The Application of New Hydrographic Survey Data to NOAA's Electronic Navigational Charts

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Abstract

Electronic Navigational Charts produced by the U.S. National Oceanic and Atmospheric Administration (NOAA) have been available for free on the Internet since 2001. Available initially as a provisional product, these ENCs were not certified for use in navigation and did not contain updates for Notice to Mariners information or new source data. In July of 2003, NOAA ENC®s were certified for navigational use and updated for new Notice to Mariners corrections. The application of new source hydrographic data to ENCs, however, remained a laborious process. The production of NOAA ENC®s consists primarily of vectorizing data from NOAA's raster chart series, augmented in some instances by higher precision source data for features such as navigation channels or harbor facilities. Thus, to update the ENC with new hydrographic survey information, NOAA would first apply the data to its base raster chart series, then digitize the new chart in order to create the ENC, essentially rasterizing vector data and then re-vectorizing the raster data. Apart from the inefficiencies associated with this process, the positional integrity of the new source data was often lost due to the cartographic generalization required with the portrayal of information on paper and raster charts. Using CARIS HIPS and CARIS HOM, NOAA's Office of Coast Survey is developing streamlined procedures to rapidly apply new hydrographic survey data to its suite of ENCs. These procedures will create vast efficiencies in the process and improve the positional accuracy of the information portrayed, resulting in a more accurate and timely product for the mariner. As NOAA looks toward a future which includes chart production managed within a centralized hydrographic database, these new processes will prove essential in the population and quality assurance of data within that database. This paper discusses the procedures developed using CARIS technology in applying new hydrographic data to ENCs.

Introduction: NOAA's ENC Program

NOAA's Office of Coast Survey (OCS) has been involved in the development of a NOAA Electronic Navigational Chart (NOAA ENC®) suite to support the marine transportation infrastructure and coastal management for a number of years. The NOAA ENC® supports all types of marine navigation by providing the official database for electronic charting systems (ECS), including the Electronic Chart Display and Information System (ECDIS). NOAA ENC®s support real-time navigation as well as the collision and grounding avoidance needs of the mariner, and accommodate a real-time tide and current display capability that is essential for large vessel navigation. NOAA ENC®s also provide fully integrated vector base maps for use in geographic information systems (GIS) that are used for coastal management or other purposes. The NOAA ENC®s are in the International Hydrographic Organization (IHO) S-57 Edition 3.1 exchange format and comply with the IHO ENC Product Specification, Edition 2.0.

NOAA’s Office of Coast Survey is working toward developing coverage with the NOAA ENC® suite that is comparable to its raster and paper charts. To date, 350 NOAA ENC®s are available for free download on the Internet, with initial production focused on charts within 40 major commercial port areas in the United States. NOAA ENC®s have been available on the Internet since July of 2001 as a provisional product. In July 2003, NOAA ENC®s provisional status was removed, that is to say, they were deemed to be suitable for navigational use. NOAA ENC®s are updated monthly for Notice to Mariners information and revised ENC cells are posted on the Office of Coast Survey web site for download.

Future plans for the program include the expansion of coverage to include smaller scale, coastal NOAA ENC® coverage. Over the next year, OCS plans to introduce incremental updating for the NOAA ENC® products. Incremental updating will provide the user with a small update patch file that can be applied to an existing NOAA ENC® that will change the file to reflect all of the latest updates that have been released. This method will replace the current practice of posting complete, updated ENC cells on the Web. These incremental updates will conform to the IHO S-57 Edition 3.1 updating methodology. OCS is also investigating producing raster and paper chart products from the NOAA ENC® production system. This process promises to eliminate the redundant processing of new source data onto multiple products and represents a new methodology that separates processing and production tasks.

