, then the only major customer for extensive hydrographic surveys is the Government of Canada.

2. The second concern was in the area of liability. As marine casualties can cause extensive loss of life and property, the Crown faces a heavy liability if the products of the Canadian Hydrographic Service are found at fault. The Assistant Deputy Attorney General (Property and Commercial Law) when asked to comment, offered the following opinion:

   "The integrity of the Chart, the Mariners' Bible is essential to Canada's national and international reputation. If all the essential steps of chart making are not carried out by the government, with government resources and government people, then the ability to provide legal proof of the data exhibited on a chart may be impossible where the private industry who did the work has gone bankrupt or has ceased to exist and its records destroyed. Essentially, the problem with the concept of contracting-out is that it does not give any weight to the quality of the surveys and the promotion of national and international standards of hydrography and chart making."

As a result of our concerns, we have recommended that all surveys in the intricate inshore and all chart production for navigation charts should be done by government, at least until a number of Canadian companies have become sufficiently proficient in offshore surveys and in surveys for pleasure boating to warrant considering them for inshore navigational charting.

We have recommended the following functions performed by the CHS as immediately amenable to contracting-out:

1. Offshore surveys and the production of the associated natural resource maps showing the gravity and magnetic fields of the earth;

2. Hand amendments to charts in stock;

3. Aerial Hydrography development and production operation;

4. Software development over and above the level required to maintain an "in-house" expertise;

5. Pleasure craft charts. There is a conflict here with the Charts and Publications Regulations issued by Transport Canada, but attempts will be made to contract out the surveys and the chart production process;

6. Engineering surveys;

7. In the chart production process for commercial navigation charts; aerial photography, reprographic functions, and the preparation of type.

In areas where it is felt that contracting should be done, tenders will be evaluated according to the following factors:

1.	Scientific and Technical strategy	- 0-30
2.	Resources - Staff, Equipment	- 0-25
3.	Company History	- 0-15
4.	Economic factors, Regional aspects and price	- 0-20
5.	Canadian Content	- 0-05
6.	Industrial Benefits	- 0-05

I personally feel that the number of points for Canadian content should be much higher. In the past, we have had tremendous co-operation from the science sector of DSS in contract monitoring and we hope that it will continue. We are investigating performance bonds, but have not pursued this issue in sufficient detail to comment at this time.

SUMMARY

In summary the contract survey question has been addressed in the following manner:

1. Recommendations have been made on what should be contracted and what should be maintained in-house;

2. A set of rating factors to be used for evaluating tender submissions has been discussed;

3. A set of Standing Orders to be followed in the conduct of surveys has been prepared.

The one remaining requirement that must be met in order to have a viable hydrographic survey industry in Canada is the availability of a stable source of funding for contract activities. It is quite obvious that because of the learning experience required, and the infrastructure that must be built up, in the initial years contract surveys will be more expensive than "in-house" surveys. To date Treasury Board has not seen fit to recognize this and allocate additional funding. They must, if Canada is to have this much needed industry.

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4. *EMERY, K.O. The Continental Shelves. Scientific American, September 1969.*

5. *Policy and Guidelines on Contracting Out the Government's Requirements in Science and Technology - Administrative Policy Branch, Treasury Board, April 1977.*

6. *Report by the Dominion Hydrographer to the Senior Review Committee A Base Review on the Possibility of Contracting Out Functions Performed by the Canadian Hydrographic Service (Internal Report) August 1977.*

User Demands on Tidal and Current Groups within Hydrography Chairman's Summary

Dr. W.D. FORRESTER
C.H.S. Ottawa

DISCUSSION:

S. O. Wigen objected to the new policy of omitting bench mark information from hydrographic charts, stating that this information had been useful to surveyors and to hydrographers and chart compilers. Mr. Mooney and Dr. Forrester replied that this information was still available from the bench mark books, and that indeed the BM information that has been shown on charts is too brief to permit recovery of the BM's. Reference of the chart datums to national vertical datums, such as Geodetic Datum, should make evident any changes in datum from chart to chart or from place to place on the same chart, should adequately document the chart datums for future compilers, and could even be of more direct assistance to local surveyors. It was conceded, however, that where reference to a national datum is not possible and local mean water level is not a reasonable alternative, then indeed the datum of the chart would need to be documented by reference to bench marks.

