Australian Hydrographic Service – Charting the Australian waters near and far

L Pietrini
Australian Hydrographic Service, Wollongong, NSW

Abstract

The Australian Hydrographic Service (AHS) collects, manages and disseminates a vast amount of hydrographic information for the Australian coastline, including New South Wales. Ensuring safety of life at sea, dictates the collection and dissemination of hydrographic data. Incidents resulting from a lack of accurate data are potentially catastrophic in terms of loss of human life, economic loss, maritime security and degradation of the marine environment. The AHS is also the Australian Defence Force agency responsible for the provision of maritime data and products for military operations, exercises and support roles.

The United Nations has decreed World Hydrography Day as the 21st of June and the focus this year is the 'Blue Economy'. The term 'Blue Economy' refers to the sum of all economic activity associated with the oceans, seas, harbours, ports and coastal zones. Every human activity conducted in, on or under the sea, depends on knowing the depth and the nature of the seafloor, the identification of any hazards and an understanding of the tides, currents and the characteristics of the water column.

Data collection includes near shore bathymetry, with the primary use of this data to depict intertidal areas, rock and coral reefs and changes to shoal areas that are navigationally critical. These datasets could be of great value for a range of purposes such as modelling coastal and flooding processes, understanding near shore changes through time, modelling of potential impacts of climate change, etc.

Issues related to applications of AHS data will be discussed, such as the management zones of Batemans Marine Park and updating the Brisbane River charts after the 2011 floods.

Introduction

The RAN Australian Hydrographic Service is the Commonwealth Government agency responsible for the publication and distribution of nautical charts and other information required for the safety of ships navigating in Australian waters. The AHS is also the Australian Defence Force (ADF) agency responsible for the provision of operational surveying support and maritime Military Geographic Information for ADF operations and exercises.

The RAN assumed responsibility for hydrographic surveys in 1920, and for the publication of charts in 1942. In 1946, Cabinet decided that the Navy would maintain the national responsibility for hydrographic surveying, nautical charting and the provision of hydrographic services. Hydrographic charts and ENCs are legal documents and the AHS is responsible for ensuring they are correct and up to date.

As the national charting authority, the AHS is responsible for the management of Australia's surveying program and charting area. We are responsible for charting over 30,000kms of coastline and more than 1/8 of the earths water surface.

The Blue Economy

Hydrographic services are essential enablers for the safe and efficient transport of goods and people within the maritime domain and are integral for the economy, development of effective infrastructure and the future growth of Australia. Australia as an island nation is dependent on maritime trade as more than 90% of our total trade by weight is carried by ship, which is valued at close to $300 billion annually.

Increased maritime trade, larger vessels and more demand for timely product delivery has placed increasing pressure on the sensitive marine environment. Providing mariners with information about shipping routes, environmentally sensitive sea areas, restricted zones and protected zones help ensure that the marine environment remains protected.

Typically, official nautical charts are used to facilitate more than 10,000 international trading voyages each year, including in excess of 25,000 port entries. Therefore hydrographic surveying and nautical charting forms a significant part of Australia's national infrastructure providing access to ports from the sea.

Safety of life at sea plays a major role in hydrography. Incidents due to lack of hydrographic data can be potentially catastrophic in terms of: loss of human life, economic impact, maritime security, degradation of the marine environment and safe navigation.

AHS Products

The AHS current portfolio consists of 463 paper charts and 853 published Electronic Navigational Charts (ENCs). All but two of the paper charts are on the WGS84 spheroid; the two charts that are on AGD66 are currently under compilation. Once the two paper charts are published we will then be able to capture them into an ENC. We are aiming to have full ENC coverage by June 2014.

The AHS also manage the Digital Hydrographic Database (DHDB), Validate and assess all incoming survey data, produce and distribute National Tide Tables, Produce and distribute Australian Seafarers Handbook, Notices to Mariners tracings and editions, e notices on the AHS website and Print on Demand (POD) services.

Chart Evolution

The earliest drawn charts were based upon limited information and were far more superstition than fact. Some charts even said here be monsters. Up until the 1700s content was built up over time through the acquisition of ad-hoc information and the occasional voyage of discovery.