NOAA’s Current Workflow

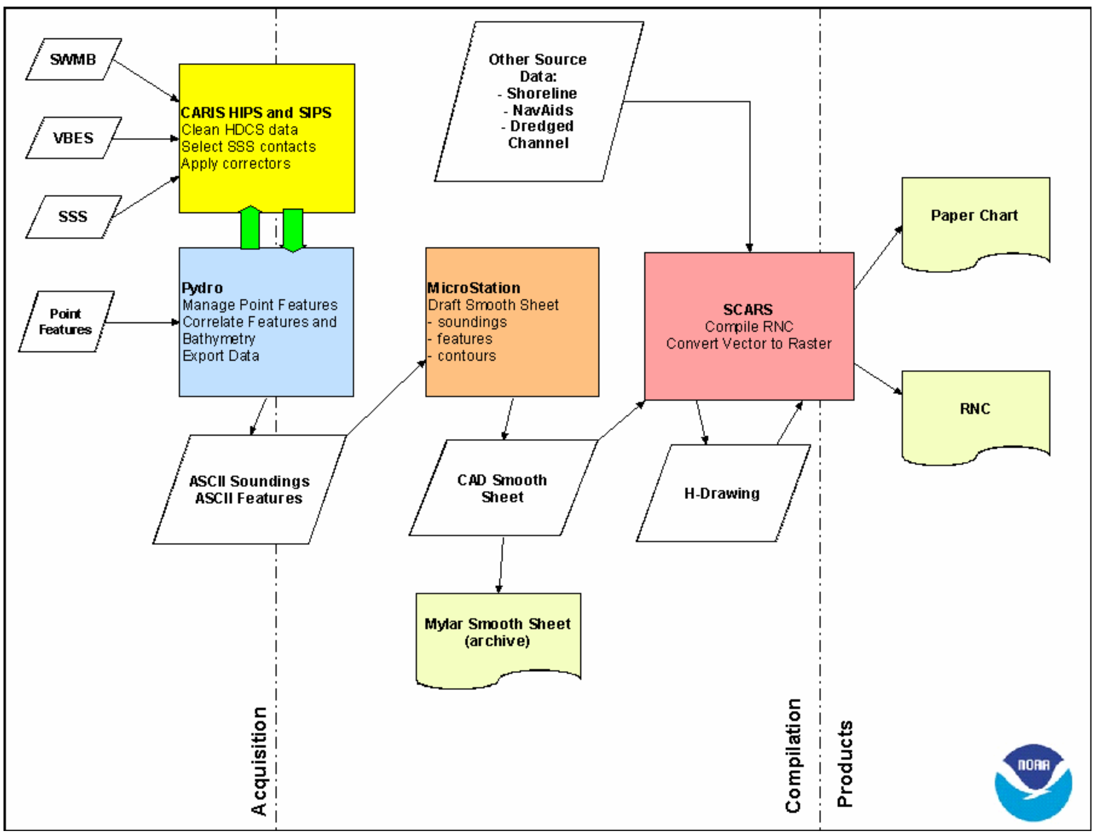
Ping to Chart

Advances in data acquisition technologies in recent years such as widespread implementation of shallow-water multibeam and high-speed, high resolution side-scan sonar have translated to vast increases in the volume of data received at NOAA. NOAA Coast Survey has utilized CARIS HIPS and SIPS as its primary tools for the processing and quality assurance of multibeam and side-scan sonar data. However, the tools as they currently exist still require an operator to manually view and inspect every sounding. Improvements such as the 3-D Subset Editor and Batch Processing in CARIS HIPS have improved processing efficiency and reduced survey throughput time. However, a large bottleneck still exists, and NOAA is looking forward to error-budget based processing using tools and bathymetric modeling, such as CARIS’ implementation of the Navigation Surface *(Smith, et. al, 2002)*, Total Propagated Error (TPE) and Bathymetry with Associated Statistical Errors (BASE), expected to be released in CARIS HIPS 5.4, as methods to significantly reduce the time between data acquisition and data certification.

The hydrographic smooth sheet remains the primary data deliverable from a NOAA hydrographic survey. NOAA’s current *Hydrographic Surveys Specifications and Deliverables Manual* requires smooth sheets to be in Computer-Assisted Drafting (CAD) formats such as MicroStation Design File (DGN) or AutoCAD Drawing (DWG) formats. “Pydro,” a suite of utilities developed and maintained by NOAA’s Hydrographic Systems and Technology Programs (HSTP) using the Python scripting language, calculates a shoal-biased, scale-driven, sounding set, from the full density CARIS HDCS data, and exports discrete soundings as an ASCII XYZ file which is imported into CAD. A cartographer manually drafts a significant portion of the smooth sheet.