S. Dee asked whether it was still the convention to use the term "stream" to refer to tidal motion, "current" to refer to non-tidal motion, and "flow" to refer to the combination of the two. It was replied that while this terminology, the British terminology, is still used in Canada, it is frequently replaced by American usages such as "tidal current, non-tidal current, and total current".

Mr. Dee commented on the sparsity of current information as compared to that available for tidal elevations. Dr. Forrester replied that this is recognized and that efforts are being made to improve the situation. The problems are that currents are much more complex than the tides since they vary in direction as well as speed, they may be different at different depths, and they can change drastically over a short distance. Because of these complications it is difficult both to obtain meaningful observations and to provide accurate descriptions. Also, unfortunately, only the Pacific Region of the CHS has a specific group equipped for and dedicated to the study of currents.

Dr. Forrester said that the tolerance of ±1 foot between chart datum and sounding datum, referred to by Mr. Mooney, applies only to revision of old work, and that normally the soundings should be corrected as accurately as possible to chart datum. He also suggested Mr. Mooney's use of the terms "mean sea level" and "mean water level" might have been confusing, and that in this context the term "Geodetic Datum" should have replaced the term "mean sea level".

S. O. Wigen asked Mr. Mitchell about the accuracy and the currency of tidal constituent data in the IHO Bank being operated by Canada. Mr. Mitchell replied that some mistakes had been found when the data was checked by the contributing states. Dr. Forrester stated that there is no regular schedule for updating data in the Bank, and that responsible agencies are expected to update their contributions at any time they feel it is necessary or desirable. The update may take the form either of a replacement set or a supplementary set of constants for a station.

There was some discussion of the inconvenience of having different values for chart datum on the Canadian and U.S. sides of the international boundary. The difficulty of changing either or both datums was recognized in that any change by either nation would propagate from chart to chart along its coasts. Mr. Dohler noted that there are much stronger legal implications attached to the establishment of low water and high water datums in the U.S. than in Canada.

International User Demands on Tidal and Current Data within MEDS

Prepared by: P.A. BOLDUC *
Presented by: D.G. MITCHELL *

Each year, the Marine Environmental Data Service (MEDS) processes water level data collected along the Canadian coasts, the Great Lakes and St. Lawrence River system. The Service archives the hourly water level data for later analysis. It is then used for the prediction of the tide. This function serves primarily a Canadian need. It is in our interest to understand better the tidal propagation along our coasts in order to predict better the tidal currents and heights. The safe movement of the ships being our ultimate achievement.

But since Canada does not live alone on this planet and that the tidal regime ignores legal boundaries, it is only natural that most of tidal and water level data gets exchanged with the United States and other countries of the world.

Stations from all coasts (Table 1) are used in a tidal prediction exchange program. The latest harmonic analyses available is used through four different prediction programs followed by formatting programs to produce the basic predictions. The output information is then sent to various countries (Table 2) which participate in the exchange.

Table 1.

Tidal stations used in the predictions exchange program.

Water Levels	Saint John, N.B.	Halifax, N.S.
	St. John's, Nfld.	Pictou, N.S.
	Pointe-au-Pere, Que.	Quebec, Que.
	Vancouver, B.C.	Tofino, B.C.
	Argentia, Nfld.	
	Harrington Harbour, Que.	
	Victoria, B.C.	
	Prince Rupert, B.C.	
Current	Grand Manan Channel, N.S.	
	Active Pass, B.C.	
	Seymour Narrows, B.C.	
	Race Rocks, B.C.	
	First Narrows, B.C.	

Table 2.

Countries which participate in the tidal prediction and exchange program.

United Kingdom:	Institute of Oceanographic Sciences Hydrographer of the Navy
Denmark:	Royal Danish Hydrographic Office
Japan:	Hydrographic Department Maritime Safety Agency
Germany:	Deutsches Hydrographisches Institut
Argentina:	Naval Hydrographic Service
United States:	National Oceanic and Atmospheric Administration

Most of the Great Lakes coastlines (except Michigan) belong to two countries, Canada and the United States. It is then obvious that each country is interested in the water level data collected by the other country. This is understandable when one considers the reservoir qualities of the system which is estimated from water level gauge reports from both coastlines. In order to do that, MEDS participates in the Physical Subcommittee of the Coordinating Committees of the Great Lakes Basic Hydraulic and Hydrologic data. Regular Exchange of water level information and weekly water level bulletins also take place between The State University College, Oswego, N.Y., the National Ocean Survey, Washington, D.C., the U.S. Corps of Engineers, Detroit, Mich., and the NUS Corporation, Maryland.