For Australia, vast sections of the continent were missing or were no more than guess work, there were gross distortions in shape and scale, and the detection and positioning of underwater hazards was limited to what was visible to the eye.

Technology progressed with the development of celestial navigation methods, time pieces, controlled survey methods and echo sounders. For example, Captain Cook's

1770 chart shows the greater accuracy achievable when using chronometers to determine longitude. The first ship to use this chart was HMS Sirius in 1787.

The path from the early charts to today may not have been as dramatic as the charting of a new continent, but the changes have been fundamental.

The imperial charts that prevailed until around 1970 were typified by the variety of horizontal and vertical datum's that prevailed both within and between national areas of coverage. The last of these charts Aus444 was replaced in March 2012 as a large project to capture all paper charts to be metric and be consistent with international standards.

The technology available during the surveys contributing to those charts meant that mariners frequently noted changes in their position depending upon whether they fixed based upon one set of features or another. In contrast, Electronic Navigation Charts are intended to be on one uniform set of datum's using metric units of measurement.

Creation of ENCs from older charts, has therefore been a significant challenge, and in the Australian experience, has involved returning to the original surveys, re-referencing many of these surveys either against modern land survey networks, against satellite imagery, or by sending survey teams into the field with GPS. The program continues to be a significant challenge and is the largest program undertaken by the Australian Hydrographic Service in 60 years.

The development of instruments and systems used to conduct hydrographic surveys and the tools used to compile the resulting navigational charts and related products has changed significantly over time. It has been a journey from lead-line to echo sounder and Sonar systems to laser. From Sextant to radar and Electronic shore based positioning systems to SATNAV and GPS. From Pen and ink to Geographic information system to collect and process hydrographic information and produce charts.

Production Tools

These days all our navigation products are made using GIS software. The Production software we use is CARIS, which is a Commercial software package customised for AHS purposes.

For paper charts, quality control consists mainly of "heads up" checking, supplemented by manuscript plots of the chart at various stages of the compilation process. For ENCs, quality control consists of manual checking every object and attributes encoding in CARIS through strict validation checks, and then rechecked through third party validation tools, to ensure the ENC is encoded correctly. Finally additional quality control of completed ENC cells is conducted in type approved ECDIS systems to visually check the presentation of features from a mariner's perspective. All products are compliant to international standards and specifications of the International Hydrographic Organisation (IHO).

Chart Products

Nautical charts are special purpose maps specifically designed to meet the requirements of marine navigation, illustrating features such as depths, nature of the seabed, elevations, configuration and characteristics of the coast, dangers, and aids to navigation.

Priorities for national chart production are:

- The inclusion of navigationally significant dangers and changes to all forms of charts as they are discovered or advised – generally termed “chart maintenance” or Notices to Mariners (NtMs).
- Port and approach coverage on ENCs - in response to emerging demands from port authorities and in recognition that navigationally constrained areas are those that will benefit most from the availability of ENC coverage.
- The expansion of small-scale coverage in response to IMO and IHO priorities to encourage the use of ECDIS.
- Portfolio Improvement Programme – predominantly the upgrading of charts to metric units and consistent datum’s namely WGS84 and LAT, particularly where these charts are essential to the subsequent production of a required ENC.
- Coastal passage and other shipping routes on ENCs - particularly those with the highest levels of SOLAS traffic.
- International obligations - the need to meet specific charting responsibilities to PNG, and meet national responsibilities under the IHO International Charting Scheme, including the Antarctic region.

Source Data

The first step in creating a new chart, new edition or update is to collect the source data. A number of sources are used to create and update the charts such as:

- RAN bathymetric data
- Non-RAN bathymetric data privately captured surveys
- Port/harbour infrastructure
- Topographic information from local, state, and commonwealth sources
- Satellite imagery
- Navigation aids
- International Notices to Mariners
- Maritime Boundaries and Limits
- Larger scale charts and plans
- Tidal/geodetic data

Sounding Selection

Sounding selection is one of the most important tasks performed by the nautical cartographer during the compilation and maintenance of a Nautical Chart. When a danger to navigation exists, soundings must be selected to represent the situation to the mariner. Soundings must also be selected to show as many routes as possible which may be followed in safety, based on the specific intended usage of the chart. Emphasis must always be placed on a shoal bias depiction of the depths and clarity of presentation if the chart is to be of any use.

