"Here Be Dragons..."

The gentle 'arte' of hydrographic risk assessment

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Nature abhors a vacuum…a blank chart exists as an invitation: to fill it with something, to go find out what is actually there, or just to fantasize and fictionalize the empty space.

The history of exploration, and fiction, and even some supposedly serious geography are full of such examples. There is the 19th-century push to map "darkest" Africa that led to the unlikely encounter between Stanley and Livingston. Or the contemporary effort to fill the "white space" of the Arctic, which resulted in the similarly improbable meeting of Frederick Jackson and Fridtjof Nansen after the latter's wintering in Franz Josef Land in 1896. The mid-1800's fantasy that the blank space hid a watery oasis of open water at the pole was disproven by Nansen's drift in Fram, but ironically is now anticipated with somewhat more justification, just as we have more or less finished "mapping" the Arctic.

The temptation to fill in the chart led many to chase the nothingness of unknown areas, but none so well qualified as Captain James Cook. As an experienced and highly skilled hydrographic surveyor, he was uniquely well-qualified to understand the risks of such a venture. Indeed, his oft-quoted ambition to go "farther than any man has been before me" was taken from his journal at the point that he achieved his furthest south in Resolution, but turned back from accepting additional risks.

In early charts, there had been clear indications to discourage more timid voyagers than Cook. A bold warning, "Here Be Dragons," or perhaps a discretely illustrated depiction of horrible sea monsters, made the point while enlivening the chart. But what warnings exist for modern mariners that the chart might not show all the dangers to be met? This article will explain some of the innovative ways in which some Hydrographic Agencies and engineering companies around the world are employing modern technology to answer this question.

Source: Pinterest

Risk …evident!

What risk?

The modern chart, with its standardized presentation, colour and neatly drawn contours, conveys an image of reliability and static perfection that is beguiling. This is even more so in the electronic form. The ability of many cheap and easily obtained chart plotters (on everyone's smartphone) to plot a position of previously unheard-of accuracy on a chart, scaled to the user's immediate area, gives a sense of comfort that might be out of keeping with the reliability of the underlying information. For example, the capability of such systems to interpolate between widely separated soundings could obscure the fact that there are *no* soundings in the user's area.

The greatest risks, of course, are totally unsurveyed areas. Luckily, there are few of these remaining, even within Canada's vast and lightly travelled Arctic waters; the last islands were outlined by aerial surveying in the late 1940s and there are now charts for every route through the north. However, the Canadian Hydrographic Service (CHS) estimates that only 10 per cent of the Arctic is "adequately surveyed" and only one per cent is "surveyed to modern standards." For the critical routes, the Arctic Marine Corridors, these numbers are 32 and three per cent respectively. While these numbers seem shockingly low, it must be appreciated that the qualifiers in those statements are used in a very precise manner related to international standards of hydrography.

That an area is not "adequately surveyed" may not mean that the available information is insufficient for all types of traffic. Hydrographic risk is not just a two-dimensional issue of comparing sounding accuracies in different areas. It is a complex problem of considering in how many different ways the totality of the hydrographic, navigational and meteorological information available might be insufficiently accurate for the intended use to which that info is subject.

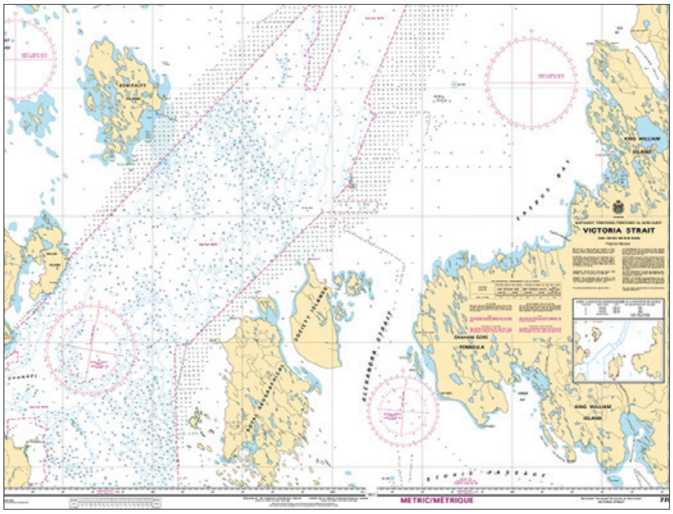
There might be many reasons for such insufficiencies. The shallow-water bottom topography could be changing due to seismic activity, silting or new obstructions (for example, wrecks, or jettisoned cargo/lost containers). The tidal range and cycles may be imperfectly predicted for a given area. The survey may have been conducted with means less accurate and less comprehensive in coverage than modern systems (i.e., not continuous, multi-beam soundings), and located with navigation systems far less precise than the GPS positions largely used today to locate navigators on the resulting charts. And those soundings may have been plotted (and so remain on dated charts) within a geodetic co-ordinate system (the frame of reference of the chart) that is at variance with the co-ordinate system of the navigation system in use. This variance in the worst cases can result in a lateral position error of a couple miles — very significant indeed if one is trying to follow an isolated track of proven soundings.