Under the guidance of the Canadian Hydrographic Service (CHS), MEDS has established an international data bank for the International Hydrographic Office (IHO). The bank consists of harmonic constants for stations in all oceans around the world. The total number of stations exceeds 3500 from more than 100 different countries. It has been opened to customers but the data quality checking phase is still in progress. Customers must submit their requests to the IHO office in Monaco, who in turn will contact the CHS, Ottawa. System 2000, a data base management system, operates the bank.

The coding of the IHO SP26 sheets began in 1974. In February 1976, a copy of all the information was sent to each country member of the IHO. Many countries have replied with their comments and the bank is now being modified accordingly. Most of the inaccuracies found were not due to coding but mainly due to errors in the original sheets.

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* *Present affiliation:* Marine Environmental Data Service

User Demands on Tidal and Current Groups within Hydrography

B. MOONEY
C.H.S. Atlantic Region

Knowledge of tides and currents is basic to Hydrography and Physical Oceanography. Our group's primary effort is of course, towards the needs of field hydrography in our region. But we also respond to requests from various other users.

It may be to provide services to oceanographers studying anything from the effects of sunlight on eel grass to numerical modeling of Tidal Regimes. Or possibly to provide tidal elevations to civil engineers who are builing dams, wharves or other coastal structures. Or for the general public we provide the "Clam Diggers' Hot Line" (which is especially busy during months without "R's" in their name).

There are two requests we receive directly or indirectly for which we can improve our response, by having,

1. the difference between Chart Datum (C.D.) and Geodetic Survey of Canada (G.S.C.) established wherever possible.

and 2. the tolerance for adjusting Sounding Datum (S.D.) to Chart Datum reduced from 1 foot to 0.5 feet.

Some of the benefits of referencing chart datum to G.S.C. datum (M.S.L.) are:

1. It allows direct comparison of datums on adjacent charts, especially in areas of overlap. (A special case of this situation is the boundary area between Canada and the United States in our region. For charts in this area soundings have to be compiled which are reduced to two different datum planes. (Mean Low Water (MLW) U.S. and Lowest Normal Tides (LNT Can.). If both datums were tied to G.S.C. the necessary correction needed to incorporate depths from one source to the other could be more easily and accurately determined.

2. Provide a more meaningful note on the Chart. As of November 1977 Cartographic Standing Order (#77-27) requires chart datum to be referenced to G.S.C. datum or M.L.W. (GSC preferred). It was felt that the old datum note referenced to a bench mark was of no real value to the mariner. Also having datum tied to G.S.C. has the backup of not just three C.H.S. BM's but really the whole Geodetic net.

and 3. Referencing C.D. to G.S.C. will have benefits to Engineers and Scientists who do their work to M.S.L. and require the difference between the datums to use our information.

In the sketch we can see the datum situation in Halifax Harbour. Note the corresponding difference between M.S.L. and M.W.L. (1973) and L.L.W.L.T. and sounding datum (S.D.). This difference is due to crustal movement over the last 50-60 years.

Sounding datum is determined by one of two ways:

1. A water level transfer (from a Reference Port)
2. From previously established Bench Marks.

Whichever method is used S.D. has to satisfy a criterion to become chart datum. At present the rule is S.D. = C.D. if S.D. = LLWLT ± 1.'0. LLWLT is a calculated elevation with respect to S.D. based on the harmonic analysis of the tidal record. So if the two differ absolutely by as much as 1 foot or less then S.D. is C.D. and no correction is applied to the recorded depths.

Some tolerance is required for two reasons:

1. the already mentioned continous rise in MSL means that LLWLT is always moving.

and 2. a difference can occur from one year to the next depending what length and stage of the tide was measured.

I would like to see this tolerance reduced from ± 1 foot to ± ½ foot. (I believe this is the criterion used in Great Britain).

This demand for change is really a demand for as realistic a chart as possible. At present in some shoal and/or harbour areas some soundings are shoal by almost one foot because of the present criterion.