Pydro also serves as the tool NOAA uses for the management of discrete point features positioned during a hydrographic survey, such as navigational aids, side-scan sonar contacts, wrecks and obstructions, and shoreline features. Using Pydro, NOAA hydrographers can correlate bathymetry with point features and side-scan sonar contacts, attribute point features, associate images with features, and manage large datasets. Point features are output to an ASCII file, imported into CAD and added to the smooth sheet.

The raster nautical chart (RNC) today remains NOAA’s primary charting product (NOAA considers the paper chart equivalent to the RNC because NOAA produces paper nautical charts by essentially printing the raster files). New hydrographic survey data are applied to base raster files using a legacy system called SCARS, the Super Computer-Aided Revision System. SCARS is a series of macros, applications, and symbol libraries built around the MicroStation95 CAD system. Hydrographic smooth sheets compiled in MicroStation95 in design file (.DGN) format serve as the foundation in SCARS for a NOAA cartographer to manually select soundings, features, and depth curves used to revise the chart. These features are represented on an interim product call an "H-Drawing" which is delivered from NOAA's regional hydrographic processing branches in Seattle, Washington, and Norfolk, Virginia, to the Marine Chart Division at NOAA headquarters in Silver Spring, Maryland, for chart production. The H-Drawing represents only the data from a hydrographic survey and is incorporated at the Marine Chart Division with data from other sources, such as aids-to-navigation information from the U.S. Coast Guard and dredged channel survey data from the U.S. Army Corps of Engineers, to produce a new edition of a nautical chart. The RNC base raster files, separated into layers representing the varying colors on the chart, are edited with the new chart information to produce the new edition of the chart in raster (MapTech® BSB format) and paper formats. In essence, vector data is rasterized to update the charts.



NOAA's current ping-to-chart (paper and RNC) process.

ENC Production

The RNC subsequently serves as the basis for the production of NOAA ENC®s. NOAA production cartographers creating new ENC cells digitize the RNC and attribute the data to create new S-57 objects. For position-critical features such as dredged channels, wrecks, and aids-to-navigation, NOAA cartographers will use the original source data rather than the RNC to create the S-57 objects for those features in order to maintain the source position. However, the majority of S-57 objects in a NOAA ENC® have been digitized from the RNC. This introduces inaccuracies into the positions of coastline, contours, soundings, and features, as they are often many pixels in width on an RNC, and the cartographer must make a choice where to draw the vector line over the raster line, or choose the exact position of a feature or sounding. Many features along the coastline, such as rocks, do not appear on an RNC in their surveyed position because they have been shifted slightly by a cartographer for purposes of clarity on a chart (otherwise they would plot over the coastline). However, when these features are vectorized as S-57 objects in a NOAA ENC®, the position may be misrepresented in cases when the original source data are not used. This may not be critical when the ENC is viewed at the proper scale, but it can introduce errors when used in conjunction with navigational features of an ECDIS or ECS, such as distance alarms and safety contours, and can cause the mariner to question the accuracy of the ENC when it does not appear to represent what he or she may be seeing in reality.

In NOAA's current ENC production process, new source data such as hydrographic survey smooth sheets would first be converted from vector to raster (.DGN to SCARS) when creating the RNC, then later from raster back to vector when the new data are digitized from the RNC and attributed into NOAA ENC®s. This not only creates inefficiencies in the process, it also can compromise the positional integrity of the data. Realizing these limitations, NOAA sought to develop a process to directly apply new hydrographic survey data to the ENC and continue to support the legacy RNC production system as long as necessary.