The available “meta-data” on the chart (date, survey means and coverage, co-ordinate system, etc.) is usually a good clue to the above hazards. Other factors, however, must be considered in forming an overall assessment of navigational risk: How are traffic patterns, volumes and sizes (draft) changing? In what ways are modern navigational systems changing practices to entail novel risks? And are changing attitudes and pressures on risk tolerance (for example, closer under-keel clearances — UKC) generating a demand for much greater accuracy in even well-travelled, well-surveyed areas? It may be the case that even in the approaches to a modern port, the consequence of a highly improbable grounding might demand a resurvey of an area that already enjoys the highest standard of modern survey.

The modern reliance on externally provided data and information means that the onus for navigational safety is shared among a large range of involved enterprises and agencies. Granted, the master is always ultimately responsible for the safe navigation of the ship. But the margins for error can be traced invariably to equipment manufacturers, navigation system providers, navigation aid maintainers, meteorological forecasters and hydrographic services. This dispersion of liability means that information providers, while progressively moving away from providing navigational advice (we see this in the eradication of routing suggestions from Sailing Directions, in lieu of merely factual Cautions and Warnings), are under increasing pressure to verify that the data they provide is not only accurate but is also the best info obtainable. The impact of this expectation is that modern means must be matched not just to the processes of hydrographic survey and chart production, but also to the business of prioritizing the annual activities of the Hydrographic Service.

Innovation with GIS

The Canadian Hydrographic Service, with one of the largest and most complex areas of hydrographic responsibility in the world, is one of the leaders in the use of advanced Geographic Information Systems (GIS) to formulate risk maps and use this to prioritize their survey and chart production activities.



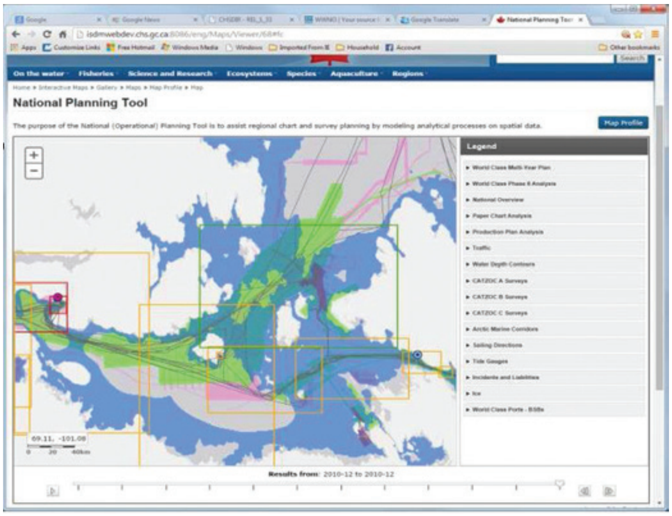
CHS Chart 7784: Survey quality self-evident (CHS)

GIS have the ability to combine large databases of geospatial information and to plot these in maps tailored to specific uses. We see this in applications as varied as comprehensive earthquake risk maps, or maps of persons of similar interests through social media. Increasingly, such systems are used to produce “heat maps,” drawing attention to geographic areas of special concern in many different disciplines.

The CHS Priority Planning Tool (CPPT) employs GIS methods to compile a sophisticated appreciation of hydrographic risk. It starts with the CHS database of soundings and related metadata from all previous surveys, so far as these have been digitized. This data is then ranked according to the International Hydrographic Organization’s (IHO) system of Category of Zone of Confidence (CATZOC). CATZOC was developed to standardize the means of qualifying and conveying hydrographic uncertainty on electronic navigational charts (ENC). It considers vertical and lateral uncertainties in measurement with completeness and currency of survey to assign a category from A to D in five levels, with A1 (five stars) being the best and U being Un-assessed. This can be selected and displayed on an electronic charting and display system (ECDIS) to alert the navigator to the quality of information upon which he is reliant.

The CPPT goes several steps further than this in combining other factors that influence the probability of grounding. These include additional hydrographic factors such as depth and seafloor complexity, tidal range and chart “wellness.” Traffic factors, such as proximity to shipping lanes and ports/anchorages as well as port volumes, introduce elements of shipping frequency, density and diverse cargo potentials. And key meteorological factors, such as wind speed and ice coverage, add distinct casual elements to the risk model. In the CPPT, values for all these factors are calculated for each geographic cell in the CHS database. These factors are then weighted, summed to give a composite risk score, and shaded on a 25-point scale to give a comprehensive “heat map” of key hydrographic risk areas nationally.