User Demands on Tidal and Current Groups within Hydrography

F.E. STEPHENSON
C.H.S. Pacific Region

(1) User demands - what is required?

Our previous speaker has mentioned some of the international uses of tidal data collected by the Canadian Hydrographic Service and by Water Survey of Canada. I would like to bring the subject closer to home and briefly discuss Canadian users of tidal and current data. Some of these users, particularly outside users, are presently being spoiled by our Tidal and Current groups.

Not too many years ago if you requested tidal information, heights were provided to the nearest 0.1 feet, but because of improvements in instrumentation, particularly with in situ gauges, users are routinely requesting tidal heights in centimetres and sometimes even in millimetres.

Likewise, current velocities are now requested in centimetres per second where not too many years ago velocities to the nearest knot were acceptable, in fact they were the best available.

I think everyone will agree that there's no harm in taking full advantage of new technology, but only if it is required. We receive numerous requests for printouts or computer plots of tide and current predictions of centimetre accuracy, and many of these are valid requests, but some could be answered satisfactorily by the user refering to the Tide and Current Tables. If we are required to provide too much information (too high a degree of accuracy) this often involves extra time and money.

When you have a need for tidal or current data, think a moment - what accuracy of data do you <u>really</u> require? Do you require tide heights in centimetres or will decimetres or metres suffice, and for currents do you require velocities in centimetres per second or decimetres per second? Also, must you have observed data or is predicted data acceptable? There is a wealth of information in the Tide and Current Tables which may already meet your requirements.

I haven't mentioned the hydrographer yet, although he is certainly one of the main users of tidal data. I won't say that the hydrographer is spoiled, but there is certainly a danger of this happening. In situ gauges, telemetry, numerical models - all of these are useful tools for the hydrographer, but only if the survey warrents the expenditure of time and money required for their use. I believe that in most field surveys, tidal reduction information is already one of the strongest links in the survey. What is the accuracy of tidal information required on a particular survey? Survey Standing Orders 70-4 specifies the maximum allowable errors in refering soundings to sounding datum. Hydrographers should keep these figures in mind when requesting tidal information or instrumentation for field surveys.

I will conclude by asking the user, particularly the hydrographer, how well he feels he is being served by the Tidal and Current groups. Does the quality of our data meet or exceed your requirements? Are the standards laid down in Survey Standing Orders 70-4 realistic? I believe the answer to both of these questions is yes.

(2) User demands on Current Survey groups.

Although hydrographers still collect much of the tidal information used in our navigational publications almost all current data is now collected by specialized groups within hydrography or by other oceanographic groups.

Hydrographers and outside users seeking information on current surveys will find the information in <u>Tidal Manual 1970</u> already badly outdated. The table titled "Current Surveys" outlines procedures for the processing, analysis and dissemination of current data in Pacific Region and shows the many forms in which current data is available to the user.

CURRENT SURVEYS

COLLECTION	(a) Hydrographic Service	
	(b) Oceanography - coastal - offshore	
	(c) Others - private sector - universities	
PROCESSING	(a) Data edited & calibrated	
	(b) Data display - component plot - polar co-ordinate plot - time series - histogram - progressive vector diagram	published as Data Record
	(c) Data processing - harmonic constituents - daily residual current - rotary spectral analysis	
ANALYSIS	(a) Differences - comparison of observed to observed - comparison of observed to predicted giving - time difference - speed factor	published under Secondary Ports
	(b) Master Station - daily prediction of slacks and maximums in tide tables	
DISSEMINATION	(a) Data Record - publication	
	(b) Tide Tables - publication	
	(c) Nautical Charts - arrows	
	(d) Scientists	

User Demands on Tidal and Current Groups within Hydrography

B. TAIT
C.H.S. Central Region

User demands and the responsive actions in the areas of current information and International Great Lakes Datum were described.

The type of current information available and the demands made for this information were described, and an assessment made of the necessity to obtain and publish more information for the areas of the St. Lawrence River from Quebec to the Gulf and from Montreal to Kingston, and for the Great Lakes. Particular attention was given to the Lower St. Lawrence River where presently published information based on a 1934-37 survey is thought by oceanographers to give too simple a picture of an area of complicated tidal streams and river flow. Recent survey data could be published but the oceanographers involved in its collection feel that it is still too sparse to describe the variability of the currents.

