Merging Marine and Land Data for Coastal Area Mapping

Mark MacKenzie and Nadia Theriault
CARIS
Fredericton, NB
mark.mackenzie@caris.com
nadia.theriault@caris.com

Abstract

As climate change continues to raise concerns about coastal areas, the need for accurate mapping of these areas is on the rise. This need has highlighted the problems of merging land and marine spatial data, as these datasets follow divergent data display standards. Disparity between data scales, symbology and vertical datum causes various data integration issues when these data sets are merged to create a representation of the coastal zone.

A combination of topographic and hydrographic spatial database technologies will be used to address land and marine data integration issues through multiple representations of objects on a continuous map surface. An object based data model that incorporates both topographic and hydrographic objects will be demonstrated, and will be used to solve the disparity between these data sets. The approach presented will maintain the integrity of each specific data set and allow for easier maintenance of the map data, as geometric objects will be edited once, and all the representations associated with that object will be updated.
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Introduction

The management of the world's coastal zone areas has taken on new urgency in recent years due to climate change, which is predicted to cause sea level rise, and increased risk of natural disasters. This has helped highlight not only the vulnerability of these areas, but also their value. Historically, populations have concentrated in coastal areas and today a large percentage of the world's population lives within 100km of the coastal area. If even the most modest predictions for sea level rise come to fruition, these populations will be at risk.

This renewed importance of coastal zone management brings into focus the inherent separation of land and marine spatial data management. Land based spatial data typically ignores the hydrographic data, and vice versa. Topographic mapping largely stops at the coastline, while hydrographic charting concentrates on waterways and shipping areas; with land based features included as an attribute to the hydrographic data. This disparity of interfacing between the two data products has produced a distinct lack of seamless data products for the coastal zone area. Users must pick which side is most appropriate for their purposes, a land or a marine based approach. The problem being that comprehensive analysis and management of the coastal zone area needs to consider both approaches, with its own set of needs and requirements.

Accurate representation of the coastal boundary can be a complicated process, especially if two separate datasets, with separate usages, are merged. The usage of a dataset determines the standards to which it is created, and effects decisions on delineation. For example, a dataset used to create electronic navigation charts uses the low water line to determine the coastal boundary because this provides the best safety assurance for shipping, and aids to navigation. This differs when one considers the delineation of the coastal zone in topographic datasets, where the goal is to produce accurate representation of the topography as it appears in the real world.

The challenge is to create an accurate and useful coastal zone map that combines topographic and hydrographic datasets. The answer has often been to take the difference between different models of coastal boundary delineation and create a coastal zone area that bounds the area between the extremes in delineation. This causes issues with ambiguity of the actual boundary of the coastal area, which can cause havoc with applications such as coastal cadastre and territorial water claims.

Add to these challenges the prospect of trying to merge the needs of the complex web of institutional and political issues presented by coastal zone management, and the explanation for the lack of standards for all coastal zone mapping are clear.

All of these issues make the prospect of a standardized coastal boundary seem daunting, and preliminary steps should be taken. One of the logical first steps would be to create a system that allows users to view hydrographic objects and topographic objects in the same map view, while maintaining these objects in their original format.

This requires that the system allow for a combined data dictionary, which maintains the individual display dictionaries of the datasets. Hydrographic and topographic data objects need to reside in the same place, and data duplication issues need to be addressed in a way that meets the needs of both usages.

A single spatial data infrastructure that combines land and marine data in a single application without compromising either dataset can provide a backbone for a comprehensive coastal zone management system.

Challenges of Coastal Zone Management

Lack of common boundaries can create ambiguity; a lack of a standard for defining a national coastline causes data overlap and inconsistencies in the coastline delineation. This is a limitation to coastal management, and for the many applications that rely on a single representation of this boundary, the most obvious being territorial water claims. For example, how can accurate quantitative measures be made of the advance of sea level rise, when a single definitive coastline is not defined?

On a national and international scale, the lack of a standardized method for delineating the coastal boundary has lead to a complex web of conflicting and overlapping coastal zone delineations based on international, national, regional and local standards. Policy makers and researchers have to pick a standard that works best and run with it, jeopardizing the decision making process. For example, one governing organization may utilize the HWM as its defining coastal boundary while another may use the LWM; often the area between these interpretations can become a “no man’s land” where no regulation exists. An overarching standard that can be utilized across political, organizational and disciplinary areas of interest must be established. The merging of Land and Marine data along the coastal zone is a key component of the establishment of this standard coastal boundary.