Modern Chart production platforms, such as the computer programs used in the office, contain tools which aid the compiler performing sounding selection in ways that were previously unavailable to cartographers that operated in a purely manual production environment. Such tools include database systems that allow for the deconfliction of all survey data in the area of interest into a single, uniform dataset on common datum’s; automated contouring; depth colour banding; and sounding suppression algorithms to perform an analysis of a sounding dataset and mathematically select a subset of the dataset that is representative of the sounding selection pattern required.

Such automated processes, while considered to be a very good tool, must not be considered to replace the human element in the sounding selection process, which must include assessment of all the variables (not just mathematical) inherent in the area to be charted. It has been recognised world-wide that there are currently no automated systems capable of producing an ideal sounding selection for navigation purposes. Additional factors that must be considered when determining a satisfactory sounding pattern for a particular area include:

- The scale of the chart. This gives an indication as to the intended usage of the chart by the mariner.
- The purpose of the chart, for example: navigation through a specific channel or general approach to a harbour mouth.
- Seafloor topography: The sounding selection pattern can vary greatly dependant on the unevenness of the seafloor. A closer, more irregular sounding selection pattern is normally required in an area of greatly undulating seafloor topography, while a more regular, consistent pattern is sufficient for a relatively flat or evenly sloping seafloor.
- The depth of the water is also a factor – in general, soundings can be more widely spaced in deeper water, gradually becoming more closely spaced as depth decreases.

Density and available surveys for production

The sounding selection pattern is often an indication to the mariner of the density and quality of the underlying survey data used to compile the charted area, for example a sparsely surveyed area covered only by track plots (individual lines of sounding) should have a sounding selection pattern that clearly indicates the tracks, and areas not covered by the tracks, to the mariner. This will indicate to the possibility of an undiscovered shoal existing outside the tracks. Differing density of the selection pattern may also be utilised to provide the mariner with an indication that areas have been surveyed to different levels of quality.

Each survey gets assigned a ZOC value for horizontal accuracy, sea floor coverage and vertical accuracy depending on the conditions the survey was performed in and the instrument used. This quality is displayed in the Zone of Confidence (ZOC) Diagram on the paper chart or as a M_QUAL feature in an ENC representing the quality of data in the area. The mariner uses this information to get an understanding of how reliable the soundings are in the area they are navigating in.

Contouring

In modern production systems functionality exists to automatically generate depth contours based on the sounding data stored in the system/database. This contouring must not be considered to be representative of the final charted contours, but may be used as a tool to aid in the selection of charted soundings and as a guide for the interpolation of charted contours.

Soundings and contours must be used to complement each other in giving a reasonable representation of the seafloor, including all significant breaks in slope.

The responsibility of the cartographer is, through the use of depth contours and soundings, to provide the mariner with as accurate a representation of the seafloor as possible, maintaining the shoalest picture. Mariners often compare echo sounder readings with charted depths as an aid to position fixing, and if the full range of depth is not indicated the mariner may be misled into thinking that they are farther offshore than they actually are.

ENC Production

An ENC is an official vector electronic chart produced in International Hydrographic Organization (IHO) S57 format.
It is a digital database of all the objects (points, lines, areas, etc.) represented on a chart.

The versatility of the ENC vector chart database and the comprehensive Electronic Chart Display and Information System (ECDIS) display and performance standards allow the mariner to select and display relevant navigational information to the requirements and the situation at any time.

ENC Attributes

ENCs contain much more information than a paper chart; each object on an ENC can have several attributes. Some attributes are mandatory while others are optional. Some determine whether an object is in the base display, some objects make no sense without certain attributes, some attributes are necessary to determine which symbol is to be displayed, and some are required for safety of navigation.

All mandatory attributes for an encoded object must be present in an ENC. Some objects are seasonal. Such as fishing grounds which are only in effect during certain months of the year. This can be encoded as an attribute, whereas on a paper chart we would have these months written next to the object.