One must choose between presenting the available but perhaps incomplete current data or waiting until the last eddy has been surveyed. The requirement for publishing additional data was also questioned in view of the intimate knowledge of the river that many users, i.e., river pilots, have.

Many requests are received to provide the difference between elevations based on International Great Lakes Datum (IGLD) and those based on Geodetic datum for various areas of the Great Lakes. The difference varies between 0.2 and 0.3 metres. It occurs because the zero for IGLD - mean water level at Father Point - is slightly higher than the zero for Geodetic datum - mean water level at five coastal tide gauges - and because IGLD elevations are adjusted for variations in gravity and given as dynamic heights, whereas Geodetic elevations are given as orthometric heights.

The difference is of concern to scientists and engineers working on coastal projects since they often must relate water levels which are given as IGLD elevations to the Geodetic elevations of land-based features.

An adjustment to the U.S. geodetic net, to be carried out in the early 1980's, will be based entirely on dynamic heights. It is possible that a similar adjustment will be made in Canada and that a North American datum will be defined. This datum would embody most of the requirements of IGLD and eliminate the need for a separate lakes datum.

Conference Luncheon Address

"The Widening Horizons of Hydrography"

REAR ADMIRAL G.S. RITCHIE
President of the Directing Committee
International Hydrographic Bureau
Principality of Monaco

On Tuesday 23rd January 1770, whilst 'Endeavour' lay securely at anchor in Queen Charlotte's Sound in the South Island of New Zealand, Capt. Cook wrote thus in his journal, "I took one man with me and climed up to the top of one of the hills but when I came there I was hindred from seeing up the inlet by higher hills which I could not come at for impenetrable woods, but I was abundantly recompensed for the trouble I had in assending the hill, for from it I saw what I took to be the Eastern Sea and a strait or passage from it into the Western Sea a little to the Eastward of the entrance of the Inlet in which we now lay with the Ship, the main land which lies on the SE side of this inlet appeared to me to be a narrow ridge of very high hills and to form a part of the SW side of the Strait. The land on the opposite side seem'd to trend away East as far as the Eye could see, to the SE appear'd as oppen sea and this I took to be the Eastern."

Thus by climbing 1300 feet did Cook widen his horizon, enabling him to see the strait which he was soon to be the first European to pass through and which bears his name to-day. He found the way and thousands, nay millions, followed.

Cook was the explorer, the discoverer, his greatest gift being his ability to lay down with accuracy vast stretches of previously unknown coastlines so that others might confidently sail to and along those coasts. "He reaped the harvest of discovery, but the gleanings of the field remain to be gathered," wrote Flinders when carrying out detailed surveys on the East Coast of Australia thirty years after Cook had first made his running surveys there.

Two hundred years ago this month 'Resolution' and 'Discovery' lay in Nootka Sound, anchored in deep water with their sterns moored to the rocky shore by hawsers. Cook was on his way to search for the North West Passage. He had discovered this inlet in which he sought refreshment and replaced some of his masts and spars from fine trees he felled in the forests. As always, instruments were landed to fix the position of the anchorage, but owing to work on the masts less time than usual was available for a survey. Cook sent his Master on some boat sounding trips in the sound and named the largest island Bligh after him.

Nootka was thus added to Point Venus in Tahiti, Queen Charlotte Sound in New Zealand, and Port Jackson in Australia as an anchorage of known security where exploring surveyors could seek with confidence respite, recreation, and refreshment. Each of such visits entailed the landing of instruments for the making of observations to improve the positional accuracy, so that these places took on a growing importance as points of geographical reference to which Pacific discoveries could be tied in. These positions were the forerunners of secondary meridians which served a similar purpose as seaborne chronometers came widely into use during the 19th century.

When Vancouver came to the North West Coast in 1792 he came more as a surveyor than an explorer. The emphasis began to change: along the southern shores of the Juan de Fuca Strait a new and more detailed form of running survey technique was developed, with detached boat parties working ahead of the following ships. Vancouver carried this painstaking technique right up through the inside passage, nearly losing 'Discovery', but proving the land which now bears his name to be detached from the mainland.