An international standard needs to be established for delineation of the coastal boundary, and it needs to be established by an international, discipline neutral organization, such as the UN. Possible this could be an extension of the United Nations Convention on the Law of the Sea (UNCLOS), or an output of the United Nations Geographic Information Working Group (UNGIWG). With the emergence of the concepts of SDI (Spatial Data Infrastructure) as the driving force behind many national geographic information initiatives, international standards for establishing national boundaries such as the coastal boundary will take on new urgencies.

The dynamic nature of the coastal environment itself presents challenges to common coastal boundary. The coastal zone is an ever changing environment with tidal, seasonal and environmental changes constantly remoulding the physical environment. How does one come up with a standard coastal boundary when the physical environment that makes up the boundary area is ever changing?

Perhaps an interim step to defining a standard for delineating the coastal boundary, would be to merge the marine and land data into a single data infrastructure which allows each to be displayed as one dataset, but maintaining the objects that make up each dataset. Merging a hydrographic navigation chart with a topographic map sheet may produce a single coastal zone map, but the marine objects (buoys, nav aids, etc.) would co-exist with the topographic objects (light houses, roads, etc.).

Merging Land and Marine Data within a Production Database

Delineation of a coastal boundary is a complex prospect, but the seemingly simple task of merging hydrographic and topographic dataset presents its own challenges. And once the datasets are merged, the real work of determining the best location of the coastal boundary begins.

What criteria do you use to determine the best rectification between the hydrographic waterline (biased low) and the topographic waterline (biased high)? At first glance it may seem like the motivations behind the hydrographic delineation (protecting the safety of shipping and thus the environment) seem to outweigh the arguments for the topographic delineation. For many nations, topographic mapping agencies represent the definitive source for spatial data, so a compromise between the hydrographic and topographic data standards must be determined. The hydrographic sector has acknowledged that navigation chart data has a use outside of navigation, and have acknowledged that topographic data can be of value to navigation. In fact, the IHO is working to make the new ENC display standard (S-100) more open and flexible to allow for easier merging of hydrographic data with other data formats and applications.

The resolution and data collection method for each data set differs between disciplines; topographic data usually originates with digitization of maps from orthophotography, while hydrographic data is often derived from sonar or Lidar data. It seems that the hydrographic data would be more accurate, based on the resolution of the origin data, and based on the processes used to produce the end product. Digitization can be error prone, while hydrographic data often undergoes intense analysis before it is published. In ether case, the accuracy of the data depends on the currency of the data.

Any compromise between hydrographic and topographic data needs to consider the safety issues presented by the fact that hydrographic data is used for navigation. It is granted that navigation data can be a separate product from that used for coastal zone mapping, but the fact remains that any standardized coastal boundary has to take into account safe navigation issues if it hopes to gain international acceptance.

The true challenges with merging marine and land data are cartographic, not technological. For this project, CARIS' production database technology allows users to merge the 2 datasets without losing the objects that make up each dataset. For this project, the hydrographic data used was an S-57 electronic navigation chart (ENC) provided by the Canadian Hydrographic Service (CHS), and the topographic data used was a National Topographic Data Base (NTDB) map sheet produced by Natural Resource Canada (NRCan).

The production database (CARIS HPD) utilizes an object based data schema, which allows for multiply representations of an object, with differing usages. This object model allows for features from various catalogues to be combined under one data schema. Catalogues are used for determining data display standards for each dataset.

Utilizing functionality in the CARIS Production Database, derived from its Oracle backbone, the S57 and NTDB catalogues were combined to provide a common display library. The S57 catalogue contains all the object types and attributes found in the S57 standard, while the NTDB catalogue is a one for one interpretation of the NTDB support files.

Combining these datasets while maintaining their individual object definitions allowed for the representation of both sets of objects, without compromising or eliminating objects from either dataset. Cartographic processes would have to be developed to determine which representation of common objects would be utilized for certain user types, and scale dependencies would have to be determined. Another cartographic issue that would also have to be addressed when allowing for the same feature to have multiply representations include the determination of which representation becomes definitive, if any.

The merger of the hydrographic and topographic data into one production database will allow data products (maps, charts) to be developed that contained either a merged version of the hydrographic and topographic objects, or containing only hydrographic or topographic objects. These products will remain current as the production database will allow the objects to be updated once and applied to all products containing those objects, automatically. The comprehensive data quality control and validation tools presented by the production database will also ensure that the integrity of each dataset is maintained, even when they are combined.