All features in the ENC have a list of attributes that can be populated, this information is then used by the ECDIS to help ensure safe navigation. This system will respond to the safety depth contour based on a vessel's actual draft, dangers or hazards will be identified automatically by warnings and alarms and the level of chart detail can be adjusted according to different circumstances for clarity and purpose.

SCAMIN

The Scale Minimum (SCAMIN) value of an object determines the display scale below which the object is no longer displayed. Its purpose is to reduce clutter, to prioritise the display of objects and to improve display speed. In encoding its value, we need to consider these factors, as well as the scale at which the object is no longer likely to be required for navigation.

Data capture

Hydrographic surveys and fairsheets were historically produced as paper products either by hand or by other means such as stencilling. Since then, all historic fairsheets have been captured electronically. There are many reasons to why they have been converted to digital as listed below:

- Take up less physical space – space efficient.
- Historical data is protected from insects, water damage etc.
- Easier to use – modern cartography is done using computers so it's easier to have the data already in electronic form.
- Files can be altered for processing purposes i.e. geo-referencing.

All fairsheets have been scanned and saved as tiff images, many of which have also been geo-referenced. These are known as geo-tiffs. The geo-referencing is primarily done using CARIS software and often involves the transformation of the data to the WGS84 spheroid. This depends on the knowledge of the datum, ellipsoid and projection used to compile the fairsheet and the shifts needed to transform the data. Geo-referencing of old paper products can also be complicated by factors such as paper stretch which can affect the accuracy.

The geo-tiffs are then viewed in a GIS so the soundings printed on the images can be captured digitally as latitude, longitude and depth. Many of the historical fairsheets have had their sounding information digitised and stored in vector format but not all as there are so many in our archives. The vector format most commonly used by the AHS is HTF, (Hydrographic Transfer Format). However the data is also stored, supplied and transferred in various other vector formats from ports authorities and other agencies.

Data Density issues

One of the biggest issues facing cartographers is the shear volume and density of sounding information collected with modern survey techniques, and how to represent this on a chart so its both easy to read and safe for navigation.

Bathymetric survey data is primarily collected using multibeam echo sounders or a Lidar sensor called the Laser Airborne Depth Sounder (LADS) and the data collected by these sensors is extremely dense. A 3 month multibeam survey can produce around 800 million soundings.

Typically these techniques can produce anywhere between 1 and 50 GB of data for a LADS survey, and 100'sGb of data for a multibeam survey.

All of this source data is used to generate the contours on a chart, however for display purposes, only a selected sample of the soundings make it onto a traditional paper chart. The soundings must be thinned so they're readable, whilst still preserving the shoalest picture, which is safest for navigation.

Sounding suppression V's gridding

Thinning a dense multibeam or Lidar survey is known as sounding suppression and it differs from surface interpolation and gridding techniques because of this preservation of the shoalest picture. Sounding suppression selects soundings using either the Circle of Influence (COFI) or Nearest Neighbour algorithms depending on the purpose for the chart.

The COFI algorithm preserves soundings that have a shallower value than those surrounding it. The COFI of a sounding is a function of the depth, with a larger radius as sounding values get deeper. The end result is more soundings shown in shallower areas than deep ones.

The Nearest neighbour algorithm performs sounding selection by removing soundings over flat featureless terrain and preserving them in areas with irregular terrain (such as the continental shelf).

Gridding techniques can produce nice looking coverage's, however the surface values have been calculated by the algorithm, they are not actually measured points. Therefore gridding doesn't preserve the shoalest soundings so it's generally not well accepted in nautical cartography. In less navigationally critical applications, gridding is accepted and is used in many instances for maritime MGI situational awareness and 3D visualisation of the battle space.

Data capture issues

When attempting to create a seamless dataset including both bathymetric and topographic data in a digital terrain model one needs to be very aware of the different vertical datum's used and the sign of the elevation (noting that soundings are positive downward from LAT).