Proposing a New Workflow

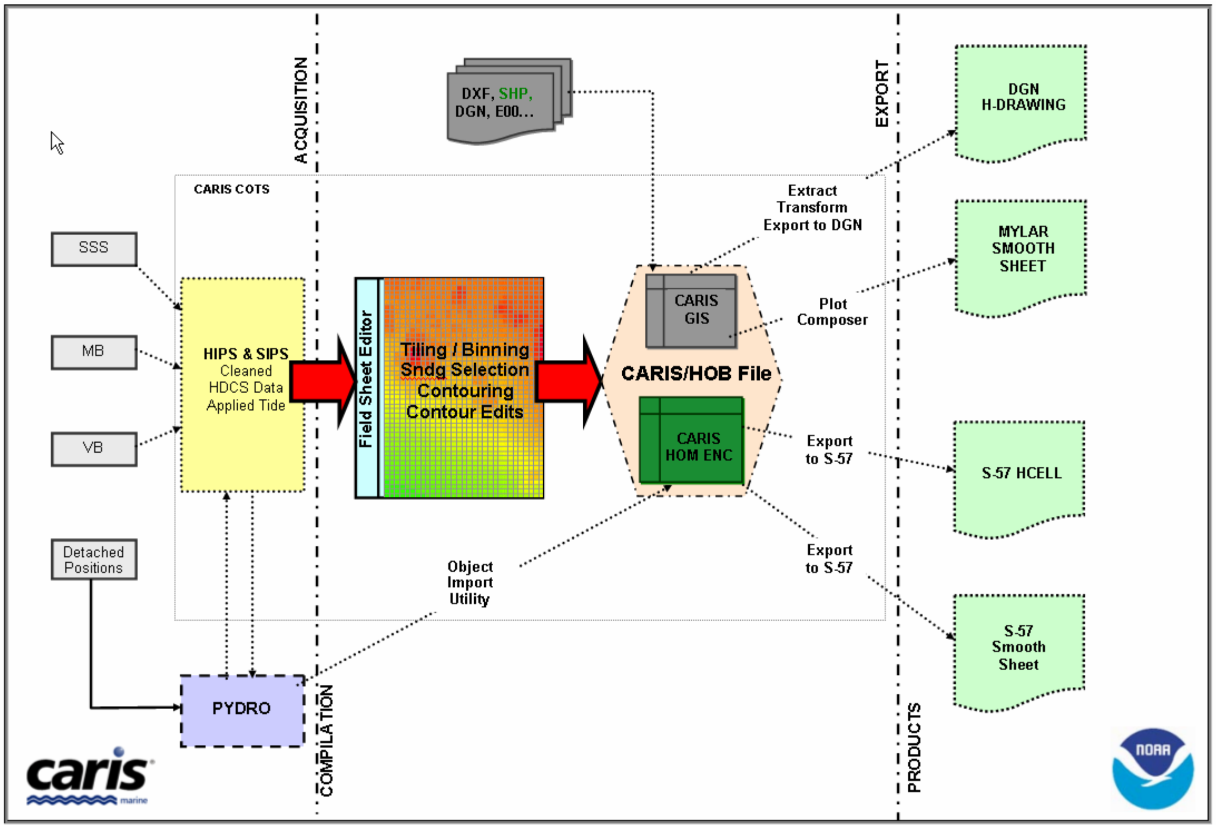
NOAA is looking forward to a future in which a single production flow supports the ENC, RNC, and paper chart. In the shorter term, NOAA will shift focus from the RNC to the ENC as the primary charting product, and the RNC and paper charts will be created from the ENC data set. In order for this to occur, NOAA needs to develop processes for new source data to directly update NOAA ENC®s. This process alone will streamline the ping-to-chart process for all three NOAA charting products.

In developing such a workflow, NOAA envisions three primary goals:

1. As long as the RNC remains NOAA's primary charting product, support both the RNC production line and the ENC production line, while eliminating redundant source data processing;
2. Design the workflow such that when the NOAA ENC® becomes the primary charting product, the RNC revision process can easily be phased out without requiring a reinvention of the ENC production process; and
3. Develop processes which can easily be transferable to supporting the population of a chart production database in the long term.