The merging of land and marine data within a single production database will allow coastal zone management to include the strengths of each dataset in decision-making processes. By maintaining the integrity of each dataset, coastal zone stakeholders can spatially view a management issue from either a marine viewpoint or a land viewpoint, and then combined the relevant information from each viewpoint to optimize data for coastal zone management.

The Process of Merging Land and Marine Data

As mentioned elsewhere, the CARIS HPD product was used to combine hydrographic data, an S-57 ENC, and topographic data, an NTDB Map Sheet, into a single dataset for this project. The data chosen was based on a requirement to utilize data readily available to any organization, and to utilize the best possible quality of data. NRCan provides 1:50,000 NTDB map sheets for free download from the GeoGratis web site, and the CHS provides S57 ENC files for most navigable waters in coastal zones of Canada. The ENC used here was a 1:20,000 scale.

The first step was to prepare CARIS HPD to accept the two datasets. Because HPD is designed as a hydrographic data management tool, a topographic data dictionary and catalogue profile had to be created. (NTDBPool.xml, and NTDBProfile.xml) Once created, these profiles can be reused by any CARIS HPD user.

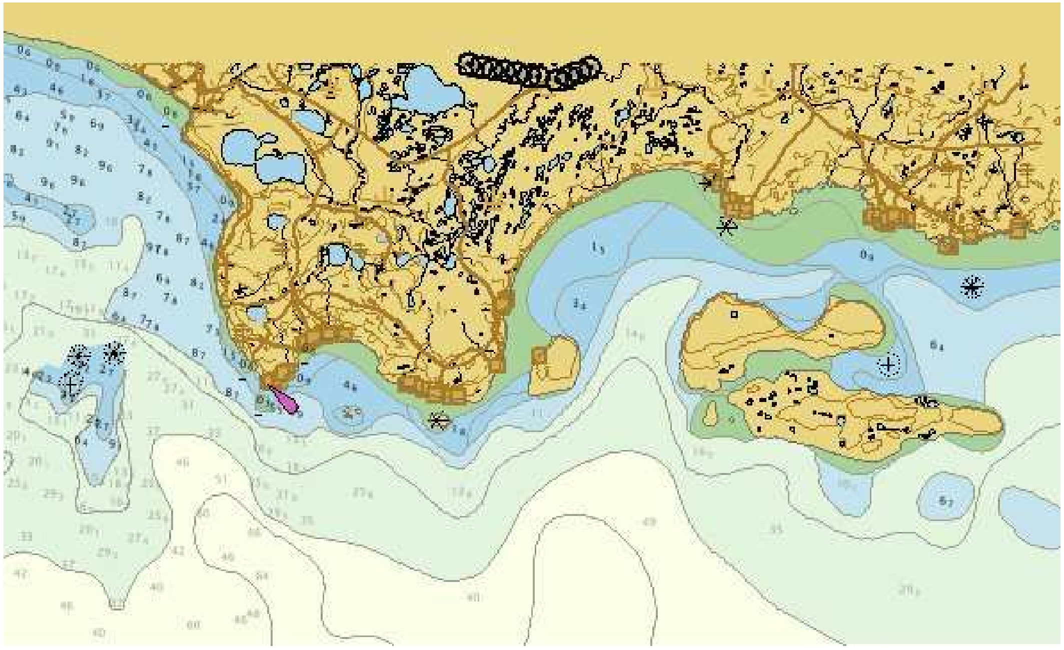
The newly created dictionary was then appended into the HPD data schema using an SQL script (LoadCatalog.sql). Once this process was complete, the HPD database had access to S57 objects and NTDB objects. Once the objects are entered, the issue of object symbolization had to be addressed, as the default HPD schema uses the S-52 and INT1 display standards. In order to allow proper symbolization of the NTDB objects, the lookup files within the data dictionary had to be modified to add the NTDB symbolization.

One thing to note in reference to vertical datum in HPD; the Vertical Datum value needs to be specified during the import of data. HPD does not automatically shift vertical datum to a common datum, the datum must be defined during data integration.