The long history of hydrographic surveying in British Columbia has been excellently told by R.W. Sandilands. In 1828 came that turbulent surveyor Commander Belcher in 'Sulphur', a name well suited to her Captain. He brought new techniques - "Only Masters still use the Azimuth Compass. In a survey ship instantly the sextant is in request; even the pleasures of the table are forgotten. Astronomical pursuits, surveying etc. have a peculiar attraction. Let but one moderate draught be taken fairly tested, a species of intoxication follows, scientific mania ensues. Example only is wanting, and if that happen to be the principal (Captain or Lieutenant) the contagion rapidly spreads - it becomes the fashion". Belcher claimed to have improved the station-pointer, increasingly in use since the turn of the century.

By 1853 the need for the exact positioning of the 49th parallel, and hence the boundary with the United States at sea and in coastal areas, revived the need for hydrographic work. The age of steam had arrived and Captain Richards in HMS Plumper, a steam sloop, began his ten year sojourn on the North West Coast, transferring to the paddle sloop 'Hecate' in 1861.

Richards' surveys soon passed from those connected with the Boundary Commission to those required for the placing of ports and townships in the developing Colony of Vancouver Island. He worked in close collaboration with Governor Douglas and the Surveyor General and advised on establishing lighthouses, laying navigational buoys and erecting beacons and on the training of pilots. Richards' period could be described as that of early development surveys.

During this period a modest shore office was established at Esquimalt and when Richards was recalled to England to become Hydrographer he was able to make arrangements for the chartering of the Hudson Bay Company Steamer 'Beaver' to continue the work under Staff Commander Pender until 1870.

Nearly 30 years elapsed before another British survey vessel came to these waters. By then Vancouver Island was a part of British Columbia, which in turn had been annexed by Canada. The Canadian Pacific Railway had arrived, the

Canadian Pacific liner 'Parthia' had struck a shoal in Vancouver Harbour, more detailed and larger scale surveys were needed, previously unimportant gaps required to be filled in. British Columbia's own surveyors had therefore commenced hydrographic work. The names of these pioneers of the Canadian Hydrographic Service - William J. Stewart, Henri Parizeau and others have been kept green, used as they have been for naming Canadian hydrographic ships.

HMS Egeria came to help on the North West Coast at the end of the century and remained till 1910, which period may be described as one of transition during which a national hydrographic surveying service took over from the British who finally withdrew. Here is a successful pattern we have seen in many, but by no means all, former colonies of European states as they have achieved their independence. In Canada's case we may perhaps regard the opening of the Institute of Ocean Sciences in Patricia Bay as a final milestone in establishing a national oceanographic and hydrographic organisation which stands, as a supreme example of such a development.

I now turn aside to speak of some of the gifted British surveying officers who were fortunate enough to serve in British Columbian waters. In 1863 Richards went straight from 'Hecate' to become Hydrographer. He had much to do with the preliminary voyages which set the scene for the famous Challenger Expedition of 1872-76. When Challenger sailed Richards stated that "an expedition such as this, which has been the hope and dream of my life, is now on the eve of realisation". The Challenger Expedition was the first to explore the depths of the oceans far beyond the continental shelves, her officers and scientists throwing open wide the windows to the far horizons.

On his retirement Admiral Richards became for twenty years the Managing Director of the Telegraph Construction Company which, under his guidance, laid 76,000 miles of submarine cable.

Among those who interested themselves in the thousands of wire sounding which cable laying necessitated was Prince Albert I of Monaco, who, adding them to his own considerable gleanings in the Atlantic, prepared the first GEBCO chart in 1904, the fifth edition of which is being published under the guidance of an international committee of hydrographers and scientists and is currently being printed by the Canadian Hydrographic Service.

Commander Learmonth of 'Egeria' has a very personal interest to me. He subsequently became Hydrographer and on retirement joined the Board of the Port of London Authority when my father was General Manager. He thus became an occasional dinner guest at my parents' house and as a young midshipman, not quite clear where I was going, I listened to his exciting yarns of life ashore and afloat as a surveying officer, including adventures in the Canadian forests. A fervant longing to join this little known band of naval officers arose within my breast and despite many attempts by gunnery officers and others to head me off I joined the ranks of the sea surveyors in 1936 and have never had a dull moment since. I owe my presence among you here to-day to Admiral Learmonth and his skill as a teller of tales.

Of the two other captains of 'Egeria' in British Columbia Captain Parry became Hydrographer and in 1919 the first President of the IHB.