It is this "white ribbon", surf zone, inter-tidal area, littoral zone, whatever you might call it, that is of significant importance to paper charts and ENCs and is often poorly understood by land-based geospatial analysts and the topographic cartographers. To a mariner these areas are to be avoided and the representation is vital for safety to navigation.

There is a requirement in nautical charting for the safest situation to always be shown which means that contours need to be drawn to represent the first occurrence of a particular depth coming from deeper water. This presents a challenge to the automated contouring packages and often contours need to be cartographically displaced to encompass a particular sounding.

It is far quicker to use automated contouring software packages to produce the contours on a chart, however none of these packages can replace the human eye in terms of accuracy, interpretation and presentation for use.

Similarly, software limitations can cause issues when geo-referencing data across the dateline. Most software is configured to think of the earth as 4 hemispheres, North, South, East and West. North and south latitudes are divided by the equator 0 deg line with North having positive values and south having negative values. East and West longitudes are divided by the 0/180 deg line, with the East hemisphere being represented by positive values and the West hemisphere by negative values. When an image is geo-referenced to positions crossing the hemispheres, often GIS software such as ArcGIS will display the geo-tiff as though it has been cut in half and mirror reversed. This can be overcome by geo-referencing the chart and assuming the earth is divided into 360 deg lines of longitude, rather than 2 lots of 180 deg.

The capture of metadata is another common issue experienced at the AHO as allot of data we use is sourced from 3rd party private companies which use their own methods and datum's that make it difficult to transform into WGS84 and LAT.

Vertical Datum's

MSL - an approximation of the geoid based on tidal measurement at individual locations, used extensively for topographic and engineering surveying and mapping. For nautical charting, MSL is not a suitable datum. The navigator needs to know what is the least depth that is below his vessel without regard to the particular tidal state.

Hydrographic charts use a low water Chart Datum which is the level below which the tide rarely falls, and to which soundings on a chart are reduced and above which tidal predictions are given. The geoid is far from a smooth regular surface. It has significant undulations up to several 100 metres in places. Heights are also important as the vertical datum must also be recorded in the GIS to assist mariners with position fixing and distance measurements.

Lowest Astronomical Tide (LAT)

- Chart datum recommended by the International Hydrographic Organisation (IHO). LAT is adopted by the AHS for our newly published products.
- Correctly determined by analysis of tidal observations over an 18.6 year period – lowest tide encountered in this period.
- LAT varies from chart to chart and along the coast as it is based on local tidal observations, and effected by the tidal regime (macro/meso/micro)
- Can result in a range of sounding adjustments for a single survey.

- LAT provides the most generous maritime boundaries and is allowed to be used for maritime boundary calculations under the 1982 UN Convention on the Law of the Sea.
- Meteorological conditions can produce a lower tidal level such as offshore winds (opposite of storm surge/wind setup) and high pressure systems.

Horizontal Datum's

Local horizontal datum's are based on the geographic position of a fixed object such as a lighthouse, observatory and a pre-defined ellipsoid. Basic mathematical 'model' (e.g. CLARKE 1858 ellipsoid) was used for simplicity as they predate the use of computers.

National horizontal datum's are based on continental scale/relevance – they have a geodetic centre not related to the centre of the earth. Australian Geodetic Datum 1966 (AGD66) – a best fit of the MSL geoid over the Australian Continent is still used extensively in Oil and Gas Exploration.

Satellite mapping has vastly improved the accuracy of the earth's geoid. A global datum requires that the reference ellipsoid has its origin related to the centre of the earth and best fit to the geoid. A geocentric datum is one that best fits the ellipsoid to the geoid over the entire earth such as WGS84 and GDA94; both are used with GPS systems.

Some issues are:

- Our current published portfolio for paper charts reflects all of the above mentioned datum's.
- The IHO has recommended that all charts be converted to WGS84 for consistency with GPS – GPS is referenced to WGS84
- The S-57 standard for ENCs states that all ENCs must be referred to WGS84.
- The AHS is pushing to recompile older charts that are not referenced to WGS84. All new charts are produced on this datum.
- Problems arise when manually navigating on two systems such as ENCs and paper charts, or from a chart on one datum to a chart on another datum.
- You would be aware that the average difference between AGD66 and WGS84 is approximately 180m. Local datum's can vary more than this.