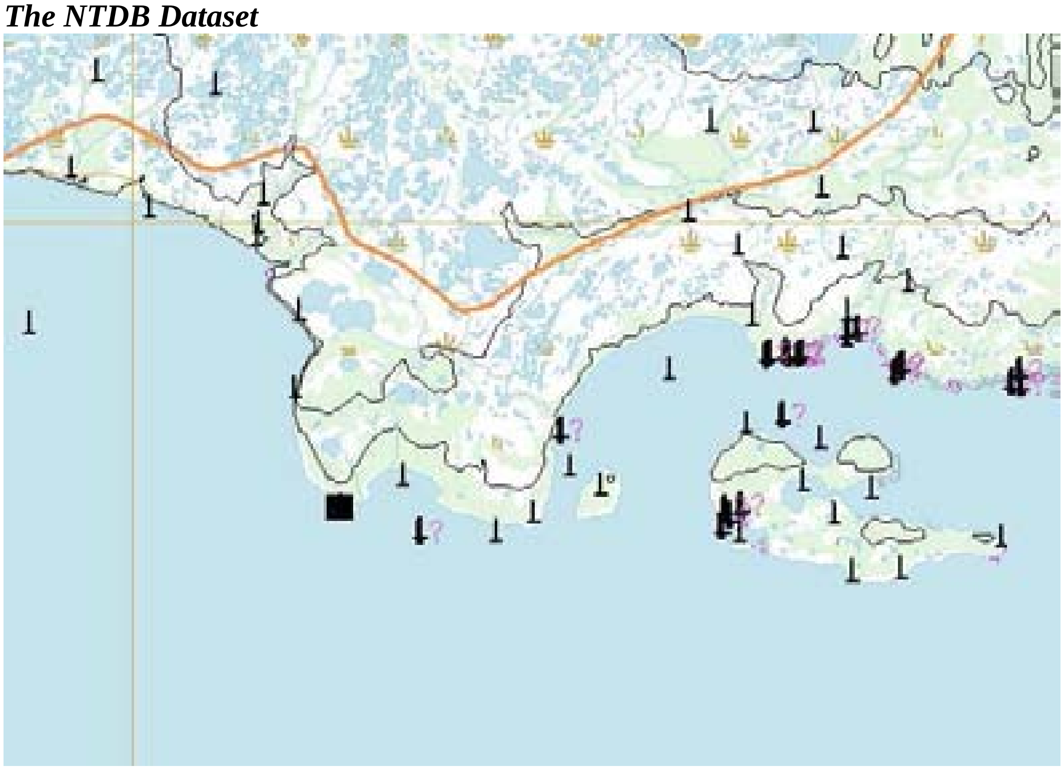
Once HPD is set up to display the NTDB data properly, the next step was to import the datasets into the database. For the hydrographic data, the ENC was loaded as a backdrop file, and then the *Import from Selection* tool was used to import the objects. The topographic data was delivered in shapefile format, so the *Object Import Utility* was used to upload the data as objects.

At the conclusion of this step, an HPD project was available with each dataset on its own usage, so they could be viewed together in a single map window. Each dataset maintained its own data display standard, and each set of objects is maintained. Now the real work to create a coastal zone map proceeded. A combined usage that would become our coastal zone usage could now be created by selecting objects from each dataset to create the best possible representation.