Captain Nares, son of the Captain of HMS Challenger on the famous voyage, did not become Hydrographer but was promoted Vice Admiral and served as President and as a Director at the IHB from 1932 to 1957.

Searching for precedent and guidance in my present post I am particularly struck by the administrative ability and foresight which Vice Admiral Sir John Parry brought to the establishment of the IHB in the early years at Monaco. As President at the 1st IH Conference held in London in 1919, Admiral Parry saw with clarity a gleam of sunlight on a far horizon fifty years ahead. In winding up a conference debate on the question of metrication of charts he said "I may say that, as far as Great Britain is concerned (possibly, I ought to say, as far as I am personally concerned, which is a different matter) the Metric System, without a doubt, is bound to come".

Metrication has indeed come about and the need for massive changes to their charts which metrication requires has presented many hydrographic offices with the opportunity to improve the style, readability and appearance of their charts at the same time. I believe that here common membership of the IHO has almost imperceptively guided these improvements along the path towards international standardisation far beyond the limits of International chart schemes themselves. We at the Bureau, with daily access to all our Members' incoming charts, are in a unique position to note this satisfactory trend. Delegates to the XI IH Conference probably noticed this trend in the exhibition of Member States' charts which will no doubt be a regular feature at future conferences.

During the last 25 years we have seen the need for accurate large scale surveys extending into deeper waters to match the increasing draughts of modern day shipping. Meanwhile in the last ten years the sea surveyor's coastal horizons have been widened to reveal the need for resources surveys and the charting of sufficiently large scales of vast areas which are selected for exploitation, with all the rig and platform building, pipelaying and ship mooring that these operations entail.

As the Law of the Sea Conference wends its way from one venue to another with its 1500 delegates and technical advisors we surveyors stand poised to assess the surveying requirements which the creation of Exclusive Economic Zones and the establishment of an International Seabed Authority would bring about, knowing as we do that many countries which will take over these exclusive zones do not have the necessary surveying capability. The importance of these zones to the countries concerned may be seen when it is realised that in many cases the areas of sea will far exceed the national land area.

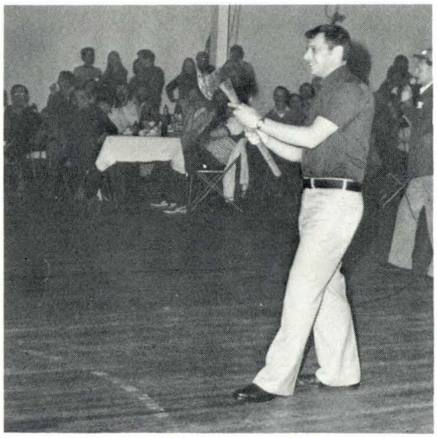
"With the interest created by the Law of the Sea Conferences and the concept of the 200-mile economic zone, many countries will re-focus their hydrographic activities to these broad new horizons." So reads a part of the Report of the Group of Experts on Hydrographic Surveying and Nautical Charting who met at the United Nations last December. Very broadly this Report recommends that countries without hydrographic potential should immediately consider the benefits of establishing a hydrographic service, and cogently sets down the many reasons for this recommendation. I commend the reading of this Report to everyone concerned with marine transportation or sea resources exploitation. We who are already in the hydrographic business must do everything in our power in the years ahead to bring about world-wide understanding of the urgent need for hydrographic expansion on the broadest front.

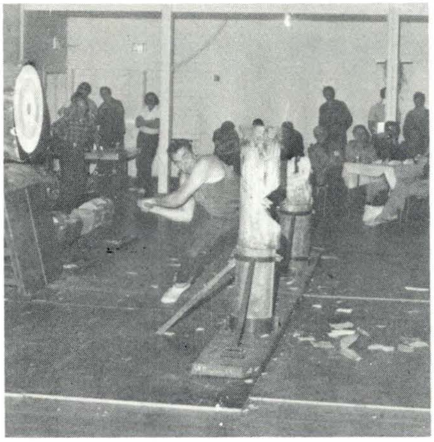
There are however dangers which I see ahead that may hinder rather than foster an advance on the broadest front internationally.