A secondary goal was to reduce the number of different pieces of software required in the process, thus reducing not only the number of data formats and translations required between each phase of the process, but also the technical support burden. Because NOAA has already invested significantly in CARIS for the processing and quality assurance of hydrographic survey data, it was logical to continue to use CARIS technology in defining the new process.

NOAA's new process was built around CARIS HIPS and SIPS, and CARIS HOM. Sounding and sonar data are still processed using CARIS HIPS and SIPS, and point features attributed and correlated using Pydro. In CARIS Field Sheet Editor, binning and sounding selection occur, and contours and smooth curves are automatically generated to create a CARIS Field Sheet in CARIS Map (DES) format. This CARIS Map serves as the foundation in CARIS HOM for creating two new interim products, the S-Cell and the H-Cell. Because the capability does not yet exist in CARIS Field Sheet Editor to work with point feature positions, these data, after attribution and correlation in Pydro, are exported to a Microsoft Access database and are subsequently brought into HOM using the Object Import Utility.



Defining a new process to support ENC, RNC, and paper chart production with new hydrographic data.

The S-Cell and the H-Cell

This initial CARIS Map is termed an "S-Cell," or smooth cell, emulating the term smooth sheet that we would typically use for a graphic representation of thinned soundings, curves, and features. In compiling the S-Cell a NOAA cartographer will utilize CARIS HOM in Spatial Mode to add cartographic features such as legends, logos, graticules, or other items. While NOAA is still refining the process and product specification for the S-Cell, some additional processing occurs in CARIS GIS, such as the addition of labels, and the creation of a plot file to support the requirement for an archiveable hard copy as long as is necessary. The potential also exists to export this data to an S-57 version of the smooth sheet. This creates an exchangeable version of the data to use for data archival, population of a production database, or creation of Marine Information Objects (MIO) to use as a supplemental data layer in ECDIS, ECS, or even coastal GIS systems.

With the S-Cell compiled, NOAA cartographers will then build the H-Cell in CARIS HOM. The H-Cell can be considered the S-57 equivalent to an H-Drawing — the feature components which will revise the NOAA ENC®. Topology is a tricky issue in compiling an H-Cell as the Group 1 (skin of the earth) objects are updated with the new data, as land areas and depth areas are revised from the ENC, and the new data must seamlessly match with the existing data. Cartographic objects identified in the field—most commonly describing extents of piers, reefs, ledges, and foul areas – are positioned as point features with the expectation that the cartographer in the office will connect the points as necessary to create line and area objects. Because Pydro manages point features only and not line or area features (although Pydro does group point objects representing a single feature for easier management), point features must be translated from Pydro (XML format) to HOM, and line and area features must be constructed from the points in HOM spatial mode. Complete S-57 line or area objects may then be created. Managing point features from acquisition to production is an area requiring tool improvement.

When updating RNCs with data from an H-Drawing, NOAA production cartographers will use a "cookie-cutter" approach. The existing information within the geographical bounds of the data is removed and replaced with the new information in whole (although some soundings and features may be retained if necessary). Using the cookie cutter approach for updating the existing NOAA ENC® is a bit more complicated than in the raster revision environment because of topology issues, however. The process will require some items to be transferred from the existing ENC cell to the H-Cell, and that makes the H-Cell fundamentally different from the H-Drawing, in that it contains data not acquired during the hydrographic survey. The resultant H-Cell, however, when transferred from the regional processing branch to Marine Chart Division at NOAA headquarters, should require a minimum of work rebuilding topology.