The CPPT is primarily used as a professional tool to help determine national priorities for field surveys, data collection and chart production. As such, it is only one input to a complex annual cycle of prioritization, planning, budgeting and scheduling. While the full capability of the tool is only available to CHS hydrographers, the general output of the CPPT is available to the public on CHS’ website, where



CPPT highlighting of work remaining in key marine corridors of the Arctic (CHS)

a comprehensive risk map and list of risk-ranked charts is available (http://www.charts.gc.ca/help-aide/about-apropos/risk-risque-eng.asp). Of interest to *BCSN* readers, approach and harbour charts of both Vancouver and Nanaimo as well many charts of the Strait of Georgia and surrounding areas, are graded as "High" risk. This reflects not so much that they are dangerously incomplete, but that hydrographic pressures are being generated by increasing traffic (volume and size) and tighter under-keel clearances.

International pace-setters

CHS is one of the pace-setters in this business of using GIS to highlight and rank areas of hydrographic risk, but many others are trying similar, if slightly different approaches.

The US National Oceanic and Atmospheric Administration (NOAA) has an elegantly simple system that makes available to the public the Hydrographic Survey Priorities in an ArcGIS web portal. They are also applying a simple model of GIS risk-calculation as part of their work with the Arctic Regional Hydrographic Commission.

Regional Hydrographic Commissions around the world have been sharing ideas and developing risk models to suit their own areas under the support umbrella and international standardization of the International Hydrographic Organization (IHO). In many places, like the North Sea and the South-west Pacific, multiple bordering maritime jurisdictions beg for a co-ordinated response in areas outside national territorial responsibilities.

A particularly sophisticated and comprehensive example of this co-ordinated approach is the work of Marico Marine in conjunction with Land Information New Zealand (LINZ, the NZ equivalent of CHS). In several projects since 2013, conducted by LINZ/Marico on behalf of the South West Pacific Regional Hydrographic Program, they have evolved a very mature methodology. Sharing some of the features of the CPPT, the Marico model goes further in considering likelihood factors such as types of traffic, and consequence factors, such as ecologically or culturally important areas that traffic transits. It has also evolved to consider cost-benefit factors, which is particularly well developed for the application of this methodology to all NZ waters.

It is one thing to know the state of hydrographic risk; the IHO estimated in 2013 that more than 95 per cent of the SW Pacific and Polar regions were not surveyed or required better data. This figure only drops to 65 per cent for Australia, and 40 per cent for the U.S., and even France had 19 per cent of their maritime territory needing attention. It is quite a different thing, however, to address this need, particularly in the face of declining global survey capacity (down 35 per cent in 25 years). The LINZ/Marico methodology includes a charting benefit assessment, measuring the cost of improved charting in heightened risk areas, alongside the risk.

With the widespread use of modern navigation systems of high accuracy, and the ubiquity of data-logging and sharing systems, more hydrographic agencies are beginning to consider if "crowd-sourcing" bathymetric data can answer the growing requirement for current and precise data of comprehensive coverage.

A couple of local solutions to this problem are worth mentioning. The use of autonomous underwater vehicles (AUV) for hydrography was pioneered by CHS in partnership with International Submarine Engineering of Port Coquitlam. What was initially known as the Deep Ocean Logging Platform with Hydrographic Instrumentation and Navigation (a comprehensively descriptive title that is perfectly visualized by its acronym: DOLPHIN) in 1981, has evolved into an impressive range of AUVs for all kinds of civil and military applications. One of these, the Arctic Explorer, has demonstrated particular prowess in under-ice surveys supporting Canada's continental shelf claims.

Another Coquitlam firm is taking a different approach — real-time bathymetric monitoring. Kongsberg-Mesotech has developed the Berthwatch system for continuous monitoring of depths in the vicinity of underwater structures. The system employs fixed hydrophones to continuously map the seabed for any changes in depth. With continuous monitoring, the vagaries of tidal predictions and dated surveys can be dispelled in order to realize greater ship drafts by as much as a metre or more. The Berthwatch maintains a safe approach by immediately highlighting changes in bathymetry.

This can be critical in berth approaches, where changes to depth (silting, seismic shifts, or just new obstructions) can pose significant risks to vessels with tight UKC. Being able to maximize the earning potential of the ship (and the port) is just one more way in which a finer appreciation of hydrographic risk is a matter of widespread interest.

The prudence of mariners…

Ships' Captains are historically reputed to be among the most conservative, careful and prudent persons. But that does not mean timid; that would certainly be a mis-characterization in a business that requires consideration of risk as an almost daily condition of service. However, the opposite of timidity is not carelessness. Far from this, the prudent mariner is one who understands the nature of the hazard, takes the care to become informed of the specifics, and then makes a plan to minimize the risk. And this is where navigational (and hydrographic) scientists meet practitioners: in the shared interests of using every conceivable means to better understand and manage their environment. Such will be the shared interests of attendees at the NIBC May conference on Managing Marine Risks, when they meet to learn more about issues such as these.

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