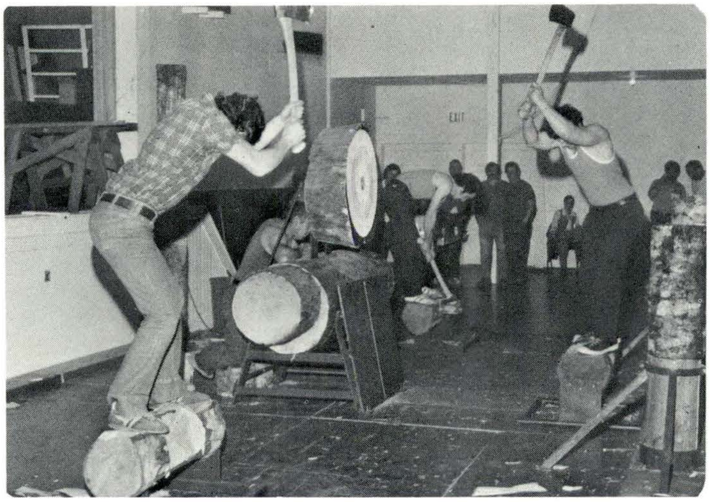
As the hydrographic survey systems get more complex only about a dozen of the world's leading hydrographic offices, the 'First League' we might call them, together with their commerical instrument makers, are engaged in the struggle to perfect these sophisticated systems for making the simple navigational chart more rapidly, more accurately and, they hope, more economically. We spend untold time perfecting the systems, improving them and describing them to our fellows in erudite papers, often incomprehensible to members of the less advanced hydrographic services.

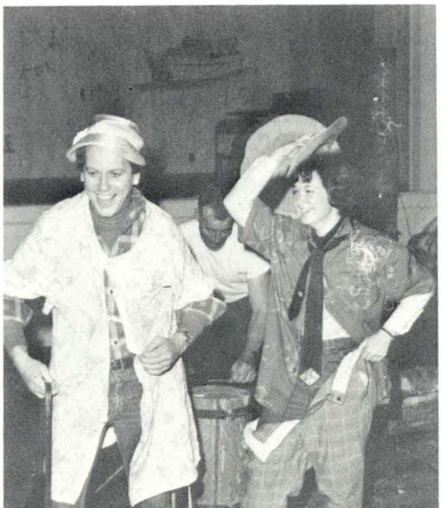
The danger I perceive, admittedly difficult to resolve, is that in our chase after sophisticated perfection we in the industrialised nations overlook the needs of the Third World, those very people whom we are urging to start up hydrographic services from scratch. We must try to close this widening gap by giving more impetus to the development of the simpler forms of echosounding and electronic fixing with a minimum use of automation and data banking and with the maximum emphasis on reliability and ease in fault finding. Indeed we should press for instrumentation which can be usefully and continually employed by men who have had months of hydrographic training rather than years, or have attained the minimum qualifications rather than a university degree. These people are our sailing companions on the voyage towards the broad new horizons, and only if we can sail together shall we arrive at our desired destination beyond those broad horizons.

Fun at the Sooke Soiree









President Wade presents the Lighthouse 1977 awards to John Watt for Best Technical Article.

Mr. McCulloch accepts Lighthouse award for Best Non-Technical Article on behalf of Adam Kerr.

Admiral G.S. Ritchie, Conference Luncheon Speaker

The "Fickle Finger" moves on to Gerry Ewing for the 1979 I.H.T.C., Ottawa, May 14-18, 1979.

List of Registrants

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EWING, G.N.
Dominion Hydrographer

BRUCE, JAMES
CHAMP, CYRIL
DEE, STAN
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DMA	Defence Mapping Agency
NOAA	National Oceanographic and Atmospheric Administration
NOS	National Ocean Survey
SHOM	Service Hydrographique et Océanographique de la Marine

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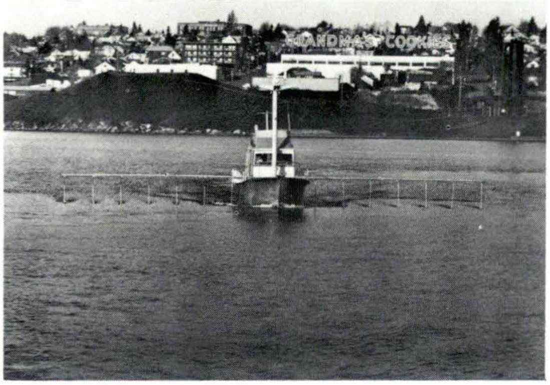

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