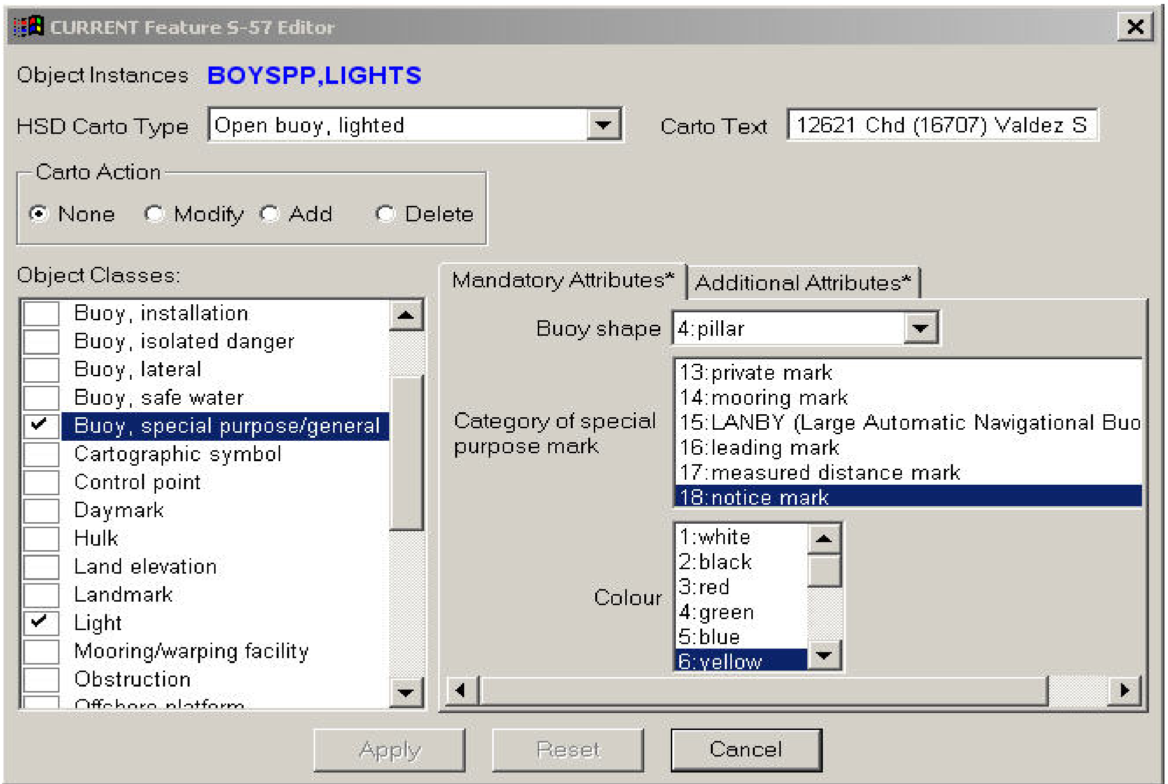
Once the S-Cell and H-Cell are completed, we can continue to support the RNC production system as long as necessary by using CARIS GIS to convert them from CARIS Map to DGN format, and using these files in the SCARS environment. Once NOAA shifts to a single production flow for ENCs, RNCs and paper charts, this step of the process can simply be eliminated and the entire process need not be reengineered.

Field Attribution

One of the essential ingredients for timely application of new hydrographic survey information was tasking the hydrographer in the field with attributing point data using the S-57 object catalog. NOAA hydrographers, in addition to acquiring sounding data, are also tasked with verifying features along the shoreline and positioning new shoreline features which may not be depicted on NOAA charts or shoreline remote sensing maps. NOAA realized early on that it was essential for the hydrographer to capture all of the S-57 attribution data at the point of data capture in the field because it would be difficult to recreate by a cartographer back in the office. This included mandatory ENC attributes as well as non-mandatory attributes which are part of the NOAA ENC® product specification. NOAA also realized that we could not expect our field hydrographers to be immediately versed in the S-57 Object Catalog and ENC product specification. As a result, we incorporated software tools which utilized the S-57 object catalog in "plain English" rather than object and attribute acronyms. NOAA HSTP developed Pydro such that hydrographers select the object and attributes by identifying the feature by name (e.g. "buoy, special purpose") rather than the S-57 object acronym.