The S57 ENC Dataset



The NTDB Dataset



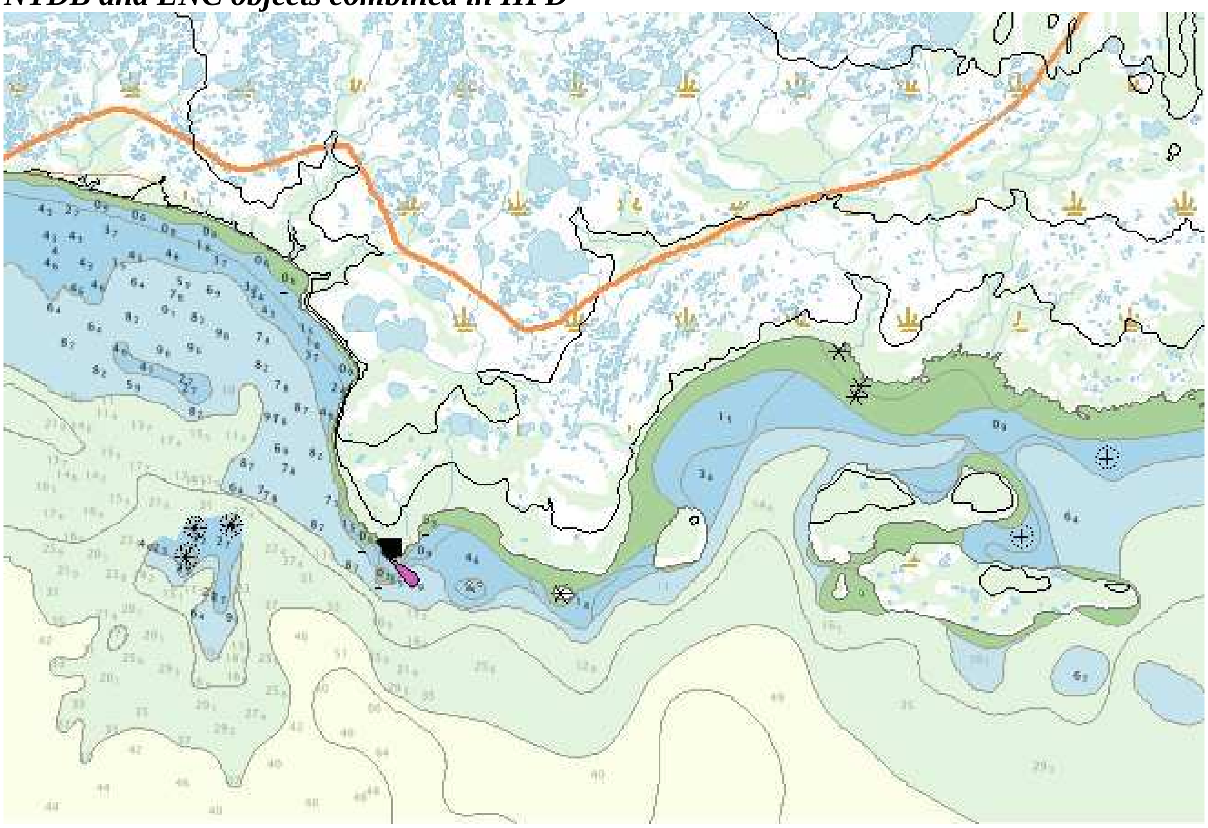
In order to decide which objects to include, the user needs to make decisions based on data available and the quality of that data, to determine which objects to include in the combined usage. The key point to remember is that the HPD technology allows the topographic and hydrographic objects to reside in the same database, and then allow users to pick and choose which objects, from each dataset, they want to include in the coastal zone map. The objects chosen for inclusion can be based on the end product desired.

For this project, the general rule of thumb was to use topographic objects to represents "land based" features, and hydrographic objects for "marine based" features. Specifically, it was decided that any features on the land side of the coast would be represented by the NTDB objects, and features on the sea side of the coast would be represented by the ENC objects.

A series of data filters were used within the HPD Source Editor were used to identify the objects within each dataset to include. These filters were saved and documented in order to allow other HPD users to utilize them.

Once the data filter process was complete for each dataset, and the appropriate objects were extracted from each, the combine usage was created using objects from each dataset. The end result was a coastal zone map combining topographic and hydrographic data objects.

NTDB and ENC objects combined in HPD



One challenge that arose when filtering the NTDB data is worth noting here. The NTDB map sheet used for this project had been set up so that the sea or coastal waters are on the same layer as the lakes, ponds and other hydrological features. Using our rule of thumb for this project, the land based hydrological objects from the NTDB would be used on our combined usage, and the sea of coastal water objects would come from the ENC. This necessitated data massaging to isolate the lakes and ponds from the sea features, but this process was facilitated by the data editing tools in HPD Source Editor.

In the end, the project proponents decided to utilize the ENC coastline as the definitive coastline for our coast zone map. This was based on the larger scale of the ENC, as well as the assumption that a coastline delineated based on safe navigation should have better quality control. While no standard for coastline delineation exists, users need to make decisions based on the data and information on hand.

The following table describes some of the issues addressed during the creation of the combined usage with decisions made to address the issue, and then the result of those decisions:

Issue	**Decision**	**Result**
Both sets of data were not on the same horizontal datum, the NTDB shapefiles were using the North American Datum of 1983 (NAD83) and the ENC is using World Geodetic System 1984 (WGS 84) datum.	When importing shapefiles, the coordinate system was specified. HPD does the projection correction “on the fly” and displays the data with World Mercator WG84.	Both sets of data were imported in the database at the proper geographic location.
Undershoot and overshoot problems had to be fixed from the ENC data.	Digitize to fix problems within the HPD Source Editor.	Topological integrity maintained.
The coastline (COALNE) was not complete on the ENC	Digitizing the coastline following (grabbing) the land area and the depth area was done to complete the coastline.	A continuous coastline along the coast for the area of interest.
The datasets are differing in scale (NTDB 1:50000 and ENC 1:20000).	Because the ENC was a newer dataset, and the larger scale provided more detail, the 1:20000 scale was chosen.	The end scale for the map produced will be 1:20000 and will include objects from each dataset.
Which objects from the NTDB data should be imported in the combine usage?	Only objects on the land ; like vegetation, lake, rivers, wetland etc. All objects that are in the marine zone or that are mandatory for navigation purpose will be coming from the ENC	Data filters were used in HPD Source Editor to import the chosen objects from the NTDB dataset and into the combined usage.
Which objects from the ENC data should be imported in the combine usage?	All objects that are in the marine zone or that are mandatory for navigation.	Data filters were used in HPD Source Editor to import the chosen objects from the ENC dataset and into the combined usage.
Land Area was not complete on the ENC.	Utilizing data maintenance tools in HPD Source Editor to digitize a portion of the land area.	Note: in this case, could still function without digitizing the land area because that feature is not required for the combine

		usage.
The coastline selection	The coastline selected for this project was the ENC coastline. The selection is based on the fact the data were at a larger scale and coinciding with the depth areas. Also, because the ENC data are regulated for safe navigation.	The ENC coastline was used for the coastal boundary for the final combined usage, or coastal zone map.
Overlapping data	By selecting the coastline from the ENC, some of the land data are overlapping the coastline and falling in the depth area, which is not appropriate. A decision was made to fix those problems by modifying the land data (topographic) on the combine usage only to adjust the data following the coastline	A cohesive coastline was established, without overlapping polygons.

Conclusions

The merging of land and marine spatial data for the coastal zone are mapping will become more and more of a priority as climate change continues to raise the threat level for our coastal zones. The social and economic challenges presented by global sea level rise will bring this area of mapping to the forefront of national and international agendas in the coming years, and it is essential that spatial data stakeholders utilize the technology available today, to prepare for the mapping needs of tomorrow.

Today’s spatial database technologies allow spatial data managers to combine varying datasets with varying data standards in a single database without compromising the data integrity of the source datasets. Once the data is merged, the object orientated data model allows data objects to have multiply representations that maintain the standards of various sectors. The objects are then used to produce map products can consist of a combination of data representations; in this way the land and marine data formats can remain independent, yet be combined.

The processes used in this project to create the combined hydrographic and topographic usage within CARIS HPD have been documented and will be distributed to users. The filtering process will be standardized and will become a definitive filter file for any HPD user combining S57 ENC files with NTDB map sheets.

The cartographic decisions made as part of this project effected the composition of the coastal zone map created; but they in no way restricted the usefulness of the process and technology used. The key point is that coastal zone stakeholders and decision makers can utilize these technologies and processes to combine these varying data sets into a common coastal zone map that reflects their needs. Objects from either data set can be utilized based on the decision being made. For example, if the coastal zone map was to be used to make decisions on navigation of oil tankers, the navigation aids of the ENC could gain a higher bias on the final map. If the coastal zone map was to be used for decision making on where to place an oil refinery, the bias may be placed on environmental features from the topographic objects.

The establishment of a standardized coastal boundary is fraught with challenges, mainly on the policy side. As with any large spatial data issue, the technology is available to create the data, it is up to the policy makers to determine the path forward. Establishing production databases that merge marine and land data is an essential first step towards a standardized coastal boundary standard, and more informed coastal zone management.

Author Biographies

Mark Mackenzie

Mark MacKenzie is the Account Manager - Canada for CARIS. Mark is a Mount Allison University graduate with a major in Geography, and a GIS Technician Diploma from the New Brunswick Community College. He has over 10 years experience in sales, marketing and project management in the IT industry. In addition to his 5+ years at CARIS, Mark oversaw the successful launch of a web marketing technology company in 2005. He has managed projects for government, private industry and NGOs. Mark has a wide range of experience in sales, customer relations and mapping software, and has been involved in product development and research throughout his tenure at CARIS.

Nadia Therirault

Nadia Thériault is a technical support consultant in the CARIS HPD product support group. Nadia is a Université de Moncton graduate with a specialization in Biology, and have a GIS Technician Diploma from the New Brunswick Community College. She has over seven years of experience in biology, field sampling, data entry, habitat improvement, projects coordination, mapping applications. During her one year at CARIS, Nadia has acquired experience in customer services and relations. She also has been involved in product development and research.