Horizontal datum's and Maritime boundaries

Different countries use different datum's for various reasons and often datum's can affect territorial claims, rather a preferred datum can relate to offshore resource exploitation, resulting in $$$. Problems arise when countries lodge territorial claims based on different datum's.

In Australia state authorities use MGA94 for accuracy; this must be converted to WGS84 for charting and database storage.

Historically territorial seas were 3NM from the coast – the canon shot rule.
Now Territorial Seas, Coastal Waters, Contiguous Zones, Exclusive Economic Zones and Extended continental shelf areas are based on the 'territorial base lines' from which all these boundaries are drawn.

Projections and boundaries

Under UNCLOS boundary and baseline definitions often use the term 'straight line' such as Territorial Sea Straight Baseline. It must be realized that a straight line on one projection may be curved on another therefore when defining straight line limits it is important to specify the type of straight line to be used. Such as:

- Geodesic (Great circle) – shortest distance along an ellipsoid.
- Rhumb line (loxodrome) – straight line of constant bearing.

The difference between the two can be significant but in some cases they are the same e.g. the equator and lines of longitude are both Rhumb Lines and Great Circles.

Whilst it may appear to be a contradiction that a curved line can represent a shorter distance than a straight line on a chart, due to the increased scale towards the poles, lines closer to the equator represent longer distances. This also affects curved boundaries defined as a distance from a particular point; the particular line used to measure the distance may affect the location of the boundary.

Aeroplanes fly along Great Circles (Geodesic lines) as it's the shortest distance between 2 points. Ships sail along Rhumb lines as they are lines of constant bearing and appear as straight lines on Mercator projected charts.

Final Products

After drawing coastline, contours and selecting soundings, the rest of the data that is product specific can be added. This includes topographic information, navigational aids, lights, beacons, buoys, port infrastructure, names of features, seafloor quality data, and any other features used for navigation.

Legal considerations

Batemans Marine Park

The departments who draft the boundary legislation would benefit if they consult GIS users for feedback on how the information is displayed or used by the customers. From a mariners perspective they use the graticule, measuring tools and coordinates to plot their position. For accuracy purposes the horizontal datum's not mentioned. This legislation is passed through parliament so the end user could be illegally in the marine park. The implications can affect users in different ways but usually financially and legally.

The Batemans Marine Park boundary is described as:

> "From a point on the 20 metre contour, as shown on chart AUS191, approximately 1.1km due east of the point where the mean high water mark on Clear Point intersects latitude 35°36.538' then generally northeast along the 20 metre depth contour, as shown on Chart AUS191 to the point of commencement"

Problems with this may be:
Firstly small boat operators are not required to carry the official published paper chart AUS 191, only ships heavier than 500 tonne.

Secondly, the words "approximately" and "generally" throw considerable amounts of personal interpretation into the description.

Thirdly, AUS 191 will most likely be printed as a new edition to show the marine park, with all new data included. If new survey information is available the contours will be redrawn. This maintenance action throws the legality of the entire park into question as the depiction will change.

Key points to think about

- The AHS relies on third parties to provide data to enhance our products – we do not generally have permission to release third party data (but can direct interested parties to the data owners). Common data suppliers are State Government Agencies, Resource Exploration Companies, Port Authorities, Maritime Safety Authorities, Infrastructure Development Companies, Private Survey Companies and similar.

- In general, the AHS has limited near shore data (this is generally supplied by third parties) – we do not survey inland waters/estuaries unless they are navigable by shipping and our surveying/charting program is driven by a range of safety, industry and Government/Defence requirements. More near shore data is needed to improve our products.

- AHS survey data is indexed on the Australian Spatial Data Directory (ASDD) (metadata is available regarding AHS Survey data coverage, date and data format) - http://asdd.ga.gov.au/asdd/

- Details of AHS chart products are found on our website – www.hydro.gov.au

- To access AHS data, contact hydro.licensing@defence.gov.au and outline area of interest and general purpose. If we have data available we will need an application form completed and will supply the data under Licence.