Pydro inherently stores point feature data in XML format. HSTP added functionality to Pydro to export the point feature data to a Microsoft Access database to be subsequently imported into the S-Cell using HOM's Object Import Utility (OIU). The Object Import Utility requires a separate import script for each CARIS feature code (CARIS HOM Spatial Mode) or S-57 object acronym (CARIS HOM Feature Mode). This limitation could potentially lead to the creation of up to 57 separate OIU scripts constructed in CARIS HOM for the objects NOAA uses in it ENCs. Pydro was setup to make OIU script writing as straightforward as possible. Rather than create a single table with a field in each record for object class, a separate table for each class is created in the database. This way, no SQL statement is needed in the OIU script wizard, as the user simply selects the appropriate database table. A one-to-one namespace was also used in the fieldnames within Pydro-exported table records for the CARIS & S57 feature attributes; for example, latitude-->latitude, longitude-->longitude for CARIS attributes, or VALSOU-->VALSOU, WATLEV-->WATLEV, for S-57 attributes.

An additional issue to be solved is the handling of bathymetry data over Group 2 ENC objects (non-skin-of-the-earth) such as wrecks and obstructions. For example, multibeam soundings on a submerged obstruction should be excluded from contouring and depth area generation, but at the moment this requires manual intervention and editing to remove the contours once generated. Pydro allows the user to set the “outstanding” flag on the HDCS soundings over such features in order to create point feature data for these features. Yet, there is no workflow in CARIS HIPS, FSE, and HOM to exclude these data from use in computation of contours and depth areas. Pydro assists by generating a point feature at the position of the item to visually alert the cartographer, but this process should be automated.



S-57 Feature Editor in Pydro. The feature objects are selected in the list box on the left, and tabs on the right indicate mandatory and non-mandatory attributes which may be selected.

The Valdez Project

NOAA chose to test the conceptual model in September 2002 during a hydrographic survey in Valdez, Alaska. Valdez was selected as the location to test the conceptual model because: 1) NOAA had already produced large-scale harbor ENCs for the area; 2) Valdez was in need of new hydrographic survey data to update NOAA’s charts; and 3) The harbor area itself was of a complex nature which would provide the greatest diversity of features and objects to test the proposed model. Following the completion of survey operations, NOAA hydrographers processed the data in the standard manner, using CARIS HIPS for processing and quality assurance and producing the standard suite of field deliverables. The only modification to this process was the attribution of point data using the S-57 object catalog in Pydro as previously discussed.

Upon receipt of these deliverables at NOAA’s Pacific Hydrographic Branch in Seattle, Washington, the Cartographic Team there began to use the data to build the first S-Cell and H-Cell. For the initial test of this process, NOAA also intended to concurrently adhere to the existing process by creating a MicroStation smooth sheet and H-Drawing. The reasons for this were: 1) continue to support the existing RNC production line while the new procedures are being refined; and 2) compare the S-Cell and H-Cell at the end of the process with the traditional smooth sheet and H-Drawing to ensure that content is comparable and that the new products are suitable for purpose.

In July of 2003, the Pacific Hydrographic Branch (PHB) delivered the first prototype H-Cell to the Marine Chart Division at NOAA headquarters. A cartographer from PHB met with ENC production cartographers to further develop the H-Cell product specification and devise procedures for revising NOAA ENC®s in the LaserScan LAMPS system which NOAA currently uses for ENC Production. The certified H-Cell is targeted for completion and delivery in January 2004, after which, following further feedback and process refinement, NOAA will implement H-Cell production for all surveys in areas with NOAA ENC®s.

The Future

NOAA considers the development of the H-cell process the first step toward integrating a single-process workflow to support production of all charting products. NOAA is currently evaluating the use of combined source and product databases to support the management of source data, high resolution bathymetry, and chart production. If adopted, NOAA envisions migrating from the "cookie cutter" approach using an H-cell, to populating the database using cartographic objects contained in the S-Cell (source) and H-Cell (product). High resolution depth areas, contours, and soundings will be supported by an underlying bathymetry model based on the Navigation Surface, such as CARIS' BASE. In the shorter term, NOAA will use the soundings, contours, and depth areas on the S-Cell and H-Cell from the bathymetry models rather than the binning and shoal-biasing of discrete soundings.

Any mention of a commercial product is for informational purposes and does not constitute an endorsement by the U.S. Government or any of its employees or contractors.

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